# Technology evaluation, development and transfer: a case study in the Ethiopian Rift Valley

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MSc thesis Plant Production Systems

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For quality of life

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# Preface

One year ago, to the day, I arrived in Ethiopia to do research for this MSc thesis. Although I have been there for less than four months, I believe this time will leave a lifelong impression on me. I have learned a lot. From the research I have been able to perform. From the everyday life that I have witnessed and experienced. Especially from the people.

I am grateful to all the colleagues at Melkassa Agricultural Research Station who taught me how to eat injera, invited me to their coffee ceremonies, and shared both their hilarious and more serious views of life. They have also meant a lot to me in understanding Ethiopias (agri)culture and the problems that both farmers and researchers have to deal with.

I am more than grateful to the farmers that have been involved in this research. They have given me their time, made great effort to answer my questions and allowed me to have a peak into their lives and minds. One farmer told me a riddle I will never forget. He held his closed fist out to me. 'I've got a bird in here. What do you think: is it alive or is it dead?'. I did not know what to say. 'I hope it's alive!'. He answered: 'Whether the bird is alive or dead is up to me. I am like the bird. I am in your hand...'. This hit me like a rock. Is that how the farmers see it? That their lives are dependent on 'us' (and who are 'we' then)? I have seen their problems. But I have also seen in them perseverance and resilience. What is the role of researchers for their lives? The farmers have been a source of great inspiration to me.

I am also grateful to all others who have stood by me, prior, during and after my time in Ethiopia. The people I lived with, the people I went to church with. Friends and family in the Netherlands and beyond who have been there for me and helped me deal with my experiences.

I am obliged to many people. I will only mention three names. Two of them are mentioned on the front page of this report. They are my supervisors: Katrien Descheemaeker from Wageningen University and Frédéric Baudron from CIMMYT, stationed in Addis Ababa. Thank you for your advice, support and feedback. The third name I would like to mention is Asheber Tegegn, with whom I shared the office at Melkassa Agricultural Research Station and who helped me in the practicalities of conducting this research. Thank you.

Last but not least, I am obliged to IFAD for funding part of the research I have performed in Ethiopia.

Jiska van Vliet
Wageningen, September 2013

# Summary

Several agricultural technologies and their dissemination as part of the SIMLESA project among smallholder farmers in Adami Tulu, Ethiopia, were evaluated in the 2012 cropping season. Several methods were used. For two technologies (residue retention and intercropping), on-station field trials were executed. The residue retention trial failed as a consequence of waterlogging. From the intercropping trial it could be concluded that intercropping maize with cowpea increases land use efficiency, with an Land Equivalent Ratio between 1.37 and 1.44, depending on which crop components were taken into account. Residue retention, intercropping maize with bean, minimum tillage and introduction of a new maize variety (Melkassa-II) were evaluated using semi-structured farmer interviews. A participatory exercise was developed for assessment of technologies and was used in assessing intercropping. In this exercise, farmers establish implications of the new technology through building scenarios, and evaluate the different options through scoring of attributes of these options. This exercise increases understanding of the technology and its costs and benefits by the farmer, and understanding of farmer perceptions, possibilities and preferences by the researcher. From this exercise it could be concluded that intercropping was perceived highly positively by the farmers, and that labour, grain production, and residue production for cattle feeding (in that order) were the most important factors in evaluating different cropping systems.

Introduction of Melkassa-II, mainly through the use of demonstration plots, has been successful in the Adami Tulu region, as many farmers were now using this variety for its high production and drought tolerance. Intercropping was not practiced much. Based on the intercropping trial, intercropping maize with a legume can provide additional legume biomass without compromising maize yield. Based on interviews and the scenario exercise, this was also the perception of most farmers. The projected Land Equivalent Ratio was 1.63. Projected Labour Equivalent Ratio (similar to the Land Equivalent Ratio, but using output per unit of labour instead of per unit of land) was 1.56. Farmers were enthusiastic about the technology mainly as a consequence of exploratory trials and related SIMLESA activities such as trainings and field days. Residue retention, though evaluated positively by the farmers on the field level, was hardly practiced because lack of grazing land forced farmers to use their residues for fodder. Cattle is important to the farmers mainly for dairy production and ploughing capacity. Ploughing could be reduced through adoption of minimum tillage. However, most farmers are reluctant to plough their land less than three or four times as the belief in the benefits of ploughing is deeply rooted. With that, lack of minimum tillage seeding equipment poses constraints in adoption of the technology. Both residue retention and minimum tillage will not reach their potential benefits when adopted in isolation of each other as they are part of the intangible conservation agriculture package. Adoption will comprise complex changes at the system level, as the livestock component will be affected as much as the crop component. SIMLESA activities proved to be insufficient in disseminating residue retention and minimum tillage as these did not allow evaluation of the technologies beyond field level.

The importance of farmer participation in the process of technology dissemination increases with complexity of the technology. Simple technologies, such as introduction of Melkassa-II, require little more than demonstration plots to enable farmers to evaluate the technology, which has proven to be effective on field scale research trials. More complex technologies, such as intercropping, require a higher level of farmer participation. Exploratory trials, interviews and scenario exercises may increase understanding of the technology and its implications for both farmers and researchers, enabling researchers to develop the technology in the way most suitable for the farmers. In the case

of technologies which will induce system-wide changes, such as residue retention and minimum tillage, a high degree of farmer participation will enable farmers to better understand associated costs and benefits. However, both exploratory trials and scenario exercises will not allow the farmers to experience these changes, and the change of mind set that is necessary to accept the technologies might be too large to allow for large scale adoption of the technology.

# Contents

# 1 Introduction

## 1.1 Context

The first of the Millennium Development Goals, which were set in 2000 and are to be met in 2015, is 'To eradicate extreme poverty and hunger' (UN 2007). However, in developing countries alone, currently about 850 million people are still undernourished (FAO et al. 2012). The situation is worst in sub Saharan Africa (Figure 1), which in 2007 was not on track for reaching any of the eight Millennium Development Goals (UN 2007). Although the number of extremely poor people has levelled off, the number of food insecure people continues to rise (Gowing and Palmer 2008). Agriculture is seen as a major key to poverty reduction (de Janvry and Sadoulet 2002; Gabre-Madhin and Haggblade 2004; Alene and Coulibaly 2009; Jayne et al. 2010; Giller et al. 2011; FAO et al. 2012). Most African farmers are smallholder subsistence farmers, depending entirely or largely on their own cereal production for their food security (Tsubo et al. 2003; Marongwe et al. 2011; Johansen et al. 2012). Hence, targeting smallholder farmers is crucial in eradicating poverty and hunger, especially in sub Saharan Africa (Alene and Coulibaly 2009; Giller et al. 2011; FAO et al. 2012). Sub Saharan Africa has been largely untouched by the Green Revolution which has boosted agricultural production in other parts of the world (de Janvry and Sadoulet 2002; Gowing and Palmer 2008; Jayne et al. 2010). The lack of appropriate technology is among the reasons mostly cited to limit achieving agricultural development (Lal 1995). Hence, the development and spread of technologies suitable for smallholders in developing countries is high on the agricultural research agenda of both donors and policymakers from developed countries (Alene and Coulibaly 2009; Jayne et al. 2010; Ralevic et al. 2010).

**Figure 1: Map of Africa, with sub Saharan Africa in dark grey and Ethiopia in black (adapted from (Wikimedia 2012)).**

## 1.2 CA

### 1.2.1 History

Conservation agriculture (CA) is an agricultural technology that aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations (FAO 2012). For centuries, agriculture has emphasised the need of a clean, ploughed seed bed (Erenstein 2002; Thierfelder and Wall 2011). However, soil erosion issues led to the uptake of direct seeding or zero-tillage instead of conventional tillage in the 1970s, mainly in the Americas (Farooq et al. 2011; Lestrelin et al. 2011). Further research to improve these practices has led to the development of CA, which has been adopted on large scale especially in South America (Giller et al.

2009; Kassam et al. 2009; Farooq et al. 2011; Lestrelin et al. 2011; Johansen et al. 2012). Adoption in sub Saharan Africa, on the other hand, has remained low, especially among smallholder farmers (Kassam et al. 2009; Farooq et al. 2011; Johansen et al. 2012; Valbuena et al. 2012).

### 1.2.2 **Costs and benefits of CA**

Conventional tillage, which farmers have practiced throughout the world for centuries, is centred around the plough. Ploughing is believed to be necessary for maximum crop production mainly through weed control, soil loosening for plant growth, moisture conservation and nutrient availability (Temesgen et al. 2008; Farooq et al. 2011; Thierfelder and Wall 2011; Johansen et al. 2012). However, repeated ploughing also induces soil erosion, may decrease soil organic matter (SOM) content and nutrient availability, cause the formation of plough pans impeding water infiltration and root penetration, reducing soil water holding and inducing run-off (Ogle et al. 2005; Montgomery 2007; Thierfelder and Wall 2009). Conservation tillage is seen as a way to alleviate these problems (Temesgen et al. 2012). The three principles of CA are minimal soil disturbance, permanent soil cover and crop rotations (FAO 2012), and it is the combination of these principles that allows for sustainable crop productivity (Erenstein 2002; Thierfelder and Wall 2011; Mrabet et al. 2012; Valbuena et al. 2012). Decreasing tillage minimises soil disturbance, which decreases erosion but only when it is combined with permanent soil cover (mainly through residue retention) (Erenstein 2002; Lal 2007; Baudron et al. 2012). SOM content and soil fertility may increase through application of adequate amounts of mulch, but will only have positive effects on crop production if oxidation is decelerated by minimising soil disturbance (Rockström and Falkenmark 2000; Thierfelder and Wall 2011; Baudron et al. 2012). Nutrient availability may be hampered by nutrient immobilisation due to an initial increase in C:N ratio of the SOM as a result of mulch application, however, this will no longer be the case once an equilibrium is reached between immobilisation and mineralisation (Giller et al. 2009; Thierfelder and Wall 2011). Nutrient availability will also be enhanced by crop rotations and/or intercropping, especially in the case of N fixating legumes (Rockström and Falkenmark 2000; Mucheru-Muna et al. 2010; Baudron et al. 2012). Furthermore, water losses are addressed through increased infiltration and reduction of water evaporation as a result of minimal soil disturbance and permanent ground cover (Rockström and Falkenmark 2000; Erenstein 2002; Thierfelder and Wall 2011; Baudron et al. 2012). A major problem of CA is increased abundance of weeds (Erenstein 2002; Giller et al. 2009; Farooq et al. 2011; Thierfelder and Wall 2011; Baudron et al. 2012; Johansen et al. 2012). Herbicide treatment may be required, especially in initial years (Lal 2007; Giller et al. 2009; Farooq et al. 2011), although it is also argued that low soil disturbance, crop rotation and soil cover (through closed canopy as a result of intercropping and through mulching) may reduce weed germination and growth (Friedrich 2005; Farooq et al. 2011; Baudron et al. 2012).

Some benefits and constraints go beyond the field level. Increased weed abundance will increase the need of herbicides and/or labour demand for manual weeding (Thierfelder and Wall 2011; Baudron et al. 2012). On the other hand, labour requirement is reduced through minimising ploughing (Baudron et al. 2012; Johansen et al. 2012; Mrabet et al. 2012). Productivity may both increase and stabilise under CA (Rockström and Falkenmark 2000; Sileshi et al. 2008; Rockström et al. 2009; Mrabet et al. 2012). Adding an intercrop to the system can increase labour and land use efficiency as it can increase overall production without a proportionate increase in labour and land demand (Willey 1990; Baudron et al. 2012). Grain legumes can provide direct additional economic yield for food and sale (Tsubo et al. 2005b; Giller et al. 2009).

### 1.2.3 **Constraints to adoption of CA in sub Saharan Africa**

Adoption (from 'To adopt': *to choose and follow (a plan, technique, etc*)(Collins 2009)) of CA has been high among different types of farmers under different agro-ecological circumstances in many parts of the world (Kassam et al. 2009; Lestrelin et al. 2011; Johansen et al. 2012). Adoption in sub Saharan Africa, on the other hand, has remained low, especially among smallholder farmers (Kassam et al. 2009; Farooq et al. 2011; Johansen et al. 2012; Valbuena et al. 2012), even though in theory, CA is well-suited for these resource-constrained farmers because many live in drought-prone areas and the moisture conservation aspects of this technology are well-established (Farooq et al. 2011). This non-adoption can partly be attributed to some of the costs and constraints as mentioned above, which may be more problematic for smallholder subsistence farmers in sub Saharan Africa. Herbicides may not be widely available and unaffordable (Lal 2007; Johansen et al. 2012). Labour constraints are generally high (Giller et al. 2009; Lestrelin et al. 2011; Johansen et al. 2012). Also, CA requires specialised equipment for sowing, which may not be available (Ekboir 2002; Lal 2007; Marongwe et al. 2011; Johansen et al. 2012). Under some circumstances, it may take up to 10 years before the benefits of CA are truly reached (Lal 2007; Farooq et al. 2011; Giller et al. 2011). Hence, during initial years, CA may result in lower yields compared to conventional tillage, which is an offset smallholder subsistence farmers cannot afford (Gabre-Madhin and Haggblade 2004; Lal 2007; Marongwe et al. 2011; FAO et al. 2012; Johansen et al. 2012). Also, the three components of CA are a package deal, as benefits are maximised and can sometimes not even be reached without adoption of the complete package. If farmers are not willing or able to adopt either of the components, the technology may not reach its potential (Erenstein 2002; Gowing and Palmer 2008). Residue retention is crucial (Lal 2007). However, in mixed crop-livestock systems under increasing (grazing) land pressure, competition for residue use as fodder is high (Valbuena et al. 2012). Livestock provide dairy, manure and traction, and serve as a saving option and a source of cash income (Ralevic et al. 2010; Valbuena et al. 2012). Traction capacity of oxen is used mainly for ploughing, which is currently still considered to be a crucial agronomic activity, a mind-set which is deeply rooted and hard to change (Erenstein 2002; Aune et al. 2006; Thierfelder and Wall 2011). Hence, adopting CA requires radical changes in many farm operations and a shift in the farm management paradigm in sub Saharan Africa (Gowing and Palmer 2008; Giller et al. 2011).

Despite these constraints, CA is still considered to offer great potential benefits, and many international organisations are promoting CA with smallholder farmers in Africa in the name of development, to reduce hunger and poverty (Giller et al. 2009; Giller et al. 2011).

## 1.3 **Development**

The term development may refer to a vision or description of a desirable state of being, to the historical process of development as it transforms societies, or to the 'act' of development (Thomas 2000a). The simplest definition of development is 'good change' (Chambers 2004), hence, the latter of the three uses of the term refers to bringing about these good changes, or deliberate efforts aimed at improvement (Hewitt 2000), which is the subject of the following sections.

### 1.3.1 **Era of development**

Development has become an important concept especially in the years after the second World War (Allen and Thomas 2000). The beginning of the so-called Era of Development has been traced to

President Truman's inaugural address, in which he states that 'we must embark on a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas' (Truman 1949; Thomas 2000b). Ideas of development were largely drawn from modernisation theory, a model of economic and social development that explains global inequality in terms of differing levels of technological development among societies (Macionis and Plummer 2002). The rich, modern nations (most notable in North America and Europe) can assist in the development of other nations (such as those in sub Saharan Africa), for instance through technology transfers that increase food production (Macionis and Plummer 2002). This development is based on the concept of trusteeship, in which "one agency is 'entrusted' with acting on behalf of another, in this case to try to ensure the 'development' of the other" (Thomas 2000a). This approach to development is inherently top-down, and technical changes which are considered to be beneficial to development are transferred linearly from researcher to farmer (in the case of agricultural technologies) (Ekboir 2002).

### 1.3.2 **Post-development era**

In the 1980s, however, critique to this approach to development was growing as many came to the conclusion that international development had failed in alleviating poverty (Escobar 1995; Kothari 2005). Dissatisfaction was so large that some argued that it was necessary to find not just an alternative form of development, but alternatives to development as a whole (Escobar 1995; Kothari 2005). Instead of explaining the global inequality with the modernisation theory, it was explained with the dependency theory, stating that global inequality is the consequence of the historical exploitation of poor societies by rich ones (Macionis and Plummer 2002). Development of the poor societies should not come from the rich societies, but should come within. People should be the agents of their own development through empowerment and the use of social capital ('the ability of people to work together for common purposes in groups and organisations' (Coleman 1988)) (Escobar 1995; Thomas 2000a). Social movements were to be the new agents of development (Escobar 1995) in the new post-development era. However, the radical transformations social movements had in mind had mostly to do with social justice and fighting for rights, for instance to land, democracy and citizenship (Hickey and Mohan 2005).

### 1.3.3 **Participatory approaches to development**

The dissatisfaction from the 1980s also gave rise to the emergence of so-called participatory approaches to development, aiming at including the beneficiaries in the process of development (Hickey and Mohan 2005; Kothari 2005). Participation in development can be defined as "a process of equitable and active involvement of all stakeholders in the formulation of development policies and strategies and in the analysis, planning, implementation, monitoring and evaluation of development activities" (FAO 2013). 'Empowerment' and 'transformation', key aspects of social movements, are still advocated in this approach (Hickey and Mohan 2005), however, participation is more an alternative form *of* development than an alternative *to* development, as are the social movements. It is a methodology. Participatory methods can be used at any stage of development interventions (Hickey and Mohan 2005). Argued benefits of a participatory rather than a linear approach to development are "increased mobilization of stakeholder ownership of policies and projects; greater efficiency, understanding and social cohesion; more cost-effective services; greater transparency and accountability; increased empowering of the poor and disadvantaged; and

strengthening capacity of people to learn and act", hence making development projects more effective (Pretty 1995).
The use of participatory approaches has also gained ground in agricultural research (Bentley 1994), and programs concerned with the spread of CA in sub Saharan Africa are no exception. Due to the complexity of the technology and its implications for the farmers, it is increasingly recognised that the traditional top-down approach in agricultural research and extension may not be suitable and that a thorough understanding of smallholders' contexts and constraints, but also aspirations and preferences, is needed (Ekboir 2002).
SIMLESA (Sustainable intensification of maize-legume cropping systems for food security in eastern and southern Africa) is one such program, which has started in five countries in sub Saharan Africa in 2010 (SIMLESA 2011). The program is aiming at "increasing household and regional food security and income, and contributing to economic development by improving the productivity of maize-legume based farming systems" (SIMLESA 2011). Cropping systems are to be developed which are "productive, resilient and sustainable" for smallholders, based on the concept of conservation agriculture and using participatory approaches (Dixon 2009; SIMLESA 2011). Farmer participation is largely based on establishing exploratory on-farm research trials in collaboration with the farmers, and encouraging them to visit trainings, demos, field days, discussion groups, and farmer visits organised through the project (Dixon 2009). For the SIMLESA objectives, please refer to Appendix I.

## 1.4 **Decision making**

The goal of projects such as SIMLESA is the adoption of certain agricultural technologies by farmers. To let farmers adopt any new technology, their decision making will have to be influenced. So: How do they make decisions?
Human decision making is a complicated process, depending on many diverse factors (Keeney and Raiffa 1993). An obvious factor is the objective that the person in question has (Öhlmér et al. 1998). What is he/she trying to achieve? In a decision, multiple options are available which all meet the objective to a certain extent. The person in question wants to choose the option that best meets his/her objective without compromising other objectives (Keeney and Raiffa 1993). Identification of the available options is the first step in the decision making process (Öhlmér et al. 1998). Already in this first step, the person might miss out on the option that by an objective outsider is considered to be best. This might happen because he/she has not heard about them or has no access to them.
The next step is the evaluation of the different options (Öhlmér et al. 1998). Several criteria are taken into account. The person identifies the benefits of the different options, and weighs them against their costs. He/she also takes into consideration the constraints and risks associated with the options (Heong and Escalada 1999). Benefits and costs encompass more than easily comparable monetary factors. Even if certain components of the option are expressable in market price, this market price may not reflect the value the person would attach to that component. The perception of benefits also depends on the person's preferences, whether these are rational or not. Opinions of others and cultural standards, norms and values also influence the persons evaluation of the options (Heong and Escalada 1999). Many of the decision criteria are based on the person's personality, circumstances and perception of reality (Solano et al. 2006). For instance, whether the person is open to trying new things or is more conservative, looking more at short term or at long term effects, and the financial margins within which the person can operate. All these criteria will be weighed against each other, consciously or subconsciously, to reach the decision (Keeney and Raiffa 1993). Weighing of the

criteria includes two aspects: the value that is attributed to the criterion itself (that is, how important is this criterion to this person) and the value that is attributed to the criterion for the particular option (that is, what is the 'score', either positive or negative, of this criterion in this option according to this person) (partly based on Keeney and Raiffa (1993)).
The 'value' of each option can thus be described as:

$$V_A = \sum_{i=1}^{n} S_{A,i} K_i$$

In which:

V = the total value that is assigned to a particular option A, B, C, etc.
i = criterion
S = the score for a particular criterion of a particular option by this particular person
K = the importance of a particular criterion to this particular person

While K will normally remain equal to a particular person for a particular criterion in each option, S will be different between the different options.
In the end, the option which receives the highest score will be chosen. However, people don't usually make their decision this rationally, based on filling in a well-considered formula. Also, usually there are no units readily available to fill in this formula. In simple value problems, the outcome can be described using one unit, such as monetary value. However, many decisions in real life are complex value problems (Keeney and Raiffa 1993). Units would always be artificial and the value outcomes would only be usable relative to each other. Hence, this formula should be seen as a guideline to understand what a decision is based on, not as an actual mathematic formula to calculate what someone's decision will be.
As every individual decision will be based not only on well-established scientific statistics but on own assumptions, experiences, expectations, perceptions, estimations, and guesses, depending on knowledge, expertise, experience and personality, someone else might come to a different decision as to what the best option will be. To influence someone's decision making process, one will have to find a way to increase the value that is assigned to a certain option by that person. This can be done by influencing the way they 'fill in' the formula, whether they do this consciously or not.

## 1.5 Research aim and objectives

Although CA is widely advocated in sub Saharan Africa, it is often not clear which factors affect suitability and adoption of (components of) CA (Farooq et al. 2011; Giller et al. 2011; Johansen et al. 2012). Both aspects should be taken into account when designing agricultural development projects such as the SIMLESA project. If a new technology seems to be suitable, a strategy needs to be designed in order to influence farmer decision making and convince farmers to adopt this technology while taking into account farmer objectives, preferences and constraints (Giller et al. 2009; Johansen et al. 2012). A higher degree of farmer participation in both technology evaluation and disemination strategy development is often advocated to advance adoption, but methods to be used are often lacking and disputed (Bentley 1994; Kapoor 2002; Giller et al. 2009; Giller et al. 2011; Mrabet et al. 2012).

In this research project, CA-based and related agronomic technologies and their dissemination in the Rift Valley in Ethiopia are being evaluated in order to identify which methods are suitable to advance adoption for which technologies. The Rift Valley in Ethiopia is a drought prone area where about 80% of the people are dependent on their own small scale agricultural production for food and income (Alemu et al. 2008). Agricultural development of this area is high on the agenda of both the national government and international development organisations and research (Girma et al. 2005; Alemu et al. 2008). One current agricultural development research project is the SIMLESA project, on which part of this research is based.

The main research question is:
What (combination of) methods are suitable for evaluation and disemination strategy development of agricultural technologies?

The agronomic technologies under research are:

- Minimum tillage
- Residue retention
- Maize-legume intercropping
- Maize variety Melkassa-II (first released in 2004)

The objectives are:
A: Situation analysis

1 To characterise the agricultural production systems and technologies that are currently in use in the research area
2 To explain why farmers have chosen for the current agricultural production systems and technologies

B: Intercropping and residue retention analysis

3 To analyse the potential effects of intercropping maize with legumes and maize residue retention on production of crop grains and residues compared to sole cropping of maize

C: Integration of findings

4 To examine ways to quantify and compare the identified trade-offs important in farmer decision making associated with the technologies
5 To evaluate whether and under what conditions the technologies would be a realistic option for smallholder farmers
6 To identify which (research) methods are appropriate for dissemination of these and other technologies.

# 2 Materials and methods

## 2.1 Linkage with SIMLESA

The field trials undertaken at the Melkassa Agricultural Research Center (paragraph 2.2) were part of a project from IFAD, co-funded through the SIMLESA project, entitled 'Enhancing total farm productivity in smallholder conservation agriculture based systems in eastern Africa' (IFAD 2010). The trials aimed to provide data in order to evaluate benefits of different amounts of ground cover and intercropping for on-farm use.

The interviews were performed in a SIMLESA target community. In the community, five farmers were hosting on-farm exploratory trials as part of SIMLESA objective 2 (Appendix I), in which each farmer managed four plots. The four treatments on the plots were sole maize with CA practice (minimum tillage and residue retention), maize bean intercropping with CA, bean-maize rotation with CA and farmers practice (sole maize with conventional practice, that is, 3-4 times ploughing with all residues removed). Hence, farmers in the area were aware of these practices, and had often attended trainings, received information from local DA's (development agents), visited the plots and attended field days (SIMLESA objective 2, Appendix I).

The author of this thesis has also attended field days, project review meetings and other activities related to SIMLESA. Personal communication and observations related to these activities have been used in writing this thesis.

## 2.2 Field trials

Two field trials were executed, one on maize-cowpea intercropping and one on residue retention. These trials served mainly for data collection to achieve objective B (Intercropping and residue retention analysis) which could be used as input for achieving objective C (Integration of findings) (paragraph 1.5).

### 2.2.1 Site description

Field trials were conducted at the Melkassa Agricultural Research Center (MARC), near the city of Adama in the Ethiopian Rift Valley. The center is located at 8°24'N latitude and 39°21'E longitude, and at an altitude of 1,550 meters (MARC 2008) (Figure 2).

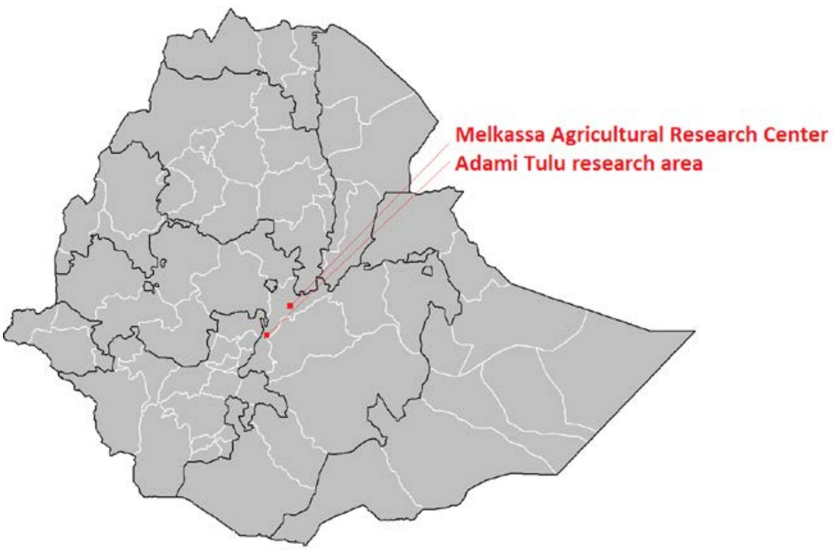


**Figure 2: Map of Ethiopia, indicating research locations (adapted from (Mapsof.net 2012)).**

The dominant soil type of the center is Andosol of volcanic origin with a pH ranging from 7 to 8.2. The textural class of the soil is loam except in a few places with sandy clay loam and silt loam. Mean annual rainfall is 796 mm, with most rain (530 mm) falling in the rainy season from June to October (MARC 2008). The rainy season started relatively late in 2012 (Figure 3). There was some substantial rainfall early May (18.3 mm in three days), followed by some rain at the end of June (with a total of 22.4 mm), but the actual season started in July (with 62.0 mm of rain on the third of July). Rain started to abate again in September, so that the rainy season was short. However, during this period cumulative rainfall was 796 mm, which is relatively high especially when considering the short duration of the season.

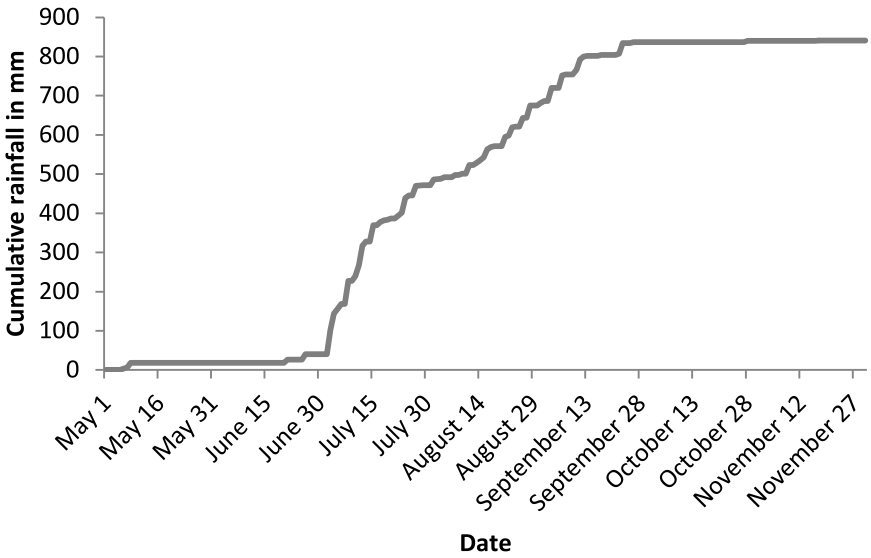


**Figure 3: Cumulative rainfall in mm at Melkassa Agricultural Research Station starting from May 1, 2012 to November 31, 2012 (NMA 2012b).**

### 2.2.2 Intercropping trial

In the intercropping trial, five different cropping schemes were tested (Figure 4).

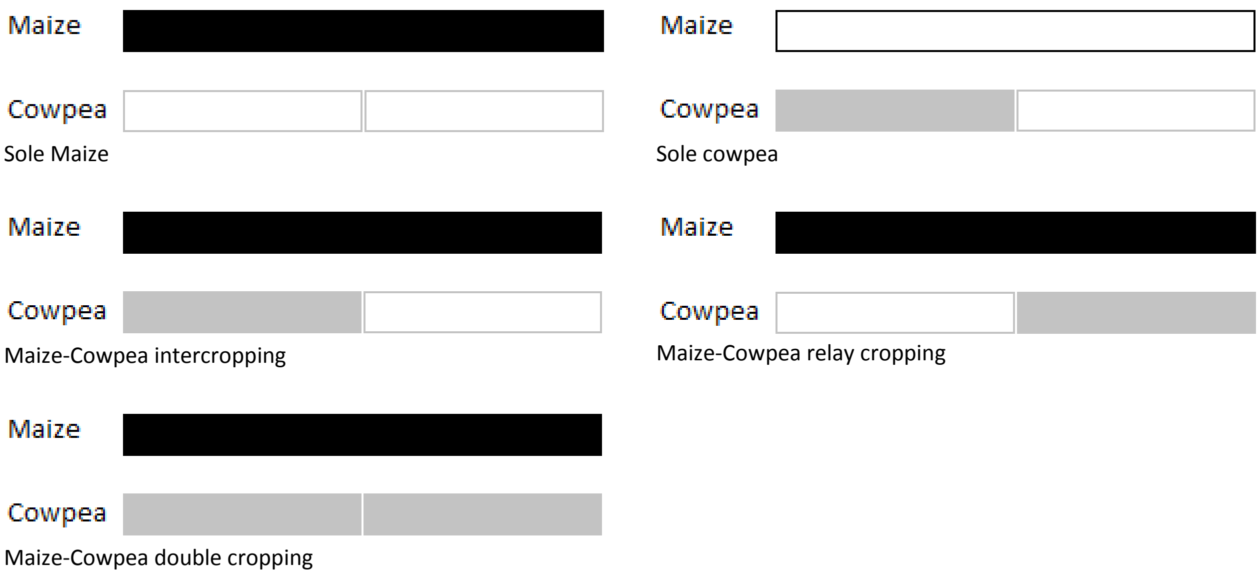


**Figure 4: The five different cropping schemes of the intercropping trial. Bars represent which crop(s) is/are grown throughout the duration of the cropping season.**

Four different varieties of cowpea (*Vigna unguiculata*) were used and one variety of maize (*Zea mays* L.), resulting in 4*4+1=17 different treatments. Treatments were tested in a randomised complete block design in three blocks. All 51 plots were 4 m*4 m=16 $m^2$. Cowpea varieties were IT98K-205-8 (a short season variety), ILRI 9334, ILRI 12688 and ILRI 12713. Cowpea was harvested at 50% flowering in order to establish total biomass production, assuming use as fodder. The maize variety used was Melkassa-II (a medium duration, drought stress tolerant, open pollinated variety). Maize was planted at a distance of 75 cm between rows and 25 cm between plants in a row (53,333 plants per hectare). Sole cowpea was planted at a distance of 60 cm between rows and 10 cm between plants in a row (166,666 plants per hectare). Intercropped cowpea was planted additively in between the maize rows, hence with a distance of 75 cm between cowpea rows, and 10 cm between plants in a row (133,333 plants per hectare). Planting date was June 28, 2012 for maize and first planting of cowpea. The second planting of cowpea (for double cropping and relay cropping) was done per variety after harvest of the first crop, except for variety ILRI 9334 which was planted two days after the first harvest. A ripped line was made for sowing, no other land preparation was done. All cowpea haulm was removed from the field upon harvesting. Basal fertilization at first planting was 100 kg/ha DAP and 25 kg/ha urea for all treatments. Top dressing, when maize was about knee-height, was 25 kg/ha urea for all treatments except sole cowpea. Weeding was done manually four times during the trial. Cowpea was harvested per variety at approximately 50% flowering. The stage was judged visually. Per plot, 15 plants from the inner rows were randomly harvested (cut at ground level) and weighed immediately (in kg, one decimal). Of these plants, a sample was taken. Then, all plants were harvested. Total number of plants was counted (by counting stubs), excluding the plants in the outer rows.

Samples were taken back to the lab, and subsamples of about 500-600 grams, consisting as much as possible of whole plants, were immediately weighed accurately (to the gram). The samples were first air dried in paper bags and subsequently oven dried for 48 hours at 70$^o$C and weighed.

Weight for the inner rows was calculated according to [#plants inner rows/15*dry weight 15 plants]. Dry weight was calculated by using the dry matter content of the samples. From this, biomass per ha was calculated.

The relay cowpea was harvested at maize harvest. Many plants suffered damage from animals. For each plot, all plants still intact were taken as a sample and fresh weight was measured. From this and the total number of plants per plot (including damaged), the total potential dry biomass without animal damage of the plot was calculated. To calculate dry weight, the average dry matter content as established for the first cowpea harvests was used.

Maize was harvested when it reached maturity. For each plot, the number of plants in the inner rows was counted. Of these, 15 intact plants were randomly selected and harvested at ground level. These 15 plants were immediately weighed (in kg, to one decimal), after which they were separated into cobs and residue, both of which were weighed. All cobs of the 15 plants were counted and collected. For residue samples, three plants were selected and separated into tassel, leaf blade, leaf sheath and stem. These fractions were put into paper bags and weighed (in grams, to one decimal). Further treatment and calculations of the thus collected samples were as described above for the cowpea samples. For maize grain weight, calculations were based on the fresh grain weight of the 15 cobs and the dry matter content of a subsample of these grains. For residue weight, calculations were based on the fresh residue weight of the plants in the inner rows as weighed in the field and the dry matter content of all residue subsamples of the three plants taken together.

As described above, the intercropping trial consisted of five different cropping schemes. However, as described in paragraph 3.1, the relay cowpea biomass was very low. The relay cowpea was considered to have failed, and could not have influenced the results of the trial. Hence, cropping schemes that included the relay cowpea were combined with the same cropping schemes that did not include the relay cowpea. The resulting cropping schemes were maize sole cropping (consisting of the former maize sole cropping and the former maize-cowpea relay cropping), maize-cowpea intercropping (consisting of the former maize-cowpea intercropping and the former maize-cowpea double cropping) and sole cowpea.

The definition of Land Equivalent Ratio (LER) used is

$$LER = \frac{Yai}{Yas} + \frac{Ybi}{Ybs}$$

In which:

Yai = mean yield of crop a in intercropping
Yas = mean yield of crop a in sole cropping
Ybi = mean yield of crop b in intercropping
Ybs = mean yield of crop b in sole cropping

Traditionally, 'yield' is the grain yield. However, yield could also be defined more broadly, taking into account other components of the crop. In this trial, of cowpea only the stover biomass production was used, as cowpea is harvested prior to grain formation (assuming use as fodder). Of maize, maize grain production, maize stover production, and total biomass production were used. Hence, three different LERs were calculated.

### 2.2.3 **Residue retention trial**

The residue retention trial had been started in 2011. Hence, this was the second year of this trial. In the first year, all plots had received the same treatment apart from the use of two different maize varieties (half of the plots Melkassa-II and half of the plots Melkassa-IV). Maize was intercropped with lablab with the same spacing as described above for the intercropping trial. Planting date of maize was early June, 2011, and of lablab at the time maize reached knee-height. Basal fertiliser application was 100 kg/ha DAP and 25 kg/ha urea. Top dressing of 25 kg /ha urea was applied at planting of the lablab intercrop.
At harvest, only ears were harvested and part of the residues were retained in the field according to the different treatments per plot. There were 13 treatments in three blocks according to a randomised block design (Table 1).

**Table 1: Treatments in the residue retention trial. For treatments 1-7, maize variety Melkassa-II was used, while for treatments 8-13, Melkassa-IV was used.**

| Treatment | Amount of maize residue retained | Amount of lablab residue retained |
|---|---|---|
| 1 | 0% | 0% |
| 2, 8 | 33% | 0% |
| 3, 9 | 67% | 0% |
| 4, 10 | 100% | 0% |
| 5, 11 | 100% | 33% |
| 6, 12 | 100% | 67% |
| 7, 13 | 100% | 100% |

Amounts of residues retained on the plots were estimated from the harvest index as calculated from a subsample of 10-20 plants, the mass of ears and the total weight per plot.
Plants to be retained were left standing anchored in the plots, other plants were harvested at ground level. When 33% of the residues were to be retained, two of every three lines of plants were harvested, when 67% of the residues were to be retained, one of every three lines of plants was harvested.
In the following season (2012), the maize was planted through the mulch by opening shallow planting stations without further land preparation, with the same maize variety on each plot as in 2011. No lablab was sown. Planting distance, fertiliser application, weeding and harvesting of maize were as described above for the sole maize treatment of the intercropping trial.
Biomass production of lablab in the 2011 season was below the expected level, partly due to intermittent rainfall after the intercrop had been planted. Residues were retained on the plots according to the protocol. However, lablab decomposition was very fast, making the function of ground cover as mulch for the succeeding (2012) season highly questionable. Retained maize residues did not show this rapid decomposition.
Due to heavy rainfall in 2012, a large proportion of the plots from the residue retention trial were severely affected by waterlogging. Data of these plots were discarded.

## 2.3 Situation analysis

In order to reach objective A (paragraph 1.5), secondary data (previous surveys, national data, literature) was used. However, this data needed to be supplemented in order to obtain relevant farm level data, including information on the current production systems and agronomic practices used. Of particular importance is the aspect of farmers' perception, which is an aspect that is not usually taken into account in surveys. Hence, an interview and an exercise were designed and conducted among local farmers in order to reach this objective and as part of objective C1. Interaction with farmers also served to get more input for achievement of objective C (paragraph 1.5).

### 2.3.1 Site description

Farmer interaction took place in a SIMLESA target community in the Adami Tulu district, near Ziway town (7°56′N latitude, 38°43′E longitude 1,643 m), in the Ethiopian Rift Valley (Figure 2). In this area, maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.), wheat (*Triticum sp.* L.) and some barley (*Hordeum vulgare* L.) and teff (*Eragrostis tef* (Zucc.) Trotter) are the main crops grown. Most farmers also keep livestock in the form of cattle, goats, horses and donkeys. The area features semi-arid and arid agro-ecologies with a minimum temperature of 12.6°C and a maximum of 28.5°C (SIMLESA 2012). Average annual rainfall over the last years (2006-2011) was 855.0 mm, with rains sometimes already commencing in February but with a main rainy season from June to October (Figure 5).

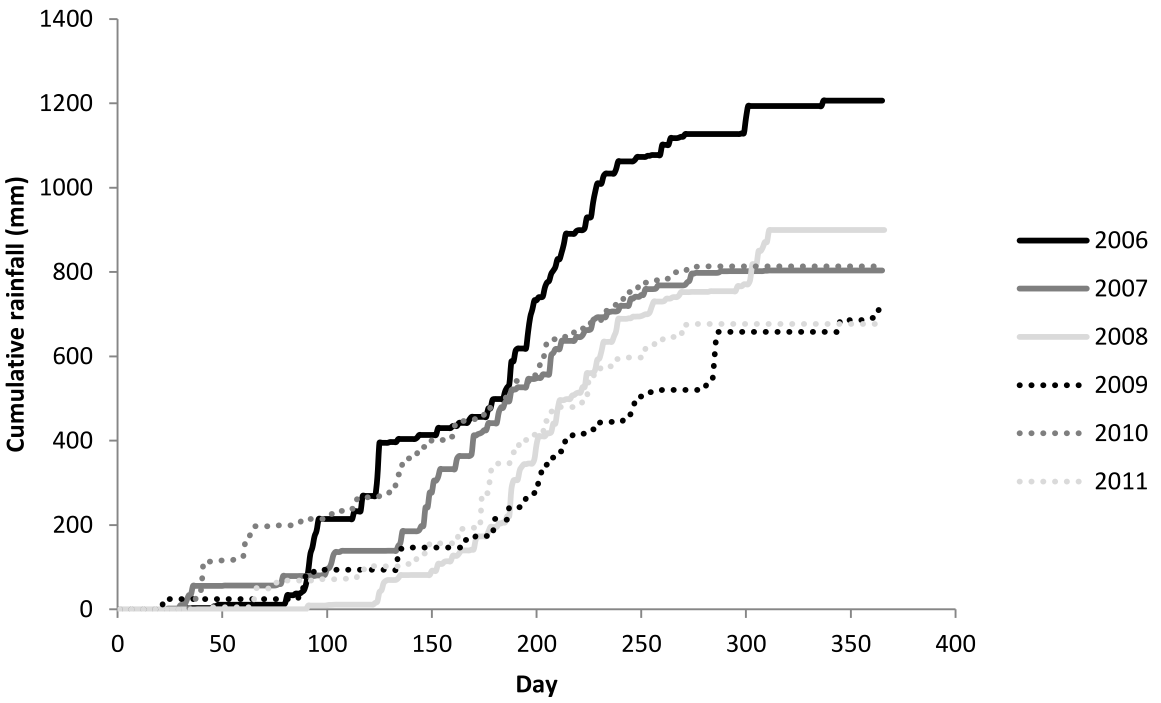


**Figure 5: Cumulative rainfall in mm in the years 2006-2011 in Adami Tulu (NMA 2012a). Day 1 is January 1.**

The soil is dominated by sandy loam to sandy clay (SIMLESA 2012).

Average maize grain yields over 2006-2010 in the Adami Tulu district vary per year between 1.6 and 2.9 tonnes per hectare (Figure 6)

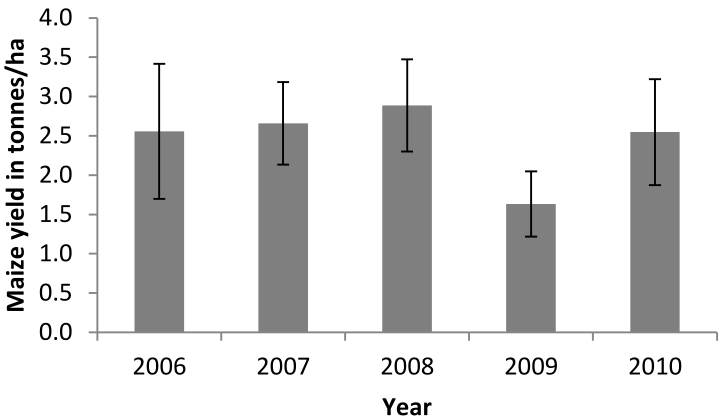


**Figure 6: Average maize grain yields per field in the Adami Tulu district for 2006-2010 (CSA 2007-2011). Error bars represent standard deviation.**

For further descriptive statistics as derived from CSA data (CSA 2007-2011) of farm characteristics of the Adami Tulu district, please refer to paragraph 3.3.

### 2.3.2 **Interactions with farmers**

Nine farmers in the area were selected who owned different numbers of oxen. Three had two or more pairs of oxen (four or more oxen, referred to as 'Type 3'), three had one pair of oxen (two or three oxen, referred to as 'Type 2') and three had no pair of oxen (no or one ox, referred to as 'Type 1') (see also Baudron et al. in press). Four of the farmers were part of the SIMLESA exploratory trials.

The first round of visits was held in October 2012, the second round of visits at the same farmers was held in November 2012. Both visits were conducted with a translator who was also involved in the SIMLESA project. Farmers were visited individually (to allow each of them to give their own opinion, which may not be the case in group discussions (Place et al. 2007)) on or very nearby their own property. Except in one case, where the interview was inside a house, visits took place whilst sitting outside on the ground, although chairs, benches or stools were often offered to the interviewer and the translator (Figure 7).


**Figure 7: Farmer interview, with interviewer and translator on chairs.**

In some cases, family members and/or neighbours were present at the visit. Family members sometimes contributed to the interview if they had knowledge about the particular agronomic practices performed on the property. Neighbours were not allowed to contribute to reduce their influence on answers (Place et al. 2007).

For detailed protocols of both interactions, please refer to Appendix II and III.

At the first visit, an interview (partly based on a SIMLESA survey (Baudron 2012)) was conducted, consisting mainly of factual questions regarding, amongst others, household and livestock composition, use of farm land, performance of agronomic activities, and income and expenditure. Farmers were also asked for the reasons why they had made certain decisions, and whether they would have wanted to do things differently if they would have had the opportunity. When applicable, questions were open-ended and the interviews were semi-structured as the purpose of the interview was to elicit the farmers' views and not the researchers (Kristjanson et al. 2002). Hence, questions were prepared beforehand, but during the interview adjustments and additions could be made to the questions.

The purpose of the design of the second round of farmer visits was to find ways to quantify aspects related to the decision making process of the farmers regarding cropping systems. As described in paragraph 1.4, a formula was established to enable the quantification of decision making:

$$V_A = \sum_{i=1}^{n} S_{A,i} K_i$$

In which:

V = the total value that is assigned to a particular option A, B, C, etc.

i = criterion

S = the score for a particular criterion of a particular option by this particular person

K = the importance of a particular criterion to this particular person

Although, as said, this formula cannot be used purely mathematically, its components give an understanding of what decisions are based on. Therefore, the formula was taken as a starting point for the design of a new exercise. Hence, in this exercise, the criteria influencing the decision (i) needed to be established, and the importance (K) and score given in each option (S) of each of these criteria by each farmer. Furthermore, the exercise needed to fit the context of interviewing farmers. The method should not be too complicated, which could confuse both the farmer and the interviewer. Questions asked should not be too abstract, as it is difficult for the target group to understand abstractions and hypothetical questions. Focus should be on realistic situations that they can easily relate to. Visual representations of different aspects that would be discussed would therefore be suitable (Pretty 1995).

From these criteria, the scenario exercise was designed (Figure 8).

Figure 8: End result of a scenario exercise.

Of three different cropping systems, scenarios were to be built and scored with and by the farmers. The three scenarios chosen by the interviewer were the most standard practice in the area (sole maize), the technology chosen to be assessed (intercropping maize with beans) and a scenario which could be regarded as a realistic alternative in between the former two by including aspects of both (i.e. half sole maize and half sole beans on separate plots of the same field). In each scenario, the total area of each field was set at one hectare. The scenarios were not pre-constructed by the interviewer any further, instead, the implications of these three scenarios were further developed step-by-step by the farmers with guidance of the interviewer. For each scenario, these implications were based on the farmers' perception of labour requirements, production of grain and residues, possibilities for residue retention and cattle feeding, and the functions of the cattle. Hence, attributes of the scenarios were not equal for all farmers, even though this would have facilitated easy comparison between the farmers (a dilemma frequently encountered in participatory exercises (Place et al. 2007)). This participatory method highly increased the farmers' ability to fully comprehend the whole scenario. Although the scenarios were abstract in principle (they did not necessarily reflect systems currently practiced by the farmer), as all attributes and their implications included in the scenario were thoroughly considered by the farmer, they were able to conceive the scenarios. With that, the scenarios were completely built by using pictures, and quantification was visualised through graphs and markers. Building of the three scenarios happened simultaneously but step-by-step, each time constructing one attribute for all three scenarios. This allowed the farmers to build the scenarios in relation to each other, starting with the scenario that they were most familiar with. This stimulated them to think in terms of 'more' or 'less' and 'better' or 'worse', which would be helpful in the allocation of values to the different attributes of each scenario. After completion of the scenario building, subsequent scenario evaluation by the farmers allowed them to first state their preference between the scenarios and then indicate which attributes (eg labour requirement, maize grain production, or dairy production) of each scenario they valued most or least. The preference between the scenarios was indicated by dividing fifteen coins between the scenarios. Subsequently, the number of coins determined the number of green and red matches that were to be distributed over the different attributes of each scenario. Green matches indicated positive scoring while red matches indicated negative scoring to the attributes of the scenarios. In designing the scenario exercise, the idea of giving the farmers a very large number of matches to be allocated between all attributes of all three scenarios has passed the review. This idea, however, was discarded as allocating such a large number of matches over so many attributes would become overly complicated. The solution found was, as explained above, to first let the farmers allocate a limited number of coins between the scenarios, and then base the number of matches for each scenario on the amount of coins it received.

Through using farmer projections of labour requirements and production in the scenario exercise, an alternative LER was calculated: the Labour Equivalent Ratio. The definition of the Labour ER is similar to that of the Land ER (paragraph 2.2.2), but 'Yield' in the equation is now not defined as production per unit of land but as production per unit of labour (paragraph 4.1.2).

## 2.4 **Statistical analysis**

All statistical analyses were done using IBM SPSS Statistics 20.0. Data were tested for normality, equal variances and homogeneity. One-way ANOVA and independent and paired samples t-tests were used for data analysis if prior conditions were met. Otherwise other variants of these tests were used (eg independent samples t-test without assuming equal variances), this is stated when applicable. Results are considered to be significant when $p<0.05$ unless stated otherwise. All tests performed in this research, including their results, are represented in Appendix IV-VIII.

# 3 Results

## 3.1 Intercropping trial

### 3.1.1 Relay cowpea

The relay cowpea biomass at harvest was negligible in both the relay cowpea treatment and the double cropping treatment. The average biomass of the relay cowpea was 6.5 kilograms per hectare with a standard deviation of 10.1 kilograms per hectare.
There were no significant differences in maize grain yield nor in maize stover yield when comparing sole cropping with relay cropping and when comparing intercropping with double cropping (Appendix IV). Results of these treatments were combined for further analysis as explained in paragraph 2.2.2.

### 3.1.2 Cowpea varieties

The time that the first round of cowpea plants reached 50% flowering, and hence time of the first biomass cut, was different for the different varieties. IT98K-205-8 and ILRI 12688 were harvested 74 days after sowing (DAS), ILRI 12713 was harvested 77 DAS while ILRI 9334 was harvested 90 DAS. Although the different varieties produced different amounts of biomass in sole cropping, these differences were not significant (Appendix IV).
When intercropped, differences between cowpea varieties in cowpea biomass, maize grain yield and maize stover biomass were all insignificant (Appendix IV).

### 3.1.3 Cowpea biomass production: sole cropping vs. intercropping

Cowpea biomass production was significantly higher in sole cropping than in intercropping, with an average of 1930 kg/ha in sole cropping and an average of 942 kg/ha in intercropping (Appendix IV, Figure 9).

### 3.1.4 Maize yields: sole cropping vs. intercropping

Maize grain and stover yields did not differ significantly between sole cropping and intercropping (Appendix IV), even though they are somewhat higher in the former than in the latter treatment (Figure 9). Harvest index also did not differ significantly between the two treatments (Appendix IV). Harvest index is 0.43 for sole maize and 0.42 for intercropping.

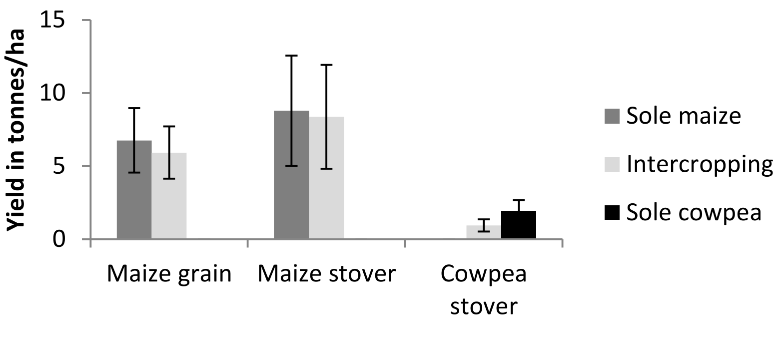


**Figure 9: Comparison of maize grain, maize stover and cowpea stover yield in tonnes (1000 kg) per hectare between sole cropping of either crop and maize-cowpea intercropping. Error bars represent standard deviation.**

### 3.1.5 **Biomass partitioning in maize stover**

There were no significant differences in biomass partitioning within maize stover between sole cropping and intercropping. That is, the weight proportions of stem, sheath, blade and tassel were similar across the cropping schemes, with stem comprising the largest proportion of biomass (Appendix IV, Figure 10).

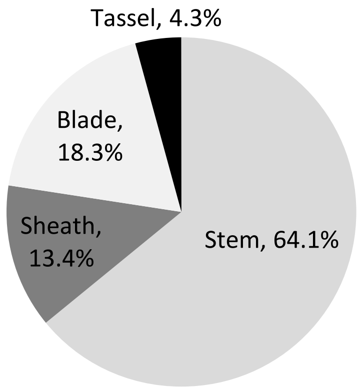


**Figure 10: Biomass distribution in maize, in percentages of total stover biomass.**

### 3.1.6 **Land Equivalent Ratio**

Land Equivalent Ratio (LER) is highest when only taking into account production of maize stover and cowpea stover, and lowest when taking into account production of maize grain and cowpea stover (Table 2).

**Table 2: Land Equivalent Ratios (LERs) when taking into account production of different crop components.**

| Maize | Cowpea | LER |
|---|---|---|
| **Grain** | **Stover** | **1.37** |
| **Stover** | **Stover** | **1.44** |
| **Grain and stover** | **Stover** | **1.41** |

## 3.2 **Residue retention trial**

A large proportion of the plots of the residue retention trial was severely affected by waterlogging (Figure 11). Data of all plots that upon visual judgement were considered to be affected by waterlogging were discarded. As a result, too little plots remained to allow for useful analysis of the variables for any of the factors under consideration.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 13 | 12 | 11 | 10 | 7 | 8 | 6 | 9 | 5 | 4 | 3 | 2 | 1 |
| 6 | 5 | 7 | 8 | 2 | 1 | 3 | 4 | 13 | 9 | 12 | 10 | 11 |

**Figure 11: Residue retention trial plot layout. Numbers represent treatments (Table 1). Waterlogged plots are shaded.**

## 3.3 **CSA data Adami Tulu 2006-2010**

Of farmers using chemical fertiliser (Table 3), 88% use DAP, 11% use urea, and 1% use both. Average fertiliser application for those who use chemical fertiliser is 74.5 kg/ha. Some farmers (2% of fields) use both chemical and natural fertiliser. Fertiliser is used relatively more often on private land than on rented or leased land. However, when fertiliser is used, chemical fertiliser is more often applied to rented or leased land, while manure is more often used on private land (CSA data (CSA 2007-2011), data not shown).
Only 11% of maize fields are intercropped (Table 3). It is unknown whether this is with legume crops.

**Table 3: Information about farming in the Adami Tulu district. Numbers represent percentage of maize fields (CSA data (CSA 2007-2011), years 2006-2010, N=821).**

| | Yes | No |
|---|---|---|
| Household head male | 73% | 27% |
| Privately owned | 85% | 15% |
| Involved in extension program | 11% | 89% |
| Improved seeds | 4% | 96% |
| Soil erosion | 35% | 65% |
| Irrigation | 0% | 100% |
| Manure | 34% | 66% |
| Chemical fertiliser | 10% | 90% |
| Intercropping | 11% | 89% |

Each year, farmers have been asked whether they experienced damage on their fields. On average, over two thirds of the fields were reported to suffer from damage, with year-to-year fluctuations (Figure 12).

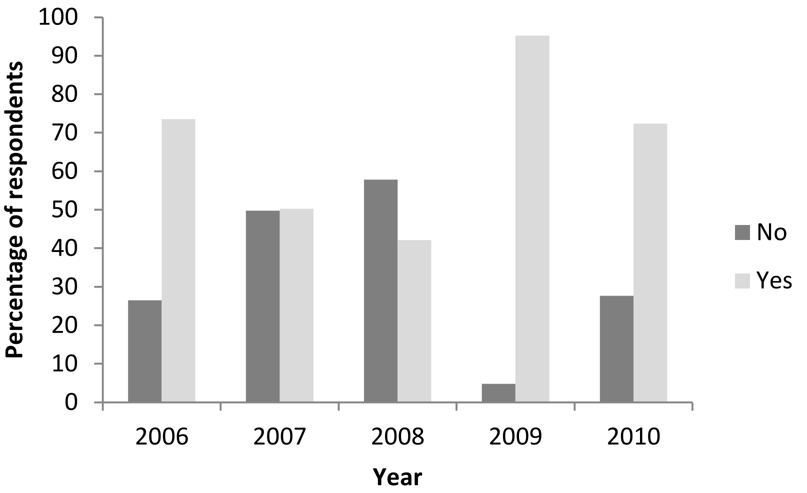


**Figure 12: Responses to the question 'Is there damage?' in percentage of respondents (each respondent representing one field) for the years 2006-2010 (CSA data (CSA 2007-2011), total N=821).**

Maize yield was highest in 2008 (Figure 6). This was a year with a higher rainfall than usual (Figure 5). Only 42% of the farmers stated that their fields had been damaged that year. In 2009 maize yield was lowest, which corresponds with a low rainfall that year. Of all years from 2006-2010, the highest percentage (95%) of fields had suffered from damage this year, as stated by the farmers (Figure 12). The highest rainfall was in 2006 (Figure 5). Yields this year were not particularly high or low compared to other years. Yield variability between farmers was higher in this year than in other years.

## 3.4 Interviews

### 3.4.1 Household characteristics

Of the interviewed farmers, four were hosting SIMLESA exploratory trials. The total area farmers cultivated ranged from 0.5 ha to 3.0 ha, with an average of 1.9 ha. Most of the cultivated area was used for maize production (Table 4).

**Table 4: Main household characteristics of interviewed farmers in 2012. Farmers 1 to 3 are type 1 farmers (0-1 oxen), 4 to 6 are type 2 (2-3 oxen) and 7 to 9 are type 3 (4 or more oxen). TLU=Tropical Livestock Units (Jahnke et al. 1988), IC=intercropped within the maize area.**

| Farmer ID | Gender | Part of SIMLESA | Number of household members (of whom working) | Number of oxen | TLU | Total area cultivated (ha) | Maize (ha) | Other crops (crop type, (ha)) | Number of people per hectare |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Male | Yes | 8 (4) | 0 | 0 | 0.5 | 0.5 | (0.0) | 16 |
| 2 | Male | No | 4 (2) | 0 | 0 | 0.8 | 0.5 | Wheat (0.3) | 5 |
| 3 | Male | Yes | 5 (2) | 1 | 6 | 2.1 | 1.3 | Beans (IC, 0.3)<br>Wheat (0.5)<br>Barley (0.4) | 2 |
| 4 | Male | No | 8 (6) | 2 | 7 | 1.5 | 1.0 | Beans (0.5) | 5 |
| 5 | Male | Yes | 15 (9) | 2 | 8 | 2.3 | 1.3 | Beans (IC, 0.3)<br>Wheat (1.0) | 7 |
| 6 | Male | Yes | 12 (2) | 2 | 6 | 2.5 | 1.5 | Wheat (0.5)<br>Teff (0.5) | 5 |
| 7 | Male | No | 9 (5) | 4 | 7 | 2.3 | 2.0 | Teff (0.3) | 4 |
| 8 | Female | No | 11 (5) | 4 | 14 | 3.0 | 2.3 | Wheat (0.8) | 4 |
| 9 | Female | No | 8 (5) | 5 | 16 | 2.0 | 1.0 | Wheat (1.0) | 4 |
| Average | - | - | 8.9 (4.4) | 2.2 | 7 | 1.88 | 1.25 | - | 6 |

### 3.4.2 Differences between farmer types

Area under maize cultivation, amount of livestock per hectare owned, and the total number of ploughing days per hectare of maize are highest for type 3 farmers and lowest for type 1 farmers, however, these differences are not significant. Estimated yield for 2012 is highest for type 1 and lowest for type 3 farmers (Table 5, Figure 13). There are no significant differences between farmers of the three types with respect to the use of manure per ha of maize.

**Table 5: Comparisons between farmers of the different types. P-values are results from comparisons of the three farm types using One way ANOVA tests (Appendix VI). * indicates differences at a significance level of p=0.05, with letters indicating grouping.**

| | Type 1 | Type 2 | Type 3 | Mean | p-value |
|---|---|---|---|---|---|
| Household size | 5.7 | 11.7 | 9.3 | 8.9 | 0.068 |
| Area under maize cultivation in 2012 (ha) | 0.75 | 1.25 | 1.75 | 1.25 | 0.109 |
| Estimated yield per hectare of maize in 2012 (kg) | 2933a | 1333b | 311c | 1678 | 0.035* |
| Amount of manure used per hectare (kg) | 2067 | 2556 | 2296 | 2306 | 0.940 |
| Livestock per hectare (TLU) | 0.9 | 3.4 | 5.2 | 3.2 | 0.061 |
| Total number of ploughing days per hectare | 12.9 | 16.6 | 23.3 | 17.6 | 0.370 |

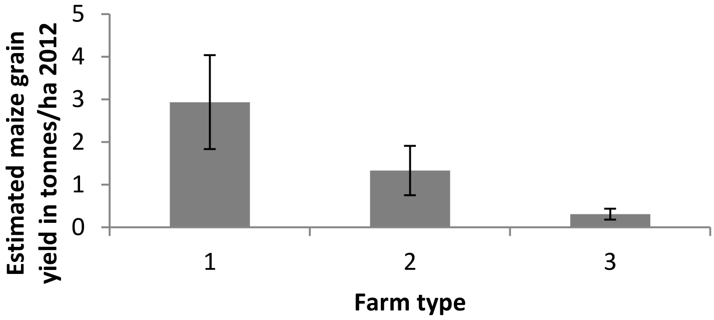


**Figure 13: Farmer estimations of maize grain yield for 2012 in tonnes per hectare, per farm type. Error bars represent standard error.**

Farmers of type 1 all used maize variety Melkassa-II, of type 2 one used Melkassa-II, one used BH540, and one used both, and of type 3 one used Melkassa-II while the other two used BH540.

### 3.4.3 Differences between estimated yield for maize varieties

Estimated maize yield in 2012 for sole Melkassa-II (2700 kg/ha) and sole BH540 (540 kg/ha) differed significantly (Appendix VI, Figure 14). The farmer growing both varieties estimated his total maize yield at 1,000 kg/ha (Figure 14).

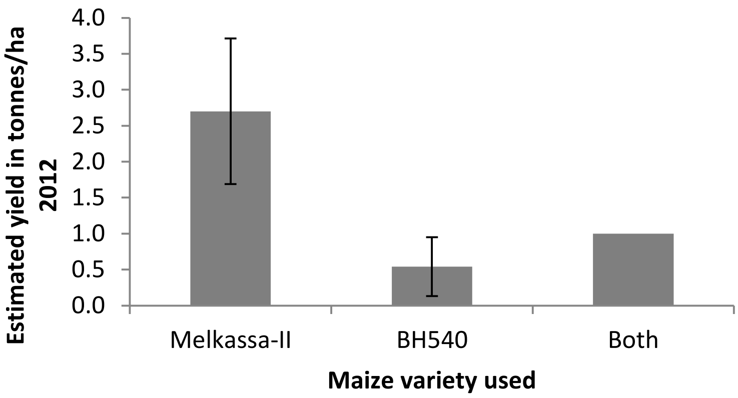


**Figure 14: Farmer estimations of maize grain yield for 2012 in tonnes per hectare, per maize variety. Error bars represent standard error.**

### 3.4.4 Maize yield estimates

Maize yield in 2011, as stated by the farmers, averaged 1,922 kg/ha, while the estimations for 2012 were lower at an average of 1,678 kg/ha (Figure 15). This difference was not significant, though (Appendix VI). Sample size was reduced to eight because one farmer refused to give an estimation of yield because of fear of bad luck.

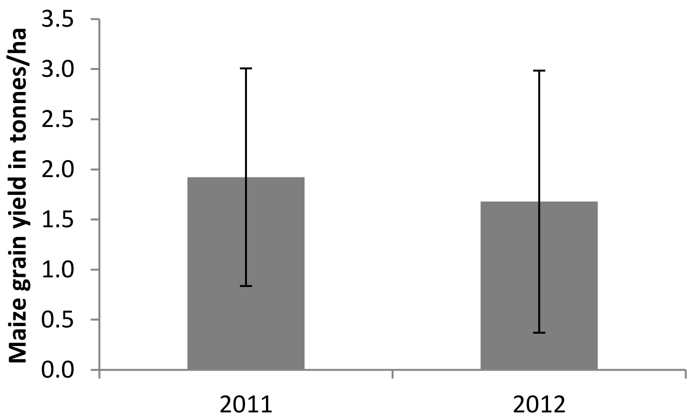


**Figure 15: Farmer estimations of yield for 2011 and 2012 in tonnes per hectare. Error bars represent standard error.**

Of those who give reasons for the low yield in 2012, all (seven out of seven) mention waterlogging, and most (five out of seven) mention the short season of 2012. Also mentioned is the use of BH540 instead of Melkassa-II.

One farmer, who estimated his yield to be 3,000 kg/ha, attributes his relatively high yield compared to his neighbours to early planting and planting on previously fallow land.

### 3.4.5 **Crop and variety choice and crop use**

In 2012, all farmers used more than half of their land for maize cultivation and all farmers except one grew other crops in addition (Table 4). In 2011, almost all maize grain produced was used for own consumption (Table 6), and some farmers needed to buy additional maize grains. Maize residues were used as fodder. Surpluses were sold. Maize grains were also used for the payment of casual work, gifts and as seed.

Table 6: Grain production and uses for crops grown by interviewed farmers in 2011

| | Number of farmers growing crop | Total produced (kg) | Home consumption (kg) | Sales (kg) |
|---|---|---|---|---|
| Maize | 9 | 25,700 | 17,800 | 10,300 |
| Bean | 6 | 3,400 | 100 | 3,100 |
| Wheat | 4 | 3,300 | 1,300 | 2,000 |
| Barley | 3 | 1,300 | 900 | 200 |

Farmers mentioned the main benefits of Melkassa-II over other varieties to be the early maturity and the high production. Also mentioned are drought tolerance, and one farmer mentioned suitability for the soil and dominance of this variety in the area. The latter two reasons are also mentioned by another farmer as reasons for growing maize instead of other crops. One farmer mentioned as a reason to grow Melkassa-II that he could get it easily and cheap from his neighbour who was part of the SIMLESA project. Another farmer would have liked to have used only Melkassa-II, but there was not enough seed available.

More common bean was grown in 2011 than in 2012, most of which was sold (Table 6). Usually, only a small portion of land is used for beans, sometimes as part of a crop rotation. Bean seeds are often scattered rather than planted in rows. Many farmers stated to have grown beans in years prior to 2012. Reasons for not growing beans this year were land scarcity, unavailability of improved seeds and the late rains. Beans can be a major source of income, but growing maize for own consumption is prioritised. Intercropping is very new in the area, where in the 2012 season, only three farmers had experience with intercropping, two of whom tried it for the first time this year. Others have only heard of it and seen it at their neighbours and/or through the SIMLESA trials. One farmer stated not to have heard of intercropping, another said to had heard of it only the week before. Nearly all farmers state to plan on either expanding their area under intercropping or start the practice next year. Some even state to plan on intercropping their whole maize area, as they have seen that production is good.

### 3.4.6 Ploughing

Even of the type 1 farmers, who did not own (enough) oxen to plough, only one did not plough at all. Others borrowed oxen for ploughing. Four farmers ploughed their maize field three times, three ploughed four times, one ploughed two times and one didn't plough. First ploughing occurs in March (three out of eight farmers) or April (five out of eight farmers), and the last ploughing by one farmer was in July. The first round of ploughing took the longest (7 lbd/ha, in which lbd is labour days: the number of days the labour took times the number of people working), and time spent per ploughing round decreases each round (to 5 lbd/ha in the fourth round) (Figure 16). The total time spent on ploughing of maize fields averaged 24 lbd/farmer, and 18 lbd/ha (Figure 17).
The farmer who did not plough would rather have ploughed to prepare the soil. He has learnt about minimum tillage from SIMLESA and would only plough once. Of those who have ploughed four times, two mentioned that they will try minimum tillage next year. One did not seem to be planning on changing. The other farmers were convinced that the number of rounds they had ploughed this year was the necessary amount.
Ploughing is done to prepare and loosen the soil. More specifically, increased water holding or water infiltration was mentioned two times. Production increase specifically was mentioned only once, but can be considered to be the underlying reason for all other arguments. The last round of ploughing is often meant to prepare the seeding furrows.

### 3.4.7 Fertiliser application

All farmers used manure on their maize fields, except for one type 1 farmer. When used, the average amount of manure applied was 3,063 kg per field or 2,594 kg per hectare. When assuming a manure production of two kg of dry matter per head of cattle per day (Fernandez-Rivera et al. (1995) in Jackson and Mtengeti (2005)) and taking into account herd size, manure production usually exceeded manure application rate. Probably, not all manure produced is collected (Rufino et al. 2006). Most farmers used between 3,000 and 4,000 kg of manure per hectare of maize and may have had an excess of manure which they could use as fuel or for construction. Some, however, used less manure per hectare while manure production should allow higher manure application. One, using 2000 kg/ha, would have preferred to use more, but had no fuel alternative due to a lack of trees. Another used 667 kg/ha because he did not have enough labour to bring the manure to the field. One farmer used only 889 kg/ha, but she said that she did not need to use more. For some farmers, the manure application rate seemed to exceed possible manure production when considering herd size. These were a farmer who did not own cattle but received manure from his father, and a farmer who did not own much cattle at the time of interviewing but had sold one oxen only a short time before manure application and who owns some other livestock (for livestock ownership, see Appendix VII). Manure is applied between March and June, often in between or before ploughing rounds.

Some farmers also applied DAP on their maize. However, all farmers preferred using manure over DAP. Some had done some experimenting themselves, seeing better results under manure than under DAP fertilisation. Reasons mentioned were better soil fertility due to its 'longer duration', as they said, in the soil. Farmers often applied manure on a field only once in two or three years while DAP needed to be applied every year. Farmers considered DAP to be too expensive and only used it on maize when they had no alternative (not enough manure or no labour to bring and apply manure to the field), or as an experiment (in which case the farmer regretted not having used manure on the whole field).

Other cereal crops than maize usually received DAP, not manure, although most farmers state that it would be better to use manure. For two farmers, the field was too far away and they had a transport problem preventing them from applying manure to their cereal field. On rented land, farmers tend to prefer using manure over DAP to keep their manure for their own fields, choosing short term production benefits over long term conservation benefits as is often done on rented land (Jaleta et al.).

### 3.4.8 **Planting**

About half of the farmers (four) planted their maize in May, before the onset of the rainy season. They say that planting early is better for a higher yield. One of these farmers however mentions that he would have preferred planting later if he had known the rainy season would start this late. Others waited for the onset of the rainy season, which was at the end of June/beginning of July in 2012. They regret that this was this late this year. One of them specifically mentions that she doesn't trust dry planting.

### 3.4.9 **Weeding and spraying**

Weeding was done at least two times on maize fields, and three farmers weeded three times. First weeding was usually done in July (six out of nine farmers) although sometimes it was done in May or June (Figure 18). Weeding was then sometimes accompanied with the thinning of the maize. Second weeding occurred about a month later, and third weeding, if done, another month later. Weeding took about 15 labour days per hectare per round, except for the third weeding round, which, if done, took 11 labour days on average (Figure 16). Many farmers would prefer weeding more often and in less days, however, they did not have enough labour available. Others didn't think it was necessary to weed more often this year, for which one gave the reason of the short season. One farmer mentioned that he didn't need more weeding because the field had been fallowed for three years and that he left residues, including weeded weeds, on the field so that weeds had no space to grow. One farmer who intercropped his maize with beans mentioned that the intercropped part did not require weeding.

Spraying was seldom done on maize fields. Only one farmer sprayed, as a consequence of lack of labour for weeding. Spraying is said to be cheap, but not as effective as weeding. The herbicide used is 2,4-D (2,4-dichlorophenoxyacetic acid). Spraying is used widely on other cereals. On wheat and barley, no weeding is done as farmers say this activity would damage the crop. Both farmers growing teff weeded their field once, one of them complementing this with spraying.

### 3.4.10 **Harvesting and threshing**

Harvesting was done in October and November, and was always completed within one week. Threshing was sometimes planned to be done very soon after harvest, in November. Others waited, sometimes even until May, for the maize grains to be dry and for maize price to be higher (see also (Kristjanson et al. 2002)). This was not the case for farmers who needed the maize earlier for own consumption.

### 3.4.11 **Labour requirements**

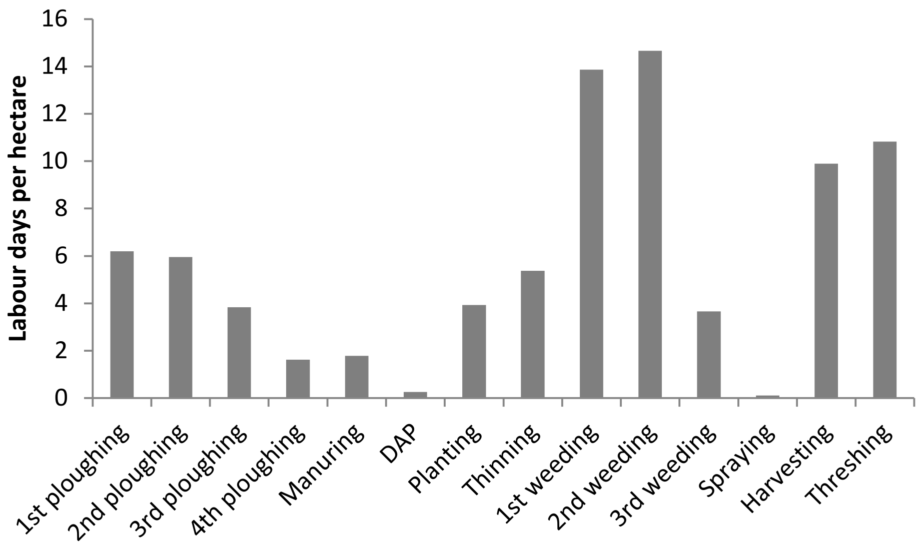


**Figure 16: Labour requirements for all agronomic activities of maize cultivation in labour days per hectare. Data are based on averages of stated labour requirements for each activity by the nine interviewed farmers.**

When combining the activities that are more or less related to one another, all activities can be divided into three main activities. These are ploughing, including manuring, DAP application and planting; weeding, including thinning and spraying; and harvesting, including threshing. Of these three, for maize weeding required the most labour (Figure 17). Comparing bean with maize labour requirement, time taken for ploughing is similar in maize and in beans (24 and 21 lbd, respectively). Weeding takes much less time in beans (13 compared to 38 lbd) and harvesting takes less time as well (16 compared to 21 lbd) because threshing of beans takes less time than of maize (Figure 17).

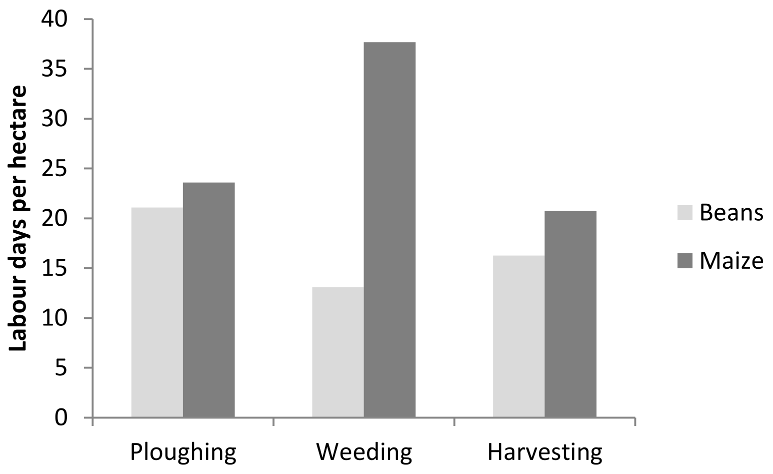


**Figure 17: Labour requirements of bean and maize cultivation in labour days per hectare. Agronomic activities are grouped into ploughing (including manure application, DAP application, and planting), weeding (including thinning and spraying) and harvesting (including threshing). Data for maize are based on averages of stated labour requirements for each activity in 2012 by the nine interviewed farmers. Data for beans are based on averages of stated labour requirements for each activity by 15 SIMLESA farmers interviewed in 2012 concerning the 2011 season (Baudron 2012).**

Labour peaks occurred in May, July/August, and November (Figure 18). The peak in May is caused by ploughing and related activities. This peak already starts in March, as the ploughing rounds are spread over a few months. The peak for weeding reaches its height in July, but much of the weeding also falls in June and August. The November peak is caused by the harvesting. Time of threshing is quite flexible and differs per farmer, with some farmers already threshing in November and others waiting as long as May before they thresh their harvested maize grains (paragraph 3.4.10).

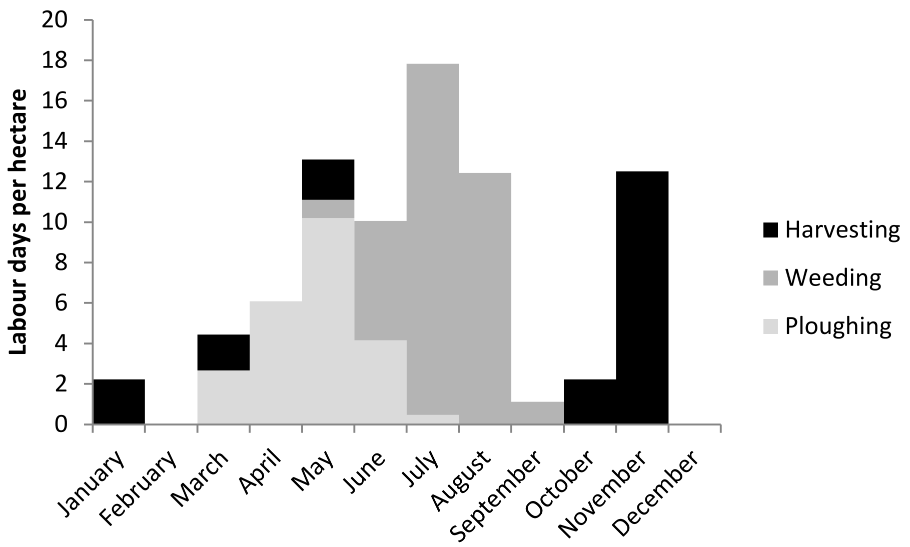


**Figure 18: Labour requirements of maize cultivation activities in labour days per hectare per month. Data are based on averages of stated timing and labour requirements for each activity by the nine interviewed farmers. Agronomic activities are grouped into ploughing (including manure application, DAP application, and planting), weeding (including thinning and spraying) and harvesting (including threshing).**

### 3.4.12 **Livestock ownership**

All farmers mention ploughing as the main use of their oxen. No other uses of oxen were mentioned in the interviews. Farmers who did not own oxen themselves stated that they would like to have

them, for ploughing. One farmer mentioned that he currently had to use the oxen from his father. However, sharing the oxen led to either him or his father not being able to plough in time.
All three farmers of type 2 owned a bull (Appendix VII). As main use, all three mentioned breeding. Two out of three mentioned that other farmers may also use their bull for this purpose. They provided this service for free, without formally expecting something in return.
As the number of oxen farmers own increases, so does the number of cows. Oxen and cows are kept in similar amounts (Appendix VII). Production of milk, cheese and butter is mentioned as the main use of the cows, also by those who do not own any themselves. Other uses are not mentioned. Products are used for own consumption, but processed products (cheese and butter) are also sold. The more cows a farmer owns, the more likely it is that sales of dairy is mentioned as a purpose of owning cows.
None of the interviewed farmers owned a horse. Several owned one or more donkeys for the purpose of transport. Four farmers (across all types) do not own any goats. Type 3 farmers owned 15 or 16 goats, while farmers of type 1 and 2 only owned one to three goats (Appendix VII). The main reason for keeping goats is cash income. One (a type 3 farmer) specified by using the word 'security', which in a way is what the use of 'cash income' comes down to. Only one farmer (also type 3) mentioned consumption and sales of meat. Some farmers also own chicken (Appendix VII). One mentions that the meat is for consumption while the eggs are for sales. Others did not specify use. One farmer mentioned that livestock serve as a bank account (type 2). Others didn't specifically mention this use for livestock in general, although it was clear from the questions on income and expenditure that they used in that way.

### 3.4.13 **Cattle feeding and other residue use**

There are two feeding periods for the cattle: the dry season and the rainy season. During the dry season, the main source of fodder is maize residues (on average 78% of total fodder supply), while those farmers who also grow other crops may use some residues from these crops. Residues are collected from the fields at the end of the rainy season and stored until feeding. During the rainy season, the main source of fodder is grass grazing (on average 90% of fodder supply), supplemented with 'Cut & Carry', which mainly consists of green material from the thinning of maize. Out of five farmer responses, four mentioned that grazing was from their own land and only one from rented land (a type 3 farmer). No cattle other than their own grazes on the private lands of the interviewed farmers. There could be some grazing on communal land.
Length of both periods is different per farmer, with the feeding period of the dry season usually lasting six or seven months in the period from November to June (five out of seven farmers). However, one farmer used the dry season feeding regime throughout the whole year, and one used this regime for 10 months (from October to July). These farmers, both of type 3, bought "Furushka" (wheat bran, a factory by-product) and grass for their cows .
All type 1 farmers retain residues on the fields, while none of the type 2 and type 3 farmers retain any residues. However, of one of the farmers retaining residues, part of the retained residues were stolen. At night, someone came and cut them. Hence, he mentioned planning on fencing his land next year for protection of the residues. The type 1 farmer who owns some cattle fenced ¼ ha of his farmland, leaving 30% of the residues. In total, this means that he left about 5% of his residues (he had 1.25 ha of maize in 2012). The rest, as was the case for farmers who did not retain any residues, was fed to his cattle. Some farmers mentioned that they do know the benefits of residue retention and that they would like to do it, but don't think it is possible without other options for feeding their

cattle. However, two mentioned that they would like to try some residue retention next year. Two farmers mention that the lack of fodder is a relatively recent phenomenon due to lack of grazing land as a result of population growth. One mentioned that she already reduced her herd, as she used to have 80 heads of cattle, but that she cannot reduce the herd size further because she needs the oxen that she has left for ploughing. The other mentioned that he used to practice residue retention 20 years ago, but that it's not possible any longer.

Most farmers used 5% of residues for fuel (six out of nine). One of them mentioned that those 5% were the maize stubs that couldn't be used for fodder. Others mainly used wood (unless trees were protected) or dung. Two type 3 farmers didn't use any residues for fuel but only used wood.

Some residues (on average 3% of total available residues) were used for house maintenance and the building of storages, although wood was used when possible.

## 3.5 Scenario exercise

### 3.5.1 Production projections

Production in scenario 2 is based on ½ ha of beans and ½ ha of maize, and indeed the projected maize production in this scenario is exactly half of that in scenario 1 (one ha of maize) (Figure 19). Doubling the projected bean production of scenario 2 gives the farmers' projection of production of one hectare of sole bean cropping.

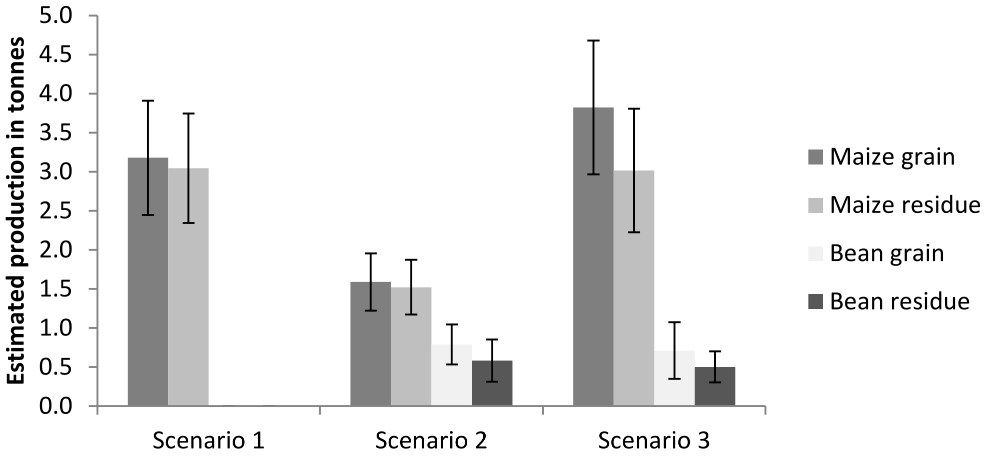


**Figure 19: Projected production in tonnes of maize and bean products in all three scenarios. Scenario 1 is one ha of sole maize, scenario 2 is 0.5 ha of sole maize and 0.5 ha of sole beans, and scenario 3 is one ha of maize-bean intercropping. Error bars represent standard deviation.**

Whereas projections of maize residue yield were nearly equal in sole cropping and intercropping, projected maize grain yield was 20% higher in intercropping than in sole cropping (Figure 20, not significant, though, see Appendix VIII). Hence, the harvest index was projected to be higher in intercropping than in sole cropping. Both bean grain and bean residue yield were projected to be significantly lower in intercropping than in sole cropping (55% and 57%, respectively (Figure 20, Appendix VIII)). There was no significant difference in the projections of absolute production of bean grains and bean residues between scenario 2 and scenario 3 (Figure 19, Appendix VIII).

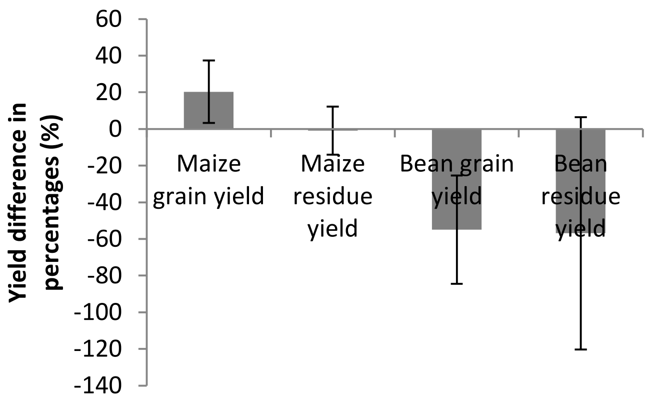


**Figure 20: Projected yield loss or gain in percentages when comparing an area of maize-bean intercropping with the same area of either of the sole crops. Error bars represent standard deviation.**

Projected Land Equivalent Ratio without taking residue production into account was 1.63.

### 3.5.2 Labour projections

There were no significant differences in the projections of labour requirements between the scenarios. When comparing sole bean (data for sole bean were calculated from data of scenario 1 and 2) with sole maize, although labour for harvesting and threshing seemed somewhat higher for beans, there were no significant differences in projections of labour requirements except for ploughing, which was higher (significance level p=0.1) for maize than for bean (Figure 21, Appendix VIII). Storage, which in the figure is put under Harvesting and threshing, was exactly equal for all scenarios, including sole bean.

When comparing these results with those of the interviews, farmers are more optimistic about labour requirements for sole maize and sole beans when asked for a projection in the scenarios than when asked for the actual requirements of the previous season. Also, in the interviews weeding in maize took the most time, while for beans weeding took the least time. This is not the case in the scenario projections, where weeding takes nearly the same amount of time regardless of the scenario, and where the differences in labour requirements between the scenarios lie mostly in the ploughing.

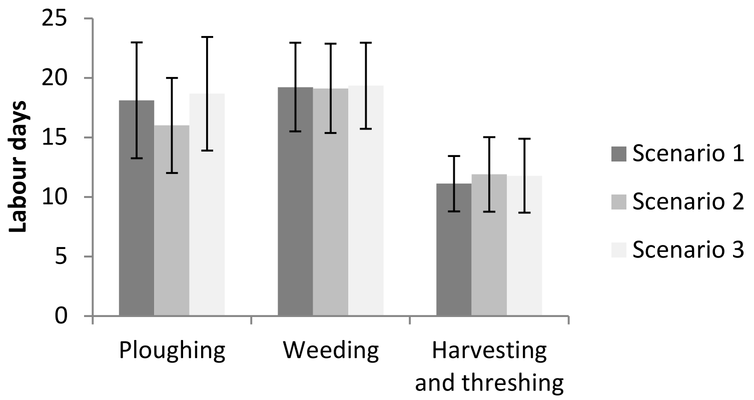


**Figure 21: Projected labour requirements in labour days for different activities for each scenario. Labour for storage is grouped under Harvesting and threshing. Scenario 1 is one ha of sole maize, scenario 2 is 0.5 ha of sole maize and 0.5 ha of sole beans, and scenario 3 is one ha of maize-bean intercropping.**

Projected Labour Equivalent Ratio without taking residue retention into account was 1.56.

### 3.5.3 Values per scenario

Coin allocation between the scenarios was very similar for scenario 1 and 2, which on average received 3.7 and 4.7 coins respectively. There was a preference for scenario 3, which received 6.7 coins on average (Appendix VIII).

### 3.5.4 Values between attributes

Through green and red match allocation, farmers scored all attributes within each scenario (Figure 22). Labour in all scenarios received high scores, especially negative (Figure 23). Positive scores were assigned to the 'Harvesting and threshing' and 'Storage' components of the labour graph that was composed with the farmers, as these components take relatively little time in each scenario. Negative scores were assigned to the 'Ploughing' and 'Weeding' components which are much more labour intensive (Figure 22).

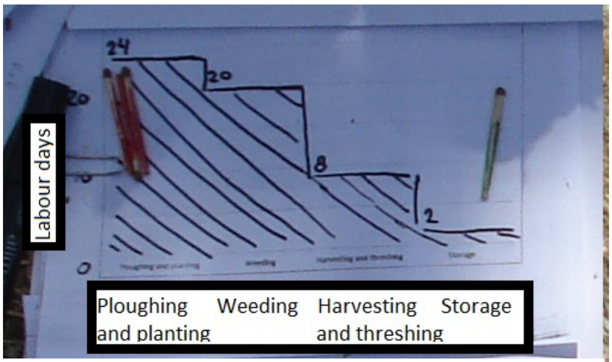


Figure 22: Labour graph as constructed during a scenario exercise, including match allocation.

There were no large differences in scoring of labour between the scenarios (Figure 21).

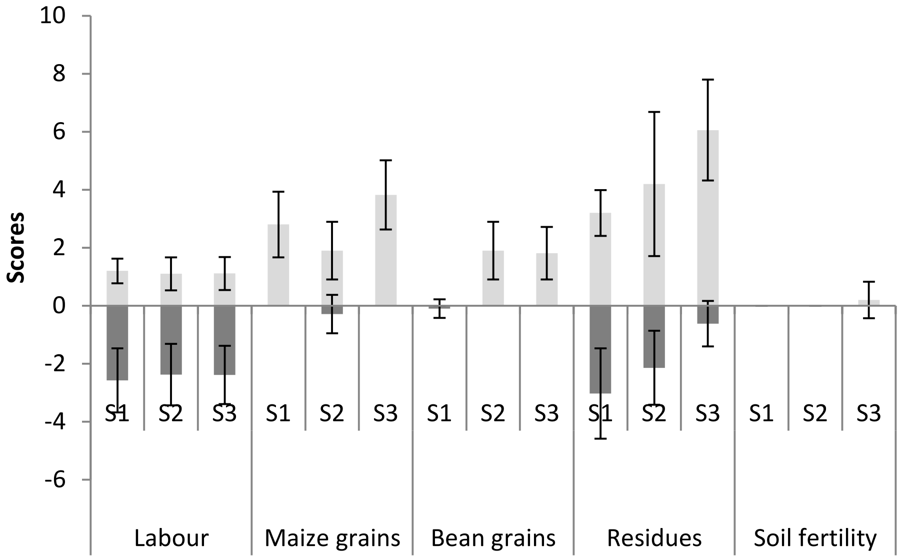


**Figure 23: Scoring of attributes within each scenario. Scores of all attributes related to residues (bean and maize residues, residue retention, cattle) were combined into 'Residues'. Error bars represent standard deviation. Scenario 1 (S1) is one ha of sole maize, scenario 2 (S2) is 0.5 ha of sole maize and 0.5 ha of sole beans, and scenario 3 (S3) is one ha of maize-bean intercropping.**

The value farmers attach to bean grains per kg produced is higher than that to maize grains. Average positive scoring of bean grain production in both scenario 2 and 3, in both of which bean production is around 750 kg, is almost two. Positive scoring of maize grains is higher (ranging from almost two to almost four between the three scenarios), but relatively speaking, it is lower, as production of maize grains is also much higher (ranging from 1.6 to 3.8 tonnes). Positive scoring for maize grain was highest in scenario 3 and lowest in scenario 2, which corresponds to trends in the projected amounts of maize grain produced in these respective scenarios (Figure 19). Relative differences are not corresponding, though. Even though production of maize grains is twice as high in scenario 1 as in scenario 2, positive scoring for maize grains is not twice as high in scenario 1 as in scenario 2. Also, maize grain production is only a little higher in scenario 3 than in scenario 1 (+20%), but maize grain production scores much higher in scenario 3 (+>30%). Negative scores were sometimes assigned to maize and bean grain in scenario 2 and 1, respectively, for lack of these grains in these scenarios. Maize grains would mostly be used for consumption and only a surplus of maize would be sold. How often sales of maize grain was mentioned in the scenarios largely depends on family size of the farmer: the larger the family, the less likely it is that maize grains were projected to be sold. Bean grains would invariably be used for sales, and in scenario 2 it was mentioned that the money earned from the sales of beans could be used to buy extra maize, as maize production in scenario 2 was low. Soil fertility was brought up by one farmer as a component of scenario 3 and received a positive score of two from this farmer. In Figure 23, all attributes related to residues were combined. It is clear that the farmers, when taking into account all costs and benefits related to residues for each scenario, were the most positive about residues in scenario 3 and the least positive in scenario 1. Overall, residues received higher scores (both positive and negative) than grains (both maize and bean). Figure 24 shows the scoring of the separate attributes related to residues. Trends in scoring of maize and bean residues correspond with trends in the projected amounts of residue production within each scenario (Figure 19). Value attached to maize residues is lower than that to maize grains, with positive scoring of residues being about 55-60% of that to grains (Figure 23, Figure 24), while production in kg is similar (Figure 19). Value of bean residues per kg is high compared to that of maize residues, but low compared to bean grains, with a score slightly higher than one assigned to a residue production of about 550 kg in scenarios 2 and 3. Lack of residue retention was considered to be most problematic in scenario 1 and the least problematic in scenario 3. Although the amount of residues produced in scenario 2 is only half of the amount produced in scenario 1 (Figure 19), negative scoring for lack of residue retention is lower in this scenario. This is due to the possibility of a maize-bean rotation scheme which would positively influence soil characteristics, reducing the need of residue retention according to the farmers. In the third scenario, the amount of residues produced is similar to that in scenario 1 (Figure 19), but again, soil characteristics are already considered to be improved due to the intercropping, hence, less residues are needed and negative scoring is low for residue retention. Cows and oxen receive similar scoring, with scenario 1 being valued the most negative and scenario 3 the most positive for both.

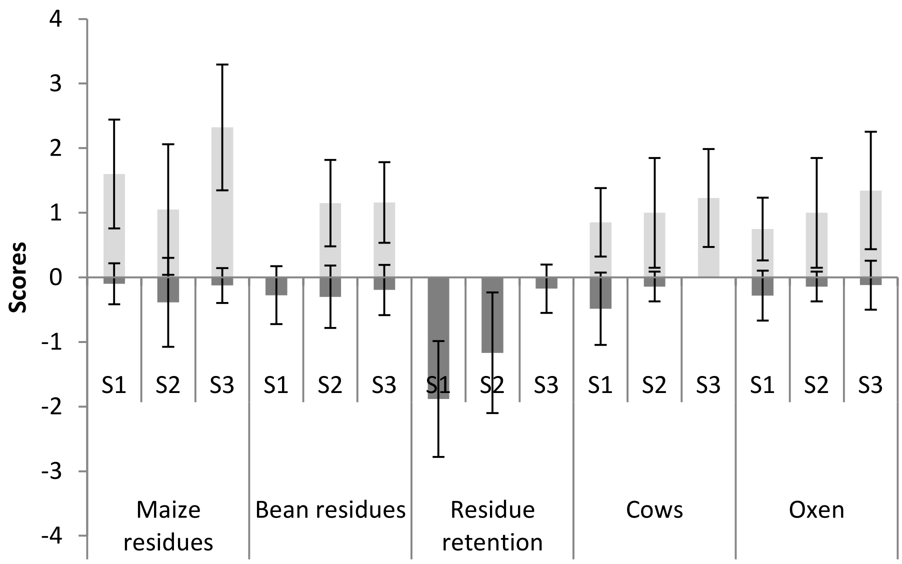


**Figure 24: Scoring of attributes related to residues within each scenario. Error bars represent standard deviation. Scenario 1 (S1) is one ha of sole maize, scenario 2 (S2) is 0.5 ha of sole maize and 0.5 ha of sole beans, and scenario 3 (S3) is one ha of maize-bean intercropping.**

Figure 25 shows the scoring of separate attributes related to the cattle. From cows, dairy production was considered to be most important, while from oxen, ploughing was the most important. In both cases, these attributes got the highest positive scoring in scenario 1 and the lowest in scenario 3, although both also received negative scoring in scenario 1 as a consequence of the lack of bean residues to feed the cattle. Manure production from both cows and oxen, on the other hand, was valued most positively in scenario 3 and least positive in scenario 1. Sales of oxen (cattle may serve as a 'bank account', that is, if a house is to be constructed or a funeral to be arranged, an oxen can be sold for the necessary cash) was also mentioned as a benefit, mostly in scenario 2 and 3. However, one farmer assigned a negative scoring of one to sales of oxen in scenario 3, because he would use the bean residues for his cows, not for his oxen, reducing benefits of sales of oxen.

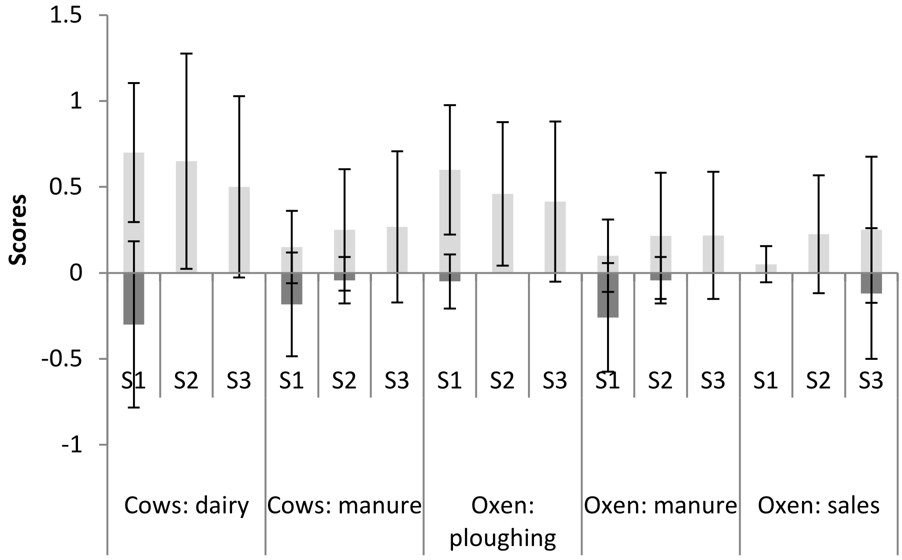


**Figure 25: Scoring of attributes related to cattle. Error bars represent standard deviation. Scenario 1 (S1) is one ha of sole maize, scenario 2 (S2) is 0.5 ha of sole maize and 0.5 ha of sole beans, and scenario 3 (S3) is one ha of maize-bean intercropping.**

# 4 Discussion

## 4.1 Trial components

### 4.1.1 Residue retention

Figure 26: The residue retention trial, severely affected by waterlogging.

Benefits of leaving residues in the crop field after harvest have been widely recognised (Rockström and Falkenmark 2000; Erenstein 2002; Lal 2007; Giller et al. 2009; Baudron et al. 2012). Although a ground cover of 30% is often mentioned as a threshold, there is still discussion concerning the amount of residues necessary to attain these benefits (Erenstein 2002; Gowing and Palmer 2008; Farooq et al. 2011; Giller et al. 2011). A major objective of the residue retention trial was to establish the effect of different amounts of residue retention on maize crop yield to determine the trade-off between residue retention and other uses of residues. However, the residue retention trial failed as a consequence of waterlogging (Figure 26). Waterlogging problems may be aggrevated depending on different soil characteristics such as soil composition and structure (Kale and Sahoo 2011). Residue retention has been mentioned to exacerbate waterlogging during wet seasons (Baudron et al. 2012), however, this could not be confirmed by the trial. Retention of lablab residues on the field was not successful in maintaining ground cover due to the high decomposition rate of these residues compared to that of maize residues. This may be the result of crop characteristics such as the lower C:N ratio of legumes, and may be different for other legume crops than lablab (Erenstein 2002). Further effects on soil characteristics and possible influence on consequent yield of neither legume residues nor maize residues could be established.

### 4.1.2 Intercropping

Figure 27: The maize-cowpea intercropping trial, showing a relay intercrop.

Although farmers in the region are accustomed to growing common beans (*Phaseolus vulgaris* L.) (SIMLESA 2012), the legume used in the intercropping trial was cowpea (*Vigna unguiculata*) (Figure 27) as previous trials have shown promising results using this legume (e.g. Rusinamhodzi et al. (2012)). Results of the trial as performed in this research should be compared to results of similar trials involving beans and other legumes (see below for some examples) in order to establish the differences between legume crops, such as suitability under prevailing agro-ecological conditions in the region, yield potential, and performance in intercropping and relay cropping. These differences may then serve as input into farmer decision making between different legume crops.

The Land Equivalent Ratios (LERs) of intercropping in both the trial and the scenario exercise were higher than one, indicating that intercropping had a positive influence on land use efficiency compared to sole cropping of either maize or cowpea. This is in line with findings from other intercropping studies. Tsubo et al. (2003) found LERs between 1.06 and 1.58 (with maize and bean yield varying between 1.3-9.0 and 0.4-1.9 t/ha, respectively) while intercropping maize with beans under low rainfall in South Africa. A model to estimate crop growth and yield in maize–bean intercropping in semi-arid regions which was calibrated using his data (Tsubo et al. 2005a) which was run for different cultural practices (planting date and plant density) and cropping seasons gave outputs of LERs ranging from 1.09 to 1.58 (Tsubo et al. 2005b). Baudron et al. (2012) have found that intercropping sorghum with several legume crops did not compete with the sorghum crop while adding to total biomass production. Rusinamhodzi et al. (2012) found LERs up to 2.2 for maize-pigeonpea intercropping (with maize and pigeonpea yields being about 1.2 and 1.0 t/ha, respectively) and 2.4 for maize-cowpea intercropping (with maize and cowpea yields being about 2.0 and 0.6 t/ha, respectively) without fertiliser in Mozambique. The LERs in the trial ranged from 1.37 to 1.44 depending on which crop components were taken into account, with maize and cowpea yields averaging 5.9 and 0.9 t/ha, respectively.

In the traditional LER, yield of sole cropping and intercropping is compared on the bases of using the same area of land for both systems (Keesman 2007; Bedoussac and Justes 2011). One could also calculate yields while keeping another factor constant, such as the amount of labour days, manure, or any other input that may constrain crop production. This gives rise to a range of 'Equivalent Ratios' that can be taken into account when evaluating the total efficiency of an intercropping system and will hence influence a decision regarding feasibility of such a system. In this research, this was done by calculating a Labour ER from the results of the scenario exercises. The Labour ER was 1.56. This indicates that intercropping maize with bean results in an increase in labour efficiency compared to sole cropping of either of the crops, similar to the increase in land use efficiency. As labour is a major production constraint, this could have a large influence on a farmers decision whether to intercrop (paragraph 4.8). When evaluating suitability of intercropping, different types of Equivalent Ratios (those taking into account different crop components and/or those based on different resources) can be taken into account, depending on farmer objectives and constraints.

The relay intercrop in the trial was a failure. This failure could be due to the short rainy season of 2012. The cowpea relay could only be sowed in September, when the rainy season was practically over and soil moisture was low. In the intercropping trial, four different cowpea varieties were used that differed in maturation time. Time until 50% flowering ranged from 74 to 90 days. In order to allow a successful relay intercrop, an early maturing variety will be advisable. Varieties further differed in main use as forage, food or dual purpose, although in the trial all varieties were harvested prior to grain formation, assuming use as forage. In case of use as food or for dual purpose, the cowpea would be harvested later than in the trial. Although this later harvest would impair possibilities of a second relay intercrop, farmers may prefer this option due to the high value of legume grains (Tsubo et al. 2005b; Giller et al. 2009). Choices between legume crops, varieties, use as food and/or fodder, and the decision on whether to plant a relay crop may also depend on labour requirements of other agronomic activities during the season that may or may not coincide with the appropriate time of harvesting of the cowpea variety. The final decisions will depend on the possibilities and objectives of the farmer and the relative importance of both stover and grains, which can be deduced from interviews and the scenario exercise.

## 4.2 Representativeness of the farmers' sample

Sample size is small, with a total of nine farmers being interviewed. In order to capture some of the variation present between farmers in the area, three farmers were selected from each of the three types as described in paragraph 2.3.2. Average area under maize cultivation per farmer was similar to that in the Adami Tulu district (CSA 2007-2011), which is an indication of representativeness of the sample for the district farmer population. Some mainly quantitative results from the interviews, such as number of labour days spent on ploughing, may not be applicable outside the Adami Tulu district, as agro-ecological, cultural and other variation between districts may exist. However, qualitative findings were elucidated that are more widely applicable in a range of contexts, and are confirmed by literature. Examples are importance of seed availability for choice between varieties (paragraph 3.4.3, 3.4.4, 3.4.5, 4.5, 4.11.1 (Ekboir 2002; Girma et al. 2005; Alemu et al. 2008; Beshir 2010)), problems caused by a growing population and the resulting lack of land availability (paragraph 3.4.13, 4.11.3 (Dessie and Kleman 2007; Gowing and Palmer 2008; Ralevic et al. 2010)), labour constraints (paragraph 3.4.6, 3.4.7, 3.4.9, 3.4.11, 3.5.4, 4.8 (Giller et al. 2009; Lestrelin et al. 2011; Johansen et al. 2012)), economic constraints (paragraph 3.4.7, 3.5.4, 4.8 (Lal 2007; Alene and Coulibaly 2009; Giller et al. 2009; Lestrelin et al. 2011; Marongwe et al. 2011; Johansen et al. 2012; Temesgen et al. 2012)), low soil fertility (paragraph 3.3, 3.4.7, 3.5.4, 4.11.3 (Rockström and Falkenmark 2000; Ogle et al. 2005; Lal 2007; Thierfelder and Wall 2009; Giller et al. 2011; Lestrelin et al. 2011; Thierfelder and Wall 2011; Johansen et al. 2012; Valbuena et al. 2012)) and importance of keeping cattle (paragraph 2.3.1, 3.4.7, 3.4.12, 3.5.4, 4.8, 4.11.3 (Aune et al. 2006; Lal 2007; Temesgen et al. 2008; Giller et al. 2009; Ralevic et al. 2010; Giller et al. 2011; Jaleta et al. ; Johansen et al. 2012; Valbuena et al. 2012)). Moreover, the methods to obtain data as developed and evaluated in this research project may be used in a variety of contexts in order to get more insight into local farmers' perceptions. Hence, the sample size was justified for use in this research project.

## 4.3 Problems of the design of the scenario exercise

When allocating matches, farmers sometimes complained that the number of green or red matches they received for a scenario was too high or too low. This could indicate that their initial division of coins (which determined match division) between the scenarios was not correct. The farmers might have allocated a different number of coins to the scenarios than they could substantiate when objectively looking at the attributes of that scenario. Reallocating the coins was proposed to the farmers in a number of cases, which sometimes solved the problem. However, some farmers stated that they did not disagree with their initial coin division. The discrepancy could also indicate that the division of coins was based on aspects not represented in the construction of the scenario and hence could not receive any matches. Farmers had the opportunity to suggest additional scenario attributes throughout the scenario building, and after finishing the construction of the scenarios were specifically asked whether all important attributes were included. Still, some attributes may have remained below the surface. For instance, from the initial interviews and from literature (Chambers 1990; Gabre-Madhin and Haggblade 2004; Tsubo et al. 2005b; Lal 2007; Place et al. 2007; Giller et al. 2011; Lestrelin et al. 2011; Marongwe et al. 2011) it was clear that risk assessment plays an

important role in decision making. However, risk assessment could not easily be represented nor quantified in the scenario exercise as risk is an abstract concept (Place et al. 2007).
When analysing the results, another weak point in method of valuation was realised. When building the scenarios, farmers were first asked about the amount of residues to be expected in each scenario, then for implications of this amount for residue retention and cattle maintenance, and uses of the cattle. Matches could be allocated to the residues themselves, but matches could also be allocated to the cattle and also to the cattle's functions. This could lead to a double allocation of matches. Matches allocated higher up the chain were actually designated for the attributes at the bottom of the chain, which in many cases had also received matches of their own. Unfortunately, no solution was found to correct the attribute scores for this possible flaw.

## 4.4 **Improvements to the design of the scenario exercise**

The problem of double match allocation can be solved by applying hierarchical levels to the scenario (Figure 28). In scenario building and representation, the first level would be the established one hectare systems of each scenario. The initial step of building the scenarios would be establishment of the amounts of primary production of each scenario, that is, maize and bean grain and residue production. This would be the second level. In the physical scenario building, the pictures representing these productions should be placed next to each other under each picture representing the scenario, that is, on one level. Farmers would then be asked what they would use the products of this level for. Hence, the third level would be the primary uses of the different items produced, such as either sales or consumption of grains, and either residue retention or cattle feeding for residues. The representative pictures of these uses should in turn be placed on the next level, under the products from which the uses are derived. This would be repeated until the last level (depending on the attribute, eg home consumption or sales in the case of dairy) is reached. The structure of each scenario build-up would become tree-like, and the number of levels and ramifications would differ per branch. For instance, the branch leading to home consumption of maize grain is shorter than that leading to home consumption of dairy products.

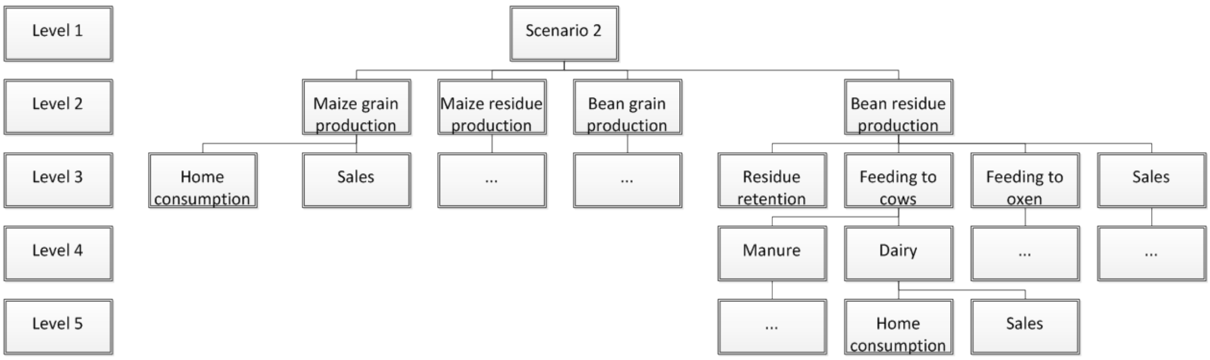


**Figure 28: Partial representation of a scenario construction tree, showing one scenario. Not all branches are fully developed; hence, boxes with dots represent possible further branching.**

In the consequent evaluation of the scenarios and their attributes, the step of the division of coins could be skipped. Instead, the farmers would have to allocate a large amount of, say, 100, matches between the scenarios, possibly in sets of 5 or 10 (the first level). Then, all matches allocated to one scenario would have to be used for allocation within that scenario on the second level, that of primary products. This would be repeated until all matches have moved down the branches and have reached the final attributes at the end of each branch. No matches would be allowed to remain at attributes which branch further into different uses of that attribute. This different method of match allocation would also ease identification of missing attributes. The time span of this research project did not allow for testing of this version of the scenario exercise.

## 4.5 **Estimated maize yields**

Many farmers considered 2012 as a bad year for growing maize due to the short duration of the season and waterlogging problems. The short but heavy rainy season was confirmed by the climatic data of 2012. Detrimental effects of waterlogging on maize yield were confirmed by the residue retention trial (Appendix V). Indeed, average estimated yield of 2012 can be considered low compared to yields of preceding years (1678 kg/ha, while from 2006 to 2010 all yields except that of 2009 exceeded 2500 kg/ha). Compared to 2011, yield was only slightly lower. 2011 however, as 2009, was a year with low rainfall (less than 700 mm throughout the rainy season). Hence, when taking climatic factors into account, farmers estimations of 2011 and 2012 are in line with the CSA data of 2006-2010 (CSA 2007-2011), confirming apparent reliability of both data sets.
Estimated yield of maize in 2012 differed per farm type. However, these differences were probably due to the differences in maize varieties used. Yield estimates were significantly higher for Melkassa-II than for BH540. This may be due to the late season this year, for which Melkassa-II was more appropriate than BH540 (Alemu et al. 2008). Use of Melkassa-II was highest for farm type 1 and lowest for farm type 3, explaining the highest yield estimates for type 1 and lowest for type 3. Melkassa-II was said by many consulted farmers and researchers to have a higher production than BH540, especially in this particular season, and superiority of Melkassa-II over other varieties is also confirmed in literature (Alemu et al. 2008).

## 4.6 **Projected maize yields**

There were discrepancies between farmer statements and CSA data regarding previous years, and farmer projections in the scenario exercise. These were most pronounced in amounts of labour per activity, grain production and biomass production for different cropping systems. Labour requirements and production levels are represented more positively in the scenarios than in the interviews, and maize yield projections are higher than even the year with the highest yield from the CSA data (CSA 2007-2011). As interviewing and CSA data are in line with each other, this cannot be explained by assuming that the sample of farmers selected for the interviews usually obtains higher yields than the average in the region, and therefore would project higher yields. The positive projections in the scenario exercise could mean that farmers based their perception of the cropping systems on some sort of ‘best case scenario’. Although the projected yields do not by far reach the potential as can be deduced from the results of the intercropping trial, they may reflect the best scenario possible from the farmers’ perspective. When asked to construct the scenarios, it was not specified what type of year the farmers should base their projections on. It is unclear where the optimism from the farmers for the scenario exercise comes from. It could be that they truly believe that the values they state are reasonable estimates; however, it could also be wishful thinking. Projections may have been different if the year for which the farmers were asked to make the projections would have been specified.

## 4.7 **Response bias**

There are several reasons why the answers regarding the opinions on different agronomic practices and technologies may not have been reflections of reality. The interviewer was white and a guest, which already commanded great respect and could lead to the farmers giving desired, respectable answers and avoidance of giving answers that may in the eyes of the farmers be considered to be embarrassing (Kapoor 2002; Place et al. 2007). Interviewed farmers knew that the interviewer was involved with the SIMLESA project, which also could have influenced answers (Kapoor 2002). They knew the objectives of the SIMLESA project and the agronomic practices and technologies that it aims to promote. Many of them have attended trainings and meetings, and know the SIMLESA rationale for adoption. They mention (aspects of) this rationale themselves, but the question is whether they believe it or that they think that this is the desired answer. Also, even if they indeed understand and believe these benefits, they might have their own reasons for non-adoption of the practices. When considering intercropping, minimum tillage and residue retention, in practice, adoption of these techniques is not as high as one would think when only judging from the positive responses from the farmers' to these techniques. These results suggest the presence of response bias. In order to establish the reliability of farmers' answers, the farmers should be visited again in the next season in order to establish whether adoption has indeed increased, as farmers' answers suggested especially in the case of intercropping.

## 4.8 **Application of the results of the scenario exercise**

Data from the exercise indirectly give enough information to reveal what the farmers base their decision of cropping system on. All attributes that the farmers take into account when judging between the cropping systems are identified, of all attributes it is established to what extent that attribute is considered to be realised in each system (eg amounts of maize production), and of all attributes, the final value that the farmer ascribes to it is established. This gives an indication of the importance of each aspect to the farmers, and which levels of the different attributes (eg what amounts of maize production) they consider acceptable.

Based on the scenario exercise, labour requirements are most important in evaluating a cropping system, and differences in labour requirement (and with that, differences in Labour Equivalent Ratios) would have a large influence on decision making. Indeed, labour is one of the major constraints in production systems in the research region, and more generally, in smallholder farming in sub Saharan Africa (Giller et al. 2009; Lestrelin et al. 2011). In the interviews, it is stated for many agronomic activities that they should have taken place earlier and/or faster. Timeliness of certain agronomic practices, especially of planting and weeding, is crucial for crop development and hence final production (Johansen et al. 2012). As a result of the time required for multiple ploughing rounds planting is often delayed (Giller et al. 2009; Lestrelin et al. 2011), reducing the duration of the cropping season which is already short due to the short rainy season. For weeding, often not enough labour is available to weed a field timely (Giller et al. 2009). This may lead to serious prolonged weed infestation.

The second most important attribute is maize grain production. Maize grains are necessary for feeding the family (see also Marongwe et al. (2011) and Johansen et al. (2012)). Bean grains are also highly valued, as they can generate income (see also Tsubo et al. (2005b) and Giller et al. (2009)). In case of a maize deficit, this money can be used for buying additional maize. Bean value per kg is higher, but production is lower than that of maize. In decision making, the farmers will opt for a minimum production of maize, and if available area allows, beans will be grown. Residues are also highly valued, although this relative quantification may not be reliable due to problems described in paragraph 4.3. Although lack of residue retention is seen as a problem by farmers, cattle feeding is prioritised (as confirmed by Giller et al. (2009)). Cows and oxen are equally important, and dairy production and ploughing capacity, respectively, are their most important uses. Manure production of both cows and oxen and sales of oxen are all of similar importance, though much less important than dairy production and ploughing. These findings largely coincide with earlier findings (Giller et al. 2009; Valbuena et al. 2012). However, the use of cattle as a means of cash income was not as prominent as it is often described (for instance in Valbuena et al (2012)), and the aspect of cattle ownership as a sign of wealth of symbol of status (Aune et al. 2006) did not come forward at all. This may be because the function of cash income is only used in specific occasions, such as the death of a family member or the building of a house (from interview data) and is hence not taken into account in considering the more consistent uses of cattle. Cattle as symbol of status is not likely to be mentioned by farmers due to the social and cultural sensitivity of this aspect.

The data as obtained through the scenario exercise do not allow for mathematical filling out of all the variables of the decision formula. The number of coins assigned to the scenario representing a particular option is a direct indication of V. However, mathematical deduction of the values of S and K separately is not realistic. The number of green and red matches assigned to a criterion or attribute can be considered to represent the value of S*K. This value is in part based on the projections of that attribute in the scenario (eg the amount of maize grain produced influences the score S). Per farmer only three scenarios were evaluated, and hence data for only three options were collected. With that, these data will not have been mathematically consistent, both due to flaws in the design of the scenario exercise and as a result of human fallibility.

There are methods which allow more actual quantifications to be made regarding importance of attributes of different options, such as in Birol et al. (2009). However, this involves surveys with many respondents, which does not allow for the in depth qualitative evaluation that can be derived from the scenario exercise (see also Place et al. (2007)).

## 4.9 **Patterns of innovation**

According to Rycroft and Kash (1999, in Ekboir (2002)), there are three patterns of innovation that can be used to classify the evolution of technologies. The first is the 'normal' pattern, implying incremental changes, that is, only minor changes of standard practices. In this case, a technology evolves within an established network along familiar technological standards. There is relatively low technological and economic risk, and the interaction mechanisms are known and relatively stable. The adoption of the maize variety Melkassa-II in the Rift Valley may be considered to have been according to the 'normal' pattern. Farmers in the area have grown maize for a long time, and have often used a number of different varieties (Alemu et al. 2008). The adoption of Melkassa-II requires little changes in the agricultural practices of the farmer. The land can still be cultivated in the same way, and Melkassa-II has no special requirements compared to other maize varieties.

The second is the 'transition' pattern, where an established network and technology turn to a new evolutionary path. The innovation may be introduced into existing production processes. Technological risk is greater as the production process goes through a substantial change, but the innovation network remains relatively unaffected. Intercropping may be regarded as a 'transitional' change. Farmers are accustomed to growing both maize and beans. Growing them in intercrop is a

new concept, but this new technology is mainly a new combination of known technologies and no additional technologies are needed.
The third is the 'transformation' pattern, implying revolutionary changes. Here, a new development path is launched by a new network for a new technology. The technologies represent a major departure from conventional practices and involve major commercial and technological risks. Technical standards and market opportunities are not well understood, hence, developers have to interact closely with other members of the network to reduce risk and to obtain all the knowledge required to develop the innovation. Both residue retention and minimum tillage may be considered to imply revolutionary changes, and hence follow the 'transformation' pattern. Together with intercropping or crop rotation, these technologies form the Conservation Agriculture (CA) package (paragraph 1.2). Residue retention and minimum tillage cannot be adopted in isolation of the other CA package components (paragraph 1.2) and imply drastic changes (Erenstein 2002; Gowing and Palmer 2008; Valbuena et al. 2012). Adopting these technologies implies adopting a whole new agricultural system, not only affecting the crop component but just as much the livestock component of the current mixed agricultural system, with all its practical, social and cultural consequences.

## 4.10 **Assessment of new technologies for adoption**

As part of this research, several methods of data collection were executed which could be used in the assessment of new technologies such as those under the SIMLESA project. This assessment is crucial at several stages of such projects. The methods used were on station field trials, official regional data, and farmer interviews and scenario exercises. In addition, SIMLESA field days, farm visits with project reviewers and project presentations were attended. Combining these different methods, even when there seemed to be an overlap in the data to be obtained, was important for several reasons. All methods may have contained flaws, some of which have been described above. Comparing the data obtained through the different methods allowed for cross checking and analysis of possible discrepancies (Place et al. 2007). The field trials were executed in a more or less controlled environment to evaluate implications and consequences of technologies on the field level. However, in case a technology seems to be worthwhile on the field level, it is also important to assess assess implications and consequences on farm or even higher levels as this may give rise to new insights (Kristjanson et al. 2002). In this research, this was done through a combination of two types of 'interviews'. The semi-structured farmer interviews were undertaken in order to explore the current production systems and agronomic practices, including their major benefits, costs and constraints as perceived by the farmers. These interviews alone already gave a lot of information; however, the subsequent scenario exercise that was developed on the basis of these interviews revealed farmers' perception on benefits, costs and constraints even further. The three methods together revealed not only the actual benefits, costs and constraints, but also farmers' perception of these and their relative importance to the farmer. As Kristjanson et al. (2002) and Place et al. (2007) also argue, it is the combination of different quantitative and qualitative methods (in this research the field trials, the interviews for situation analysis, and the scenario exercise) that allows for assessment of new technologies to be considered for large scale adoption by farmers. Through using these research methods, it can be assessed to what extent the new technology would either fit into the current systems and practices or would require drastic changes on field or farm level. Hence, it can be determined which pattern of innovation would apply to the technology, which is crucial in determining the dissemination strategy (paragraph 4.11). If drastic changes in the current agricultural system are necessary, feasibility of these changes should be evaluated (possibly again using all three methods). It can be assessed how farmers currently perceive the new technology, and which factors are most important to them in their own assessment of the technology. These can then be taken into account in the researchers' assessment of the technology. If there are factors that are considered to be important by the researchers which the farmers do not take into account, it can be evaluated whether the farmers should be made more aware of these factors. Farmer perception of factors may not coincide with reality as deducted from the field trials. This discrepancy may either positively or negatively influence their decision of adoption of the new technology, which should be addressed as well, for instance through the use of exploratory trials or trainings.

## 4.11 **Dissemination strategy: understanding and influencing decision making**

In a wide range of disciplines, there has been on-going discussion and evaluation of different methods of 'spreading ideas' that are considered to be beneficial to the target audience, which in the health sector has even led to the emergence of so-called Dissemination and Implementation Research (Tabak et al. 2012). Dissemination is often seen as the means of transferring a technology to the target group after it has been completely developed in the scientific community (Gagnon 2011). However, research, assessment (paragraph 4.10), and transfer of the technology can all be part of an iterative process which will eventually lead to adoption of the most suitable technology by the farmers. This process will be referred to as the dissemination strategy. Emphasis on the different components (research, assessment and transfer of the technology) and the order and frequency in which they take place will differ between technologies in different contexts. The strategy to be adopted largely depends on the pattern of innovation that is applicable to the technology. The understanding and possibly influencing of the decisions that farmers make between existing and new technologies are crucial in the dissemination strategy.

### 4.11.1 **The normal pattern: the example of Melkassa-II**

Melkassa-II is one of the 'Melkassa' maize varieties that have been developed and specifically adapted to the semi-arid agro-ecologies of Ethiopia's Rift Valley. Since their release around the change of the millennium, these varieties have been promoted with smallholders throughout the Rift Valley. According to Alemu et al. (2008) adoption in the region had remained low. Other authors (Girma et al. 2005; Beshir 2010) claim successful adoption under certain projects. However, none of these authors quantify adoption. Currently, the Melkassa-II variety is promoted through the SIMLESA program, mainly for its early maturity and drought tolerance. Demonstration plots are the most important component of the dissemination strategy. Farmers visiting these plots, where several different maize varieties are grown, will receive some information and can judge the varieties for themselves, according to their own criteria (Girma et al. 2005; Beshir 2010). Melkassa-II was also the variety used in the exploratory trials.

Differences between options (maize varieties) are simple rather than complex. When filling in the decision formula for the options, only some S values, such as that for grain production, will differ. Demonstration plots will give the farmers sufficient input to make their decision, as the relative degree to which the S values differ can be estimated from the demonstration plot.

Adoption of Melkassa-II in the Adami Tulu area is now high and Melkassa-II is now the dominant maize variety (confirmed at a farmer field day in Adami Tulu, 2012, no quantitative data available). Of interviewed farmers, all SIMLESA farmers had adopted the variety in 2012, and others had started using it after seeing it being used by their neighbours. Indeed, imitation was found to be one of the major drivers for using agricultural technologies (Kristjanson et al. 2002; Lestrelin et al. 2011). Benefits farmers mentioned for using Melkassa-II compared to other varieties are similar to those used in SIMLESA argumentation. However, seed availability remains a constraint to farmers. This is in line with findings from Alemu et al. (2008) who found that variety use is largely dependent on seed availability, often resulting in farmers not being able to obtain seeds of the variety that they prefer in the desired quantity. Improved seed availability of Melkassa-II compared to other varieties, partly as a result of the SIMLESA project, may have been more influential in variety choice than the actual preference of the variety.

When introducing a new technology following the normal pattern, the use of demonstration plots after initial development of the technology may be of great value as a component of the dissemination strategy. Although these demonstration plots as a means of technology transfer are not as indirect as Rycroft and Kash (1999, in Ekboir (2002)) imply for the normal pattern, the degree to which farmers are actually involved in the development of the technology is relatively low. Due to the relative simplicity of the changes, using the scenario exercise to compare the different options may not be necessary, as the implications of the new technology can be understood without the scenario exercise. However, even if there seems to be initial adoption, thorough understanding of the farmers' decision is needed. In the case of Melkassa-II, more research could be done to explore the relation between maize variety use and its' availability (related to both supply and prices) in different years. If indeed seed availability is a greater determinant of variety use than preference of the variety, seed availability of Melkassa-II must be ensured also after the end of the SIMLESA project in the region. The dissemination strategy, in that case, can be more focussed on enabling farmers to adopt than on convincing them to adopt.

### 4.11.2 **The transitional pattern: the example of intercropping**

As part of the SIMLESA project, farmers have been informed of benefits of intercropping and have received training on how to apply the technology. Through the exploratory plots and farmer field days, they have experienced the new technology and several of its' implications for themselves and/or have seen it being used by their neighbours, and they have discussed it amongst each other and with others, such as DA's and researchers.

Compared to a normal change, a transitional change, such as that from the current system to intercropping, encompasses more changes for the farmers, which they may not be able to oversee easily. In the decision formula, more S values will change. For intercropping, not only maize grain production will differ but also bean grain and residue production should be taken into account, and other factors, such as labour and cattle use, may also differ between the options. These complicated changes, which the farmer does not have experience with so far, make it difficult for the farmer to determine the relative degree to which the S values change compared to the current situation. Also, as more attributes will change simultaneously, determining their relative importance (K) will become more important in the final decision making process.

Due to this complexity, the implications of the new technology may be better understood by using the scenario exercise in addition to the before mentioned SIMLESA methods. The scenario exercise will engage the farmers in establishing the implications of the technology and enable them to evaluate these implications and, with that, the technology as a whole. During the execution of the scenario exercise within this research, this method was indeed received very positively by some farmers who explicitly mentioned that this method was a clear and comprehensive way for them to evaluate the new technology. The scenario exercise, together with semi-structured interviews, also serves as a way to obtain information from the farmer for assessment and further iterative development of the technology as described in paragraph 4.10.

Intercropping was not widely practiced in 2012 and some farmers had not heard of the practice. General opinion of intercropping, though, seemed highly positive. Projected Labour Equivalent Ratio and Land Equivalent Ratio both exceeded one and all farmers but one were convinced that intercropping was the best cropping scenario. Nearly all farmers planned on either expanding their area under intercropping or start the practice next year. Some even planned on intercropping their whole maize area, as they have seen that production is good, without much trade-offs, and easily incorporated within the existing system. Enthusiasm was high both among farmers who had already tried intercropping this year and those who had seen the practice on the fields of their neighbours. SIMLESA's trainings, exploratory trials and field days thus seem apt dissemination methods for the transitional pattern and can be embedded within the iterative dissemination strategy together with field trials, semi-structured interviews and scenario exercises. In the transitional pattern, the farmers are more involved in the dissemination strategy of the technology than is the case for the 'normal' pattern, which is in line with Rycroft and Kash (1999, in Ekboir (2002)).

As with all technologies, only time will tell whether the ostensible enthusiasm will indeed lead to adoption in the following cropping season, and if so, whether this adoption is of a lasting nature (Place et al. 2007). Problems such as seed availability or crop failure may discourage the farmers from proceeding to use this system. In the exploratory trial, intercropping was practiced in combination with minimum tillage and residue retention; hence results of this trial may not reflect results farmers can obtain in absence of these technologies. Also, further spread of the practice outside the community, as anticipated in the SIMLESA project through both organised dissemination activities and unorganised spill-over effects, can only be judged after a longer period of time. When judging solely from the results of the interviews and scenario exercises as performed among the nine farmers in this region, adoption of intercropping will be successful. See, however, also paragraphs 4.2 and 4.7.

### 4.11.3 **The transformation pattern: the example of residue retention and minimum tillage**

Within the SIMLESA project, the dissemination strategy for residue retention and minimum tillage is the same as for intercropping. However, residue retention and minimum tillage are more complex technologies than intercropping, constituting a transformation pattern instead of a transitional pattern. Although exploratory plots are widely advocated for use in CA projects (Farooq et al. 2011; Marongwe et al. 2011; Johansen et al. 2012), the drastic changes involved in CA uptake cannot be demonstrated using exploratory trials alone as these trials are conducted at the field level, while interactions with other components such as livestock take place at the system level. These interactions determine whether the technology package is feasible for the farmer. In the residue retention/minimum tillage case, the residue retention aspect of the exploratory trials was evaluated positively at the field level by the farmers. Positive evaluation was sometimes strengthened through farmers' own previous experiences from the time they still practiced residue retention, which was only one or two decades ago. However, farmers argued that they could never adopt this technology now as all residues were required as cattle feed. This wasn't a problem before as there was more land available for grazing, see also Dessie and Kleman (2007) and Valbuena et al. (2012). This coincides with findings from Lal (2007) who states that most farmers are fully aware of the benefits of using crop residues as soil amendments, yet are not able to apply the technology. The only farmers who retained residue were those who owned no or little cattle, and even then residues were only retained on small plots as most residues were either used for feeding livestock of family of sold for use as fodder (see also Giller et al. (2011)). Although some farmers mentioned planning on retaining (more) residues on their field in the following cropping season, this seems unlikely without simultaneously changing other components of the system. An alleviation of the pressure on residues could be achieved by a reduction in livestock herd size and a simultaneous increase in amount of residue biomass produced and can be mitigated through adoption of minimum tillage and intercropping (Giller et al. 2011; Valbuena et al. 2012). As described above, adoption of intercropping is not unlikely. Adoption of minimum tillage, on the other hand, will be more difficult. Although farmers have reduced the number of ploughing rounds they apply to their fields, most of them still plough three to four times. Extensive ploughing has been practiced for years and is believed to be necessary to obtain high yield (Ekboir 2002; Aune et al. 2006; Temesgen et al. 2008). As such, ploughing and the keeping of oxen is deeply rooted into culture. Also, the keeping of cattle serves many other functions such as dairy production and savings (Ralevic et al. 2010; Valbuena et al. 2012), and cattle ownership is a sign of wealth (Aune et al. 2006), increasing the reluctance of farmers to reduce their livestock herd. Concerning minimum tillage, the farmers are right. Ploughing can only be reduced if this reduction is accompanied by the other components of the CA package, residue retention being one of them (Farooq et al. 2011; Mrabet et al. 2012). As long as residue retention cannot be practiced, neither can minimum tillage.

Apart from the above problems, other constraints may limit adoption. In order to adopt minimum tillage, specialised equipment is needed, which is still largely unavailable in the area and is described by Ekboir (2002) as one of the key factors limiting adoption of minimum tillage (Ekboir 2002). His findings were confirmed at a farmer field day in Adami Tulu in 2012[1]. Weeding requirements and herbicide unavailability and prices are described as main constraints of using minimum tillage (Giller et al. 2009; Thierfelder and Wall 2011; Baudron et al. 2012). However, none of the interviewed farmers indicated weed control as a reason to plough. The zero tillage farmer mentioned residue retention as a means to control weeds. Farmers said that herbicides were cheap, but less effective than manual weeding. From this research, it is unclear what the effects of adopting CA on weed control would be in the area.

When evaluating transformational changes, in the decision formula many S values will be different from those of the current system. Also, the farmers might need to reconsider their perception of K of each attribute. In order to reach the same objectives, a new set of attributes may be needed (Thierfelder and Wall 2011). In the case of CA, high maize grain production is no longer achieved through ploughing the field with residue-fed oxen. Instead, high maize grain production is accompanied by bean production, and is achieved through intercropping the maize with beans, leaving residues on the field without ploughing. K of oxen would decrease drastically, while the attribute of beans is added. This complexity of implications for the decision formula underlines the difficulty to comprehend all implications of technologies following the transformation pattern on the system as a whole. Exploratory trials may reveal some costs and benefits, but the technology can only be evaluated if these costs and benefits are related to the implications on other components of

[1] Questions were raised by farmers concerning the extra equipment necessary for minimum and zero tillage. The ripper (a device which can be used instead of a plough to open a furrow for seeding under minimum tillage), it was answered, could be delivered as much as needed through the project. However, the jab planter (another device which can be used for planting seeds under minimum tillage, which does not require the use of oxen) currently needed to be imported. Only when demand would be high enough it would be feasible to start fabricating it in the region. Hence, it would not be easily obtainable for farmers, even if they were enthusiastic about using this device instead of conventional tillage.

the package and vice versa. This crucial linkage between the components does not seem to have been adequately made by the farmers in the Adami Tulu area. Various SIMLESA activities, such as the trainings and the farmer field days, may be suitable to clarify this linkage to the farmers. The scenario exercise as it is developed and used in this research project may not be suitable for comprehensive evaluation of technologies implying transformational changes. This exercise is based on three scenarios representing the current situation, the situation in case of adoption of the new technology, and an intermediate situation. In the case of transformational changes, it would not be possible to find an appropriate intermediate scenario, as, by definition, this situation does not exist in transformational changes. A different version of the scenario exercise could be used, in which only the scenario representing the new system is built. Although this scenario building would allow the farmers to get a complete picture of all attributes and their implications of the new system, they would still not be able to experience this new system.

Dissemination of technologies comprising transformational technologies is difficult. The changes and their interactions and implications for the system are highly complex to comprehend, both for researchers and for farmers. Effects will be site specific and short term effects of the technology may be different from long term effects (Lal 2007; Giller et al. 2009; Farooq et al. 2011; Thierfelder and Wall 2011; Johansen et al. 2012; Valbuena et al. 2012). The transformational pattern requires close interaction between researchers and farmers (Rycroft and Kash (1999) in Ekboir (2002)). A combination of dissemination methods (fields trials, on-farm trials, interviews, scenario building, etc) may contribute in unravelling the technology with all its implications further and further. However, it may turn out that, apart from practical barriers that may be possible to overcome, the necessary change of mind set (Thierfelder and Wall 2011) is currently too large to enable adoption by the farmer.

## 4.12 **Participation?**

The term ‘participatory research’ is currently used by many (agricultural) research organisations working in developing countries. It seems to be seen as the panacea in the development and spread of new technologies which are to improve the livelihoods of many. In agricultural research proposals, participatory research is often presented in a highly romanticised way (Bentley 1994), with farmers and researchers working side-by-side in developing new technologies. In reality, participation of the farmers is limited (Chambers 1990; Bentley 1994). The SIMLESA project proposal contains many concepts such as participation, collaboration, relevance and capacity building (Dixon 2009). According to the proposal, farmers are involved in all steps of the development of new technologies for “sustainable intensification of maize-legume cropping systems for food security”. However, the technology to be spread in order to achieve this had actually already been determined: CA (Dixon 2009). This predetermination seems inevitable, especially for large-scale, donor-driven projects such as SIMLESA. Donors will appreciate the idea of farmer participation, but will never invest their money if the research plan goes no further than ‘we’ll go to the farmers and see what we come up with’. It is the job of researchers to develop technologies which farmers would not come up with, and they may do this behind their desks without direct farmer involvement. Farmers and researchers have different objectives; observational, experimental and communicational styles; and backgrounds and future outlooks. Also, social, geographical and economic barriers may create a distance (Bentley 1994) limiting possibilities of effective collaboration. Farmer involvement prior to initial development of new technologies is essential though. It is a requisite for the researcher to have some understanding of the objectives of the farmers, the system currently practiced, and both the benefits and problems of this system. According to many research proposals, reaching this understanding is part of the project. In reality, it has often already taken place. Projects build on previous projects and data in order to identify problems and opportunities to address. A technology that has shown promising results in preliminary trials will be proposed. This technology will then be taken to the farmers. The iterative process continues: researchers interact with the farmers, develop the technology a bit further, and take it back to the farmers. Interaction with the farmers, or participation of the farmers, will consist of the whole range of interviews, on-farm trials, scenario exercises, farmer field days and trainings as described in this research. Farmer participation will enable the scientist to understand farmers' objectives, perceptions and trade-offs they have to deal with, feeding back into the development of the technology. Farmer participation will also enable farmers to understand and experience new technologies and their implications, and their involvement increases their sympathy for and dedication to the project (Bentley 1994; Pretty 1995; Chambers 2004). Mutual understanding and involvement of scientists and farmers are crucial in the development and adoption of a technology (Bentley 1994; Pretty 1995; Chambers 2004; Kothari 2005). In the SIMLESA project, this approach has been applied to a certain extent. However, adequate use of farmer input in the choice and development of technologies is questionable. According to the project proposal, the choice of technologies for the exploratory trials would be largely based on a baseline survey, and made in collaboration with the farmers. The trials would then be further discussed, evaluated and adapted to local circumstances, again in collaboration with the farmers. However, at the time the exploratory trials were initiated, results of this baseline survey were not available yet. The practices introduced in the exploratory trials around Adami Tulu all involved minimum tillage and residue retention. Even though constraints of these technologies largely involve the livestock component, the linkage of the technologies to livestock is hardly addressed in dissemination of the technologies to the farmers in the SIMLESA project.

Importance of farmer-researcher interaction increases with complexity of the technology, as indicated in the different innovation patterns (Rycroft and Kash (1999) in Ekboir (2002)). When a technology is unsuitable under current conditions (which may range from seed availability to farmers' mind set), either the technology or the conditions or both will need adaptation. In some cases, the final conclusion of the iterative process of farmer participation in technology development may be that adoption is not realistic.

By definition, dissemination to a certain extent remains a top-down process. The word 'dissemination' comes from the Latin word 'disseminare', which can be translated as 'scattering seeds' or 'sowing' (Collins 2009). There have to be a receiver and a transmitter of the seed, and the receiver (the soil) can never produce a new seed on its own. Similarly, a new technology needs to be brought to the farmer. The technology, however, is brought to the farmer as a seed, rather than as a tree that has been grown elsewhere, as would be the case in a truly top-down approach. The seed needs time to grow, establish itself in the soil and develop into a tree. The tree may need trimming. The soil it grows on may need initial fertilisation. Similarly, the technology may need adaptations to meet the farmers' possibilities and objectives, and the farmers might need different forms of input (such as trainings) for the technology to be successful. However, a soil may not be suitable for a specific tree. No matter how far the tree is trimmed down, and even when it is possible for the tree to survive with continuous adding of input, existence, let alone proliferation of the tree, will not be sustainable. Similarly, a technology may not be suitable under certain conditions, no matter how much is tried to adapt the technology. If using the technology is merely possible while farmers receive inputs only available to them through a project, the technology will go out of use as soon as the project ends.

This analogy falls short mainly with respect to the passive nature of the soil, while if given the chance, farmers will be able to actively participate and share their ideas with the researchers.

# 5 Concluding remarks

Food insecurity is still a large problem in sub Saharan Africa, and Ethiopia is no exception. Improving current agricultural practices in order to increase sustainable production of food crops is crucial. In this research, four alternative technologies, believed to improve agricultural productivity, and their possible dissemination were evaluated. The introduction of a new maize variety (Melkassa-II) was the most succesful. This was the most simple technology, following a normal innovation pattern, and was easily comprehendible and applicable for farmers. Intercropping maize with beans would comprise slightly more changes to current farmer practices. However, benefits of intercropping were easily evaluated from exploratory trials and confirmed by formal field trials (although with cowpea instead of beans) and literature. Judging from interviews and scenario exercises, farmers were enthusiastic about this technology. Hence, adoption does not seem unlikely. Both residue retention and minimum tillage, on the other hand, comprise system wide changes to the current system. Farmers are aware of the benefits of residue retention on the field level, however, they are not able to apply this technology without simultaneously changing other components of the system. Cattle rearing, largely for the purpose of ploughing, is a major constraint as residues are necessary for use as fodder. Farmers are reluctant to reduce ploughing as the belief in benefits of ploughing are deeply rooted and minimum tillage equipment is still largely unavailable. Moreover, cattle also serve other purposes (e.g. dairy production, financial security and prestige), making a reduction of the cattle herd size even more unlikely. Without this reduction, residue retention cannot be adopted. Even on the field level, residue retention and minimum tillage cannot provide the anticipated benefits unless applied simultaneously. Hence, currently, adoption of residue retention and minimum tillage seems unlikely.

A combination of both quantitative and qualitative methods, including amongst others field tests and different forms of farmer participation, was found to be appropriate for technology evaluation, development and transfer. For evaluating intercropping systems, different versions of the Land Equivalent Ratio, depending on farmer constraints and objectives, may be used. With labour being a major production constraint in the area, the Labour Equivalent Ratio was a useful indicator. Additionally, the newly developed scenario exercise was of great help in increasing farmers understanding of the technology and researchers' understanding of farmer perceptions and therefore decision making. Besides an understanding of the complexity of the technology, this is useful in choosing a suitable dissemination strategy. Costs and benefits of technologies following the normal pattern are easily analysed at the field level both by researchers and farmers through the use of field trials, demonstration trials and/or exploratory trials. Dissemination of these technologies poses the least challenges. Dissemination of transitional technologies is already more complicated. A higher level of participation of the farmer is necessary in order to assess the suitability of the technology for the farmers. Field level tests need to be supplemented with interviews and exploratory trials and further in-depth understanding can be achieved through assessment with the scenario exercise. Transformational technologies comprise the most complex changes, and are most difficult to evaluate for both researchers and farmers. The technologies can be tested at field level, however, this will not give sufficient input for assessment as the changes implied by the technology go beyond the field level. Using interviews and an adapted form of the scenario interview may shed more light on the perceptions, objectives and constraints of farmers. However, even with a high degree of participation, it is difficult to enable farmers to fully comprehend the implications of the technologies on a system wide level. In some cases, the change of mind set necessary for adoption of these technologies may be too large to overcome.

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# APPENDIX I SIMLESA project outline

(Information taken from SIMLESA brochure and SIMLESA Program Document (Dixon 2009; SIMLESA 2011))

This research was related to the SIMLESA project (Sustainable intensification of maize-legume cropping systems for food security in eastern and southern Africa). This project, which was launched in 2010, is funded by the Australian Government through ACIAR (the Australian Centre for International Agricultural Research). The program is managed by CIMMYT (the International Maize and Wheat Improvement Center) in close collaboration with publicly-funded research organisations in the partner countries. SIMLESA aims at increasing farm-level food security and productivity in the context of climate risk and change. Its main outcome is resilient, profitable and sustainable farming systems that overcome food insecurity for significant numbers of farm families. That is, the project aims to improve maize and legume productivity by 30% and to reduce the expected downside yield risk (farmers' risks from seasonal yield variation) by 30% on approximately 500,000 farms within ten years, with significant spill-over effects in neighbouring regions and countries. The initial target regions are Ethiopia, Kenya, Tanzania, Malawi and Mozambique in Africa, and Australia. The project objectives and their outputs are:

Objective 1: To characterize maize-legume production and input and output value chain systems and impact pathways, and identify broad systemic constraints and options for field testing.
Outputs

- Initial characterization of ten maize-legume farming systems and selection of thirty research sites/communities.
- Understanding farmers' maize and legume production constraints and opportunities, crop and livestock interactions, resource use, technology preferences and market access in the ten farming systems.
- Understanding maize and legume input and output markets and value chains including chain constraints and opportunities, costs and pricing patterns associated with the ten farming systems.
- Major farm-household typologies and system options that reduce risks and enhance profitability identified for each of the ten farming systems for testing in the research sites/communities.
- Effective adoption and impact pathways assessed for ten maize-legume systems.

Objective 2: To test and develop productive, resilient and sustainable smallholder maize-legume cropping systems and innovation systems for local scaling out
Outputs

- Identified options for systems intensification and diversification that reduce risk in the ten farming systems using systems modeling.
- Functioning local innovation systems which engage 5,000 farmers each in at least ten maize-legume systems for local scaling out.
- Evaluated exploratory trials of current best options for maize/legume smallholder systems for different farm types in with 5-6 cooperating farmers in each of thirty research sites/communities.
- Adjustments to the smallholder systems tested in the exploratory trials and farmer experiments developed with farm communities in the thirty research sites/communities and soil quality, system productivity and disease, pest and weed dynamics quantified.
- Appropriate interventions for improving seed and fertilizer delivery and farmer access to technologies and markets field tested in at least thirty research sites/communities. A synthesis

- Lessons from active farmer experimentation with CA-oriented systems incorporated into on-farm research and/or demonstration plots in each of the thirty research sites/communities.
- Farmer learning through annual facilitated visits of farmers and their local extension agents between the targeted communities in each of the five countries.

Objective 3: To increase the range of maize and legume varieties available for smallholders through accelerated breeding, regional testing and release, and availability of performance data
Outputs

- Ten to 15 stress tolerant maize varieties and 10 higher yielding legume varieties available to farmers in the selected farming systems through farmer- and seed company-participatory variety evaluation and release.
- Regional nursery for further improved (2nd generation) maize and legume varieties and hybrids.
- Environmental characterization:

Objective 4: To support the development of regional and local innovations systems
Outputs

- Mainstreaming of gender sensitivity in research activities in the five primary program countries.
- Functioning program M&E system incorporated into the program providing information system assessments to national and regional program managers.
- Knowledge of relevant program innovations and germplasm available in five additional countries in the region.

Objective 5: Capacity building to increase the efficiency of agricultural research today and in the future
Outputs

- Training on technology targeting and value chain analysis will be provided to build and enhance capacity of national and regional programs.
- Training course on simulation model utilization and participatory evaluation
- Training on cropping systems management research including the principles and practice of conservation agriculture.
- Training on crop improvement
- Training and APSIM model parameters

In order to sustainably intensify maize-legume cropping systems while reducing yield variability, according to SIMLESA, an integrated approach to the complex production and marketing system for these crops is required. SIMLESA aims to meet its aims through participatory research and development with farmers, extension agencies, non-governmental organizations, universities and agribusinesses along the value chains. Through sub-regional research organizations and existing networks, the program will foster spill-overs of improved crop systems management practices, knowledge and germplasm to other countries in the region. Benefits to Queensland will arise from improved maize germplasm and better rain fed maize-legume systems options for summer cropping. For the conceptual framework of the SIMLESA projects, see Figure 29.

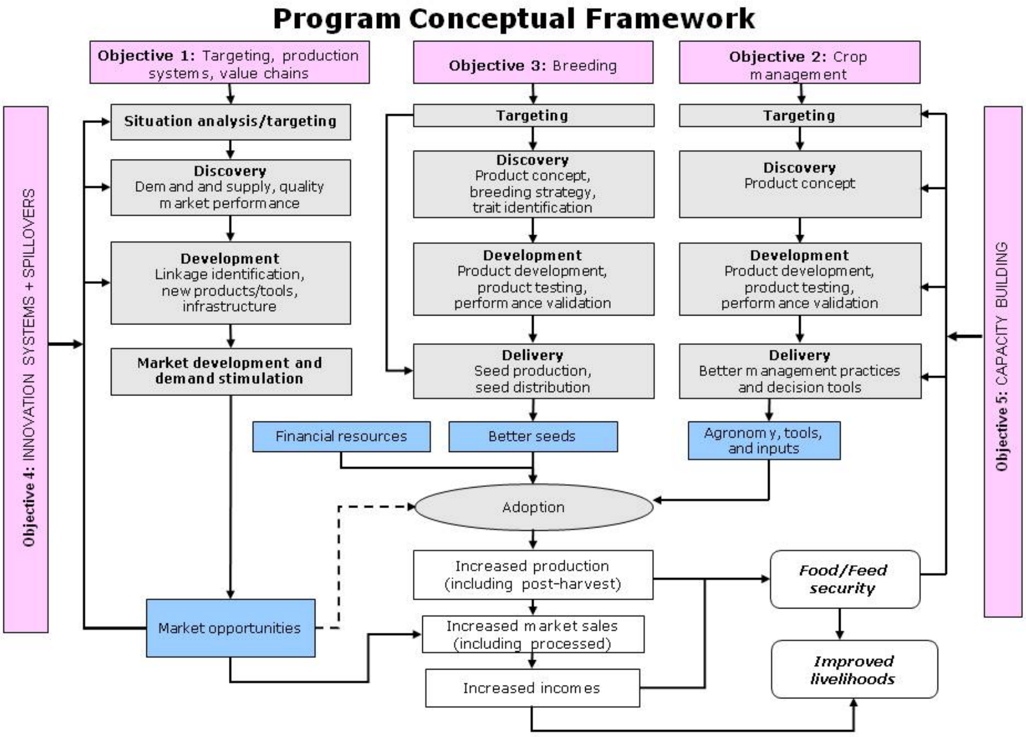


**Figure 29: Program conceptual framework and impact pathway (SIMLESA Program Document (Dixon 2009), p34)**

# APPENDIX II Interviews with farmers October 2012

General information of interviewed farmer
District:
Farmer Name:
Telephone number:
Date:

Exact composition household
- # Children including ages
-Do they help with the work?

Is there any other labour available (eg hired, if yes how many and when)?

Per field (current season):
-Size of field?
-Crop on field?
    What is the crop used for (food/fodder)?
    Variety? (eg maize Melkassa II?)
    WHY?

*Ploughing*
    How often?
    Depth?
    When?
    Labour required (#days and #people per day)?
    WHY?
    If you could have done it differently, what would you have done?

*Manuring*
    Amount (if in gari, include amount (kg) per gari)?
    How (eg incorporate)?
    When?
    Labour required (#days and #people per day)?
    WHY?
    If you could have done it differently, what would you have done?

*Fertilising*
    What?
    Amount?
    Prices (birr/kg)?
    When?
    Labour required (#days and #people per day)?
    WHY?
    If you could have done it differently, what would you have done?

*Planting*
    How?
    When?
    Labour required (#days and #people per day)?
    What made you decide when to plant?
    WHY?
    If you could have done it differently, what would you have done?

*Thinning*
    When?

Labour required (#days and #people per day)?
WHY?
If you could have done it differently, what would you have done?

*Weeding*

How often?
When?
What made you decide when to weed?
Labour required (#days and #people per day)?
WHY?
If you could have done it differently, what would you have done?

*Spraying*

What?
When?
Labour required (#days and #people per day)?
WHY?
If you could have done it differently, what would you have done?

*Harvesting*

When?
What made you decide when?
Labour required (#days and #people per day)?
How much did you harvest (grain, residues)?
WHY?
If you could have done it differently, what would you have done?

*Threshing*

When?
Labour required (#days and #people per day)?
WHY?
If you could have done it differently, what would you have done?

*Continue after filling in the above for each field of the farmer.*

Have you heard of/have experience with intercropping?
Did you do any intercropping?

Exact composition livestock herd (#)?

Bulls:
Cows:
Oxen:
Heifer:
Calves:
Donkeys:
Horses:
Goats:
Chicken:
WHY do you keep livestock (each type)?

What is the condition of the livestock throughout the year (Lean/Medium/Fat)? (fill in table)
What do the livestock eat throughout the year (food type with percentage of total intake in that period)? (fill in table)

| | Nov | Dec | Jan | Feb | Mar | Ap | May | Jun | Jul | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Condition (L, M, F) | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Composition of the feed ration (%) | | | | | | | | | | | | |

If you could have done it differently, what would you have done?

Is there any communal grazing?

Is any residue retained on the fields (%)?
If you could have done this differently, what would you have done?
Are any of the residues used for fuel (%)?
Are any of the residues used for house maintenance (%)?

Income/expenditure previous year (fill in tables) (for crop income: include which type of crop and size of field)

| | *Grains? (kg)* | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harvest | | | | | | | | | | | | |
| | Buying | | | | | | | | | | | | |
| | Casual work | | | | | | | | | | | | |
| | Services | | | | | | | | | | | | |
| IN | | | | | | | | | | | | | |
| | Consumption | | | | | | | | | | | | |
| | Hired labour | | | | | | | | | | | | |
| | Service | | | | | | | | | | | | |
| | Sales | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| OUT | | | | | | | | | | | | | |

| | *Cash (Birr)* | Nov | Dec | Jan | Feb | Mar | Ap | May | Jun | Jul | Aug | Sept | Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maize | | | | | | | | | | | | |
| | Beans | | | | | | | | | | | | |
| | Wheat | | | | | | | | | | | | |
| | Cattle | | | | | | | | | | | | |
| | Sheep/goats | | | | | | | | | | | | |
| | Chicken | | | | | | | | | | | | |
| | Milk, dairy | | | | | | | | | | | | |
| | Fruits | | | | | | | | | | | | |
| | Vegetables | | | | | | | | | | | | |
| | Firewood | | | | | | | | | | | | |
| | Casual work | | | | | | | | | | | | |
| | Service | | | | | | | | | | | | |
| | Employment | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| IN | | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cereals | | | | | | | | | | | | |
| | Other food | | | | | | | | | | | | |
| | School fee | | | | | | | | | | | | |
| | Clothes | | | | | | | | | | | | |
| | Household material | | | | | | | | | | | | |
| | Fertiliser | | | | | | | | | | | | |
| | Seed | | | | | | | | | | | | |
| | Herbicides | | | | | | | | | | | | |
| | Pesticides | | | | | | | | | | | | |
| | Vet. Services | | | | | | | | | | | | |
| | Hired labour | | | | | | | | | | | | |
| | Service | | | | | | | | | | | | |
| | Support | | | | | | | | | | | | |
| | Other | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| OUT | | | | | | | | | | | | | |

# APPENDIX III Setup scenario interviews November 2012

*Three scenarios:*

*1 ha sole maize*

*½ ha sole maize, ½ ha sole bean*

*1 ha intercropping*

*End result of a scenario interview*

## 1 Explanation

For each scenario, there is a paper attached to a cardboard/paper background with a picture indicating what cropping system is on the field, which is briefly explained to the farmer.

## 2 Labour requirements

For each scenario, the farmer is asked to estimate how much labour (in man labour days) he would need to fulfil the practices of 1) ploughing and planting, 2) weeding, 3) harvesting and threshing, and 4) storage. Per scenario, results are indicated in a graph for each activity. The graph is attached to the background.

## 3 Maize grain yield

For each scenario, a piece of cardboard with some maize grains glued to it is attached to the background using a paper clip, below the field picture of each scenario.

Per scenario, the farmer is asked how much maize grain yield he would expect for this scenario assuming an 'average' year.
This amount is indicated by marking the appropriate amount of squares on a 5x10 grid which is attached to the background next to the grains using a paper clip. Each square represents 1 Quintal.

**4 Bean grain yield**

As 2: Maize grain yield.

**5 Maize residue yield**

For each scenario, a piece of cardboard with a picture indicating maize residue is put next to the grain yield indications.

Per scenario, the farmer is asked how much residue he would expect for this scenario assuming an 'average' year.
This amount is indicated by marking the appropriate amount of squares on a 5x10 grid which is attached to the background next to the residue picture using a paper clip. Each square represents 1 Gari (note the content (in Q) of the gari).

**6 Bean residue yield**

As 5: Maize residue yield.

**7 Residue retention**

For each scenario, the farmer is asked whether he would retain any residues on his field.

If yes, a picture indicating residue retention is attached to the background.
If not, a similar picture but with a cross through it is attached to the background.

If yes, the farmer is how much residue he would retain, and what the yield increase would be.
If not, the farmer will be asked how much residue he would have to retain to get a yield increase, and what this yield increase would be (note).

**8 Cattle feeding**

The farmer is asked whether, in feeding residues to his cattle, he would make distinctions between different kinds of residues for different types of cattle (eg use bean residue only for cows, note).

Per scenario, the farmer is asked how suitable the diet of the obtainable residues would be for oxen and/or cows.
Suitability is indicated by attaching a number (1, 2, or 3) of pictures of oxen and/or cows to the background.

**9 Cattle functions**

Per scenario, the farmer is asked to indicate which functions the oxen and/or cows would fulfil (eg ploughing, cash from sales, manure production and dairy production).

In the case of ploughing and cash from sales this is represented with a picture. In the case of manure and dairy production, this is indicated by assigning a certain number (1, 2, or 3) of specific tokens to the scenario.

**10 Additions**

The farmer is asked whether he has any additions to the attributes assigned to each scenario that he considers to be important to that scenario. If so, an appropriate method is found to indicate this additional attribute for the scenario.

## 11 Scenario preference

The farmer is asked to evaluate all three scenarios and indicate his level of preference using 15 coins to be divided over the three scenarios.

## 12 Scenario evaluation

'Positive' markers (green matches) are allocated to the three scenarios in the ratio as established in previously by multiplying the number of coins allocated to each scenario by two
Per scenario, the farmer is asked to divide these markers among the different attributes of that scenario, indicating which attributes of the scenario he considers to be most positive about that scenario.

'Negative' markers (red matches) are allocated to the three scenarios in a ratio reversely proportional to the ratio as established previously by subtracting the number of coins allocated to each scenario from 10.
Per scenario, the farmer is asked to divide these markers among the different attributes of that scenario, indicating which attributes of the scenario he considers to be most negative about that scenario.

## 13 Concluding remarks

The farmer is asked whether he has any other remarks and/or questions.

# APPENDIX IV Results of statistical tests performed on data from the intercropping trial

| | Comparison | Test used | Statistic | Degrees of freedom | Result |
|---|---|---|---|---|---|
| Maize grain yield | Sole cropping and relay cropping[a] | Independent samples t-test | t=0.211 | 12 | p=0.837 |
| Maize stover yield | Sole cropping and relay cropping[a] | Independent samples t-test | t=-0.407 | 13 | p=0.690 |
| Maize grain yield | Intercropping and double cropping[a] | Independent samples t-test | t= -0.857 | 22 | p= 0.401 |
| Maize stover yield | Intercropping and double cropping[a] | Independent samples t-test | t=-0.606 | 22 | p= 0.551 |
| Sole cowpea biomass | All four cowpea varieties | One way ANOVA | F=0.875 | 3, 8 | p=0.493 |
| Cowpea biomass in intercropping | All four cowpea varieties | One way ANOVA | F=0.225 | 3, 20 | p=0.878 |
| Maize grain yield in intercropping | All four cowpea varieties | One way ANOVA | F=0.145 | 3, 20 | p=0.932 |
| Maize stover biomass in intercropping | All four cowpea varieties | One way ANOVA | F=0.160 | 3, 20 | p=0.922 |
| Cowpea biomass | Sole cropping and intercropping | Independent samples t-test | t=4.220 | 14.5 | p=0.001[b] |
| Maize grain yield | Sole cropping and intercropping | Independent samples t-test | t=-1.264 | 36 | p=0.214 |
| Maize stover biomass | Sole cropping and intercropping | Independent samples t-test | t=-0.351 | 37 | p=0.727 |
| Maize harvest Index | Sole cropping and intercropping | Independent samples t-test | t=0.629 | 36 | p=0.534 |
| Percentage stem weight of total stover weight | Sole cropping and intercropping | Independent samples t-test | t=0.062 | 34 | p=0.951 |
| Percentage sheath weight of total stover weight | Sole cropping and intercropping | Independent samples t-test | t=-0.083 | 34 | p=0.934 |
| Percentage blade weight of total stover weight | Sole cropping and intercropping | Independent samples t-test | t=0.034 | 34 | p=0.973 |
| Percentage tassel weight of total stover weight | Sole cropping and intercropping | Independent samples t-test | t=-0.129 | 34 | p=0.898 |

[a] Comparison was done prior to combining treatments (paragraph 2.2.2)
[b] Equal variances are not assumed (according to Levene's test)

# APPENDIX V Results of statistical tests performed on data from the residue retention trial

| | Comparison | Test used | Statistic | Degrees of freedom | Result |
|---|---|---|---|---|---|
| Maize grain yield | Waterlogged and non-waterlogged plots | Independent samples t-test | t=-4.559 | 26 | p=0.000 |
| Maize stover yield | Waterlogged and non-waterlogged plots | Independent samples t-test | t=-6.249 | 26 | p=0.000 |
| Harvest index | Waterlogged and non-waterlogged plots | Independent samples t-test | t=1.680 | 26 | p= 0.105 |

# APPENDIX VI Results of statistical tests performed on data from interviews held in October 2012

| | Comparison | Test used | Statistic | Degrees of freedom | Result |
|---|---|---|---|---|---|
| Total number of ploughing days per hectare of maize | Three farmer types | One way ANOVA | F=1.178 | 2, 6 | p=0.370 |
| Area under maize cultivation in 2012 | Three farmer types | One way ANOVA | F=3.273 | 2, 6 | p=0.109 |
| Amount of DAP used per hectare | Three farmer types | One way ANOVA | F=0.618 | 2, 6 | p=0.570 |
| Amount of manure used per hectare | Three farmer types | One way ANOVA | F=0.062 | 2, 6 | p=0.940 |
| Household size | Three farmer types | One way ANOVA | F=4.333 | 2, 6 | p=0.068 |
| Estimated yield of maize in 2012 | Three farmer types | One way ANOVA | F=7.093 | 2, 5 | p=0.035 |
| TLU/ha | Three farmer types | One way ANOVA | F=4.612 | 2, 6 | p=0.061 |
| Estimated yield per hectare of maize in 2012 | Two maize varieties (Melkassa-II and BH540) | Independent samples t-test | t=3.422 | 6 | p=0.019 |
| Estimated yield per hectare of maize | 2011 and 2012 | Paired samples t-test | t=0.589 | 7 | p=0.574 |

# APPENDIX VII Livestock ownership of interviewed farmers

| Farmer ID | Oxen | Bulls | Cows | Heifer | Calves | Horses | Donkeys | Goats | Sheep | Chicken |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 1 | 3 | 1 | 0 | 2 | 3 | 0 | 4 |
| 4 | 2 | 1 | 2 | 2 | 2 | 0 | 1 | 2 | 0 | 0 |
| 5 | 2 | 1 | 3 | 3 | 3 | 0 | 1 | 1 | 0 | 0 |
| 6 | 2 | 1 | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 2 |
| 7 | 4 | 0 | 4 | 1 | 1 | 0 | 0 | 0 | 2 | 10 |
| 8 | 4 | 0 | 5 | 5 | 5 | 0 | 1 | 16 | 0 | 0 |
| 9 | 5 | 0 | 5 | 4 | 3 | 0 | 4 | 15 | 5 | 4 |

# APPENDIX VIII Results of statistical tests performed on data from the scenario exercise

| | Comparison | Test used | Statistic | Degrees of freedom | Result |
|---|---|---|---|---|---|
| Maize grain yield | Intercropping and sole cropping | Independent samples t-test | t=-1.718 | 16 | p=0.105 |
| Maize residue yield | Intercropping and sole cropping | Independent samples t-test | t=0.079 | 16 | p=0.938 |
| Bean grain yield | Intercropping and sole cropping | Independent samples t-test | t=4.134 | 16 | p=0.001 |
| Bean residue yield | Intercropping and sole cropping | Independent samples t-test | t=3.473 | 10.1 | p=0.006[a] |
| Bean grain production | Scenario 2 and scenario 3 | Independent samples t-test | t=0.525 | 16 | p=0.607 |
| Bean residue production | Scenario 2 and scenario 3 | Independent samples t-test | t=0.724 | 16 | p=0.479 |
| Ploughing labour days | Three scenarios | One way ANOVA | F=0.857 | 2, 24 | p=0.437 |
| Weeding labour days | Three scenarios | One way ANOVA | F=0.008 | 2, 24 | p=0.992 |
| Harvesting and threshing labour days | Three scenarios | One way ANOVA | F=0.282 | 2, 24 | p=0.756 |
| Storage labour days | Three scenarios | One way ANOVA | F=0.000 | 2, 24 | p=1.000 |
| Coins | Three scenarios | One way ANOVA | F=14.824 | 2, 24 | p=0.000 |
| Ploughing labour days per hectare | Sole maize and sole bean | Independent samples t-test | t=2.049 | 16 | p=0.057 |
| Weeding labour days per hectare | Sole maize and sole bean | Independent samples t-test | t=0.112 | 16 | p=0.912 |
| Harvesting and threshing labour days per hectare | Sole maize and sole bean | Independent samples t-test | t=-1.112 | 16 | p=0.283 |
| Storage labour days per hectare | Sole maize and sole bean | Independent samples t-test | t=0.000 | 16 | p=1.000 |
| Total labour days per hectare | Sole maize and sole bean | Independent samples t-test | t=0.649 | 16 | p=0.525 |

[a] Equal variances are not assumed (according to Levene's test)