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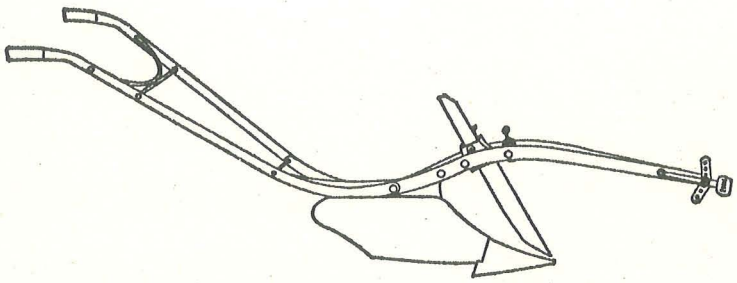

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Conservation Farming in Zambia

Master of Science Thesis

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Conservation Farming in Zambia

Part 1: A study of adoption among small stakeholders in the southern province

Part 2: Minor soil fertility study comparing Conventional Tillage and Conservation Tillage

Master of Science Thesis
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FOREWORD

In 2000, an initiative was taken to investigate conservation farming in series of case studies across the world. Fatima Ribeiro and Larry Harrington (2002) at the Global Program for Direct sowing, Mulch-based and Conservation Agriculture (GP-DMC) started the project together with other organisations like Centre de co-operation International en Researcher Agronomique pour le Développement (CIRAD) and African Conservation Tillage Network (ACT). This study is a part of the aforementioned, larger series of case studies. While the objective of the study was to observe the adoption of conservation farming, the aim was also to create a basis for further studies and new targets for research. It is also meant to provide an overview of conservation farming and the problems involved in promoting the system. We have tried to keep the level of this thesis so that someone who is not an agronomist can understand what we are talking about.

This thesis is based on a minor field study (MFS) in Zambia. The eight week MFS was financed by the Swedish international development agency (Sida) and was performed in Zambia by two students from the Swedish University of Agriculture (SLU). The students extended the study to twelve weeks to gather more information and to have time to do the soil fertility study. With the added material the MFS report eventually evolved into a master thesis. The MFS report, Conservation Agriculture in Zambia, and the master thesis, Conservation Farming in Zambia (Essen & Nolin, 2005), complement each other.

Though in close co-operation, each student had a different focus in the study, one agronomy student whose major is in plant and soil science focused on nutrients, practical agriculture and economics. The other student, whose major is in soil science with environmental studies, focused on the soil, environment and social/cultural factors. The students worked closely with local farmers, Zambian extension staff, and experts from different organisations.

AKNOWLEDGEMENTS

The list of people that has helped us with this study is enormous. If we would write them all down it would make the rest of the report seem short. Here is a shortened list of people that we feel especially indebted to.

First of all our supervisors in Zambia & Kenya: Mr. Mikael Segerros (ASP), Mr. Reynold Shula (ASP) and Mr. Soren Damgaard-Larsen (RELMA). Without them this project would have never got off the ground. Thanks for all your support, aid and feedback. Also great thanks to Mr. Herbert Mwanza, our supervisor at ASP in Choma, who even though he had a mountain of work at the time we were there, took the time to give us feedback and aid our work. Finally, to our supervisors in Sweden, Dr. Tomas Rydberg, Prof. Erasmus Otabbong, and Prof. Magnus Ljung, thanks for all the time you have invested into this project.

We would like to especially thank the two CEOs, Mr Hamuwele Gestin and Mr. Sailas Sakala at Camps Mboole and Mujika, for their help with conducting the interviews. They spent long hours with us on this project and often provided us with feedback and good ideas.

Finally, a great thanks to all the farmers that took the time to answer our, on occasion quite silly questions and who welcomed us with great warmth wherever we came. Special thanks to Mr. Iron Hachizibe and Mr. Hachizibe senior who allowed us to perform a soil study on their fields.

We would also like to send a "thank you" to:
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ABSTRACT

The first objective was to evaluate farmers' perceptions, rate of adoption, and constraints to adopt conservation farming. The second objective was to give an indication of the soil fertility and to verify if the CF tillage practices changed the soil properties.

In the first part of the study, flexible in-depth semi-structured interviews, participatory rural appraisal tools, and questionnaires were performed. In the second part, soil samples were analysed from three different fields: conventional ploughing, permanent planting basins, and ripping. Infiltration rate, bulk density, organic matter, pH, mineral nitrogen, and Olsen-phosphorus content were measured with the intention of comparing the different farming practises. The overall study was carried out in Mboole and Mujika in the southern province of Zambia.

Most farmers tried different tillage techniques in different ways, not always as recommended, and adopted sometimes these techniques on the whole or parts of their farm. Those who were less wealthy and did not have access to animal draft power adopted permanent planting basins of food security reasons. The Magoye ripper was used as a complement to the plough and was not used as prescribed. Crop rotation was inadequate, partly due to lack of market for the produce, partly because farmers found no use of cover crops or green manuring. Conservation farming practices gave better yield but demanded more labour input, especially for land preparation and weeding. Occasionally, the extension personnel did not satisfactorily carry through essential steps in the Agricultural Support Programme outline. The farmers' norms, cultures, and traditions were not comprehensively investigated to evaluate theirs attitude and values. The statistical analysis revealed that basins had a significantly higher infiltration than the other treatments. No significant differences of pH and organic matter content were detected in the compared treatments. There were no significant differences in soil fertility.

Keywords

Conservation farming, conservation agriculture, conservation tillage, permanent planting basins, Magoye ripper, Zambia, adoption, diffusion of innovations, PRA, RRA, organic matter management, infiltration, soil properties, soil fertility, crop rotation.

ACRONYMS

ACT	African Conservation Tillage Network
ADP	Animal Draft Power
ASP	Agriculture Support Program
CA	Conservation Agriculture
CEO	Camp Extension Officer
CF	Conservation Farming
CFU	Conservation Farming Unit
CIRAD	Centre de co-operation International en Researcher Agronomique pour le Développement
CT	Conservation Tillage
DMC	Direct Sowing Mulch-based and Conservation Agriculture
FAO	Food and Agriculture Organisation
GART	Golden Valley Agriculture Research Trust
GFAR	The Global Forum on Agricultural Research
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
ICRAF	International Centre for Research on AgroForestry
IRT	Improved Reduced Tillage
LM&CF	Land Management and Conservation Farming
MACO	Ministry of Agriculture and Co-operatives
MFS	Minor Field Study
NGO	Non-Governmental Organisations
OM	Organic Matter
PRA	Participatory Rural Appraisal
RELMA	Regional Land Management Unit
SCAFE	Soil Conservation and Agroforestry Extension
Sida	Swedish International Development Agency
UNZA	University of Zambia
ZNFU	Zambian National Farmers Union

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PART 1 - STUDY OF ADOPTION

INTRODUCTION

In many areas of sub-Sahara Africa, lack of water, depletion of soil nutrients, and erosion are great problems. Like many places in Africa the high population growth rate in Zambia, 3% (Sida, 2000), has lead to an extensive agriculture as well as an increased use of marginal land less suitable for agriculture. This expansion of extensive agriculture has taken place without considering a replenishment of the nutrients removed from the soils or maintenance of a good soil structure. Hence the still ongoing traditional agriculture systems deplete the soil, which already have low intrinsic fertility, of organic matter and nutrients and lead to increased erosion by rainwater run-off and wind. (Haggblade &Tembo, 2003)

The traditional techniques involve ploughing and hand hoe ridging. Both techniques leave the soil open to the elements and do not improve the deep soil structure. Hardpans and poor soil structure, caused by ploughing and hand hoe cultivation, result in little rain water penetration and moisture retention, which makes the water situation even more critical. Since most of the small stakeholders have no mean of irrigation, they are entirely at the mercy of the rains whose absence or magnitude may result in total crop failure. (CFU, 1997)

The timing of the sowing is also critical to a successful crop. Every day's delay will cause a yield drop. This results in a peak of labour shortly after the first rain and in many cases the farmers do not have time to start weeding the fields because they are still busy in land preparation. During this time of year food scarcity and malaria are most severe, which reduces and weakens the farm labour (World Bank, 2000). This problem is worsened by the HIV/AIDS epidemic that often strikes the young and able-bodied people, leaving the farms with a lack of labour (Allen & Thomas, 2000).

The government of Zambia has provided subsidised fertiliser and seed to farmers for a long time (Haggblade & Tembo, 2003). This attempt to instil the "Green Revolution" in Zambia has only been partly successful and has resulted in a dependency on artificial fertilisers. Since the subsidy program was withdrawn the farmers have had to rely on the co-operatives and non-governmental organisations (NGO) to provide them with fertiliser. The farmers often end up waiting for basal dressing that arrives late and further delays the planting (Gibbons, 2004). The use of natural sources of nutrients, such as manure and composts, are scorned even though they are sometimes used as complements to artificial fertilisers. This is because the farmers are used to fertilisers. The lack of nutrient input is as big a cause of failed crops as the lack of water. (Gachene & Kimaru, 2003)

Conservation farming (CF), incorporating reduced tillage techniques with nutrient and organic matter (OM) management, is one option and the practical methods used are well within reach of even the most economically disadvantaged farmers. It can have a major impact on poverty, as has been shown in the regions where it has been adopted (Ribeiro & Harrington, 2002). The aim of CF is to improve soil properties like organic matter content, water penetration and retention, to increase yields and decrease erosion and soil fertility loss (CFU, 1997).

Research and development programs to extend and promote CF and similar technologies exist in more than 40 countries and some of these programs are several decades old

(Ribeiro & Harrington, 2002). In many cases the findings appear positive, for example in Tanzania the yields increased 100% and soil properties were improved (Molin and Åström, 2001). In Zambia, CF and related techniques have been promoted since the mid-eighties (Haggblade & Tembo, 2003) and in Zambia CF has had greater success than in many other African countries, but adoption rates are low compared to those in Latin America and Asia (Ribeiro & Harrington, 2002).

Objectives

The objective of this study was to investigate why local farmers choose to adopt or not adopt CF. Explicitly, what are the factors that influence the adoption of agricultural innovations and CF techniques? The objective was divided into sub-questions:

- Why do some farmers adopt CF techniques and others not? What practises are being used and why?
- Are there a functional interplay and a satisfying link between farmers and extension service? On what information does the farmers base their decisions?
- Are there any major practical constraints for adoption?
- Are adoption hindered by any other factor?

Hypothesis

Different CF experts have proposed that the low adoption rate of CF is caused by the farmers' perception that the system does not meet their needs or fit into their agriculture system (Ribeiro & Harrington, 2002). Our hypothesis is that variation of adoption depends on one or several reasons listed below.

- The farmers may perceive the problems and possibilities of their agriculture system differently. They do not see the need to use the innovations.
- The innovations may not fit the farmers' current condition because they lack the necessary assets and/or knowledge to apply the innovations.
- The extension service might not function properly because the extension officers lack knowledge or there may be weak links in the communication between farmers and extension staff. Farmers and extension officers may have different perceptions of the problems and the innovations.

Partly, we based our hypothesis on Everett M. Rogers' (1995) characteristics of innovations to understand the target groups' different rate of adoption. Partly we considered the importance of the key factors in the Sustainable Livelihoods Approach (Scandiaconsult Natura, 2002), and these characteristics and factors in relation with the internal and external factors as seen in Figure 1 (Ljung, 2004).

According to Rogers (1995), an innovation's characteristics determine its potential diffusion. Five basic qualities can be seen.

(1) Relative advantage, if innovations are perceived as advantageous or not compared to current use.
(2) Compatibility, if innovations are consistent with values, experiences, and needs of potential adopters.
(3) Complexity, the degree how an innovation is difficult to understand and use.
(4) Trialability, to what extent an innovation may be experimented on.
(5) Observability, the degree to which the results of an innovation are visible to others.

If an individual perceive an innovation having greater relative advantage, compatibility, trialability, and observability and less complexity the innovation will be adopted more rapidly than other innovations. (Rogers, 1995)

The key factors in the Sustainable Livelihoods Approach are as follows.

(i) Access to resources: *i.e.* natural capital; land seed, animals etc, human capital; labour, health, education etc, social capital; networks and ability to participate, financial capital; incomes and credits, and material capital; assets, transportation, animal draft power (ADP) etc).

(ii) Ability to cope with chocks and insecurity, *i.e.* vulnerability and risks.

(iii) Institutional frameworks and capacities, rules and policies, etc. These factors play an important role when reducing poverty as well as achieving a sustainable development. (Scandiaconsult Natura, 2002)

Further, when implementing new techniques and innovations the inner and outer factors in Figure 1 become important because they affect and clash with farmers' perceptions, ability to be open-minded and capability to receive influences. For small-scale farmers with restricted means everything is risky and these factors, *e.g.* learning ability, personal barriers, and attitude together with socio-economic, environmental, and governmental policies, play a significant role in the household's process of decision making. (Ljung, 2004)

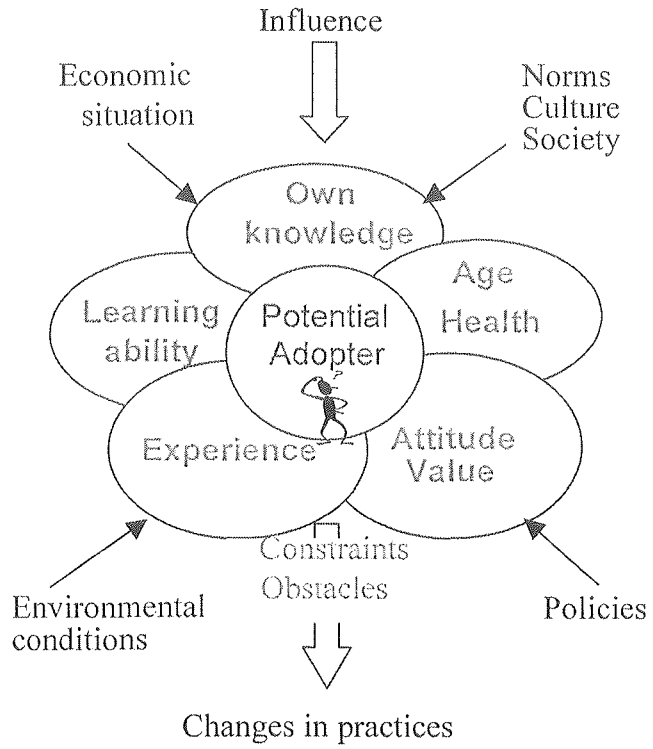

Figure 1. The internal and external factors that affects and distorts outside influence on a potential adopter, a farmer for instance (Ljung, 2003).

The term Conservation Farming

To avoid confusion we will at this point further explain some of the terms that have been used and will be used in this report. There are as many different opinions of what these terms mean, as there are people involved in the promotion of farming techniques. Probably a few more opinions because not everyone can make up their minds. Below is the essence of the knowledge on this subject from Mr Peter Aagard, Conservation Farming Unit (CFU) and Mr Herbert Mwanza, ASP.

Improved Reduced Tillage (IRT) – This system uses techniques such as permanent planting basins and ripping but does not incorporate practices like crop rotation or OM management. These techniques are explained thoroughly in section "The Conservation Farming practices".

Conservation Tillage (CT) – Incorporates reduced tillage and erosion control measures but not crop rotation. In this system tillage is still in focus. However, this is clear example of how the definitions of the terms differ. Regional Land Management Unit (RELMA) uses this term for system that involves both crop rotation and mulching (RELMA, 2002).

Conservation Farming (CF) – This system involves tillage measures, erosion control, nutrient management, and OM management. The practices used are listed in the section "The Conservation Farming practices" below.

Conservation Agriculture (CA) - This term includes a multitude of systems and practices (Damgaard, 2003) including the use of trees and shrubs, *i.e.* agroforestry (Aagard, 2004). According to Food and Agriculture Organisation of the United Nations (FAO) CA is about managing OM content in the soil, thus rejuvenating or protecting the soil. In order to achieve this most of the CF practices are used (FAO webpage I, 2004).

In this report we have chosen to use the term CF because it is the most commonly used term in Zambia (Mwanza, 2004). In the CF system, different practices are integrated to constitute a cropping system. It encompasses a range of activities to conserve the soil, manage nutrient input and OM in the soil.

Conservation Farming in Zambia

In Zambia, several CF innovations have been developed since the mid-eighties (Jonsson, 1999). The agriculture before this time was characterised by subsidies on fertiliser and other inputs. The trend was towards more extensive agriculture with increased use of artificial inputs and greater areas under cultivation, this in turn lead to a decline in soil fertility and greater acidification due to fertiliser use. (Haggblade & Tembo, 2003)

Independently or co-operatively, different organisations and government agencies started a variety of projects to stop the decline in productivity and destruction of fertile land. Below is a list of a few of the innovations, practices and terms that are part of the current CF system. (Haggblade & Tembo, 2003)

- Zambian National Farmers' Union (ZNFU) started with trials on permanent planting basins at the Golden Valley Agriculture Research Trust (GART) in 1985. Later that year the CFU was established to perfect this hand-hoe system to Zambian conditions. (Haggblade & Tembo, 2003)

- In 1986 the Magoye ripper was developed at the Ministry of Agriculture's Magoye research station. The Magoye ripper was designed for a reduced tillage system with animal draft power (ADP). (Haggblade & Tembo, 2003)

- At about the same time the International Centre for Research on AgroForestry (ICRAF) started to explore the possibilities to rejuvenate the soil with improved fallows. They concluded that two-year fallows with herbaceous shrubs proved most viable in a typical farm situation. (Haggblade & Tembo, 2003)

- The Ministry of Agriculture and Co-operatives (MACO, but at the time named MAFF) together with Soil Conservation and Agroforestry Extension (SCAFE), that later became Land Management and Conservation Farming (LM&CF) and in 2002 the ASP, started a project in the mid 1980s. The aim was to promote both soil conservation practices, like contour tillage, bunding, vetiver grasses, and soil fertility measures, such as cover crops, mulching, green manure, improved fallows, and conservation tillage. (Haggblade & Tembo, 2003)

At the present date (2004) there is an extensive network that is promoting CF. FAO is a strong supporter of CF, though they use the term conservation agriculture, and they are a major agent for promotion of CF under African conditions. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ, German government development co-operation) has throughout provided considerable financial and technical support and was a major force behind establishing an African Conservation Tillage Network (ACT). The Global Forum on Agricultural Research (GFAR) took initiative to create a global body in 2000 and created Direct Sowing Mulch-based and Conservation Agriculture (DMC) as a unit hosted by the French Centre de co-operation International en Researcher Agronomique pour le Développement (CIRAD). The Swedish International Development Agency's (Sida) programme: Regional Land Management Unit (RELMA), and a number of Sida bilateral projects, amongst them LM&CF project in Zambia that is now called ASP, started to work with CF in Africa in the late 1990s. This Sida-CA network soon came to include close contacts to ACT and via that links were established to the DMC. (Damgaard-Larsen, 2004) ASP is the program that hosted this study in Zambia.

Agriculture Support Programme

Agriculture Support Programme is a programme under the Ministry of Agriculture and Co-operatives (MACO) in Zambia. The programme is funded by Sida and implemented and managed by a partnership of consulting companies, except the leading consultant Scandiaconsult Natura, also Gibcoll, HJP international, Rural Net Associations, and Rural Economic Expansion Services (REES). (ASP brochure, 2004)

ASP originates from previous Sida funded projects that dealt with different aspects of the agriculture sector in Zambia, LM&CF, Multiplication & Distribution of Improved Seed & Planting Materials Programme (MDSP), Small Holder Agriculture Processing, Extension & Storage (SHAPES), and Economic Expansion in Outlying Areas (EEOA). (Ramboll Natura, 2004). ASP has six main components: (1) Entrepreneurship and business development, (2) Improved land, crop, and livestock husbandry, (3) Infrastructure Fund, (4) Seed production and promotion, (5) Capacity building of support structures and local organisations, and (6) Management, Information and Learning System. (Scandiaconsult Natura, 2002)

The overall objective of ASP, in line with the national objective, is poverty reduction. ASP's immediate objectives are two fold: increase livelihood for small-scale farmers, partly by food security partly by increasing income among the target group, small-scale farmers who have a potential to develop into entrepreneurs, through selling agricultural products. The objectives will be achieved through the processes' of the facilitation cycle (see Figure 2), and within them constant dialogue, learning, action, and reflection with the local communities to improve the group's understanding of their current situation. An ASP key principle is not to give any loans or handouts but instead provide and facilitate appropriate training and understanding so that the target group can exploit local

opportunities. By doing this the target group become food secure and run agricultural businesses. (ASP Agric News, 2003)

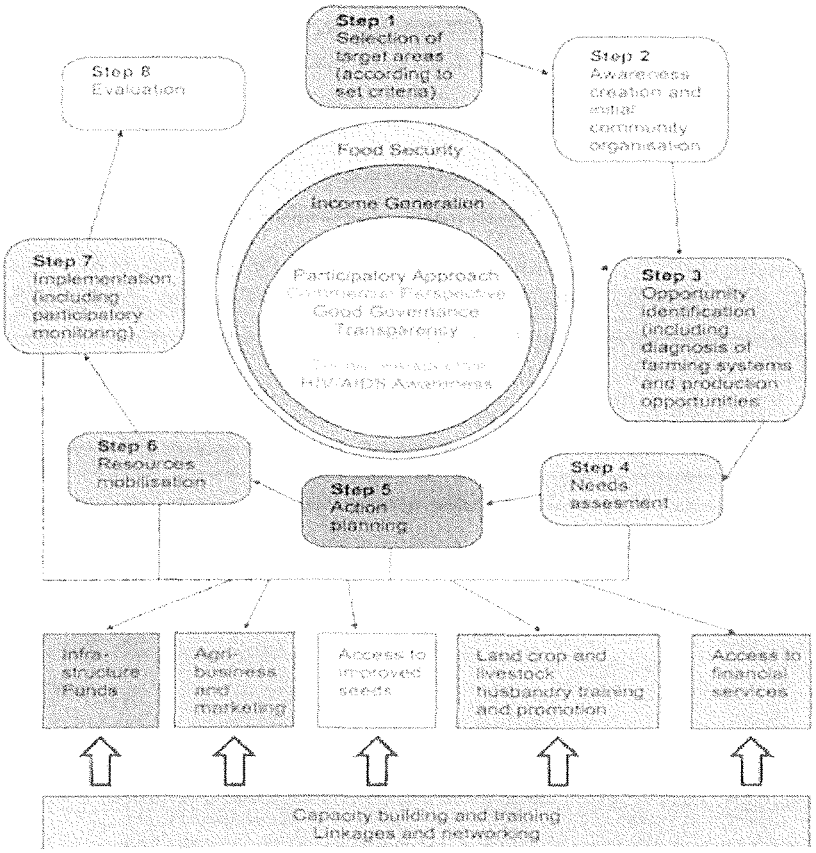

Figure 2. The facilitation cycle (ASP brochure, 2002).

The Conservation Farming practices

Conservation farming is a package of many different techniques and practices combined to create a cropping system. The ASP has preferred to keep what practices are used an open issue, as each farmer has to adapt his farming system to his specific situation and environment (Otteby, 2004). However, many of the practices have to be used together for the system to be functional and if one is left out the gains are often lost. Listed below are some of the practices that can be used in a CF cropping system.

- Permanent planting basins are shallow basins that are roughly 15 by 40 cm wide and 15 cm deep (Figure 3). The basins are re-dug in the same place each year and this is preferably done during the dry season to maximise the growing season. The seeds are planted in the basins together with fertiliser, manure, and/or compost. The advantage is that only the soil in basin will be disturbed leaving the surrounding soil untouched and less exposed to erosion. The basins will also improve water infiltration and is a good water harvesting technique. In theory only the crops planted in the basin will benefit from the applied nutrients. This is the most common reduced tillage technique in Zambia.

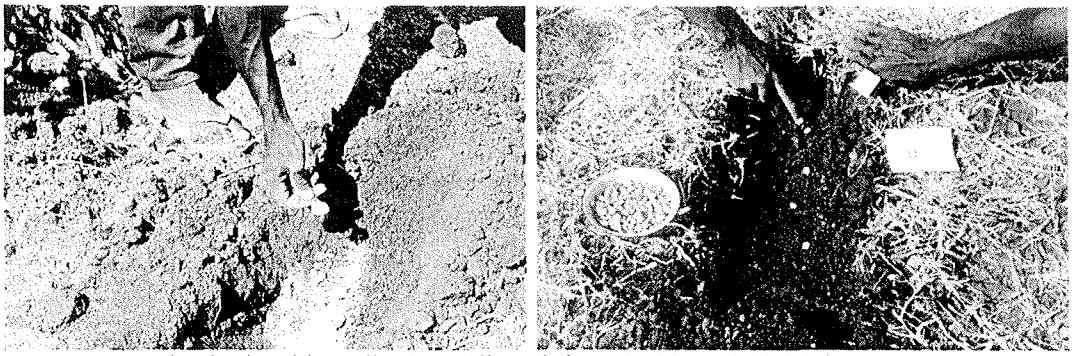

Figure 3. Planting basin with application of lime (left) and with seed (right) (Mwape *et al.,* 2004).

- Ripping using a Magoye ripper (Figure 4) creates a deep but narrow groove in the soil where the seed is planted and nutrients are applied. Ripping should be performed before the rains. It is desirable that the ripp lines are in the same place every year and the soil in between remains undisturbed. In theory only the crops in the lines will benefit from the nutrients. The idea is that the workload is spread during the year, the growing season is maximised, and the permanent planting furrows generate a softer and a more nutritious soil. This technique also improves water infiltration.

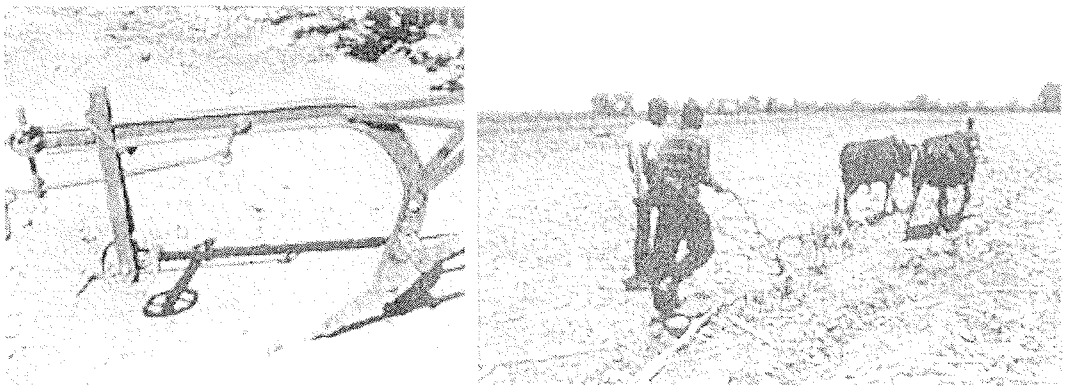

Figure 4. Magoye ripper and Ripping in progress (CFU, 1997).

- Timely planting and reduction of labour peaks are not so much a practice within CF but rather a desired result. In conventional systems the farmer have to wait for the rains to soften the soil enough to allow ploughing. Permanent planting basins and ripping allows the farmer to prepare the field before the rains start. This allows the plants to establish themselves early and take advantage of the whole growing season and the weeds will not get such a great head start. The farmer can concentrate on weeding rather than the tillage (Segerros, 2004).
- Planting pits or Myamba pits as they are called after their inventor Petro Myamba, are pits that are 60 cm deep and 120 cm in diameter, though size may vary (Figure 5). In the pits crop residues, compost, and manure, are layered with cut grass and soil until the pit is full. The decomposed material will provide sufficient with nutrients for many seasons and further inputs during this time are not necessary. (Myamba, 2004)

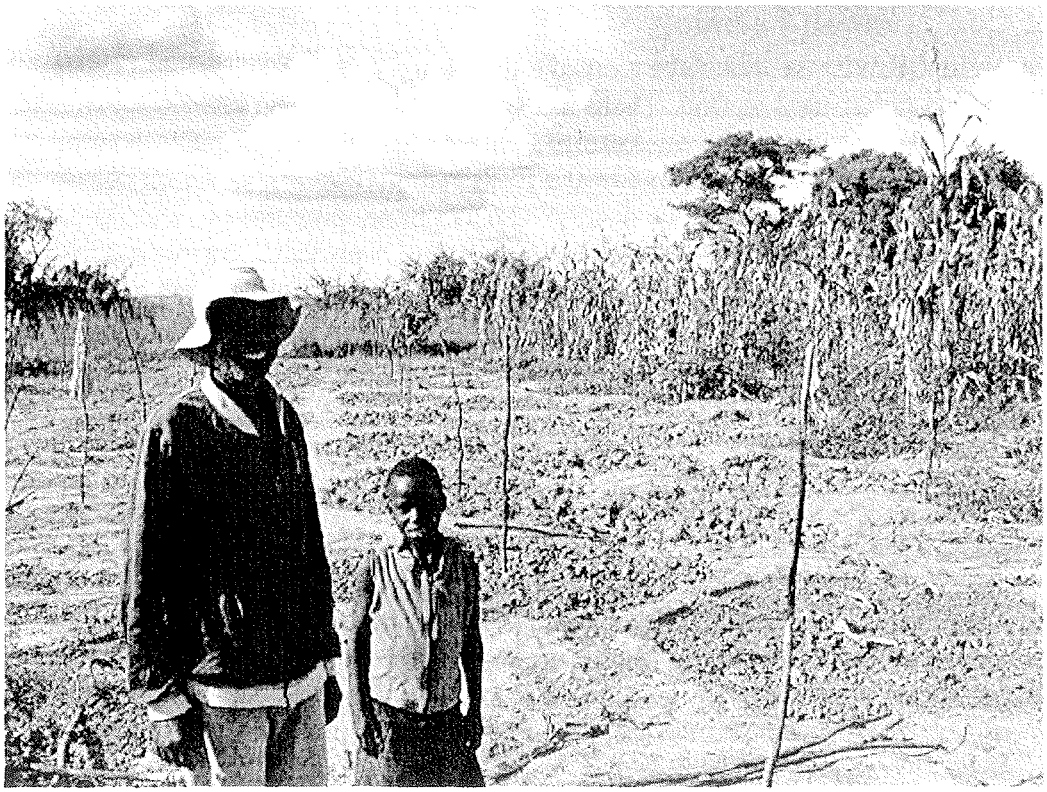

Figure 5. Mr Petro Myamba and son in front of some pits ready for planting.

- Crop rotation with nitrogen-fixing legumes. How often the legumes should reoccur in the crop rotation is a debated question. CFU has a system where 30 % of the cultivated land is planted with a nitrogen-fixing crop (CFU, 1997). This may prove to be a too inflexible system when outside factors such as markets and demand for produce are taken into account. In any case it is important that crops with high nutrient demand are rotated with less demanding crops or legumes.
- Crop rotation as weed and pest control is an important aspect. Crops that are competitive may help to weaken weeds and reduce the seed bank. Crop rotation also suppresses the propagation of many host specific pests and diseases. (Ohlander, 1997)
- Mulch is a thick layer of organic matter, covering at least 30% of the surface. It protects the soil, moderates soil temperatures and creates a climate favourable to the micro fauna (Erenstein, 2002). Mulch also suppresses weeds and the decomposing organic matter is an important pool of nutrients (Raunet & Séguy, 1998). For a proper management of mulch, the livestock should not be allowed to graze on the fields.
- Green manure and intercropping is another way of both suppressing the weeds and improving nutrient content and OM contents in the soil. Proposed species in this region is sunnhemp (*Crotalaria juncea*) and velvet bean (*Mucuna pruriens*). (Gibbons, 2004)
- Certified seed should be used, if possible, to ensure better yields and food security (ASP, 2003).
- Weeding should be performed 4-5 times a year to reduce the seed bank. Techniques using an ox-drawn cultivator and weed wipe (glyphosate application) have been introduced but are not commonly practised. (Gibbons, 2004)
- Residue should be left on the field as a ground cover and to improve OM content. Burning of residue should be strictly avoided in a true CF system. (Gibbons, 2004)
- Agroforestry practices with trees like Winter thorn (*Faidherbia albida*) are encouraged.

Definition of Conservation Farming

A good definition of CF, *i.e.* the practices that should be used if the cropping system should be called CF, is rather hard to find. There are many different terms and definitions used by the different organisations. As an example we can use the CFU's CF system. Retention of crop residues and reduced tillage in the form of a precise and permanent grid of planting basins, planting furrows or contoured ridges. Land preparation should be completed in the dry season and early, continuous weeding during the growing season. Rotations or inter-cropping with nitrogen fixing legumes that occupy a minimum of 30% of the cultivated area (CFU, 1997). This provides a well working but rigid cropping system that makes sure the farmers follow the directives. However, this definition does not work well with the ASP approach as ASP wants the farmers to adapt their cropping system to their current situation, production capability and market possibilities (Otteby, 2004).

In order to grasp the amount of adoption we had to find a suitable framework in which to compare the different farms. Mr. Herbert Mwanza, an experienced veteran in agriculture programs and within the field of CF, gave us a number of aspects that has to be considered in any cropping system, particularly in a CF system (Table 1). These aspects address issues that need to be addressed for the cropping system to work. We choose to use this line of thought because we found it agronomically correct because it is aimed to conserve the soil and improve production. All issues should be addressed in the cropping system for us to deem it a CF system.

Table 1. This table shows the aspects that we considered in our CF definition. Each aspect addresses issues that need to be addressed in a cropping system. The third column describes the practices or criteria we used when evaluated the farms

Aspects	Issues	Practices in Zambia
Tillage aspects	• Water loss and water harvesting • Exposure of the soil • Timely planting • Erosion	Permanent planting basins and ripping.
Soil fertility aspects	• Recycling of nutrients • Nutrient input • OM management	The cropping system should have adequate crop rotation with at least one nitrogen-fixing crop or green manure. Nutrient inputs should be at least to some extent matched with the losses.
Erosion control aspects	• Soil erosion • Loss of nutrients	Contour bunds, grass strips, and contour ploughing should be used if needed. Ground cover if possible, either cover crops or mulch.
Carbon sequestration aspects	• Loss of OM.	No burning of crop residues, at least some should be left on the field. Reduced tillage systems will also reduce OM losses as the soil is less exposed.
Agro-biodiversity aspects	• Soil as a living system. The practices have impact on all above-mentioned issues.	Crop diversification, crop rotation and perhaps even some agroforestry techniques, *e.g.* leaving *Faiderbia albida* in the fields. Good OM management and careful use of fertiliser will also help to keep the soil healthy.

General description of region

The area where the study was carried out belongs to Region IIA, which encompasses the Central, Southern and Eastern Plateau. Region IIA is one of four agro-ecological zones of Zambia. Region IIA's sub-tropical climate is largely modified by altitude in this zone, which has three distinguishable seasons: warm and wet, cool and dry, and hot and dry. Annual rainfall reaches 800mm to 1000mm, which falls in the warm wet season between October and April. The single rain period support only one harvest. Even though the rains normally fall between October and April they are of erratic and irregular character (Figure 6). The cool and dry season begins in April and ceases in August where the subsequent hot and dry period starts and will last until October.

The soils are mainly Haplic Lixisols, Haplic Luvisols, and Haplic Acrisols. These soils are considered productive but sensitive to bad management practices. The process of land

degradation has worsened due to population pressure and traditional cultivation. (Mulenga, 2003)

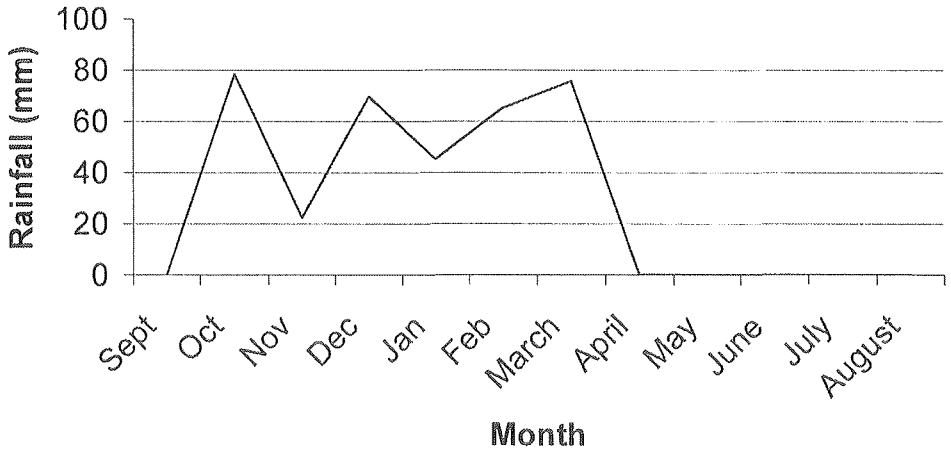

Figure 6. Example of rain pattern in the southern province. Figures are from Monze, 2003 (Mwape *et al.*, 2004).

Study site

The fieldwork was carried out in two Camps, Mboole and Mujika, in the Southern province of Zambia (see Figure 7). Mboole is located 10 km from the main road northeast of Choma and Mujika is 20 kilometres east of Monze. During the rainy period, November to April, the traffic accessibility is reduced and terrain vehicle or a motorcycle is necessary in order to transport goods. Vegetation is of sub-tropical character and mainly consists of deciduous trees and shrubs, such as *Brachystegia* and *Acacia*.

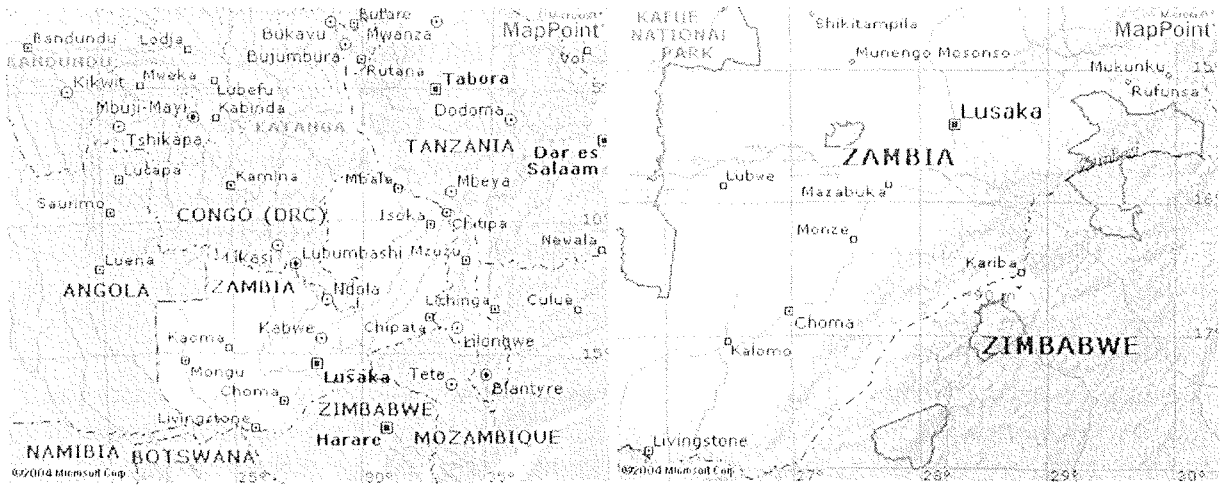

Figure 7. Map of Zambia (left) with an enlargement of the southern province (MSN Encarta, 2004).

The small-scale farmers belong predominately to the Tonga tribe, who are mainly agriculturists, breeders, and raisers of livestock. The animals are considered as security in times of hardship. Except cattle, also poultry and goats are commonly raised. Household size varied between four to twenty family members and one man can have several wives. The households are mostly male-headed but female-headed households exist as well. Houses are clay or brick cottages, which mostly have straw roofs. The fields are grouped around the farm so in general there are several hundreds of meters between the farms. Farmland is mostly private property but after harvest the fields become lands for common

use. Free-grazing cattle in combination with harsh climate have excluded the possibility to grow cover crops in dry season. Ox-drawn ploughs and hand-hoes, burning crop residues, and fertilisers dominate the conventional farming. Maize, groundnuts, cow peas, and in some degree also cassava are the most common annual food crops in the area. In addition a range of cash crops such as sunflower, soybean, cotton, and horticultural crops are cultivated (Mulenga, 2003). Cultivation is mostly for subsistence but surplus and some harvest is set aside to sell and to buy daily commodities.

During many years the farmers received subsidised fertilisers and seeds from the government, which also bought the produce at fixed prices. In mid 1990s the subsidies were withdrawn and the markets were opened to free trade (Haggblade & Tembo, 2003). Fertilisers compensate the loss of essential nutrients when crops and organic residues are removed from the fields but extensive cultivation combined with large amounts of fertilisers will deplete the soil of OM and eventually it will become acidic. Since the subsidies were removed not many farmers can afford to buy sufficient amount of fertiliser. The agricultural and economic situation worsened when the corridor disease struck and eliminated as much as 90 % of the cattle in the area. The region that used to be a net exporter of food turned into a net importer (Malesu *et al.*, 1999). The final blow to the producers in the southern province was in 2000 and 2001 when drought struck the region causing widespread crop failure (Haggblade & Tembo, 2003).

Throughout the years a number of NGOs and other agencies have been present in the area. The ASP has promoted CF in the area since 2003. Before ASP, several organisations such as LM&CF, SCAFE, and ZNFU, and simultaneously today also GTZ and CFU have been working in the area disseminating CF.

METHOD

In order to achieve its main objective, this study was carried out using the 7-step process described in Table 2. These steps constituted the foundation for the collection of information to understand the farmers' use and perceptions of conservation farming (CF) innovations and how these perceptions may differ depending on the farmer's socio-economic status. The steps also provided a picture of how the available inputs affect the adoption rate. The research process further encompassed the extension staffs' perceptions of the innovations and the farmers, in order to see if there is any weak links in the farmer-extensions communication.

Table 2. Research process with objectives, involved actors in each step, methods and expected output

Objective	Actors	Method	Expected output
1. Finding the community to study	Agriculture Support Programme (ASP) staff	- Studying baselines and discussion of appropriate study site	- Identifying suitable communities as per criteria - Identifying key informants - Collecting further relevant secondary information
2. Finding farmers which are suitable for our study	Local camp extension officers (CEOs)	- Discussions and Selection of farmers - Target Matrix (Table 2)	- Identifying farmers who are suitable as per criteria - Get a general picture of the study farms
3a. Establishing farmers perception of the CF innovations	Selected farmers	- Semi-structured interviews - Farm sketch - Seasonal calendar	Farmers perception of: - Agricultural techniques and innovations - Extension service - Crops and inputs used - Labour demands and gender roles
3b. Establishing CEOs perception of the CF system	CEOs	- Semi-structured interviews	CEOs perceptions of: - Farmers - The CF system
4. Strategy check	Supervisors, experts in CF, CEOs, University employees	- Workshop Mid Term Review	- Clarifying the different perceptions - Determining further focus
5. Analysis 1	Minor Field Study (MFS) students, supervisors, CF experts	- Comparing interviews, sketches, and calendars - Testing conclusions - Feedback	- Identifying differences and similarities among farmers - Evaluation of statements
6. Verifying information	Selected main farmers and CEOs	- Questionnaire with statements that appear general	- Finding statements that mirrors general perceptions - Other present statements - Confirming our assumptions
7. Analysis 2	MFS-students, supervisors, CF experts	- Data filtration programme	- Identifying differences and similarities among farmers

1. Finding the community to study

As newcomers in the society and the area we did not have much experience of the present conditions except influences from written material, so we turned to the programme staff for advice and guidance. Information, reading material, and study tours to different innovative and leading CF farmers and to different organisations and projects in Lusaka region and Southern province constituted an insight in different farming practices, both in conventional and CF.

Selection of study site was made in collaboration with the ASP and its personnel. We asked ourselves a number of questions (Why?, Where?, What?, How?, Who?, and When?) and broke them down in their constituents, trying to define targets, people, consequences and (dis-) advantages with all. The project was then planned and lined up.

2. Finding the farmers which are suitable for our study

The next phase was to enter the community and build contacts and trust, to understand local conditions, institutions, and needs better. With the aid of ASP staff (CEOs) that acted as translators, we introduced our project and ourselves to the Chief, village leaders, and farmers in the two selected camps. Key concepts such as dialogue, discussion, participation, respect, and learning were used to guide our work. We then discussed the selection and division of target farmers with the CEOs. In order to find enough variation among respondents, age, wealth, and sex, were considered. 20 farmers were selected for this study and they were put into four different groups depending on rate of adoption: (I) full adopters of CF, (II) semi-adopters, (III) non-adopters, and (IV) dis-adopters. The criteria for the selection were:

- Communities composed of farmers who I) used, II) had used, and III) are not using the CF system
- Farmers who were willing to take the time to help us with our research
- Preferably some farmers that had fields under both CF and traditional agriculture
- Female and male-headed households
- Farmers who had different socio-economic status
- Farmers who grew similar crops that were common to the region
- Communities which were within reach of our base station

Finally the target matrix (Table 3) was developed and our aim was to interview farmers from each box of the matrix to receive a broad variation among the respondents.

Table 3. Target Matrix where each box represents a category of farmers and each number represent one farmer interviewed. The CEOs made this division of the farmers

Households character	Adopters	Semi-adopters	Non-adopters	Dis-adopters
Male, old	3,4,5,17	2,9,13,18	7,11,12,19	16,20
Male, young		8		1
Female, old	14, 15		10	
Female, young		6		

3. Establishing farmers perception of the innovations & Local Camp Extension Officers perception of the system

In qualitative interviews and surveys, relations between human beings are investigated, while in quantitative studies it is the relation between variables. Jan Trost (1995) argues that if the objective is to understand peoples' way of reason or reaction, or discern varying

pattern of behaviour, a qualitative survey is reasonable, but when the question at issue concerns how often, how many, or how ordinary, a quantitative survey is more suitable. Further, social studies see social structures and social processes as the sum of individual peoples' personal characteristics. The interdisciplinary approach of this study is a source of new ideas and modes of thought that contribute to new knowledge. Therefore, we initially used qualitative, semi-structured interviews as our main method in this study. These semi-structured interviews raised discussions and created dialogue, were adapted according to the situation on site. Flexibility was necessary since the farmers were different to each other and the conversations often took new courses. The interview-guide (Appendix 1) acted as a checklist for us to go back to questions and subjects and issues after free speech.

Besides taking notes during the semi-structured interviews we simultaneously used participatory rural appraisal (PRA) techniques such as farm sketch and seasonal calendar. These simple methods gave greater participation with the interviewees and served as a foundation for a continuous discussion and questioning in our interviews. In addition it reduced the risk of misunderstanding or lack of interpretation from our side.

The framework for the semi-structured interviews is described below and the full interview-guide can be found in Appendix 1. The template for the interview-guide is based on the key external and internal factors mentioned earlier (see section "Hypothesis").

- Basics facts about the Farm – ownership, area, practices, inputs, crops, livestock
- Basics facts about the farmer – background, education, marital status, household makeup
- Farmer knowledge – knowledge of CF and other agricultural practices, sources of information
- Farmer perceptions – perception of CF, perception of other practices, role of government and non-governmental organisations (NGO)
- Food and market – food security, market access, economy and income
- Other big questions – what is your future plans and vision, effect of HIV/AIDS in agriculture

In addition to the interviews and the PRA methods we also used a knowledge questionnaire (Appendix 2). With this we tried to determine the amount of concepts that are being used and the knowledge that the farmers have. It also had a ranking of different practices to help us determine the farmer's perceptions of agriculture.

The project was adjusted via continuous contact, discussion, and exchange of ideas and thoughts with supervisors and local ASP staff. New angles of approaches were added after each farmer interview and this meant ceaseless development and improvement of the interview guide and the knowledge questionnaire. Before we choose to implement the different methods to reach our aim, we put up expected consequences and results of the various actions (Table 2). By this we could in advance be able to analyse, test, and evaluate possible outcomes, increase awareness to do corrections along with the implementation phase and furthermore facilitate the evaluation phase of the project.

4. Strategy check

The first phases dealt with establishment of contacts and creation of a dialogue. The interviews covered a broad spectra of farmers, his or hers farming practices, thoughts and ideas. Halfway in study schedule a workshop was set up. This midterm review acted as an evaluation phase and a possibility to reflect on the data collected at that present time. We

presented our preliminary findings to an assembly, composed by personnel in various CF organisations such as ASP, Conservation Farming Unit (CFU), Regional Land Management Unit (RELMA), African Conservation Tillage Network (ACT), and Direct Sowing Mulch-based and Conservation Agriculture (DMC). Experts from the University of Zambia (UNZA), and members of the Swedish embassy were also present. The discussion that followed provided feedback and new ideas that we could use and implement in our continued study.

One major topic of discussion at the mid-term review was how to define what is an adopter. A clear distinction between adopters and non-adopters can be hard to make. It was settled in the end of the workshop to proceed developing the interview-guide to a revised version (Appendix 3). The new adjusted version looked more into what practices of CF the farmers' use and what the reasons for were. Finally, it was decided to return to same farmers for in depth interviews and later on verify statements and trends in a knowledge questionnaire.

5. Analysis 1

After the in-depth interviews were finished, all information was analysed. Notes of the farmers' and the CEOs' practices, statements, and opinions were put in a database to facilitate filtering and evaluation of the data. Patterns in differences and similarities of practices and thoughts between and within the groups of farmers and CEOs were identified. This material was discussed with supervisors, and various CF experts to further understand the meaning of the analysis. This was the foundation for the next phase, verifying the information.

6. Verifying information

In this phase of the project we moved towards a more quantitative study to find out how often and how many statements reoccurred. We had at this point collected and evaluated the statements and could design a broader questionnaire (English version Appendix 4), a translated version in Tonga for the farmers (Appendix 5) and an edited English version for the CEOs (Appendix 6). The aim of this questionnaire was to verify our hypothesis, assumptions, and the farmers' statements in a broader scale as well as compare it with the ideas and thoughts of the CEOs. In an area of approximately 3000 households in co-operation with ASP this farmer questionnaire was delivered to 100 households and the CEO questionnaire handed over to 30 officers.

7. Analysis 2

The collected data from the questionnaires described in phase 6 "Verifying information" was filtered and analysed using a database and MS Excel's filtering functions. The information was shared with the supervisors and other CF experts so that we could receive new angles and ideas.

Limitations of the Methodology

Although we continuously developed our interview-guide during the period of the study and made use of new knowledge and influences when the questionnaire were drawn up, limitations in method can be seen, especially when we had the results in front of us.

First there is the selection of respondents. The farmers we choose to interview were predominately involved and co-operated with ASP and the farmers were, naturally, familiar of terms and practices within CF. This problem could have been better attended with a greater number and variety of interviewed respondents. We could also have involved more so-called 'rural dwellers'; urban non-farmers that move to rural areas and

start some form of agriculture. Unfortunately, we also did too few interviews with female and young farmers, mostly because there was not so many of them.

Second there is the interpreters, who guided us and helped us interview farmers. The interpreters were CEOs that were retained by ASP and had established a relationship with the farmers. In cases like that there is always a risk of interviewees and interpreters' self-interest being reflected. Even though we were aware of this dilemma we still used ASP staff but tried to find and use some farmers that was not active or participated in any farming organisation or ASP.

The third weakness is about the knowledge questionnaire that was used and acted as a complement in the interviews. We were not sure how the knowledge questionnaire should be constructed for us to receive as much information as possible. It turned out that the form had weak links from beginning and had to be under continuous construction during the entire study, making comparisons difficult.

Fourth, the importance of attitude and values were not comprehensively investigated. The short visit in the area did not give enough time to gather adequate background information and deep understanding about the strong impact of norms, culture, and tradition in the society. Further, we received insufficient knowledge of the society's' institutional hierarchy and beliefs.

Fifth, we do not know to what farmers the questionnaire was distributed. It is likely that it was only handed to farmers that attended the ASP meetings because we gave them to the CEOs retained by ASP. This means that the questionnaire results are representative for ASP farmers only and not for all the other farmers.

In retrospect we noticed that the mid-term review was held too late in the study. The workshop was very fruitful. It helped us focus and enter more deeply into some interesting questions. Unfortunately it was late in the study thus giving us a very narrowed time window after the meeting to investigate and collect information. We also recognised that our hypothesis, *i.e.* farmers are distinct adopters and non-adopters, was incorrect from the beginning. The term adopters and the term non-adopters did not reflect the reality of a broad variety of CF practices that were used. We also see a need of further study of the techniques used by CEOs in their promotion of CF.

RESULTS & FINDINGS

The general results are divided into the two tables below (Table 4 and Table 5). Table 4 shows the statements that reoccur in the interviews. These statements cannot be quantified but they seem to be thoughts that many farmers shared. Table 5 contains averages from the questionnaire database for all farmers and female and male-headed households.

Table 4. This table contains the statements from the interviews that were mentioned repeatedly

Statement
• Conservation farming (CF) increases the need for weeding
• With CF it is possible to finish land preparation early
• Permanent planting basins/ripping gives better yield than ploughing
• Ripping is easier than ploughing
• CF is good when there is a drought
• Maize is fresher longer in basins and ripped fields compared to ploughed fields
• Ploughing removes the weeds
• Most common future investment: Buy animals
Most common answer to the question: What could the Government do to improve farming?
1. Provide fertiliser subs and improve input availability
2. Provide cheap loans
3. Improve market for produce

Table 5. The variables and averages for all the farmers and the percentage of farmers that are above the average. The averages are based on the number of farmers that actually answered the question (column three). Column four and five is the average values for male and female farmers

Variable	All	Above average (%)	No. of farmers that answered	Female	Male
No. of Farmers	50			12	38
Age (years)	49	38	50	51	48
Household Size (people)	9	56	50	7	9
Available labour (people)	6	28	50	5	6
Land owned (ha)	12	24	50	6	14
Land cultivated (ha)	4	20	50	2	4
Land rented (ha)	1	46	15	0	1
No. of Oxen and Bulls	1	36	48	1	2
No. of cows	3	30	27	0	4
Months lacking food	4	60	50	4	4
No of different crops grown	6	48	49	5	6
Land Ploughed and ripped (ha)	2,1	11	18	1,3	2,3
Land ploughed (ha)	2,9	30	40	2,3	3,3
Land ripped (ha)	1,3	50	10	0,8	1,7
Planting basins (ha)	0,35	26	27	0,28	0,39
No. of planting pits	65	33	15	23	81

The questionnaire also had a section where the farmers were asked to determine which practices are good for soil fertility, food security and yield. This data is depicted in Figure 8.

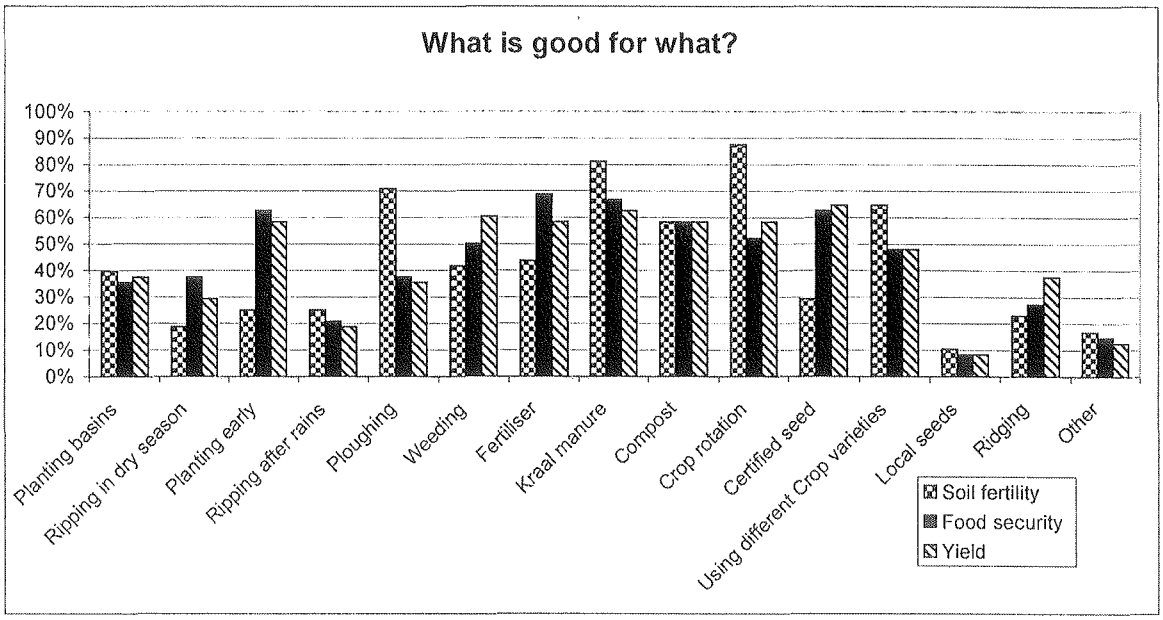

Figure 8. The farmers' perception of what practices that is good for soil fertility, food security and yield. Data is taken from the questionnaire.

The data of the questionnaire was filtered with different variables like gender, houshold size, size of land, number of animals, and level of education. There was not any great differences in either statements, practices or perceptions, no matter how we filtered the data. This is either because the perceptions and practices are quite homogenous across the different groups or becuase the groups are too small samples to show any differences compared to the whole group.

The term 'Adoption'

When we started this project, we read several proposals and reports about other conservation farming projects. Many of these used the terms "adopter", "non-adopter" and "dis-adopter" repeatedly and we made the assumption that this meant that farmers had either adopted or not adopted a CF system as a whole. This assumption proved wrong, at least when we defined an adopter as a farmer that uses CF according to the definition stated earlier in this report. We could not find one single adopter of CF! When we used the practices prescribed by the Conservation Farming Unit (CFU) as a framework for comparison, no farmer could be called an adopter either. What we found was that the farmers have adopted some practices on the whole or parts of their farm. Most farmers have tried different tillage techniques in different ways, not always as recommended, and have sometimes adapted these techniques (for examples see "Case Studies" in Appendix 7).

When we realised that this mix of CF and traditional practices existed, we decided to look further into the "Why, How, and When" of adoption for each practice. We looked at the basins, ripping, crop rotation, mulching, green manuring, and other practices as separate concepts. We also explored subjects such as practical constraints and others factors that we thought could influence adoption, *i.e.* gender, extension service and so on.

Conservation Farming practices

Basins

Many farmers keep a small area, about a lima (~0.25 ha), of basins for food security reasons. This is apparent in both interviews and the questionnaire, 84% say this is true (for all the statements see Appendix 8). They have noticed that the crops in the planting basins remain fresh longer when there is a drought. For those that do not have animal draft power (ADP) the basins are considered the best alternative and it is widely recognised that the basins give a higher yield per lima than other tillage techniques. When gender is taken into account, the women consider basins an effective way of making money more often than men, 86% compared to 46%, in the True or False (ToF) statements in the questionnaire. This could be because the female-headed households have less land and less access to ADP.

The farmers seem to have more knowledge and experience with the basins than with other tillage systems in CF. The reason for this is that the basins have been promoted for a longer time and the information has had time to disseminate more. The questionnaire reveals that 46% of all farmers started with the basins because they improve soil fertility and 40% started because the basins use less fertiliser. 33% of the farmers started with the basins for improved food security but we got the impression that this reason was more common than that. The most common reason for starting with the basins was that they were told to do so by the camp extension officers (CEO), 56%.

While people without ADP (*e.g.* Figure 9) used planting basins exclusively, unless they rented some ADP, even people with ADP used basins on a smaller area. It is claimed that the basins are more work than the fields that are ploughed, even though the basin can be made during the dry season, thus reducing the labour peak. The main bottleneck is the weeding, and ploughing reduces the weeds significantly. The reason for using both basins and ploughing is a risk mitigating strategy for the farmers. A good year ploughing will produce more than the basins because a larger area can be cultivated. Should the rains fail the basins will still give enough yield to get some food for the following year.

Figure 9. Mrs Mary Munza, lacks ADP and is using basins exclusively. She is very happy with the results but says it is a lot of work.

Basins are not always done as per recommendation; mostly they are not kept as permanent planting basins but are instead moved every second or third year. Some farmers seem not to be aware of the reasons for keeping a system of permanent planting basins and others have ideas that this will improve the soil fertility over the whole field and that they later can use the plough again.

Ripping

The outcome from the 20 main interviews showed there was basically no farm using the ripping according to how CF is prescribed by the extension system. For this latter, best result is obtained when the field is ripped in the dry season in order to facilitate soil preparation and achieve planting at first rainfall.

Both the interviews and the questionnaires revealed broad variations in the use of the Magoye ripper for different reasons. Normally the soil was initially ploughed when the first rain fell and a ripper, when involved in farming practices, served as a complement after the fields had already been ploughed. The questionnaires show there are only 16% using ripping in dry season on parts of their land, but 36% in combination with a plough. Only one interviewed farmer used ripping as CF recommends, but then it was only on a small fraction of his total cultivated land size. On the other hand, many of the farmers said they had tried the Magoye ripper, mostly on small scale in combination with ploughing in one or a few seasons to see its effects and output. The farmers could then draw their own conclusion to see how the system fits the household's assets and needs.

Despite the low usage of rippers many of the farmers with access to own or borrowed ADP, said they used or wanted to use a Magoye ripper. Many of the interviewed households recognised the potential in water harvesting and wanted to utilise this advantage. Using a ripper was also considerable faster and easier to handle than a plough.

The farmers had also recognised other advantages such as homogenous furrows and suitable depth for seeds to germinate when using a Magoye ripper.

Why so few farmers tend to apply the Magoye ripper technique depends on a variety of reasons. The major argument expressed for not using ripping as prescribed was the great disadvantage concerning increase of weeds in the fields. Many of the farmers had noticed the benefits but did not have the time or enough supply of labour needed for weeding. In these cases they saw the benefits of combining ploughing with ripping because the plough turned the soil over and buried the weeds, thus reducing both weed infestation and seed bank. Another argument against using a ripper in dry season was that the soil was too hard and the ADP did not manage to draw the ripper.

The amount of and access to available Magoye rippers play an important role. Both interviews and questionnaires pointed to too few available rippers. The farmers mean that there is no other alternative than using a plough or receives the ripper too late in the season. Except for mixing a plough and a ripper the farmers had their own interpretations about how to use the ripper for maximum output. The choices made, *e.g.* shifting ripp lines season to season, ripping in rainy season and using the ripper in combination with a plough were often based on rumours or own conclusion combined with lack of knowledge.

Crop rotation & Organic Matter management

Crop rotation as CF prescribes is one of the greatest problems for the farmers. It is a vital part of CF and also a powerful tool in the fight against weeds and pests. However, since many farmers can only cultivate a certain area of land, they have to focus on crops that will provide food for the family. The most common "crop rotation" works so that only a small part of the field is planted with alternative crops while the remainder is planted with the main crop, usually maize. This means that, in reality, the crop rotation is several years of maize interrupted by one season of alternative crops. The inadequate crop rotation is partly a cultural trait. Traditionally the man grows the main crop, maize, and the women grow smaller crops such as groundnuts and beans. But from the interviews we gathered that this is only part of the reason for the poor crop rotation, both female and male-headed households wanted to grow maize primarily to secure food supply for the next year.

A major problem is to find a market or use for the produce. Groundnuts and beans are not considered main crops and they are not easily transformed into cash. There is not enough demand for them locally and the farmers have difficulties transporting them to the market.

- In the questionnaire only slightly more than 50% of the farmers consider that crop rotation is good for yield and food security but almost 90% think it is good for soil fertility.
- Half the farmers started with crop rotation to improve soil fertility and because it reduces the pests, but only 13% started to reduce the weeds and 21 % to reduce the fertiliser use.
- 98% of the farmers consider "Planting sunnhemp or velvet beans one year gives better yield of maize next year" to be true.
- 91% of the farmers consider it true that the crops on a field only have to be changed when the yield is starting to go down.

The findings can be summarised as follows. The farmers are mostly aware of the positive impacts of crop rotation but do not apply it because: a) they do not have enough labour to grow both sufficient amounts of maize and other crops, b) they do not have any use or market for the produce of alternative crops.

Cover crops and green manuring are not very common. A reoccurring comment is: "I can not eat sunnhemp!" The farmers expressed that there has to be some immediate gain from the green manure to make up for the work and the land that is used. In the case of cover crops there is an additional problem. During the dry season the cattle, not only the farmer's own animals but also those of his neighbours, are allowed to graze freely on the fields. Any plants or residues on the fields will be consumed long before the dry season is over and the cattle does not always have the good discipline to leave some nutrients behind when they eat. Furthermore there are few species that can act as a cover crop and will survive during the harsh dry season.

No farmers that we encountered still practised burning and most left at least part of the crop residues on the field. It was common to bring the leaves and stalk tops back to the farm to use as fodder or in the compost, so one way or the other the some nutrients found their way back to the fields. According to the farmers, the residues that are left did not serve as mulch since free ranging livestock or termites ate most of it. The rest quickly decomposed and there was no ground cover left to protect the soil during the harshest part of the dry season or when the rains started. This means that mulching, which is considered an important part of CF according to FAO (FAO webpage I, 2004) is not possible. At least not if mulch should be a several centimetres thick layer of organic matter that will protect the soil and create a favourable microclimate.

Equipment & Inputs

Equipment availability

74% of the farmers would have tried ripping if they had access to a ripper. ASP has Magoye rippers and the farmers can borrow these, but there is only 3-4 available in each camp. Many farmers are interested in trying ripping, at least on a small scale, but could not borrow the ripper in time.

Nutrient input

Fertiliser is the preferred input, both as basal dressing and as top dressing. During the interviews many farmers expressed views that fertiliser is a very important factor for a good yield and that the agriculture has been going worse since the government stopped subsidising the fertiliser. Generally the farmers want to use fertiliser and they do not think that agriculture could work well without it.

Another interesting finding is that the farmers also recognised that fertiliser may be harmful to the soil. This was said in the interviews as well as on the ToF of the questionnaire where 73% considered this to be true. About 60% of the farmers claimed that fertiliser, compost and kraal manure was important for a good yield, only 40% thought that fertiliser improved the soil fertility but gave compost and kraal manure better marks in that aspect. However, there are some conflicting messages. In the ToF statements 60% thought that fertiliser is more important than compost and kraal manure for the yield and 59% considered the statement "Fertiliser cannot be replaced by compost and manure" to be true.

Farmers seem to consider fertiliser an important input that can only to some parts be replaced by compost and kraal manure, but these still remain important inputs. The result is the same no matter how the data is filtered with the exception that women seem to hold compost and kraal manure in higher esteem compared to fertiliser than the men. While more than 60% of the men thought fertiliser was important for the yield only 42% of the women agreed. 60% of the both men and women thought that kraal manure and compost was important.

Farmers sometime find it hard to get fertiliser even if they have money to buy them. The fertiliser they buy from the government program does often not arrive on time. On one occasion the top dressing did not arrive until nearly harvest time. For many farmers it is hard to get to town and buy fertiliser, even if they could afford it. Many of the more successful farmers pointed out that one reason for their neighbours poor yield was that they waited for the fertiliser and seed handouts, thus planting late, or did not use any nutrient input at all.

Lime

The farmers use lime if it is available and it is recognised that it improves yield. 85% thinks that lime acts as a sort of fertiliser (ToF statements). During the interviews we encountered many different views of liming and the knowledge of the "how" and "why" of liming seems to differ greatly. In some cases farmers would apply lime every year but in the questionnaire 69% said this should not be done.

Seed

Certified seed seems hard to come by and the farmers complained that it was better when the government provided it. The better-off farmers, *i.e.* the ones with sufficient labour, ADP, and food supply, often made sure that they acquired certified seeds. Those farmers planned ahead and used several varieties with different maturing times and varied drought resistance to ensure good yields and food security. The farmers who were not so well off had to make do with what remained of last years crop, but wanted to get different varieties for food security. Some thought it was quite confusing with so many new varieties and recommendations each year, making it hard to choose. In the questionnaire more than 60% considered certified seed as important for a good yield and food security.

Seed for crops recommended for crop rotation and green manure were seldom available to the farmers. This constrains the use of these practices.

Socio-Economic factors

Labour

The result from interviews indicated that the households act differently when it comes to labour. Wealth and family size are of great importance in the process of decision-making concerning cultivation practises and work duties. The majority of the interviewed households pointed out that CF practices needed more labour input, especially for land preparation and weeding. If CF were done as recommended, the total labour input would be spread out during the year and gradually decrease over time.

Increased labour is often the result of practices that are not done as per recommendation. For example, the weeding is supposed to be repeated 4-5 times during the season to reduce the seed bank. Normally, this was only done 2-3 times in fields under CF practices, hence increasing the total labour input in the long term because the seed bank is not reduced over time. At the same time, farmers are used to weeding 2-3 times in a conventional system and claimed that they did not have the capacity to weed as many times as prescribed.

Field visits during the interviews indicated that limited access to land is not the foremost obstacle to increased farm production, but instead lack of labour for weeding and land preparation. The farmers also considered lack of ADP a major problem. Traditionally ADP has been used extensively in this area and is also a sign of status. They think that it is not possible to operate a farm properly without ADP and in general they all want to use ADP more.

Gender

The interviews revealed that traditionally there are clear distinct gender roles, the men plough and the women plant and weed. The whole family is involved in the harvest. Though, in some cases the men helped with both planting and weeding. Especially in smaller families with less labour and capital, where all family members shared the work duties in order to handle the workload. Families, which adopted CF practises and regularly participated in ASP meetings, generally did not have as fixed gender roles as in conservative farming families or in larger households with several wives.

The awareness of how the labour changed with CF was varied. In most cases the focus was on tillage aspects and the results thereof. Sometimes the man was very much aware of the increased weeding caused by using ripping or basins, in other cases they were not. On more than one occasion the man had to send for his wife so that she could answer how many times a field was weeded. Once we got the following answer from a male farmer: "I do not have a problem with weeding. I have three wives". When we interviewed female farmers or the wives only, we usually got a more descriptive answer to questions about weeding and how this had changed with the different tillage systems. They all concurred that the amount of labour put into weeding had increased.

Awareness and knowledge about farming seem to be just as good among women as among men. The wives followed their men to farmer meetings and took part in at least some of the activities. Unfortunately there was not the same number of female participants in fieldtrips and farm visits. The female farmers took an active role in the ASP action plan meetings and many of the older women from female-headed households was held in a great deal of respect from their fellow farmers. This we gathered from the interviews and the meetings we attended.

It also seems common, but not always, that farming and planning is discussed with the women of the household. We noticed that male farmers often compromised and took the women's suggestions into consideration when deciding. We gathered that any man with several wives would avoid quite a lot of headache by making the "right" decision or compromise. On the other hand, while women are to some part included in the decision process of a male-headed household, the man always has the last say in any matter.

Transport & Market Availability

As we have mentioned earlier the farmers have to produce what they can eat in first hand. Whatever surplus there is may then be sold. Most of the farmers we spoke to were active on the local market, selling their produce to neighbours. Needless to say, when they did have surplus to sell so did all their neighbours so the prices were not great. For many farmers the transport to markets often involves a journey of first 5-10 km on a narrow track and then another 20-50 km on larger roads to the nearest town or market, at least in the camps where we conducted this study. The cost of renting transport is often too high for the farmers and there is also not much transport available for rent. 83% of the farmers considered the statement: "I sell locally because I cannot find transport to market" to be true. This was most true for farmers that are not so well off, those with more money usually had more cash crops and other sources of income such as fishponds. One entrepreneur explained how he sold some of his produce and fish locally so he could afford the transport to the town market where he got double prices for the rest.

We often asked farmers if they had considered a joint effort to get transport to the market and even if some had thought about it the plan had not yet been put into action. Yet again

the problem was finding transport. The farmers are left with buyers that travel around the countryside, paying very poorly for the produce.

Entrepreneurship

We mentioned earlier the farmer that sold some produce locally to pay for transport to a market. This is one thing that seems more common among farmers that are a little better off, *i.e.* they have cattle, more labour available and more cash crops. They have enough production to satisfy their own food requirements. There seems to be an economic break-line where a farmer can start doing business this way. It has proved hard to find this break and to find the data that may enable us to understand what it takes to cross it. There is one more factor that these entrepreneurs also have. They have what we call "drive", this character trait became apparent when we interviewed them. "Drive" is hard to describe but in short it is the will to improve the situation and the will to try new things.

The level of entrepreneurship is also a question of knowledge and skills. When we spoke to some CEOs about this problem they said that many households were unaware of the prices that they could get at the market and what products where in demand.

Other sources of income

There was a range of traditional activities to bring in extra cash, ranging from crafts to breeding livestock (Table 6). This was a major source of income for many households and proved less a problem of transporting to markets. What can be carried on one's own back is not a problem but larger bulk loads prove an insurmountable hurdle for many farmers.

Table 6. Other sources of income that the households had beside agriculture

Alternative sources of income
Brick making
Fishpond
Fruit orchard
Basket and mat weaving
Beehives
Livestock rearing
Clothes maker
Oil and soap manufacture
Milk

Extension Service

We noticed that the CEOs are not always fully aware of ASP's facilitation cycle. Essential steps such as No. 3 and 4 (see Figure 1) were not always adequately carried through. Further more, it seemed that not all them believed in a CF cropping system themselves. Some CEOs also expressed that they lacked time to have both group meetings and meetings with individual farmers. Due to the few returned CEO questionnaires we could not get statistical data on this but it became apparent both during the CEO interviews and CEO monthly meetings.

Monthly and yearly reports from the CEOs to ASP show numerous problems in the studied area. Two great obstacles are the inadequate follow-ups of both study tours and prepared farmer action-plans. The CEOs are aware of the problem and expressed their concerns and stressed the importance of emphasising these issues. They think that by increasing the number of follow-up visits and by doing them individually farm-by-farm, the general knowledge and deeper insight about the CF system will be enhanced.

The CEOs also pointed out the impact of funerals and effects of HIV/AIDS on the agricultural system. Many household members attend funerals and less time is spent participating in farming meetings. AIDS has a direct negative impact on the agriculture by reducing the labour force, but also by creating a great mental stress on both household and community level.

DISCUSSION

Practices & Inputs

While the following discussion is mostly focused on adoption or lack thereof, it is important to remember that it takes time to change practices. Make the following comparison: On one hand, the use of subsidised fertiliser and extensive farming was promoted on a national scale for thirty years and are still practised (Haggblade & Tembo, 2003). On the other hand, the promotion of various CF practices started on a small scale less then two decades ago. It is not until middle of the nineties that CF was promoted on a broader front in Zambia (Haggblade & Tembo, 2003). Farmers are often careful about trying new methods because a failure may have devastating results. This is the same no matter where in world you are.

The basins have readily been adopted because the farmers have seen the immediate benefits, such as drought resistance. The basins have also been in focus longer than most conservation farming (CF) practices. The Magoye ripper is fairly new but there was a lot of interest in its use. Most farmers recognised the water harvesting benefits when using the ripper but relatively few had tried it as a system. There was not a lack of will to try but rather a lack of Magoye rippers and knowledge about how a ripping based system worked. Mwape *et al.* (2004) noted this problem as well. And as both Mr. Hamuwele Gestin (camp extension officer (CEO) in Mboole) and Mr. Sailas Sakala (CEO in Mujika) said: "it is an ongoing process and the farmers are just starting with this practise".

The adoption of crop rotation and intercropping are low for reasons that will be further discussed later in this section. We think that the need for organic matter (OM) and nutrient management is as important for the cropping system as the tillage. The system will not function optimally without all the aspects addressed (see section "Definition of Conservation Farming"). Therefore a large part of the following discussion is focused on the lack of adoption concerning crop rotation, green manure, and intercropping.

The use of fertiliser is widespread and most farmers consider it a very important input. They do not think that compost and kraal manure can replace fertiliser as nutrient source in their cropping system. Only a few thinks that crop rotation can be used to reduce the use of fertiliser. This is because the use of fertiliser has been promoted for a long time in the attempt to instil the green revolution (Haggblade & Tembo, 2003), but also due to the fact that the soils are highly weathered and have a low nutrient content (see Part 2, "Minor Soil Fertility Study"). We agree with the farmers: legumes, compost, and kraal manure alone will probably not cover the whole nutrient need of the crops. Especially phosphorus will be deficient without fertiliser (see discussion in Part 2, "Minor Soil Fertility Study"). There is also many practical problems constraining the use of crop rotation and green manure, such as lack of seed, use for produce, and restricted amounts of labour.

The foremost obstacles against adoption of the CF are different practical constraints. In all the interviews the amount of labour needed for CF was stated as the greatest problem and the farmers did not consider CF labour saving. This problem is also indicated in the

Agriculture Support Program (ASP) baseline (Tembo, 2004) and by Dr. Mwape *et al.* (2004). In order to grow sufficient amounts of maize the farmer need to cultivate a certain amount of land. If they have insufficient amount of labour they cannot grow any large amounts of other crops. This reduces the farmers' possibilities to practice crop rotation and similar practices.

There are two areas of CF that are especially labour consuming; land preparation and weeding. Land preparation takes time but if done as recommended, *i.e.* in the dry season, it should reduce the labour peak that otherwise is created when the first rains come. One stated reason for not preparing the land in the dry season was that the soil was too hard. However, in some cases we had the feeling that it also depended on how much labour the farmers wanted to put into their crops. As we mentioned in the "Results & Findings" section we sometime got comments from more successful farmers that the reason their neighbours failed was because they were arrogant and lacked foresight. This is part of a greater problem that should be explored better. Not all people living in rural regions are farmers with sufficient knowledge or ability to farm the land. The term used by Dutch Gibbons (Conservation Farming Unit, CFU) was 'rural dwellers'. Rural dwellers are people who are just trying to survive and see no other way than attempting farming.

Weeding labour is definitely a more real problem. Reduced tillage will increase the amount of weeds and hand weeding takes a long time and requires a lot of labour. If there is not enough labour available or the weeding is not done as recommended the weeds will quickly take over and the yield will decrease. The farmer end up being disappointed at the result and the chance of adoption is reduced.

What other ways are there to reduce the weeds? One way is to use crop rotation with crops that will inhibit the weeds (Ohlander, 1997). But as long as there is no marketable, or usable, produce from alternative crops it is not likely that the farmers will put their labour into crop rotation. Change may be on its way, ASP has just recently launched a livestock project and this would be one good way of increasing the value of crops and green manure. The comment "I cannot eat sunnhemp" will be replaced with "I use the sunnhemp as fodder". The livestock has a cultural importance for the Tonga and better fodder would also increase the animals' health, ability to produce power (animal draft power, ADP) and food (milk and meat). The ASP has an action plan program aimed to increase business awareness and help the farmers to find markets for their produce. This will also open up the possibility for a better crop rotation.

Mulching will also suppress weeds (Kristiansen *et al.*, 2003). But from what we gathered the mulching does not work in this region and very few farmers actually use it (Mwape *et al.*, 2004). Even if the entire residue is left on the field it is quickly eaten by termites or decomposes long before the rains. That is if free grazing cattle do not eat it. Cover crops may provide organic material for mulch but there are not yet any species that are both good cover crops and will survive the dry season.

Different mechanical and chemical measures against weeds have been tried. CFU has developed a weed wipe for their farmers but it is still not available to all farmers (Gibbons, 2004). Cultivators and similar ox drawn implements were sometimes used but it is a big investment for a small-scale farmer and usually required some amount of hand weeding afterwards.

Promotion

The promotion aspect is one that we feel that we have not explored properly. We have indications that this has a great impact on adoption, or to be more precise: HOW CF is promoted has impact on HOW and WHY it is adopted. One clear example that indicates this is the basins that have been promoted as a food security and a water harvesting measure. For people without ADP it is the only working choice but most farmers had a small field of basins in case of drought. When we asked the farmers why they started with the basins most said that it was in connection with the drought of 2001. They would not have started with the basins unless they had seen how well the basins worked during the drought. It is clear that the promotion of basins as a food security measure has been very successful. However, the result is that people only consider them a complement to their conventional cropping system or for people without ADP.

It seems that the extension in the area has focused mostly on tillage aspects (planting basins and ripping) in the past. When reading different reports on CF, successes reported are often concerned with the amount of ripping and basins used among farmers, for example in Haggblade & Tembo (2003). This is still very present in the current programs and we feel that somehow the organic matter (OM) aspects have been lost. Especially crop rotation has not been as thoroughly promoted, despite its importance. Other reports point to the same conclusion. Malesu and Luputa (1999), in their report on the impact of Soil Conservation and Agroforestry Extension (SCAFE) projects in the southern province, stated the following: "Although crop diversification has been adopted, the level of adoption does not facilitate crop rotation. Farmers need to be educated on what crop rotation really is and the benefits drawn by practising it."

Knowledge

The practical constraints, lack of markets or good prices for produce, lack of labour and seed, are still the greatest constraint against crop rotation and green manuring. But we think that farmers would be more encouraged to solve these problems themselves if they fully understood the impact of the nutrient and OM management in the cropping system.

We cannot point to any particular weak part of the farmers' knowledge. We met farmers that had very thorough understanding of agronomy and they had a great understanding of their own farming system but they had been taught CF as individual practices, not as a full cropping system. Therefore they missed many vital points and there were blanks in their understanding of the CF system. For example, the farmers need to understand how important crop rotation, mulching, and organic matter management is, not only as a way to improve soil fertility but also as a tool to reduce weeds and pests. If blanks like these were filled and all the farmers were made fully aware of how the different practises work in the cropping system they would probably adopt more of the CF cropping system rather than individual practises. They have to see for themselves how the different parts of the system interact and how the effects change as they apply new methods. Or as is stated by Mwape *et al.* (2004): "CF is largely about educating farmers". This is not something that is specific for farmers in Zambia. When promoting a new cropping system or technique it has to be put in relation with the existing farming system, whether you are promoting it in Sweden, USA, or Zambia (Rydberg, 2004)

When we presented the aforementioned line of thought at a presentation one in the knowledgeable audience said: "you do not really have to understand the mechanics of the combustion engine to drive a car". This is very true. We do not mean that the farmers should have to go through Agriculture University to learn CF. However, what happens if

the driver does not know how to put in second gear? Or what the warning lamps are? He does not have to know these things to drive the car but it helps - he or she will be a better driver. This is especially true for the less experienced farmers. They need to understand both the short-term and the long-term benefits of their actions just as much as they need to see immediate benefits to be convinced to adopt CF.

The lack of knowledge has another negative impact on adoption. Discussion of practices' outcome among farmers, relatives, and neighbours frequently provides incorrect information about how to use practises. When CF is not practised as prescribed the promised result does not appear and the farmer will be disappointed. This is how CF as an expression gains bad reputation. Naturally, a technique's reputation plays a significant role when the households decide to implement different techniques.

Extension Service

The camp extension officer is employed by the Ministry of Agriculture but is retained by ASP to teach CF (Segerros, 2004). We attended several district meetings and talked to different CEOs and got very different feedback on CF. It seems that many CEOs interpreted CF in different ways and sometimes not the way ASP wants. The CEOs have more experience with conservation tillage and have in previous projects marketed this as a food security measure. We got the impression that this was still present in the current program.

The CEOs generally tried very hard to extend CF to the farmers, and to some degree succeeded, but it seemed that some of the CEOs did not always follow the facilitation cycle as prescribed. They did not start from the farmers' problem base and made too great generalisations of the farmers. This could be because many of the CEOs are of the old school of extension where the farmer was told what to do rather than to use participation and interaction (Phiri, 2004). One thing that indicates this is the questionnaire where a large part of the farmers stated that they started with basins and ripping because the CEO told them to.

There is also a lack of follow-up on field and farm visits. It was stated in the CEOs monthly reports that the follow-ups did not happen. The ASP's own district co-ordinators also confirmed this. If more time were set aside for this approach, the CEOs could explain better how the CF practices function in the farmers cropping system. The lack of follow-ups is one reason why farmers know about CF practices but do not understand the CF cropping system. They see the practices on a field visit but it is not discussed further and put in relation with their own cropping system. Therefore they often draw conclusions on the wrong premises.

The ASP must make sure that all the CEOs know and understand the facilitation cycle and how it is supposed to work. The program must also give a clear message on how the practices should be promoted. In the SCAFE report (Malesu and Luputa, 1999) it is also mentioned that many of the Ministry of Agriculture & Forestry's extension officers have not received sufficient training. The Basic and Advanced Land Management and Conservation Farming (LM&CF) courses had not been conducted since sometime in 1995. This report was written 1999 and we do not know how much training has been conducted since then.

The CEOs felt there was a competition for the farmers' attendance at meetings and training sessions. This is one problem that often occurs in a region where several different non-governmental organisations (NGO) with food relief or similar handout programs are

present. These NGOs tended to draw the farmers to them but without offering sufficient training or knowledge in CF. A phenomenon like this tend, according to Mats Hårsmar (2004), lead to little interest, awareness, and intervention in CF practices by the farmer and thus less willingness to do things without economic support. Not much can be done about the negative impact of handouts but the information chain from ASP to the farmers could be improved. Not only so that information gets through but also so that it disseminates in the right way.

CONCLUSIONS

Our main objective, to investigate why farmers choose to adopt or not adopt conservation farming (CF), was based on the assumption that farmers can be divided into adopters and non-adopters. We made this assumption after we studied several reports and proposals on CF during our initial research. These used the terms: 'adopter', 'non-adopter' and 'dis-adopter' repeatedly. In many cases these documents did not state a definition of CF, nor if they meant the term adoption as "the farmers have adopted the whole CF system" or " the farmers have adopted some CF practices". Therefore it is hard to make any comparison of the actual adoption rate when reading and evaluating documentation on CF projects.

The question "how to define what is an adopter?" was raised because it turned out during the study that there is no clear distinction between adopters and non-adopters. At least not when we defined an adopter as a farmer who uses CF as system with all practices integrated (see section "Definition of Conservation Farming").

However, we have seen that there are some differences between farmers who remain with the conventional farming and farmers that try or adopt new practices. We saw that the four of the factors listed below appeared in every farmer that had tried some part of CF.

- Direct and immediate need forces farmers to change their practices. For example, lack of food will cause a farmer to find new ways to improve food security. The 2001 drought caused many farmers to try planting basins.
- Sufficient knowledge about different options and new techniques and their place in the farming system.
- Personal drive. This very abstract personal trait is very hard to capture in statistical research but becomes apparent in interviews. These farmers have the will to try new things and they see possibilities in every situation. They have the will to improve the current situation.
- Sufficient capital or inputs to practically implement a new technique. The farmer must also feel sufficiently secure to try something new. This is why most of the better off farmers tried new practices. They could afford to fail.

The practices

When it comes to the different practices of CF we can conclude that planting basins have successfully been adopted as a food security measure, but not always practised as prescribed. The Magoye ripper is still new to the farmers but many wants to try it. It is not used as per recommendation but many farmers use it as a complement in their conventional cropping system since they noticed improvements mentioned in "Findings". But the adoption is an ongoing process and we think it is moving in the right direction.

Crop rotation is only partially adopted. The main constraint is lack of use for produce from alternative crops and insufficient labour to grow both the amount of maize required for food and the other crops. There is also a need to promote crop rotation as an integrated part

of the CF system and not as a practice in it self. But the most important obstacle that needs to be overcome is to find a way to make the crop rotation worth the effort for the farmers.

Promotion

The adoption of various CF practices depends on how it is promoted. The technique used and what is being said when trying to introduce a CF practice determines how the farmers see the practice and thus how it is implemented. So far different non-governmental organisations and camp extension officers have been giving different messages and the information varies from year to year. For example, when the farmers see basins or ripping as a food security measure or as something used when they lack ADP, it is not something they would use on their entire farm.

One reason for the low adoption of CF is that the CF techniques are not promoted as a coherent, integrated system, nor are they put in relation with the old cropping system. The Farmers need to understand both the short-term and the long-term benefits of their actions just as much as they need to see immediate benefits to be convinced to adopt CF. It is of major importance to improve the understanding and raise awareness that other possibilities to increase yield and retain a fertile soil are available. There has to be more focus on the use of legumes in crop rotation, intercropping, and compost as an alternative to fertiliser and manure. The ASP need to make sure that CF is promoted according to the program definition.

Knowledge

Many farmers need to complement their knowledge with an understanding of the CF cropping system, their own farming system and how the CF practices fit into their farming system. The farmers have to be able to see what effects the different practices have. They need to understand both the long-term benefits as well as gain immediate benefits, to adopt CF.

We have mentioned that we have seen some gaps in the agronomy knowledge and that this varies from person to person. These gaps have led farmers to adopt only some techniques, *i.e.* the ones that give immediate benefits, or they do not practice the techniques as recommended. This is because the farmers make assumptions on the wrong premises, which in turn has led to disappointing results, thus reducing the chance of adoption. This is especially true for the less experienced farmers.

Practical issues

There has to be a framework that supports the practical issues in the CF system. We found that most of the constraints were of practical nature.

- If new crops are promoted then there must be a reasonable gain from these.
- There has to be a market or use for the produce. The market must be accessible and provide reasonable returns.
- New tools must be available to buy or rent at reasonable prices.
- Whatever practice is being promoted it has to be within the farmers ability to provide labour and other inputs to support it. CF is labour intensive, even if this labour is spread out over the year. Especially weeding was a great concern for the farmers using ripping and basins and this has to be addressed. The farmers do not consider CF labour saving.

FURTHER RESEARCH

- It is clear from other reports like Soil Conservation and Agroforestry Extension impact assessment (Malesu and Luputa, 1999) and the Agriculture Support Program baseline (Tembo, 2004), that the harvest per hectare increases significantly when using CF, basins specifically. It would be interesting to determine the amount of harvest per hour of labour. Conservation farming is often proposed as a labour saving system but in all interviews the farmers' claim that the labour increased, especially for weeding and preparation. Haggblade & Tembo (2003) also want to see further studies of the economic of CF. For Example, they have not found any reports that have measured differences in profitability by comparing the value of differential output to the differential input costs.
- When it comes to aspects such as crop rotation and cash crops there is something like an economic break-line that we have not been able to establish properly. Farmers above this break-line are more likely to adopt new practices and try new things. We think that it is wealth, access to labour and animal draft power that is the factors that make this break-line. The farmers will first focus on food, then cash crops and if they then can afford it, *i.e.* have sufficient inputs, they will look further. The question is where does the break-line go?
- We have mentioned that need is one factor that drives change. But what is the farmers' perception of need? Is it when they starve? Do they feel they need to improve the fields? What differences between farmers and rural dwellers are there in this aspect? This aspect could be explored better than we have in this project.
- The problem of weeds has to be resolved. Research on ways to get functioning cover crops or mulch practices has to be done. Weed wipes and mechanical measures have to be explored.
- There are so many organisations trying to promote sustainable development techniques and related practices. Explore the possibilities for co-operation between different non-governmental organisations and stakeholders trying to promote and implement sustainable development techniques, from farming to business and marketing practises.

PART 2 - MINOR SOIL FERTILITY STUDY

INTRODUCTION

In many areas of sub-Sahara Africa, lack of water, depleted soils, and erosion are great problems. Like many places in Africa the high population growth rate in Zambia, 3% (Sida, 2000), has lead to a more extensive agriculture as well as an increased use of marginal land less suitable for agriculture. This expansion of extensive farming has taken place without considering a replenishment of the nutrients removed from the soils or maintenance of a good soil structure. Hence, the still ongoing traditional agriculture practices deplete the soil of organic matter and nutrients and lead to increased erosion by rainwater run-off and wind.

Traditional Farming

The traditional farming techniques, ploughing, hand-hoe ridging, burning, and use of fertiliser has not maintained or improved soil properties. Hardpans and poor soil structure (Figure 10) caused by ploughing and hand hoe cultivation, result in little rain penetration and moisture retention (Mulenga, 2003). The soil is left bare and exposed to the elements, causing both erosion and degradation of soil organic matter (OM). The nutrients are lost and due to less OM the capability of soil to hold moisture and retain nutrients decreases (Brady & Weil, 2002).

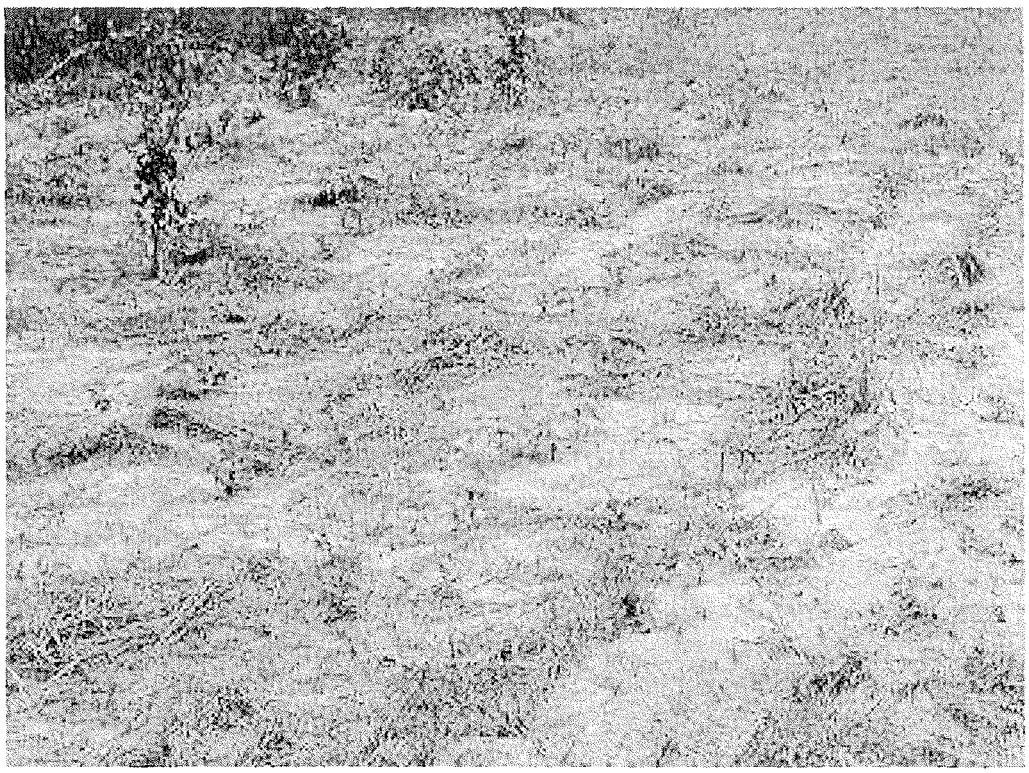

Figure 10. Damage caused by plough pan.

Ploughing and hand-hoe ridging increases the disturbance of the soil and cause greater transport of gases, *e.g.* oxygen (O_2) that has a fundamental role in the mineralisation of OM, which is rapid under tropical conditions (Brady & Weil, 2002). These practices will also create a hardpan, which prevent rain penetration and increase rainwater runoff. Ploughed fields are exposed to rainfall splash, capping, and erosion. This interferes with crop emergence and fertiliser may be washed away. Traditionally, the fields are ploughed

after the first rain. This delays planting and there is a loss of potential yield caused by not keeping up with weeding so that the crops suffer from competition with the weeds for nutrients and moisture (Figure 11) (CFU, 1997).

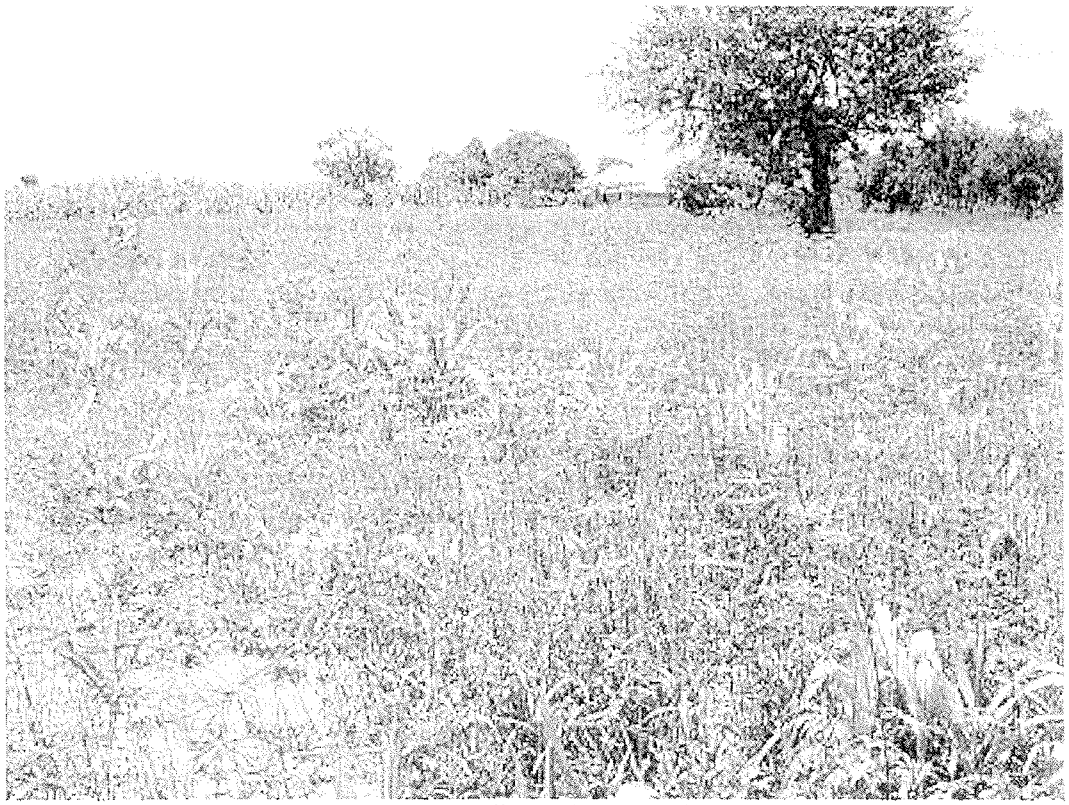

Figure 11. The result of late, inadequate weeding and poor seed.

Burning of crop residues decrease recycling of organic matter and convert essential nutrients such as nitrogen (N) and sulphur (S) and some part of phosphorous (P) to gaseous forms in which they are lost from the site. Other important nutrients such as soluble potassium (K) magnesium (Mg), calcium (Ca), and P remains in the ash, which may be lost in runoff or by wind erosion. (Brady & Weil, 2002)

The most commonly used fertilisers in the area of study is D-compound, NPK [$N:P_2O_5:K_2O$] with the ratio of 10:20:10, and urea [$CO(NH_2)_2$]. These compounds are not themselves a cause of acidification. It is during the plant uptake that H^+ is released causing the lowered pH. This is because the plants will release a proton (H^+) when taking up a cation, *e.g.* K^+, Mg^{2+}, to maintain the equilibrium in the soil solution. For example when a NH_4^+, the ion in the soil solution that is formed from urea, is absorbed the plant will release a H^+. Similarly, other soil microbiological processes will cause acidification, as well as OM breakdown, when fertiliser is applied. It is therefore of great importance to apply correct amount of fertilisers to avoid acidification. (Brady and Weil, 2002)

Conservation Farming Advantageous

There are several positive expected outcomes from the use of conservation farming (CF) practices. Listed below, according to CFU (1997), are some improvements of the soil, which would arise if the CF techniques are followed correctly (see Part 1, section "The Conservation Farming practices").

- Improves water infiltration and water holding capacity
- Increases organic matter content in the soil
- Increases soil pH & act as a buffer
- Improvement of soil fertility
- Improved soil structure

(Brady & Weil, 2002, Wiklander, 1976, Otabbong, 2004).

Objective

The objective of this soil study was to give an indication of the soil fertility (N, P) and to verify if the CF tillage practices changed the soil properties (OM, infiltration, pH) in this agro-ecological region.

Introduction to some Soil Properties

Infiltration

The infiltration rate is measured in centimetres per minute (cm/min) and is a measure of how fast water will infiltrate into the soil. Explicitly, this shows how much water a soil can 'swallow' per time unit and is important because it tells us how much of a given amount of rain will infiltrate and be stored in a soil profile. A high infiltration mean that more water will be stored and less will be lost as runoff during a rain.

Nutrients

Plant nutrients are different ions, *e.g.* K^+, Mg^{2+}, NH_4^+, Ca^{2+}, that are dissolved in the water in the soil, *i.e.* the soil solution. Plant nutrients are divided into macro nutrients and micro nutrients (Table 7). The nutrients are important for a plant growth and living processes. Plants consume large amounts of N and P, and these are usually the nutrients that are lacking in the soil. (Taiz & Zeiger, 1998)

Table 7. The essential macro and micro nutrients according to Taiz and Zeiger, (1998)

Macro nutrients		Micro nutrients	
N	Nitrogen	Cl	Chlorine
P	Phosphorus	Fe	Iron
K	Potassium	B	Boron
S	Sulphur	Mn	Manganese
Ca	Calcium	Na	Sodium
Mg	Magnesium	Zn	Zinc
		Cu	Copper
		Ni	Nickel
		Mo	Molybdenum

Organic matter

OM is important in a soil because it acts as a pool of nutrients. The living matter, *e.g.* bacteria, fungi, micro fauna, and the dead matter can absorb and release nutrients depending on availability so that the OM acts as a buffer, thus to some extent restraining leaching of nutrients. OM improves the soil's structure so that water infiltration/retention

and aeration is increased. This creates a favourable climate for plants and soil dwelling organisms. (Wiklander, 1976)

pH

The level of acidity or alkalinity is commonly measured with the pH scale, a negative logarithmic scale calculated on the concentration of H^+ and OH^- in a solution. It is considered that pH 6.5 to 7.0 is the optimum for most crops but a pH as low as 5.6 will not affect the crops negatively to a great extent. (Brady & Weil, 2002)

Cation Exchange Capacity

Cation exchange capacity, CEC, is the sum of all exchangeable cations that a soil can absorb at a given pH. CEC is expressed as the number of moles of positive charge adsorbed per mass unit; CEC values are reported in centimoles of charge per kilogram ($cmol_c$ per kg). If an soil for example possesses 24 $cmol_c$ per kg, this indicates that 1 kg of the soil can hold 24 $cmol_c$ of H^+ and exchange between the cations take place on a charge-by-charge basis, not an ion-for-ion. (Brady & Weil, 2002)
Base saturation (BS) is the percentage of a soil's negatively charged sites, CEC, that are occupied by attracting basic cations (Formula 1) (Brady & Weil, 2002).

Formula 1. $$BS = \frac{CEC}{\sum(Ca, Mg, K)} \times 100$$

Aluminium toxicity

When pH drops from 7.0 to 5.5 the concentration of exchangeable aluminium and H^+ ions increases but the effective CEC is essentially saturated with basic cations like Ca^{2+}, Mg^{2+}, K^+, *i.e.* the concentration of toxic Al^{3+} are not near dangerous levels. At pH 5.5 and lower (Reaction 1 peaks around pH 4.0), Al^{3+} substitute an increasing portion of exchangeable basic ions and the effective CEC is highly reduced. (Brady & Weil, 2002)

Reaction 1: $$Al(OH)_3(s) + 3H^+ \Leftrightarrow Al^{3+} + 3H_2O$$

Aluminium toxicity affects a range of processes in both plant growth and transformations in the biological nitrogen cycle. Toxic aluminium ions enter plants passively via osmosis or with the flow of transpiration water. The ions damage membranes of young root tips, can cause physiological drought, and can block sites where calcium is taken in. Further, aluminium precipitates phosphorous and thereby interfere with the plant metabolism of energy transfers (ATP) and genetic coding. (Brady and Weil, 2002)

Study site

The area where the study was carried out, in the southern province of Zambia, has sub-tropical climate and is largely modified by altitude. Three distinguishable seasons are seen. (i) October to April is warm and wet with irregular rainfall of 800 to 1000 mm (Figure 12). The rain normally comes in October and continues to April but there are variations from year-to-year and within the year (Figure 13). (ii) April to August is cool and dry and (iii) August to October is hot and dry.

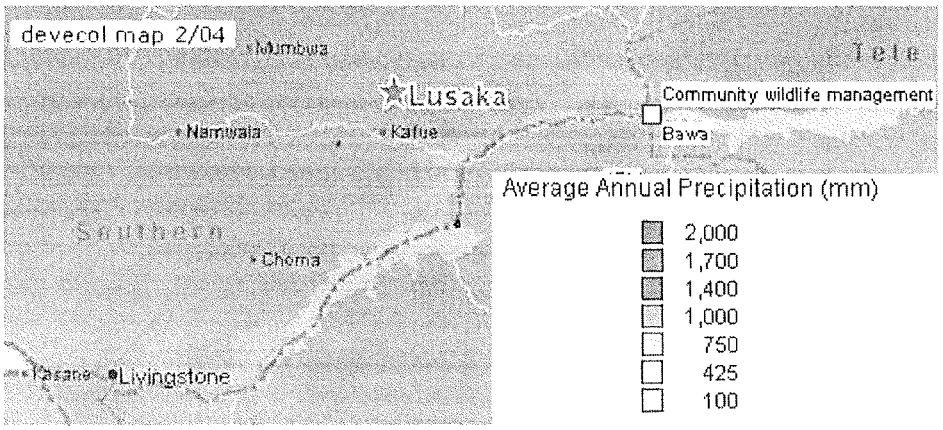

Figure 12. Annual precipitation in southern province, Zambia (Devecol homepage, 2004).

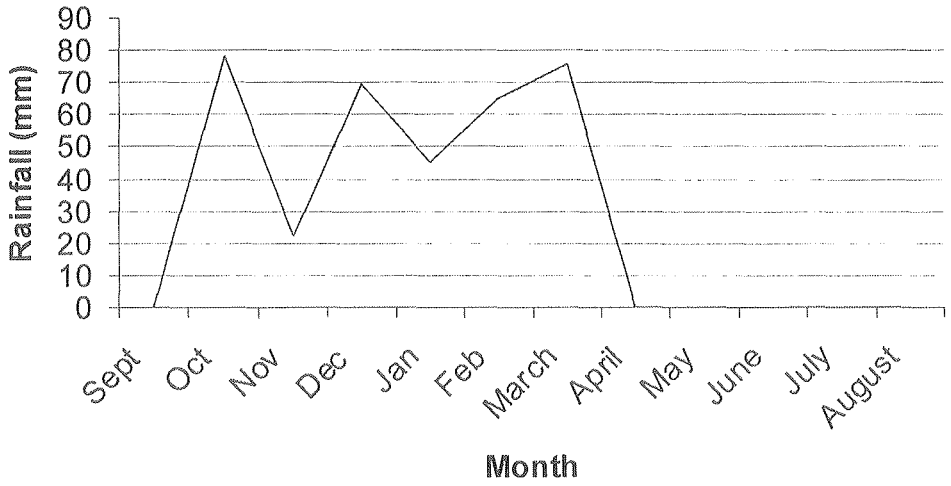

Figure 13. Example of rain pattern in the southern province. Figures are from Monze (Mwape *et al.*, 2004).

There is only one cropping season and the harvest of the staple food maize is normally in May. The yield varies depending on what cropping system the crop been under. According to Malesu and Luputa (1999) a field under conventional farming will produce an average maize yield of 14 bags (90kg) per ha in the area of the study. Advocates of the CF practice permanent planting basins claim that yield can be as much as 27 bags (90kg) per ha (Mwape *et al.*, 2004).

The specific study site was at camp Mboole, east of Choma, at the farms of Mr Iron Hachizibe and his father. Iron used both ripping and planting basins on his fields. He did not use permanent ripp lines and also used a plough to make ridges in the same field. He shifted his planting basins every three years. His father had used the traditional plough for ten years. Mr Hachizibe senior use a field until it no longer gives a good yield and then he breaks new land.

Soils at the study site

The soils in the area of investigation (Figure 14) are considered to be Acrisols, Lixisols, and/or Luvisols (Mulenga, 2003), according to the United Nations FAO classification. Translated to the US classification, Acrisols and Lixisols become Ultisol, and Luvisols become Alfisol (USDA, 1999). These soils are considered productive but sensitive to bad

management practices. The process of land degradation has worsened due to population pressure and traditional cultivation (Mulenga, 2003).

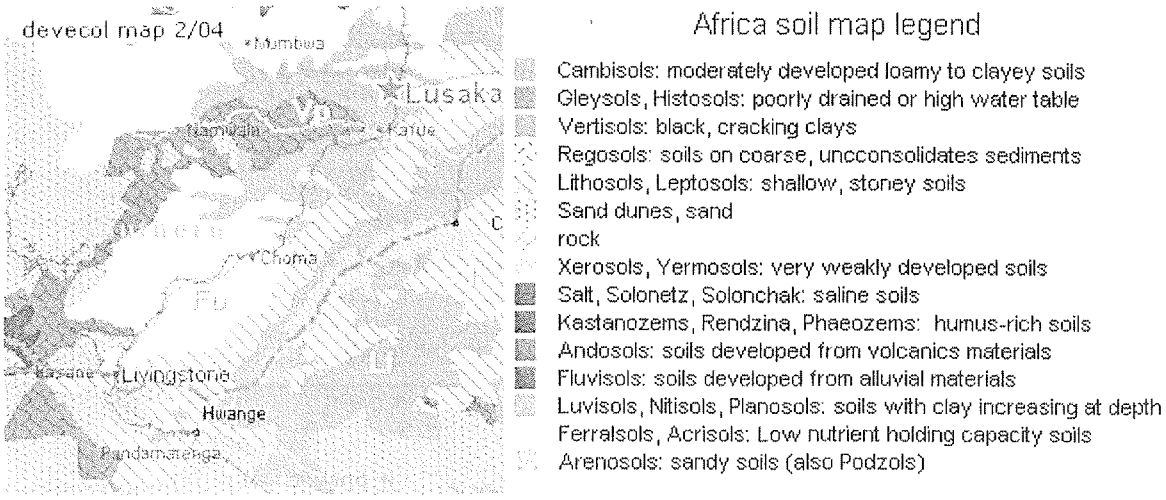

Figure 14. Soil map of the southern province, Zambia (Devecol homepage, 2004).

Acrisols, Lixisols, and Luvisols are all soils characterised by clay that have washed down from the surface and accumulated in the lower horizon, *i.e.* these soils have an agric horizon. This is a subsurface horizon with distinct higher clay content than the overlying horizon.

Ultisols (Acrisols and Lixisols), whose clay minerals are dominantly sesquioxides, *i.e.* hydrous oxides of iron and aluminium, and kaolinite, are acidic and highly weathered and leached soils where all nutrients, except aluminium, decrease substantially. CEC is low, average 3.5 $cmol_c$ per kg soil, and average pH is around 5.60. Due to the clay types and the low pH Ultisols have high phosphorous-fixing capacities and therefore low plant available P (Brady & Weil, 2002). Acrisols and Lixisols, as is seen in Table 8, has low activity clays and a CEC of less than 24 cmolc kg^{-1} clay, either starting within 100 cm or 200 cm from the soil surface, if the argic horizon is overlain by loamy sand or coarser textures. BS is of less than 50 percent in the major part between 25 and 100 cm. (FAO webpage II, 2004).

Acrisols can be used as pasture or arable land but their sustainable use highly depends on appropriate land management. Acrisols are generally of low fertility because of nutrient deficiencies in combination with aluminium toxicity and low pH. (FAO webpage II, 2004).

Table 8. Clay content, CEC and base saturation (BS) of Acrisols, Lixisols, and Luvisols (FAO webpage II, 2004; Brady & Weil, 2002)

Soil type	Clay content	CEC	Base Saturation
Acrisols	Low activity clays	Low, < 24 $cmol_c$ per kg clay	Low, < 50 %
Lixisols	Low activity clays	Low, < 24 $cmol_c$ per kg clay	High, > 50 %
Luvisols	High activity clays	High, > 24 $cmol_c$ per kg clay	High, > 50 %

(BS by 1M NH_4OAc at pH 7.0)

Lixisols occur dominantly in the drier parts of the tropics and subtropics, primarily in the seasonally dry tropical, subtropical, and warm temperate regions. Lixisols are soils with high BS and low CEC. The agric horizon has a CEC of less than 24 $cmol_c$ per kg clay in some part, either starting within either 100 cm from the soil surface, or 200 cm from the soil surface if the agric horizon is overlain by loamy sand or coarser textures throughout the profile.

According to Stocking and Murnaghan (2002) Ultisols is one of the most inherently infertile soils of the tropics, and when utilised they become chemically and organically degraded very quickly. The soils have very low resilience to degradation and moderate sensitivity to yield decline. In addition they are highly susceptible to erosion if used for arable cultivation.

Luvisols have high activity clays-enriched in lower horizon, a high CEC, and BS. The CEC is equal to or more than 24 $cmol_c$ per kg clay throughout and a BS of 50 percent or more throughout the B-horizon. Luvisols are most used by small stakeholders because of its ease of cultivation and no great impediments. The soils are greatly affected by water erosion and loss in fertility. Nutrients are concentrated in topsoil and they have low levels of OM. Luvisols have moderate resilience to degradation and moderate to low sensitivity to yield decline. (Stocking & Murnaghan, 2002)

Alfisols (Luvisols according to FAO) are seen as productive soils and crop yield are favoured by their medium- to high BS status, generally favourable texture, and location with sufficient rainfall. pH is in average 6.0 and CEC, $cmol_c$ per kg soil, 9.0. (Brady & Weil, 2002)

Materials & Methods

The soil study was constituted of two parts: physical properties and chemical properties. The comparison was done on two neighbouring farms and was intended to determine the impact of different tillage systems on the soil over a longer period of time, *i.e.* five growing seasons or more. The fertiliser scheme and crop rotations were similar on the two farms. We only sampled the top 5 cm of the soil profile (0-20cm), as this is where it is likely that there are any significant changes in soil properties (Triomphe, 1996).

The physical properties were determined by means of simple field tests according to Berglund *et al.*'s (2002) field test manual for farmers, and by samples analysed at the University of Zambia (UNZA). The following properties were analysed:

- Soil description
- Infiltration rate
- Bulk density
- Organic matter

For the chemical properties we took soil samples that were analysed in Zambia at UNZA and in Sweden at the Swedish University of Agricultural Studies (SLU). The following properties were analysed:

- Soil pH
- Nitrogen content
- Phosphorous content

Sampling

Each field was divided into four boxes and samples were taken in each box. This made for a total of 4 repetitions in each field (Figure 15). In the basins the double number of samples was taken, as we wanted to sample both inside and in between the planting basins (Table 9). One soil description was made in each field.

Table 9. The number of Infiltration tests, bulk density cylinders and soil samples taken in each field

	Basins Inside	Outside	Ripped	Ploughed	Total no. of samples
Infiltration tests	8	8	8	8	32
Bulk density cylinders	16	16	8	8	48
Soil samples*)	4	4	4	4	16

*) Each soil sample is made up of at least 4 sub samples, evenly distributed in the box, that were mixed to give a composite sample.

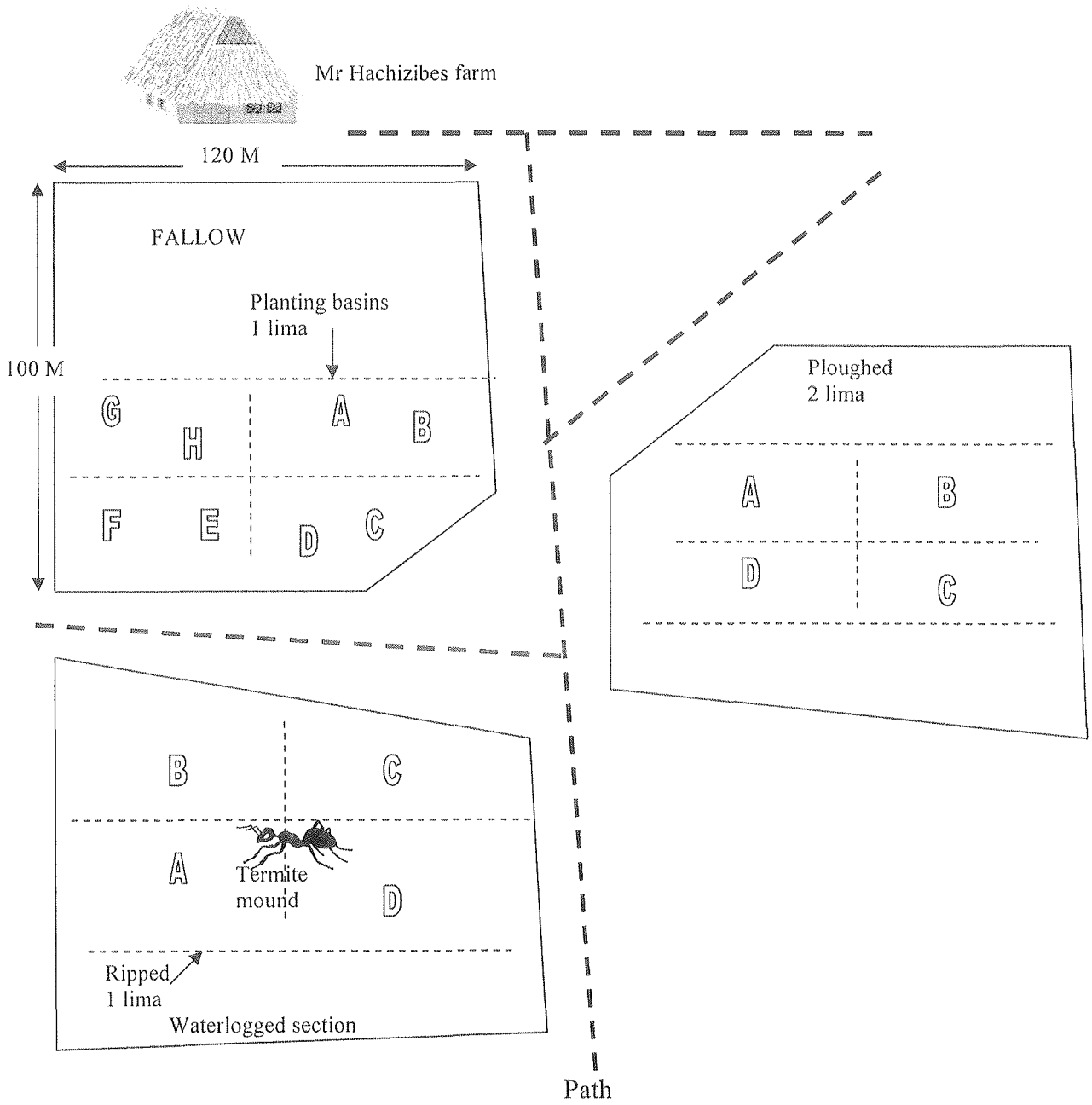

Figure 15. Schematic map of the fields and soil sampling.

Physical Properties

Soil description

The first part of the soil description was to dig a hole about 50-70 cm deep (Figure 16). During the digging we also performed a simple spade test to determine if there were any compaction layers such as plough pans. Not having a penetrometer we simply counted the amount of times we had to step on the spade to drive the entire spade head into the ground. We also made a note of how much the blade descended for every step. This gave a hint to where there might be a plough pan present. This rather crude method was still quite effective and we deemed the results good enough when repeated several times.

Figure 16. Jens is digging a hole in the ploughed field of Mr Hachizibe senior.

Once the hole was dug we made a thorough description of each layer or horizon determining the colour, texture, structure, aggregate stability, amount of roots, and other visible organic material.

Texture

The texture was determined by a rollout test and placed in the categories according to Table 10. The soil was mixed with water to form a moist paste and vigorously rolled on a piece of flat wood until it was as thin as possible. The thinner the roll can be made without crumbling entirely, the more clay is present.

Table 10. The different texture types of soils depending on soil content

Soil type	Clay content (%)	Main particle size (mm)	Roll thickness (mm)	Colour of soil when dry
Gravel to Sand	<2	2-20	Crumbles	Reddish-sand colour
Sandy Loam	<2	0,06-2	Crumbles	Light grey to slight sand
Loam	<2	0,02-0,06	4-6	Light grey
Claye loam	2-5	0,002-0,02	4-6	Light grey to almost white
Loamy clay	5-15	0,002-0,02	3	Light grey / brown
Light clay	15-40		1-1,5	Grey to brown
Heavy clay	>40		<1	Dark grey or brown

Soil structure

Structure of the soil was determined by observing the dry soil in the hole. The soil can be divided into four categories listed below and the aggregates can be further classified according to Table 11:

- Single particle structure – the soils primary particles are not grouped into aggregates. The aggregates cannot be further classified
- Aggregate structure – the particles have formed aggregates that are stuck together in more or less stable structures
- Massive structure – the soil forms one massive lump that is unbroken except for larger cracks
- Chunky structure – massive chunks with no internal aggregates, like very big aggregates

Table 11. Aggregate classification for lose and compact soils

Aggregate class	Size of aggregates (mm) and description of compact layers	
Loose soils		
S1	Fine	1-6
S2	Intermediate	6-10 with some aggregates as big as 20
S3	Big	10-30 with some aggregates as big as 50
S4	Very big	30-70
Compact soil		
S5	Compact layer that can be easily broken into aggregates that can be placed in classes S1-4	
S6	Compact layer that with some difficulty can be broken into aggregates that can be classified	
S7	Layer is compact (massive) or chunky and can only with great difficulty be broken into smaller pieces (chunks > 70 mm)	

Aggregate stability

The aggregate stability is the final factor in the soil structure description. It was classified according to Table 12.

Table 12. Description and classification of aggregate stability

Stability of aggregates	Description
Strong development	Easily distinguished aggregates in undisturbed soil. The aggregates are only loosely attached to each other and the aggregates do not break easily when disturbed. No material as single particles.
Moderate development	Aggregates are distinguishable in the undisturbed soil and layer breaks into aggregates when disturbed. Some single particles.
Weak development	Aggregates not easily distinguished. The soil breaks into some aggregates and lots of single particles. Aggregates break easily when touched.

Root structure

From each layer a 100-cm^3 chunk was removed and the amount of thin roots (<1-2 mm) and thick roots (2-5 mm) present in each layer was counted.

- Very few (1-20 thin and/or 1-2 thick)
- Few (20-50 thin and/or 2-5 thick)
- Many (50-200 thin and/or 5-20 thick)
- Lots (>200 thin and/or >20 thick)

We also paid attention to the shape of the roots in the wall of the hole, observing whether they had to work around hard structures or grew in straight paths.

Infiltration rate

Material

1 Infiltration cylinder of steel, 20 cm high, 15 cm diameter, total volume 3,53 l
1 Stopwatch
2 Water containers 20 l
1 tape measure or ruler

The infiltration was performed in the following way. The ground surface was cleared of debris and flattened slightly but not so much as to disturb the top layer. The cylinder was placed on the surface of the soil and pushed 1-2 cm into the ground. Before the infiltration tests the cylinder was once filled with water (~3 l) to saturate the soil below. In order not to disturb the surface more than necessary we placed a pumpkin leaf in the cylinder every time we poured the water, the leaf was then removed and the water was allowed to infiltrate the soil (Figure 17).

Figure 17. The infiltration test. In the picture Mr Iron Hachizibe and Jens Nolin.

The cylinders were prepared so that we had two markings spaced with the 5 cm (Figure 18). We filled the cylinder to the highest mark, not forgetting the pumpkin leaf, and started the clock for the first infiltration test. When the water level reached the lower mark we took note of the time. The volume of water for the reading was 0,9 l. We then allowed the rest of the water to percolate into the ground before refilling the cylinder for the second infiltration test. The total volume of water for each test (between the markings and the remaining volume in the cylinder) was 2,8 l.

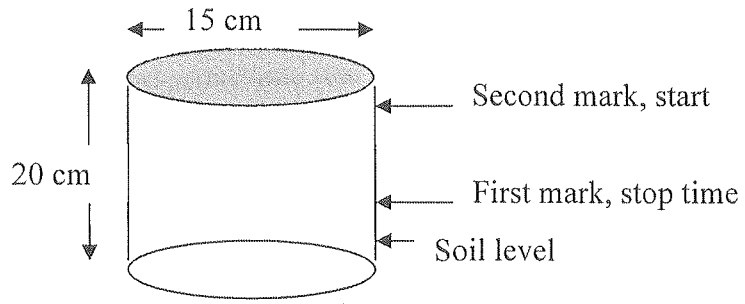

Figure 18. The infiltration cylinder.

Each infiltration was repeated a first and second time in each place and we performed two infiltration tests in each test box in the fields.

Bulk density
Bulk density was determined using a set of bulk density cylinders 75 mm in diameter and 50 mm high. We used two cylinders for each sample site in the field, taking great care not to destroy the soils structure while taking the soil sample. These were analysed by UNZA using the Core Ring Method (Blake & Hartge, 1986)

Organic matter
OM content was measured at UNZA.

Chemical Properties

pH
pH was measured using a 0.01M $CaCl_2$ at 1:2.5 soil suspension at UNZA.

Phosphorous content
The phosphorous (P) content was measured according to Olsen *et al.* (1952). 1 g of soil was shaken in 20 ml of 0.5 M $NaHCO_3$ (pH 8.5), for 30 min. The P concentration in the solution was measured using ascorbic molybdate procedure on a calorimeter (Murphey *et al.*, 1962).

Nitrogen content
Mineral nitrogen (N) ($N\text{-}NO_3$ and $N\text{-}NH_4$) was extracted with 2 M KCL and measured on calorimeter.

Statistical analysis

We used the SAS package (SAS Institute, 1990) for statistical analysis of the soils pH values, OM, mineral N, and Olsen-P contents, and the mean values were separated by the so called student's *t*-test (95% probability).

Limitations of the Methodology

When doing comparisons of soil properties with limited time and funds, it is preferable that the soil is of the same class in order to eliminate faults due to the different properties. In order to achieve our goal we needed farms with the same soil type and where the different farming techniques had been used as prescribed. Even though the farms of Mr. Iron Hachizibe and Mr. Hachizibe senior did not fully met our prerequisites, *e.g.* basins were moved around every third year and ripping had only been practised during four seasons, these farms met our requirements to the greatest extent possible.

RESULTS

Soil description - Ripping

23 April 2004
Southern Province, Zambia
Mboole Camp in Choma district
Farmer: Mr. Iron Hachizibe
Tillage system: Ripping and ridging since 4 seasons. Does not use permanent ripp lines.
Crops: 2000/01: Groundnuts, 2001/02: Maize, 2002/03: Maize, 2003/04: Maize.
Inclination: mostly flat, slightly sloping in places.
Inputs this season: Compost of kraal manure mixed with green leaves and maize stalks. 1 coke can per basin. Basal dressing is D compound, 1 *50 kg bag/lima. Top dressing urea, 1 *50 kg bag/lima.
Digging: 9-12 steps to bury the entire blade. Soil was hard and a hoe was required to dig a hole.

Horizon O-15 cm, weak A-horison
Colour: Grey
Texture: Sandy loam with some clay, Rolls to 3-4 mm and sheens slightly.
Structure: Compact, falls into small aggregates or single particles when dry. The aggregates are classified as S5-S1. Aggregates smooth and weakly developed.
Other observations: Few pores, many roots; both taproots and lateral roots.

Horizon 15-50 cm
Colour: Reddish brown
Texture: Sandy loam with some clay. Rolls to 3-4 mm without crumbling.
Structure: The soil is compact, very hard and falls into small aggregates or single particles when dry. The aggregates are classified as S5-S1. Aggregates are smooth and weakly developed.
Other observations: There are few pores and few roots, which are mainly taproots. The roots are growing quite straight and do not appear to have a difficulty penetrating the soil.

Soil description - Ploughing

23 April 2004
Southern Province, Zambia
Mboole Camp in Choma district
Farmer: Mr Hachizibe senior
Tillage system: Ploughing Since 1996.
Crops: Maize in monoculture.
Inclination: mostly flat, slightly sloping in places
Inputs this season: Compost of kraal manure
Basal dressing is D compound, 1 * 50 kg bag/lima. Top dressing urea, 1 * 50 kg bag/lima
Digging: 2-3 for the first part of the blade, then 8-10 for rest of spade. The soil was very hard and it was difficult to dig.

Horizon O-20 cm,
Colour: Greyish, brown.
Texture: Sandy loam. Does not roll well and does not sheen. Texture remains homogeneous through out the profile (Figure 19).
Structure: The soil is compact and falls into small aggregates or single particles when dry. The aggregates are classified as S5-S1. Harder layer at 15 to 20 cm depths but it was not an impenetrable plough pan. There is not enough clay for that to develop. Aggregates smooth and weakly developed.
Other observations: There are few pores but many roots; both taproots and lateral roots.

Figure 19. The profile of the ploughed field.

Horizon 20-50 cm
Colour: Reddish brown or yellow brown.
Texture: Sandy loam. Does not roll well and does not sheen.
Structure: Compact, very hard, becomes slightly softer at ~35 cm. Falls into small aggregates or single particles when dry. The aggregates are classified as S5-S1. Aggregates smooth and weakly developed.
Other observations: Few pores and few roots; mainly taproots.

Soil description - Planting basins

22 April 2004
Southern Province, Zambia
Mboole Camp in Choma district
Farmer: Mr. Iron Hachizibe
Tillage system: 4000 Planting basins/lima. Since 5 seasons.
Crops:1999/2000: Maize, 2000/01: Beans, 2001/02: Maize, 2002/03: Groundnuts, changed position of basins, 2003/04: Maize.
Inclination: mostly flat, slightly sloping in places.
Inputs this season: Compost of kraal manure mixed with green leaves and maize stalks. 1 coke can per basin. Basal dressing is D compound, 0,5 50 kg bag/lima. Top dressing urea, 0,5 50 kg bag/lima
Digging: 3-5 steps inside basins but 5-6 outside basins. Fairly easy to dig.

Horizon O-15 cm, A-horison, more defined than in the other fields. The basin is seen as a depression in the horizon border (Figure 20).
Colour: Greyish, brown.
Texture: Sandy loam. Does not roll well and does not sheen.
Structure: Compact, falls into small aggregates or single particles when dry. The aggregates are classified as S5-S1. Aggregates smooth and weakly developed.
Other observations: Few pores but many roots; both taproots and lateral roots. The roots are well developed and grow without constraints.

Figure 20. Profile in the basins. To the left is the top part of the profile with the basin in the middle and to the right is the basin to the right of the photograph. The basin is outlined with a dotted line.

Horizon 10-50 cm
Colour: Reddish brown or yellow brown.
Texture: Sandy loam. Does not roll well and does not sheen.
Structure: Compact, very hard, falls into small aggregates or single particles when dry. The aggregates are classified as S5-S1. Aggregates smooth and weakly developed.
Other observations: Few pores and few roots except under basin; mainly taproots.

Infiltration rates

The results from the infiltration tests, both first (1) and second (2) measurements, are depicted in Figure 21. We measured both inside and between the basins to make a comparison. We also placed the infiltration cylinders right on top of the rippline as well as between them. This was meant to give us an average for the whole field but as it turned out there was a difference in infiltration depending on where the cylinder was placed. The infiltration was visibly higher on the ripp lines. The statistical analysis revealed that the basins had a significantly higher infiltration than the other treatments.

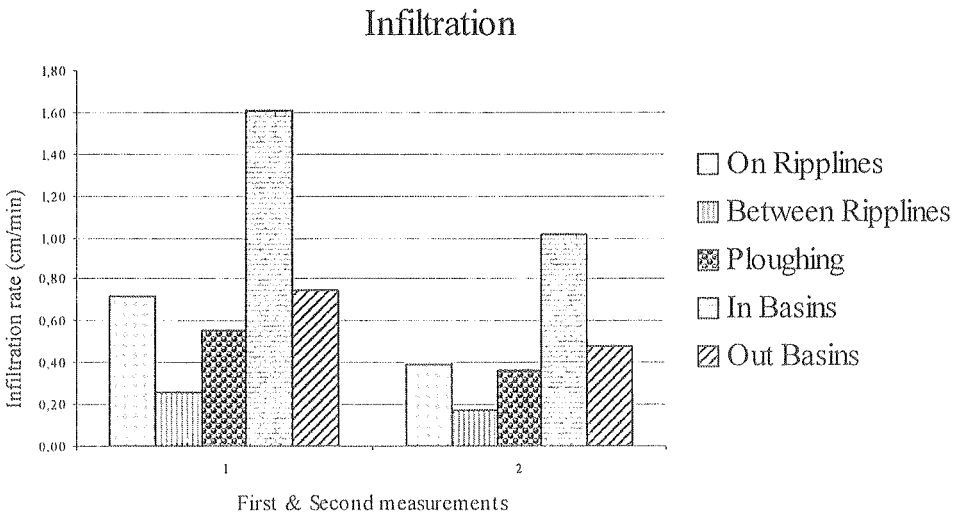

Figure 21. The graph shows the mean infiltration rate, first (1) and second (2) measurements, on each field.

Soil Chemical Properties & Organic Matter

We analysed the soil for pH, organic matter (OM), bulk density, Olsen phosphorous (Olsen-P) content, and mineral N (Min-N) contents. The means of each treatment, ripping, ploughing, planting basins, were compared to see if there were any significant differences, using least significant difference (LSD) at 95% probability. The results are summarised in Table 13.

Table 13. The means, coefficient of variation (CV) and LSD for pH, OM, bulk density, Olsen-P content and min-N content for each of the treatments: ripping, ploughing and planting basins. For the basins the results are divided into samples that were taken inside and outside the basins

Treatment	pH	OM (%)	Bulk density (g/cm^2)	Olsen-P (mg/kg soil)	Min-N (mg/kg soil)
Ripping	5,35	2,20	1,37	6,03	11,65
Ploughing	4,82	1,08	1,37	5,82	6,95
Inside basins	5,26	1,94	1,37	5,62	5,80
Outside basins	5,37	1,79	1,36	5,01	13,00
CV (%)	8,679	52,017	7,060	9,969	45,877
LSD	0,695	1,404	N/A	0,903	6,609

Both OM and min-N gave high CV indicating extreme differences in the sites (Appendix 9). The CV for the pH and P are low, implying that the sites were homogenous.

There are no significant differences of pH and OM in the compared treatments. There is a significantly higher mean min-N content outside the basins than inside.

There was no significant difference in Olsen-P between the treatments except in ripping where Olsen-P was higher than outside basins. One of the four samples in ripping was excluded as the plant available P went above the scale used for analysis. This was most likely because that sample was taken too close to the termite mound in the field (Figure 15).

DISCUSSION

There is not much reference material describing the soil types in the area. The soil maps we have seen are not very specific but they indicated that it is likely that there are Acrisols, Lixisols and/or Luvisols, according to the FAO classification, present in the area. From the limited data that we collected during our soil study we have made the assumption that the soil in the area of study is Acrisol/Lixisol. The data actually fits better to the USDA classification of a Ultisol, which is the closest counterpart to the aforementioned FAO soils. According to Kellman and Tackaberry (1997) the Ultisol is characterised as follows:

- The colour in the horizon 0-18 cm is grey, texture is described as fine sand with some loam and clay with single grain structure. Acidity should be pH 5.0.
- Horizon 19-25, light grey, sandy loam with single grain structure. Acidity should be pH 5.0.
- Horizon 26-60, Grey brown or reddish-yellow to dark brown. Sandy loam with increasing amounts of clay, weak platy structure or single grain structure. Acidity should be pH 4.8.

In the study, pH was slightly higher than the description mentioned above, and that means that the soil is closer to a Lixisols. However, it is important to remember two things about this soil classification. First, there are very many different descriptions of each soil and there is quite a large variation within each soil class. Second, the above-mentioned description is for a natural soil (virgin savannah or bush land in this case) and the soils studied have been under cultivation for some time. This means that the top layers could very well have been lost to erosion or mixed with lower horizons, *i.e.* the soil's use has great impact on the soil properties.

The soil was definitely more compact in the ploughed fields but we did not detect a serious plough pan. There is not enough clay content in the upper layers of the soil to create a serious plough pan but the compact structure may still affect root development negatively. The pressure of the plough and the effects of the rains are likely to cause the more compact soil in the ploughed field. The lower OM content probably also adds to the development of a harder soil.

The infiltration is very good (Thomasson, 1975), especially in the basins and on the ripplines, but this is not a surprise as the soil has very high sand content (Rydberg, 2004). The infiltration is significantly higher in the basins compared to the other fields and there was a detectable, though not significant, difference between the ploughed field and the ripped field. There was also a detectable difference between the infiltration on and beside the ripplines. This confirms that the ripping and the planting basins improve infiltration. The result is further confirmed by the farmers' observations that the soil become more

moist and that the crops remain fresher longer in the basins and in the ripped fields (see also "Result & Findings" in Part 1).

The soil had heterogeneous fertility and we cannot say that there are any significant differences due to the tillage practices. This is probably because they have been practised for only 4-5 seasons and not as CF extension prescribes. It takes longer time and a correct use of the techniques to get any major changes in the soil (Ganry *et al.*, 2001). The significant difference of N content outside and inside the basins is the only significant difference concerning fertility that was found. We have no factual explanation for this.

The pH is low and at pH 4-5 toxic levels of aluminium is likely. This may cause serious damage to the crops (Brady & Weil, 2002) but we could not see any visible signs of Al-toxicity except in the ploughed field, which had the lowest pH. The crop in this field was smaller and less healthy than the in the other fields. It showed signs of nutrient deficiencies, *i.e.* discoloured leaves and stunted growth (Gachene, 2003), even if it received as much fertiliser and nutrient input as the other fields. This is an indication that aluminium is inhibiting the nutrient uptake (Brady & Weil, 2002),

The soil OM is important because it conserves moisture and improves infiltration. It also improves aeration, soil structure and facilitates root penetration. Finally OM is an important pool and buffer for nutrients in the soil-plant system. An OM content of about 3-5% is considered moderate but sufficient for agriculture (Otabbong, 2004) but at the moment this is only 1-2% in the top layer. This is higher than normal for this type of soil (Kellman & Tackaberry, 1997) but it would be desirable to increase the OM for the sake of agriculture. Even though there was not a significant difference in the OM in the fields, there was a visible difference in colour in the top layer of the soil in the basins compared to the other fields. The ploughed field had by far the smallest OM content.

The soil has low fertility but is not unsuitable for agriculture. However, it is very sensitive and will respond negatively to bad management. If the soil is a Lixisols this may already have happened because a Lixisols is supposed to have a higher pH and high nutrient content. The effects of bad management, like decreased yields and increased erosion, will appear quickly (less than a decade) if the soil is not managed properly and this is already seen in the ploughed field. Available N and P are low (Otabbong, 2004) and in the ploughed field there were signs of P deficiency, *i.e.* antocyanin is present in the older leaves causing them to become purple or red (Gachene, 2003).

The tillage changes such factors as infiltration quickly but it takes longer time to change other soil properties such as OM as the turnover is fast (Hernández & Lopez, 2002). Differences in nutrients and pH depends more on the total management of the soil, *i.e.* fertiliser scheme, liming, crop rotation, than the tillage. Since the OM management has been neglected and the soil show insufficient fertility, only changing the tillage system will not improve the soil to a great extent. It is therefore crucial to put extra focus on other factors and practises that can increase fertility such as crop rotation, legumes, compost, and manure. We can conclude that basins improve infiltration significantly and there was also a visible difference in OM content. Much of these improvements are due to the preferred practices mentioned above. We also saw less OM and a lower pH in the ploughed field. This was most likely caused by the use of fertilisers and a plough in combination with low input of OM.

Conservation farming will only be effective in conserving the soil and increasing production if all the practices are applied as a system. The tillage will address issues like

erosion and water harvesting but equal attention must be put into nutrient management and weed reducing practices. That is why CF must be applied as a system of integrated techniques and not a set of individual practices.

Further research

- While we can see that CF increases water harvesting and in some ways reduce the fertiliser use, we question some of the theories that surround CF. For example, that only the crops in the basin benefit from the nutrients applied there. This needs to be further verified by research because nutrient ions will diffuse from high concentration to low, to create equilibrium. The weeds also have lateral roots.
- A simple nutrient balance on farm level is likely show that compost, kraal manure and crop rotation will not sufficiently cover the nutrient losses unless large amounts of organic material is brought from outside the fields. We think that the economics of nutrients in CF has to be looked into. The fertiliser can not be excluded but how much can the dependency on fertiliser be reduced? Are there other external sources of nutrients that can be utilised, especially P, and are these realistic options?
- When trying different farming practices it is more informative if several tests are performed on different soil types. With many soil types, you can single out which parameters respond most to the cultivation system used, for example, CF. A system can be effective in improving soil properties in certain soil types and not in others.

SUGGESTIONS TO THE FARMER

- To get better effect from the fertiliser, manure, and lime, you should consider making permanent basins and ripp lines, *i.e.* they should be made in roughly the same place each year. This means that you only have to apply to nutrients and lime in that site, *i.e.* in the basins or ripp lines, and you can use less. The nutrients that remain after the crop is harvested can then be utilised by next year's crop. Use pegs in each end of the field and a rope to mark the permanent basins and ripp lines.
- Manure can be a valuable source of both macro and micro nutrients if it is handled correctly. It is a great source of organic matter and works well as a soil improvement measure. The nutrient content in applied manure varies depending on the nutrition quality of the feed, how the manure is handled, and under what conditions it is stored. Before applying it on the fields, it is advantageous to store the manure in a heap or compost rather than spread out in a kraal.
- Since the pH is low it would be a good idea to apply lime if it is possible to get at a decent price. It would help to make the nutrients available to the plants and otherwise improve the soil.
- Intercropping maize with some sort of legume (beans, peas, sunnhemp) often have positive effect on the maize. The legumes fixate nitrogen from the air and also make other nutrients more available to the maize. It is best to use some legume that does not grow too high so that it competes with the maize. Many of the species that are common in the region can be used as both food for humans and fodder for animals.
- Organic matter should be increased. If possible use more manure and compost on the field. The possibilities to use residues of intercrops or other vegetation from around the field as a mulch cover could also be explored. This would be a source for nutrients and would also protect the soil. However, we realise that there is a problem to find seed for intercrops and that mulching is not yet functional in this region. One alternative is to place fresh organic matter, such as cut grass, between the rows once the maize has emerged.
- The termite mound contains a great amount of phosphorus. This is the nutrient that is most lacking in the fields so this could be an advantage. It may be too much work to move that soil to use as fertiliser on other fields and it is not appropriate to move the mound. But extra attention should be placed on crops that are grown on the termite mound, as these crops are likely to give a good yield.
- This season the ridger was used in the ripped field. As there was quite a lot of rain in this camp it was a good idea because this practice keeps the crops from getting drowned. However, when using a ridger it is important to consider the slope of the land to avoid erosion. Make sure that the ridges do not run down slope so that there is erosion and the eroded material is washed off the field. During the field test we expressed that the ridger may make the soil to hard. This is a minor problem on this soil but it is important to remember that the ridger or plough will make the soil below more compact and this will result in slower water infiltration.
- If it is possible livestock should not be allowed to graze on the fields during dry season. This is good for two reasons: 1) it enhances the mulching effect of crop residues that protects the soil and improves soil fertility. 2) The livestock loosen the soil by repeated tramping, rendering the soil vulnerable to both rain and wind erosion.

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Appendix 1 – Interview guide

1. Presentation & Introduction

    - Who we are
    - What we are doing

2. Farm intro

    Farm sketch - Area, crops, woodlots, Kraals, Grazing lands, soil, rotation, water/moisture, yield, soil quality
    Seasonal calendar - Labour, inputs, who does what?

    The following questions shall preferably be answered during Farm sketch and Seasonal calendar exercises

    - What are the ownership arrangements of the farm?
    - What fields do you have?
    - What do you grow on your farm? Why?
    - What are the different fields like? Dry, fertile, moist, distance?
    - How do you work the farm? CF/CA? Implements, fertilisation, irrigation?
    - Why do you rip or plough, Use both?
    - Where do you get the inputs? Implements, fertilisation, irrigation?
    - When do you do what?
    - Other labour inputs in the fields? Family members? Hired labour?
    - During the year - when do this labour occur?
    - Do you have animals on your farm? Using Animal Draft Power?
    - Had animals before?

3. Farmer intro (Background, education, family)

- How long have you had this farm? Farms before? Moving around farming?
- Do other people in the household work with farming? In these fields?
- How many is in your household? Who is head
- How long have you been working with farming? On this farm?
- Have you gone to school? What grades?
- Do you have other activities than farming? Fishing, charcoal, timber, trading etc? Rest of household?

4. Farmer knowledge

    - How has agriculture changed since you started? Different crops? Prices? Inputs and outputs?
    - What do you think you are the most significant changes in agriculture in the past? Cause? Effect?
    - What are signs of a good soil?

List of CF concepts and terms related to CF

    - What do you know of these things? Do you use them yourself?
    - Where did you hear about them?
    - What is your opinion of CF?

- From who did you hear it?
- What made you to adapt / not adapt CF?
- Is the support given by extension officers enough?
- Do you have confidence in the extension officer
- Do you participate in any activity connected to farming? Farming groups? Farmers club? CA network?
- Do you plan / discuss farming practices with your wife? Family? Relatives? Others? neighbours
- What do they think?

5. Farmer perceptions

Ranking of what is the most important for yield
SW of CF (good or bad)

- Is there something you would like to know more about?
- Have you noticed any difference since you started with CF/CA?
- More or less yields?
- More or less weeds? Pests? Diseases?
- Are the crops in better condition now than before implementation? How come?
- Changes in crops or soil? Moisture? Health?
- What is the most important thing in a good soil? What is a good soil?

6. Food & Market

Food security
Food processing and storage
Market availability
Vision
Economy, income

- What do you do with your harvest?
- Where do you sell your harvest?
- Do you plan for the year (food security)?
- What do you spend the money on?
- What would you like to buy if you had more money?
- Do you need to buy food? When?

7. Other questions

- What do you think the government should do to improve agriculture?
- Have you earlier been in contact with different aid and development programs concerning agriculture? How many?
- Have you had to change your farming practices due to sickness (if this question is not answered during labour enquiry)
- How does HIV/AIDS affect your farm? What can be done to cope with it?
- What would you like to do on your farm? With your life?

Appendix 2 – knowledge questionnaire

CF concepts and terms - which do you know?

Term	I Know what it is	I do not know	I often use myself	I have used sometimes	I have not used
Planting basins / Potholing					
Ripping					
Magoye ripper					
Planting trenches / planting pits					
Deep soil ripper / sub-soiler					
Lime / Liming					
Crop rotation					
Green manure					
Sunnhemp					
No burning					
Sesbania					
Tephrosia					
Mulching					
Chaka hoe					
Legumes					
Phosphate					
Compost					
Kraal manure					
Contour Bunds					
Zam-wipe					
Pesticide sprayer					
Vetiver grass					
pH					
Acid soil					
Water harvesting					
Musangu					
Faidherbia albida					
Legumes effect on soil fertility					
Acacia albida					
Organic matter in soil					
Plough pan					
Agroforestry					
Nitrogen fixation					
Living soil					
Timeliness					

How important are these things for a good yield? 1 to 5, (5 = most important.)

Manure	
Fertiliser	
Compost	
Early planting	
Weeding	
Crop rotation	
Legumes in crop rotation	
Water	
Adding plant material from outside field	
Leaving residues on field after harvest	
Ripping / re-digging basins before rains.	
Other:	

Appendix 3 – Revised interview guide

1. Presentation

    - Why we are coming back, purpose of visit

2. Farm intro
    - Ownership arrangements of the farm? From when & till when?
    - Total size, under cultivation?
    - Fields: how many, sizes, crops, crop rotation? Yield?
    - What do you grow on your farm? Why?
    - (What are the different fields like? Dry, fertile, moist, distance?)

3. Farmer
    - Background: Age? Family size? Education? Earlier employment?
    - Why started with farming?
    - Other activities than farming? Why?

4. CF-questions

    - From Ranking Exercises: What do you know of these things? Do you use them yourself?
    - What is your definition of CF?
    - How do you see the different practises? (Reduced tillage, Crop rot., Legumes, Erosion control?)
    - How was it introduced? What was said? By Whom, When?
    - Had you seen the technique / practice before? When? Where?
    - What were your first impressions before implementation? After? Impressions today?
    - What would you like to know more about? Why?
    - How have you changed your farm / production since you started? Crops? Implements? Inputs and outputs? When?
    - Involvement of CF-practices? Where? Less productive soil? Plot size?
    - How was these changed made? Why?
    - What are the differences / results since you started with the different practices? (Impact on soil, Yield, Pests, Weeds, Food security, Implements, Economy). Why?
    - Use both ripper and plough? Why?
    - Different practices in different fields? Why?
    - During the year - when do this labour occur? Who does what? Why?
    - Future changes within agriculture? What? How? Why?
    - More practices? In combination with others? Where? Why? Plot size?
    - Possible to use CF for commercial use? Large production?

TIME PERSPECTIVE: <u>Understand the impact of correct use of CF over longer time periods?</u>

Effects of Weeding that extra fourth time?
" Ripping in same lines?
" Digging of basins?

6. Food & Market

Food security
Food processing and storage
Market availability
Vision
Economy, income

- Do you have enough production of food for the year?
- What do you spend the money on?
- What would you like to buy if you had more money?
- Do you need to buy food? When?
- Plan for the year? Plan for nextcoming years?
- Short and Long term goals?
- Do you think there is a good future for farming?
- What else would you like to do?

Appendix 4 – Questionnaire english version

Questionnaire for farmers in the Southern Province of Zambia

Dear Sir/Madame!
Our names are Jens Nolin and Carl von Essen. We are students from the Swedish University of Agricultural Sciences and we are carrying out a study project in co-operation with ASP (Agriculture Support Programme). We are interested in farming practices in Southern Province of Zambia.
Please note that this is not a test and You should not write your name on the questionnaire. There is not necessarily a right or wrong answer to the questions. This questionnaire is designed to give us understanding how You are cultivating your land and how You perceive agriculture. If you normally discuss or plan farming matters with your family, then please do this questionnaire together with your family.
Thank you for taking the time to fill in this questionnaire. It is a great help to us!

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1. What is your main occupation? ☐ Farming ☐ Trading ☐ Other_____
2. How old are you? _____years. I am ☐ Male ☐ Female
3. In what camp do you have your farm? _____
4. What is your level of education? ☐ Primary ☐ Secondary ☐ College ☐ University ☐ None
5. How many people live on your farm? _____ people. How many people work on the fields? _____ people.
6. What is the total size of the land you own?
_____ hectare or _____Lima (use whichever measure you prefer).
In this growing season (-03/04), how much land do you grow crops on?
_____ hectare or _____ Lima.

How has your cultivated land changed the last 5 years? Please fill in cultivated land size under respective growing season.

Growing season:	-98/99	-99/-00	-00/-01	-01/-02	-02/-03
Cultivated land size:	_____	_____	_____	_____	_____

7. Do you also rent or borrow land? How much? Please fill in land size to respective growing season.
This growing season (-03/04): _____hectare or _____Lima.

Growing season:	-98/99	-99/-00	-00/-01	-01/-02	-02/-03
Rented/Borrowed land size:	_____	_____	_____	_____	_____

8. Is this household male headed or female headed? ☐ Male headed ☐ Female headed
9. How long have you had this farm? _____ years.
10. Have you had farms before your current one? How many? _____ farms.

11. Do you have your own Animal Draft Power?
☐ Yes Number of Oxen: _____ Cows:_____
☐ No
12. Do you hire or borrow Animal Draft Power?
☐ Yes I use hired or borrowed Animal Draft Power: Oxen: _____ Cows:_____
☐ No

13. Do you lack food or have to buy food because the yield is not enough? How often?
☐ Every year
☐ Once in 2-5 years
☐ Only if rains are bad
☐ Only if seed or fertiliser is late

14. Indicate in the boxes below in which months you usually lack or have to buy food.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

15. In your household, who does what? Please tick the boxes for the group or groups which do what.

	Ploughing	Ripping	Ridging	Digging basins	Weeding	Harvest
Male	☐	☐	☐	☐	☐	☐

Female	☐	☐	☐	☐	☐	☐
Male youth	☐	☐	☐	☐	☐	☐
Female youth	☐	☐	☐	☐	☐	☐

16. What crops do you grow?
Please tick the boxes depending on how often you grow the crops; if you do not grow them at all just leave the boxes blank.

Crops	Every season or every second season	Sometimes
Maize	☐	☐
Ground nuts	☐	☐
Velvet beans	☐	☐
Sunflower	☐	☐
Cow pea	☐	☐
Sugar beans	☐	☐
Sweet potato	☐	☐
Sorghum	☐	☐
Cassava	☐	☐
Sunnhemp	☐	☐
Cotton	☐	☐
Pumpkin	☐	☐
Other _____	☐	☐

17. Which crops do you grow on the larger part of your land and which do you only grow on small portions?

	Less than 1 Lima	1-2 Lima	2-4 Lima	More than 4 Lima
Maize	☐	☐	☐	☐
Ground nuts	☐	☐	☐	☐
Velvet beans	☐	☐	☐	☐
Sunflower	☐	☐	☐	☐
Cow pea	☐	☐	☐	☐
Sugar beans	☐	☐	☐	☐
Sweet potato	☐	☐	☐	☐
Sorghum	☐	☐	☐	☐
Cassava	☐	☐	☐	☐
Sunnhemp	☐	☐	☐	☐
Cotton	☐	☐	☐	☐
Pumpkin	☐	☐	☐	☐
Other_____	☐	☐	☐	☐

18. How do you prepare the land?
I combine Ploughing and Ripping on _____ hectare or _____ Lima
I use / have used Ploughing and Ripping from _____ to _____ Total number of seasons: _____

I use Ploughing on _____ hectare or _____ Lima (Use whichever measure you prefer).
I use / have used Ploughing from (year) _____ to _____ Total number of seasons: _____

I use Ripping on _____ hectare or _____ Lima
I use / have used Ripping from _____ to _____ Total number of seasons: _____

I use Planting Basins on _____ hectare or _____ Lima (Basins are sometimes called potholes)
I use / have used Basins from _____ to _____ Total number of seasons: _____

Do you use the big planting pits? How many do you have? _____ pits
I use / have used Pits from _____to_____ Total number of seasons: _____

19. Why did you start with these farming practices Tick the boxes for the main reason.

	Basins/Potholes	Pits	Ripping	Compost	Crop rotation	Legumes
Improve soil fertility		☐	☐	☐	☐	☐
Better food security		☐	☐	☐	☐	☐

More yield	Î	Î	Î	Î	Î
More cash crops	Î	Î	Î	Î	Î
Better economy	Î	Î	Î	Î	Î
Less use of fertiliser	Î	Î	Î	Î	Î
Less pests & diseases	Î	Î	Î	Î	Î
Less labour	Î	Î	Î	Î	Î
Less weed	Î	Î	Î	Î	Î
Wanted to try it	Î	Î	Î	Î	Î
Camp officer told me to	Î	Î	Î	Î	Î

20. Read through the different options below and tick the boxes that best describes your practice.

☐ Ripping after rain starts ☐ Ripping right after harvest
☐ Ripping in dry season ☐ Plough after rain starts
☐ Winter plough ☐ Plough and then ripping

I use ripper in some fields and plough in some fields. This depends on:
☐ What crops I am planting ☐ Amount of Weeds in field
☐ Access to Ripper ☐ Other: _____

21. I make ridges using
☐ Plough
☐ Ripper with wings
☐ Ridger
☐ Hoe
☐ I do not make ridges

22. If you use Magoye Ripper, where do you get it?
☐ Use own ripper ☐ Borrow / rent camp ripper ☐ Borrow / rent from neighbour

23. According to your opinion, which of these statements are True or False? Tick the appropriate box. If you do not know then leave the boxes unmarked.

I grow mostly for my own consumption	☐ True ☐ False
I often get a surplus that I sell	☐ True ☐ False
I grow both for my own consumption and cash crops	☐ True ☐ False
I have capacity to produce great surplus	☐ True ☐ False
Basins are good if rain is bad	☐ True ☐ False
There are more weeds in a field that is only ripped than in a ploughed field	☐ True ☐ False
The yield is bigger in 1 Lima of basins than in 1 Lima that is ploughed	☐ True ☐ False
Crop rotation improve soil fertility	☐ True ☐ False
The maize looks fresher longer on fields that are ripped	☐ True ☐ False
Ripping is more work than ploughing	☐ True ☐ False
Ploughing is more work than ripping	☐ True ☐ False
Ripping allows early planting	☐ True ☐ False
Basins are less labour once they are dug	☐ True ☐ False
Ripping gives more moisture in soil	☐ True ☐ False
Basins improve soil fertility	☐ True ☐ False
Lime acts a sort of fertiliser	☐ True ☐ False
Lime should be applied every year	☐ True ☐ False
Ripping does not improve soil fertility	☐ True ☐ False
Ripping after ploughing works just as well as ripping before the rains	☐ True ☐ False
Planting sunnhemp or velvet beans one year gives better yield of maize next year	☐ True ☐ False
I am doing / have done ripping in dry season to see how it works	☐ True ☐ False
I would have tried ripping if I had better access to a ripper	☐ True ☐ False
I am satisfied with my farming system as it is now	☐ True ☐ False
It is worth making basins on fields bigger than 4 Lima	☐ True ☐ False
I don't produce more because my storage is not good enough	☐ True ☐ False

24. What other activities do you do to bring in money?
    - ☐ Gardening
    - ☐ Orchard
    - ☐ Making baskets, mats, similar
    - ☐ Making oil
    - ☐ Pottery
    - ☐ Beehives
    - ☐ Fishpond
    - ☐ Buying / selling cattle
    - ☐ Rearing / selling livestock
    - ☐ Making bricks
    - ☐ Other_____
    - ☐ Other_____

25. What of the things listed below are good for or improve A) Soil fertility B) Food security C) Yield? Please go through each column before starting on the next column.

	A) Soil fertility	B) Food security	C) Yield
Planting basins (potholes)	☐	☐	☐
Ripping in dry season	☐	☐	☐
Planting early	☐	☐	☐
Ripping after rains	☐	☐	☐
Ploughing	☐	☐	☐
Weeding	☐	☐	☐
Fertiliser	☐	☐	☐
Kraal manure	☐	☐	☐
Compost	☐	☐	☐
Crop rotation	☐	☐	☐
Certified seed	☐	☐	☐
Using different Crop varieties	☐	☐	☐
Local seeds	☐	☐	☐
Ridging	☐	☐	☐
Other_____	☐	☐	☐
Other_____	☐	☐	☐

26. According to your opinion, which of these statements are True or False,? Tick the appropriate box. If you do not know then leave the boxes unmarked.

Basins are for people without cattle for draft power	☐ True ☐ False
It does not pay to produce more because market is not good enough	☐ True ☐ False
Manure or compost is just as good as fertiliser	☐ True ☐ False
Ripping is good for extra food security	☐ True ☐ False
Basins are mainly for extra food security	☐ True ☐ False
Fertiliser can be harmful to the soil	☐ True ☐ False
It is only necessary to change the crop in the field when the yield go down	☐ True ☐ False
Legumes (beans, peas, sunnhemp) add more nutrients to the soil	☐ True ☐ False
Farming is a good way to make money	☐ True ☐ False
Basins can be made on fields bigger than 4 Lima	☐ True ☐ False
I would like to try other crops but cannot find seed	☐ True ☐ False
I sell locally because I cannot find transport to market	☐ True ☐ False
Making basins is effective for making money	☐ True ☐ False
Fertiliser is more important for a good yield than manure or compost	☐ True ☐ False
Only ripping is not good for growing crops on a big scale	☐ True ☐ False
Fertiliser cannot be replaced by compost and manure	☐ True ☐ False
Ploughing can makes the soil too hard for the crops	☐ True ☐ False
I have to extend farming land if I want to make more money	☐ True ☐ False
Weeding four times decreases the weeds next coming seasons	☐ True ☐ False
Using full crop rotation uses too much land	☐ True ☐ False

Appendix 5 – Questionnaire Tonga version

Questionnaire for farmers in the Southern Province of Zambia

No muyandwa,
Mazina esu ngu Jens Nolin a Carl von Essen. Tuli basi cikolo kuzwa ku cikolo cipati ca bulimi mu cisi caa Sweden aboobo tu iya zya bulimi kuno kumusanza mu kubelokela antoomwe asa ASP.
Tatu musunki pee aboobo mutabiki izina lyenu apepa eli pele eyi mibuzyo isola kutugwasya kuti tuzyibe nzila zyo mubelesya mubulimi bwenu ambomubwene bulimi bwenu.
Kuti naa bulimi bwenu bula endelezegwa a mukwasi wenu twalomba kuti mibuzyo eeyi muivwiile antoomwe mu mukwasyi.
Twamulumba ku vwiila mibuzyo eeyi nkaambo cila tugwasya kapati.

1. Mubeleka nchito nzi? ☐ Bulimi ☐ Busambazi ☐ Izimwi _____
2. Muli amyaka yongaye _____ Muli... ☐ Basankwa ☐ Bakaintu
3. Ino mpulazi yenu ijanika mu kampu (Camp) / busena nzi? _____
4. Myaka iya kusika ku? ☐ Primary ☐ Secondary ☐ College ☐ University ☐ Taakwe
5. Ino mujisi bantu bongai ampulazi yenu? _____. Bali bongai bagwasya ku bulimi? _____.
6. Ino mpulazi yenu nimpati buti? _____ hectares antela _____Limas.
   Ino mwaka uno (2003/2004) mwakalima nyika mpati buti? _____ hectares antela _____ Limas.
7. Ino mu myakayakainda bulimi bwenu bwa ka cinca buti?

Mwaka:	98/99	99/2000	2000/2001	2001/2002	2002/2003
Kukomena ilimwa kwa myunda:	_____	_____	_____	_____	_____

8. Ino mula lomba nyika ya ku lima? Ino nimpati buti? Amu lembe kukomena kwanyika amwaka-amwaka.
   Mwaka uno (2003/2004): _____ hectares antela _____Limas.

Mwaaka:	98/99	99/2000	2000/2001	2001/2002	2002/2003
Nyika yaka lombwa:	_____	_____	_____	_____	_____

9. Ino ngwani ulanga mukwasi oyu? ☐ Musankwa ☐ Mukaintu
10. Ino mpulazi eyi mwailima myaka yongaye? _____ .
11. Ino mwakalijisi mpulazi imbi? Mpulazi zyongai? _____ .

12. Ino mulijisi n'gombe zyenu na? Zyakulimya
    ☐ Ihyaa Basune bongai _____ Mpwizi zyongai _____
    ☐ Peepe

13. Ino kuli nemu lomba antela ku bbadela basune?
    ☐ Ndibelesya basune baku lomba _____ Basune:_____ Mpwizi:_____
    ☐ Peepe

14. Ino mujisi cakulya cinji na pe? Hena mula ula cakulya?
    ☐ Mwaka-a-mwaka
    ☐ Ciindi comwe mumyaka ikwana yobile ku sika yosanwe
    ☐ Pele nekuli cilanga
    ☐ Pele kuti mbuto a fetalaiza zya celwa kusika ku balimi

15. Amu enge mu tubbokesi tutondezya myeezi jomu tajisi / jomuula cakulya.

Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

16. Amu toondezye milimo Ibeleka Basimbi, aibele ka basankwa ampulazi yenu. Amweenzi mutubbokesi.

	Kulima	Kulima kubelesya Magoye ripper	Kukoloreka tulindi	Kupanga nsaku	Kulimina	Kutebula
Baalumi	☐	☐	☐	☐	☐	☐
Bamakaintu	☐	☐	☐	☐	☐	☐
Bamakubusi basankwa	☐	☐	☐	☐	☐	☐
Bamakubusi basimbi	☐	☐	☐	☐	☐	☐

17. Ino mulima mishobo nzi ya zisyango?

Amyeenge mutubbokesi kutondezya nemu lima zisyango ezi. Naa tamuzilimi zisyango ezi mutaengi mutubbokesi.

Zisyango	Amwa-amwaka / Kufumbwa / Lyoonse	Abona / Muziindi
Mapopwe	☐	☐
Indongwe	☐	☐
Mabingobingo	☐	☐
Malanga-zuba	☐	☐
Nyabo	☐	☐
Chilemba	☐	☐
Cimbwali	☐	☐
Cipusile / Maila	☐	☐
Mwanja	☐	☐
Sanyembe	☐	☐
Baluba	☐	☐
Muungu	☐	☐
Izimwi zisyango _____	☐	☐

Zyishango nzi zitola busena bupati bwa nyika yenu alimwi azi tola busena bu syoonto buyo?

Zisyango	Busena bulela ku 1 Lima	1-2 Lima	2-4 Lima	Busena buindilila 4 Lima
Mapopwe	☐	☐	☐	☐
Indongwe	☐	☐	☐	☐
Mabingobingo	☐	☐	☐	☐
Malanga-zuba	☐	☐	☐	☐
Nyabo	☐	☐	☐	☐
Chilemba	☐	☐	☐	☐
Cimbwali	☐	☐	☐	☐
Cipusile / Maila	☐	☐	☐	☐
Mwanja	☐	☐	☐	☐
Sanyembe	☐	☐	☐	☐
Buluba	☐	☐	☐	☐
Muungu	☐	☐	☐	☐
Izimwi zisyango _____	☐	☐	☐	☐

18. Ino mubamba buti myuunda yenu?

Ndibelesya jamba lya n'gombe a Magoye ripper ciindi comwe kulima _____ hectares antela_____ Limas

Ndakabelesya jamba lya n'gombe antoomwe a Magoye ripper kuzwa mwaaka wa ___ kusikila mwaaka wa ___
Antoomwe myaka ikwana: _____

Ndibelesya jamba lya n'gombe kulima_____ hectares antela_____ Limas
Ndakabelesya jamba lya n'gombe kuzwa mwaaka wa_____ kusikila mwaaka wa _____
Antoomwe myaka ikwana: _____

Ndibelesya Magoye ripper kulima_____ hectares antela_____ Limas
Ndakabelesya Magoye ripper kuzwa mwaaka wa _____ kusikila mwaaka wa ____ Antoomwe myaka ikwana: ____

Ndibelesya bulimi bwa tulindi kulima_____ hectares antela_____ Limas
Ndakalbelesya tulindi kuzwa mwaaka wa _____ kusikila mwaaka wa _____ Antoomwe myaka ikwana: _____

Ino mulabelesya bulimi bwa malindi mapati ? Ino mujisi ongaye?_____
Ndakabelesya malindi mapati kuzwa mwaaka wa _____ kusikila mwaaka wa _____
Antoomwe myaka ikwana: _____

19. Ino nkaambo nzi cemubelesya nzila eyi? (amweenge mukabbokesi)

Tulindi /	Magoye	Bufumba	Kucincanya	Legumes

	Malindi	Ripper			Zisyango
Kubika mbolezi	Î	Î	Î	Î	Î
Kubaacakulya cinji	Î	Î	Î	Î	Î
Kuyungizya butebuzi	Î	Î	Î	Î	Î
Kuyungizya zisambalwa	Î	Î	Î	Î	Î
Kuba amali manji	Î	Î	Î	Î	Î
Kubelesya fetalaiza musyoonto	Î	Î	Î	Î	Î
Kucesya malwazi a tuuka	Î	Î	Î	Î	Î
Kucesya kubeleka	Î	Î	Î	Î	Î
Kucesya nsaku	Î	Î	Î	Î	Î
Ba nasibulimi baka tu ambila	Î	Î	Î	Î	Î
Ku sola nzila impya	Î	Î	Î	Î	Î

20. A mubale kabotu-kabotu nzila zyapezwa ansi awa mwamana musale nzila njomu belesha ilwenu.

□ Mu belesya Magoye ripper mainza □ Mu belesya Magoye ripper mwa mana kutebula
□ Mu belesya Magoye ripper cilimo □ Ndibesya jamba kulima mainza
□ Mu lima mupeyo □ Kulima a jamba lya n'gombe mwamana a ku ripinga (kubelesya Magoye ripper)
Ndiblesya Magoye ripper mu myuunda imwi a ku belesya jamba. Kuli imwi myuunda eci cila citika Kwinda:
□ Muzisyango zyelima □ Nsaku zili mumuunda
□ Bujane bwa ka Magoye ripper □ Izimwi: _____

21. Ndilabamba mifolo kubelesya: □ Jamba / Pulawu
□ Ripper ijisi mababa
□ Nkoholo
□ Jamba lya maanza
□ Tandi bambi mifolo

22. Na mubelesya Magoye ripper ino muijana kuli?
□ Ndibelesya yangu □ Ndilalomba yakapegwa ku kampu (Camp) □ Ndilalomba ku benzuma

23. Muku yeeya kwenu, amusale masimpe antela bubeji mu twaambo tuli ansi awa. A mweenge mu kabbokesi.
Nataakwe nco mu zi amuleke buyo mu ta engi.

Ndilima cakulya cikwene mukwasi wangu buyo	□ Masimpe □ Kubeja
Lyoonse ndilalima zya kulya aku sambala	□ Masimpe □ Kubeja
Ndilima cakulya cinji acaku sambala	□ Masimpe □ Kubeja
Ndila konzya kulima cinji	□ Masimpe □ Kubeja
Tulindi tubotu kuti imvula kaili nsyoonto	□ Masimpe □ Kubeja
Nsaku ninji mumuunda kuti mwabelesya kalipa kwiinda pulawu	□ Masimpe □ Kubeja
Butezi mu 1 lima wakubelesya kalipa bunji kwiinda mu 1 lima wa kubelesya pulawu	□ Masimpe □ Kubeja
Kucincanya zisyango kupa mbolezi ku bulongo	□ Masimpe □ Kubeja
Mapopwe mu muunda wa kalipa alangika butete ciindi cilamfu	□ Masimpe □ Kubeja
Ku belesya kalipa kupa nchito kwiinda kusinda	□ Masimpe □ Kubeja
Kusinda kupa nchito kwiinda kubelesya kalipa	□ Masimpe □ Kubeja
Kalipa kapa kufwaambana kusyanga	□ Masimpe □ Kubeja
Tulindi tatupi nchito kufumbwa kuti mwatusya kale	□ Masimpe □ Kubeja
Kulipa kupa mudumo munji kubulongo	□ Masimpe □ Kubeja
Tulindi tuyungizya mbolezi kubulongo	□ Masimpe □ Kubeja
Laimo(Lime) ube ubeleka kumbolezi	□ Masimpe □ Kubeja
Laimo weelede kubikwa amwaka-amwaka	□ Masimpe □ Kubeja
Kulipa takuyungizyi mbolezi kubulongoRipping	□ Masimpe □ Kubeja
Kulipa kamutana sinda cilibuyo mbuli kulipa kaitana wa mvula.	□ Masimpe □ Kubeja
Kusyanga sanyembe na Mabingo bingo kwa mwaka omwe cipa butebuzi bubotu bwa mapopwe amwaka uchilila	□ Masimpe □ Kubeja
Ndila belesya kalipa cilimo kutegwa ndibone mbocigwasya.	□ Masimpe □ Kubeja
Nindaka belesya Magoye ripper kuti ka ndiijisi	□ Masimpe □ Kubeja

Ndila komana anzilazyangu zya bulimi lino.	☐ Masimpe ☐ Kubeja
Cilagwasya kubelesya tulindi mu myuunda iinda 4 Lima kukomena	☐ Masimpe ☐ Kubeja
Butebuzi bwangu bulacesya nkaambo buyobozi (storage)bwangu mbubi	☐ Masimpe ☐ Kubeja

25.Milimo nzi imbi njomucita imupa mali?

- ☐ Kulima ma gadeni
- ☐ Kulima micelo
- ☐ Kuluka mitanga,minseme azimwi
- ☐ Kubamba saladi
- ☐ Kubumba
- ☐ Kuvuba nzu
- ☐ Kuvuba nswi.
- ☐ Kuula akuulisya ng'ombe.
- ☐ Kuvuba akuulisya ng'ombe.
- ☐ Kubamba matina.
- ☐ izimwi_____
- ☐ Izimwi_____

26.Ino ezi zilembedwe nzibotu buti ku A)kuyungizya mbolezi ku bulongo B) Cakulya cinji.C) Butebuzi?

	A) kupa mbolezi kubulongo	B) cakulya cinji	C) Butebuzi
Tulindi (potholes)	☐	☐	☐
Kulipa cilimo	☐	☐	☐
Kufwaambana kusyanga	☐	☐	☐
Kulipa yamana mvula	☐	☐	☐
Kusinda	☐	☐	☐
Kulimina nsaku	☐	☐	☐
Chamutunzya	☐	☐	☐
Bufumba bwa ng'ombe	☐	☐	☐
Mbolezi	☐	☐	☐
Kuchincanya zisyango	☐	☐	☐
Buto zya cikuwa	☐	☐	☐
Kubelesya zisyango zyandeene	☐	☐	☐
Nseke zya cisi	☐	☐	☐
Kubamba mifolo	☐	☐	☐
Izimwi_____	☐	☐	☐
Izimwi_____	☐	☐	☐

27.Mukuyeeya kweenu ntwaambo nzi twa masimpe atutaasi twa masimpe?Amweenge mutubbokesi.

Tulindi ntwa Bantu batajisi ng'ombe.	☐ Masimpe ☐ Kubeja
Tacigwasyi kulima maningi nkaambo taakwe musika	☐ Masimpe ☐ Kubeja
Bufumba ambolezi yak u bamba zili buyo mbuli chamutunzya	☐ Masimpe ☐ Kubeja
Kulipa nkubotu kumakani a kuba acakulya cinji	☐ Masimpe ☐ Kubeja
Kanji kanji tulindi tupa cakulya cinji	☐ Masimpe ☐ Kubeja
Chamutunzya ujaya nyika	☐ Masimpe ☐ Kubeja
Cigwasya buyo kucinca cishango kuti naa butebuzi bwa ya ansi	☐ Masimpe ☐ Kubeja
Zisyango mbuli sanyembe,bunyangu zilapa busani kubulongo	☐ Masimpe ☐ Kubeja
Bulimi nenzila mbotu yakupanga mali	☐ Masimpe ☐ Kubeja
Tulindi inga twa bambwa mumyuunda iinda 4 Lima kukomena	☐ Masimpe ☐ Kubeja
Ndilayanda kusola zisyango zimbi pele buyo nseke zilandisyupa kujana	☐ Masimpe ☐ Kubeja
Ndisambalila mweena muno nkaambo ziyendela kuinka ku maketi zilashupa	☐ masimpe ☐ Kubeja
Kubamba tulindi nenzila mbotu kupanga mali.	☐ Masimpe ☐ Kubeja
Chamutunzya ulapa butebuzi bubotu kwiinda mbolezi	☐ Masimpe ☐ Kubeja
Kulipa kwalo takuli kubotu kulima zisyango mubunji	☐ Masimpe ☐ Kubeja
Chamutunzya taakonzi kwiindwa ku mbolezi a bufumba	☐ Masimpe ☐ Kubeja
Kusinda ku yumya nyika kuzisyango	☐ Masimpe ☐ Kubeja
Ndeelede ku yungizya nyika yakulima kuti keyanda kupanga mali manji	☐ Masimpe ☐ Kubeja
Kulimina zyiindi zyone cipa kuceya nsaku mwaka utobela	☐ Masimpe ☐ Kubeja
Kucincanya zisyango cibweza busena bupati mumuunda	☐ Masimpe ☐ Kubeja

Appendix 6 – questionnaire for CEO

Dear Sir / Madame! This questionnaire is not a test of your knowledge or ability to perform your tasks. This is to help us understand how you perceive CF and facilitation. Some of the questions are the same as for the farmers, the reason for this is to see if you share their statements on some issues.
Please note that you should not write your name on this questionnaire.
Thank you for taking the time to do this. It is a great help to us. Carl & Jens

1. Have you been farming yourself? ☐ Yes ☐ No
2. How old are you? _____years
3. What is your level of education? ☐ Primary ☐ Secondary ☐ Tertiary ☐ College/University ☐ None
4. What is your experience in farming? Please tick the boxes that match with your background.
   ☐ Grew up on a farm ☐ Agricultural college/university ☐ Still farming

5. How long have you been a camp officer? _____years
6. How many Magoye rippers are available for the households in your camp? ____ rippers/_____ households
7. How many Magoye rippers do you think would be enough? _____ rippers

8. How many individual farm visits do you perform during one year? _____ number of farmers
9. To perform the ASP tasks adequately, I should have _____number of farmers.
10. How do farmers practice crop rotation? Rank the practices according to what is most common among your farmers. 1= very common, nearly all farmers; 2= common, most farmers use; 3= about half of the farmers use; 4= not very common, some farmers use; 5 = nearly no farmers use.
    __ The entire field gets a new crop next season
    __ Parts of the field gets a new crop next season
    __ Some fields have crop rotation every year
    __ Crops are only rotated once in while
    __ Crops are rotated when yields go down

11. How are these CF practices promoted to farmers? What is the reason given to farmers why they should adopt each practice? Tick the appropriate box and also indicate the most promoted reason by circling it.

	Basins	Ripping	Compost	Crop rotation	Legumes
Improve soil fertility	☐	☐	☐	☐	☐
Better food security	☐	☐	☐	☐	☐
More yield	☐	☐	☐	☐	☐
More cash crops	☐	☐	☐	☐	☐
Better economy	☐	☐	☐	☐	☐
Less use of fertiliser	☐	☐	☐	☐	☐
Less pests & diseases	☐	☐	☐	☐	☐
Less labour	☐	☐	☐	☐	☐
Less weed	☐	☐	☐	☐	☐

12. Read through the different options below and rank the practices according to what is most common among your farmers. 1= very common, nearly all farmers; 2= common, most farmers use; 3= about half of the farmers use; 4= not very common, some farmers use; 5 = nearly no farmers use.

A) Plough and then ripping __ B) Winter plough __ C) Plough after rain __
D) Ripping right after harvest __ E) Ripping in dry season __ F) Ripping after rains __
G) Ridging __ H) Ripping and ploughing depending on crop __

Farmers make ridges using	Plough	☐
	Ripper with wings	☐
	Ridger	☐
	Hoe	☐
	Do not make ridges	☐

13. Which of these statements are true or false? Tick the appropriate box. If you do not know then leave the boxes unmarked.

Farmers grow mostly for their own consumption	☐ True ☐ False
Farmers often get a surplus that they sell	☐ True ☐ False
Farmers grow both for their own consumption and cash crops	☐ True ☐ False
Farmers understand how and why their practices affect soil & crop	☐ True ☐ False
Instructions and written material in Tonga would improve farmers learning	☐ True ☐ False
There is not any written material to give farmers (in tonga or english or other)	☐ True ☐ False
There should be more field trips	☐ True ☐ False
There are not enough support from head office to do follow-ups properly	☐ True ☐ False
It is easier to teach farmers in big groups than in small	☐ True ☐ False
It is better to teach farmers in large groups than in small	☐ True ☐ False
There are more weeds in a ripped field than in a ploughed field	☐ True ☐ False
The yield is bigger in 1 Lima of basins than in 1 Lima that is ploughed	☐ True ☐ False
Crop rotation improve soil fertility	☐ True ☐ False
Basins are good if rain is bad	☐ True ☐ False
Ripping is more work than ploughing	☐ True ☐ False
Ploughing is more work than ripping	☐ True ☐ False
Ripping allows early planting	☐ True ☐ False
There is not enough time to visit all the ASP farmers	☐ True ☐ False
Ripping gives more moisture in soil	☐ True ☐ False
Basins improve soil fertility	☐ True ☐ False
Ripping does not improve soil fertility	☐ True ☐ False
The other NGOs activities do not affect my meetings negatively	☐ True ☐ False
Basins are mainly for extra food security	☐ True ☐ False
Ripping after ploughing works just as well as ripping before the rains	☐ True ☐ False
Handouts do not motivate farmers	☐ True ☐ False
Basins are for people without cattle for draft power	☐ True ☐ False
It does not pay to produce more because market is not good enough	☐ True ☐ False
Manure or compost is just as good as fertiliser	☐ True ☐ False
Ripping is good for extra food security	☐ True ☐ False
I have enough time for all farmers in my camp	☐ True ☐ False
Fertiliser can be harmful to the soil	☐ True ☐ False
It is only necessary to change the crop in the field when the yield go down	☐ True ☐ False
Legumes add more nutrients to the soil	☐ True ☐ False
Farming is a good way to make money	☐ True ☐ False
Basins can be made on big fields	☐ True ☐ False
Farmers would like to try other crops but cannot find seed	☐ True ☐ False
Farmers sell locally because they cannot find transport to market	☐ True ☐ False
Making basins is effective for making money	☐ True ☐ False
Fertiliser is more important for a good yield than manure or compost	☐ True ☐ False
Only ripping is not good for growing crops on a big scale	☐ True ☐ False
Fertiliser cannot be replaced by compost and manure	☐ True ☐ False
Basins are best for the small scale farmers	☐ True ☐ False
Farmers have to extend farming land to making more money	☐ True ☐ False
Weeding four times decreases the weeds next coming seasons	☐ True ☐ False
Farmers feel that full crop rotation with legumes is not worth waiting for	☐ True ☐ False
It is a problem that farmers do not do Action planning	☐ True ☐ False
Farmers think I should visit them more often	☐ True ☐ False

14. What of the things listed below are good for or improve A) Soil fertility B) Food security C) Yield? Please go through each column before starting on the next column. When you are done also circle the box of the 3 things that you think is the most important in each column.

	A) Soil fertility	B) Food security	C) Yield
Planting basins (potholes)	☐	☐	☐
Ripping in dry season	☐	☐	☐
Planting early	☐	☐	☐
Ripping after rains	☐	☐	☐
Ploughing	☐	☐	☐
Weeding	☐	☐	☐
Fertiliser	☐	☐	☐
Kraal manure	☐	☐	☐
Compost	☐	☐	☐
Crop rotation	☐	☐	☐
Certified seed	☐	☐	☐
Using different Crop varieties	☐	☐	☐
Local seeds	☐	☐	☐
Ridging	☐	☐	☐

15. In your opinion, what is the best way of teaching CF to farmers? Rank the following, nr 1 is best

Show by doing	___
Focus on farmer's problems	___
Individual instructions	___
Group meetings	___
Written material to hand out	___
Field trips & farm visits	___

16. Do you feel that you lack anything from MAC O that you need to perform your tasks?
If so, what?_____

Do you feel that you lack anything from ASP that you need to perform your tasks?
If so, what?_____

The end!

Thanks!

Appendix 7 – Case studies

Case study 1 – Male, 39 years old

Family & Available labour: Wife and six children, from the ages of 3 to 19 years old.
Education: Secondary school.
Started farming: He comes from a farming family and got the current farm from his father when he was 20 years old, in 1985, in that time the farm was 10 ha.
ADP & Animals: Has no own cattle, but borrows his father's two cows when possible. He had own cattle, two oxen and three cows, but they died in corridor disease1996. Chickens and turkeys are for extra food.
Food security: He depends for harvest for food during the year and is therefore sensitive to agro-climatic fluctuations.
Other activities: No.

Land, Fields, & Crops: Today he has in total 15 ha but cultivates (this year) 4 ha (~16 lima) on 4 fields. He said he would cultivate more land if he had access to ADP, own or rented. Before 1999 he ploughed all his fields. Maize, beans, sunflower, cassava, groundnuts, and bambaranuts are these years' crops. He has also tried being a seed grower, but the harvest was bad and he thinks he must change the tillage practice into ploughing to reduce the weeds more sufficiently.

Crop rotation: For maize usually two years then other crops, but those alternative crops do not cover the whole field. However, he points out he cannot waste his land on crops that he can not eat or sell ("I cannot eat sunnhemp") because there is a limited amount of land that he can manage properly.

Inputs: For his ripped fields (2 lima) and ploughed fields he uses two bags top dressing and two bags basal dressing on each practise, where each bag is 50 kg. He adds for basins (2 lima) one bag top dressing and one bag basal dressing, and one coke-can of mixed homemade compost and manure from his father per basin.

Practices
The first time he came in contact with basins was on a study tour to the adjacent Camp, Mujika, via SCAFE in 1999. Later the same year, he tested basins on 1 lima and in 2000 he increased the area to 2½ lima. He wanted to reduce needed labour input so in season 2003/04 he decreased the field to 2 lima (4000 basins per lima). He stresses the significance of the drought in 1999 and says that was the direct reason why he started with basins; he saw how good the basins were doing when the rains were bad and that he could manage to feed his family by means of the basins. He point out he would not have started with basins if there not been a drought. One reason except for the drought resistant quality, he also uses basins to increase soil fertility on the whole field and that is the reason why he changes basin sites within the field every 3rd year. By this he can then start ripping and ploughing on parts of these fields. He receives today 40 bags of maize per season and that is almost the double than before 1999.

He first saw the ripping technique on a study tour in 2000 and in late October the same year he ripped 2 lima. He started ripping because he wanted to try it after he saw that it worked well when there was little rain Season 2003/04 he uses 2 lima ripping in combination with a ridger plough, this to avoid and reduce weeds and to make the maize stalk more stable. He does not use the same ripp-lines since he wants to increase average

soil fertility. He wants to increase ripping in his system but lacks animals and access to ripper. If more ripping, he would then use it in combination with a cultivator and ridger to reduce weeds over the years. He has noticed that the weeds in the field are reduced since he started ripping and thinks this is due to the ripper and the ridging disturb the weeds and because the soil has become more fertile.

The plough is used on 10 lima because he says he got not the time needed to do the weeding if there were basins or ripping. By using a plough he manage to keep the area cultivated under control.

Cassava was first sown on a field day in 1996 when the current Sida project promoted it, and has today two lima of the crop. He planted 200 cuttings in 2000, and today 2003/04 he has 3000 cuttings. The harvest in either sold or used for own consumption (maize porridge). He uses cassava because to secure food for the year.

Perception of CF

Less time needed for preparation in the rain season and labour is more spread during the year. Less fertiliser is needed and moisture is better kept and by that more yield. On the other hand there is a problem with increase need of weeding, about three times more weeding in basin system.

Farmers that do not use CF practises think it is a waste of time, and those older farmers are not easily convinced because they are used to a certain way of farming. The solution is study tours that are what convinced him.

Future & Governmental role

He thinks that lead farmer and Camp representatives should take responsibility and adopt CF practises and act as a good example for others. He wants to be able to send his children to school and buy oxen and cows so he can start ripping and ploughing.

Case study 2 – Male, 53 years old

Family & Available labour: On farm lives 8 male and 12 female of which 6 are grown ups (years 15+)
Education: Grade 7.
Started farming: He started farming in 1982 because it generated more money than his previous job; trading animals.
ADP & Animals: Today he has 2 oxen and 6 cows but had many more before, during late 1990s he lost 15 animals to corridor disease. He also had 12 goats, s a lot of chickens, guinea fowls, and turkeys.
Food security: Get enough food from the fields to feed his family.
Other activities: Except for making bricks he also has a fishpond, but so far only for own consumption.

Land, Fields, & Crops: He has in total 10 ha but cultivates 5,5 ha and 0,5 lima. There are bigger 4 fields with maize on 4 ha, and the remained cultivated land is divided into smaller portions with cowpeas, sunflower, sugarbeans, and sunnhemp.

Crop rotation: He is mainly growing maize in larger parts of his land but likes to grow cash crops such as sugarbeans and sunflower. He also uses sunnhemp in crop rotation every 3 years to improve soil fertility. This technique he was told from the CEO 3 years ago. Except for the crops mention, also groundnuts, tomatoes, and cabbage are also used in the crop rotation. He tries to rotate whole fields and crops every year, but maize is sometimes grown 2 –3 years on same field. Observe that the crop rotation does not replace the area under cultivation of maize.

Inputs: 20 oxcarts (approximately $1m^3$ each) kraal manure per ha, 4 bags top and 4 bags basal dressing per ha (bag of 50 kg).

Labour: The labour input consists only of the family most labour is needed in January for the weeding. All fields are weeded 2 times.

Practices
In 2001 he started with 2 lima of basins because there was a drought and he had heard from agricultural specialts the water holding qualities of the basins, and the next coming year the field was enlarged to 4 lima. This year, 2003/04, he only use 0,5 lima because he could not be bothered to do more. On the question why he reduced basins although the yield is better he higher "Basins are better when there is a drought and will increase yield by 3 bags a' 90 kg / lima on an ordinary year and made it possible to send my children to school. However, the basins are too much labour and we are used to and wants animals."

The Camp ripper are being used after the plough for making planting lines and applying manure / fertiliser in the past 3 years. He started the technique when he noticed that yields were going down and he had trouble feeding his large family. He heard that ripped fields had kept water better and that kraal manure was more useful. Once he used the ripper in the dry season on a small field to see how it worked and noticed that the yield was very good but there were more weeds. Due to more weeds, he does not want to try it on more land yet and says, "To change attitudes take a long time, ripping in dry season is a new technique and takes time to learn".

The plough is frequently used on whole fields before the ripper. He uses the plough to reduce weeds and clear the ground. "The ripper makes soil hold water better and allows the maize roots to grow deeper. There is also no waste of kraal manure".

Compost was first used in combination with manure 3 years ago to be spread using a ripper. The season after that the extra yield enabled him to buy fertiliser and found the technique simple and cheap. He will continue using compost and manure but in combination with fertiliser since that mixture would result in best yield. Where only the plough had been used he only applied fertiliser because he has not enough manure and compost for these fields.

Perception of CF

CF practises are good when drought but demands to much labour. According to this farmer there are several reasons why farmers tend not to use CF techniques: They do not understand the CF cropping system fully and that is one reason why they do not dare to try and they think it is too much labour. Farmers with many animals are usually not adopting because they ate used to ploughing and in general people do not care, "they are arrogant".

Future & Governmental role

Wants to rotate crops and increase ripping in combination with ploughing. He also wants to dig another fishpond and start selling fish as an extra source of income. The government should subsidise fertilisers and also improve the market system. He had not considered trying to form a coop but would like to try.

Case study 3 – Female, 67 years old

Family & Available labour: Except for herself, her children and grand children are living on the farm, 3 grownups.
Education: NA
Started farming: She has had this farm during 15-17 yrs and before she had another farm with oxen and a system under ploughing.
ADP & Animals: Has no cattle for draft power, but have some chickens and ducks.
Food security: If there are bad rains she has to buy food from October to April.
Other activities: To receive extra income she is making doormats and crocheting.

Land, Fields, & Crops: Total land size is 4 limas and she cultivates 3 limas. There are 4 fields; 1 lima maize, 0,5 lima sunflower, 0,5 lima beans, and 1 lima sweet potatoes.

Crop rotation: There are normally 1-4 years between different crops but this depends on which crop being grown, e.g. maize – cowpea – maize. Except for the above-mentioned crops she also grow sugar beans and cowpeas.

Inputs: Homemade compost.

Labour: Only she prepares basins and compost. It takes 1,5 month for 2,5 limas to dig the basins. She weeds 3-4 times.

Practices
She started with basins in 1990 after information from Zambian National Farming Unit. Her main reason why she started was because she did not have any animals and it was hard to feed her family. She first dug the basins round but this procedure demanded a longer preparation time so she changed to square shaped basins later on. She starts digging in May just after harvest when the soil is moister and softer. Have used pits for one year and thinks they are good since she does not have to re-dig them every year.

Compost is made to put in pits and basins. The compost is made from fresh grass, leaves of maize, and other "dead material" since it is "too expensive with fertilisers".

Perception of CF
With the CF practices it is now possible to feed herself and her family. With basins and pits it is possible to start planting early, which gives earlier and more production. She stresses the importance to do correct weeding, that is 4 times, to start early, and by removing the roots of weeds, by this way the recognised that the weeds became less abundant. She also points out that making basins and pits are very labour demanding and hard work. She means that the weeding sets the limit on the farm size.

Future & Governmental role
Due to the hard labour and limited size to enable she wants to invest in animals. She can then start winter ploughing the first year to open and loosen up field and then use a ripper so she can plant early. She would also like to make more money to invest in tin roof. She wants that government starts to subsidise fertilisers and facilitate the ability to take loans so it will be easier to do improvements and investments in the farm.

Case study 4 – Female, 28 years old

Family & Available labour: She and her husband lives on the farm together with 5 children plus one adult on the farm.
Education: Secondary school
Started farming: This is her first own farm and moved here 3 years ago in 2001. Before she used to work on her mothers farm where they only used a ploughing system.
ADP & Animals: Chickens and 13 goats for sale.
Food security: She depends on good conditions for harvest and all harvest is for own consumption.
Other activities: She sells fishes and bananas for extra income.

Land, Fields, & Crops: She has 6 Fields; 3 fields of tot 2 lima with maize, 1 lima cassava, 1 lima tomatoes and beans.

Crop rotation: She have a system where she first grow maize for 2 years, then cassava, sweet potato, groundnuts, and beans.

Inputs: Compost for basal, 1 bag/lima fertiliser as top dressing, limed last year: 2 * 25 kg/lima

Labour: Only family as labour input. Most weeding in December to January and she weeds 2 times per field.

Practises
She uses mainly a system of basins of which she came in contact 3 years when a CEO told her to start with it since she has neither own animals nor money to rent and she must feed her family. Still, she borrows cattle from relatives to plough one field due to lack of time and labour needed to weed the basins.

Perception of CF
She thinks women use CF more frequently than men because they seldom have cattle. With basins you can get a good yield from a small area without depending on animals. On the other hand basins have more weeds and the basins take a lot of labour. She also points out "You can concentrate fertiliser in the basins and to get a harvest you must have fertiliser and good seed".

Future & Governmental role
She wants to go on more study tours to see other farmers and make comparisons of their cropping system. She said her own family had started with basins after they seen her farm and the good harvest. To simplify her basin digging she wants to invest in a Chaka hoe but buy animals for draft power. The basins should in the future act as food security measure. She means it is easier to convince people with animals to start with different CF practices because the can use a ripper. It is harder to convince farmers about basins because these are considered more work. The government must provide inputs locally, facilitate that the inputs are available at the right time and they should continue with fertiliser and seed subsidies.

Case study 5 – Male, 22 years old

Family & Available labour: The farm consists of himself, his mother, one brother, 2 sisters, and some cousins.
Education: Study at agricultural high school, but had to go back to back to farm when father died in 2000.
Started farming: He became a serious farmer after he took after his fathers' farm.
ADP & Animals: He has 1 ox and 6 cows as he uses for ADP, and he also has 3 calves. Besides the cattle he has chickens and turkeys. Before 1987 the farm had more than 60 animals but they died in various diseases.
Food security: He means he is partly depended on harvest but managed well with oranges and the other crops, mainly sunnhemp. The business as a tailor is not very profitable and when harvest is bad he has occasionally has to buy food. The different farming techniques in different areas are used to act as a security.
Other activities: To make extra money he is a tailor, rearing pigs and chickens for sale as well as an orange orchard.

Land, Fields, & Crops: The farm is in total 12 and of them 5 ha is under cultivation. The main crops are sunflower on 2,5 ha, maize on 1,5 ha and on rest of the land are beans, groundnuts, sweet potatoes, and cassava grown.

Crop rotation: He says he rotate crops every year, however maize and sunflower may be rotated several times but beans and groundnuts usually occupy only small fields or parts of the fields.

Inputs: The kraal manure from his cattle is put on the fields. Since he stopped burning in 2000 he now leaves some of crop residues on the fields and collects rest for animal fodder.

Labour: Only family as labour input. Ploughing demands 2 days per ha, making furrows 1 day per ha, planting takes 1day/ha, and using the weeder 2 days ha. He weeds 2 times per field.

Practises
Planting basins are used on a very small fraction on his fields as a food security measure but he thinks they are performing badly. Every year he changes the spot where the basins are dug since he thinks that will give most effect in the long run. He says he does not attain ASP meetings but knows most of the information given as well as hears about the practises from neighbours and friends.

He mixes both ploughing and ripping on different fields early in the wet season. He means, "It is good to use ripping for half of the land and then plough the rest because ripping performs better if rain is poor". Later on he plants and combines furrows, weeding, and ridging. He started with ripping because he heard its good qualities when rain is poor and also that it inhibit erosion, which his land has.

Perception of CF
Overall he thinks the CF cropping system is good, it allows planning which is essential and it is shortening workload when it is time to plant. CF in a cropping system generates good yield, and the crop rotation and the N-fixating crops are important factors. He says that specific manure output when ripping give better yield than compost. Compost as a single input is not enough but can be used only as basal dressing, but at the same time there is a need of fertilisers.

Vision & Governmental role

He wants to go back to college and finish his studies and for that he needs money. He wants to extend the paddock for the cattle, plant more fruit trees; orange, guava, and mango, and also build a fishpond.

He thinks that the problems in the agricultural sector started when the animals died and the subsidies on fertiliser stopped. The government should therefore subsidise or lower the price for tools and inputs since farmers hardly have any surplus and extra income. Further, he says the buyers that passes by offer very low prices for the produce and going to closest city it to expensive and non-profitable.

Case study 6 – Male, 81 years old

Family & Available labour: He has 5 wives and some of his children and grand children on the farm.
Education: NA. He used to be a businessman but was married in 1942 and moved then to the farm
Started farming: In 1942. He moved to current farm in 1958.
ADP & Animals: 12 oxen, 2 bulls, 50-60 cows, and 70 goats. In addition to these animals he also had numerous chickens, ducks, and turkeys.
Food security: Usually good food supplies and does not suffer from shortages. He has invested in cement storage for 72*90 kg which keep bugs away.
Other activities: He sells the milk from his cows, vegetables, and cattle locally.

Land, Fields, & Crops: In total he has 31 acres (~15 ha) on 3 big fields and several smaller plots. Maize is grown on the 3 larger fields, and cotton, groundnuts, sweet potato, sunflower, beans, sunnhemp, and also sometimes sorghum is cultivated on the smaller fields.

Crop rotation: Rotation of the crops is done every year; he likes to have sunnhemp ploughed under every now and then and this comes from the time when he was a master farmer (improved farming) in colonial times.

Inputs: 30 oxcarts per ha. Fertiliser is used if kraal manure is not available. He had never used lime.

Labour: The whole family does the weeding: first the man goes with a harrow, and then the women go for hand to weed. They weed only once per season.

Practises
He first came in contact with basins in 2000 via neighbours. During the drought he tried it and had good results. Although better yield he says they are not suitable on big fields since they take too much labour. His wives agreed to same part but mention as well that they talked too much instead of digging and weeding.

Ripping was also first seen in year 2000, both via neighbours but also on a field day. The first time he tried ripping was in last year on 3 lima in combination with winter ploughing, and he recognised that the fields got better water holding capacity and that ripping was faster than ploughing. His farming system is in general winter ploughing if possible and applying kraal manure, otherwise he plough when the rain starts and uses a oxdrawn planter and harrow for weeding. He wanted to use it this year but did not have access to it. In the future he would like to continue using a ripper in combination with a plough because it gave good impression on him. He said he do not want to use it as CF prescribes since the weeds will become a too big problem. Another point was that when using ripping they had to start weeding directly after planting to get the weeds under control. When he tried ripping last year this was no problem because he ploughed as well and used sunnhemp and cover crops such as pumpkins.

Perception of CF
Basins are good on a smaller portion of land for food security and are not suitable on bigger areas since they demand too much labour. Ripping is not worth doing without ploughing due to the rapid growth of weeds. CF is better when there is a drought but if not then the yield is equally good.

Future and Governmental role

He wants to build a fence in homestead to keep cattle out and create a fruit orchard. His wives want to buy a grinding mill, a vehicle to go to town, and buy more nutritious food. The government should help to create working coop to sell crops; marketing centres for crops. Seed and inputs have too bad quality and arrive too late and the government must take their responsibility in this matter. Now he gets certified seed on loans from CLUSA.

Appendix 8 – statements

True	False	
78%	23%	I grow mostly for my own consumption
28%	72%	I often get a surplus that I sell
25%	75%	I grow both for my own consumption and cash crops
39%	61%	I have capacity to produce great surplus
94%	6%	Basins are good if rain is bad
81%	19%	There are more weeds in a field that is only ripped than in a ploughed field
55%	45%	The yield is bigger in 1 Lima of basins than in 1 Lima that is ploughed
96%	4%	Crop rotation improve soil fertility
94%	6%	The maize looks fresher longer on fields that are ripped
50%	50%	Ripping is more work than ploughing
41%	59%	Ploughing is more work than ripping
97%	3%	Ripping allows early planting
76%	24%	Basins are less labour once they are dug
95%	5%	Ripping gives more moisture in soil
84%	16%	Basins improve soil fertility
85%	15%	Lime acts a sort of fertiliser
31%	69%	Lime should be applied every year
48%	52%	Ripping does not improve soil fertility
84%	16%	Ripping after ploughing works just as well as ripping before the rains
98%	2%	Planting sunnhemp or velvet beans one year gives better yield of maize next year
84%	16%	I am doing / have done ripping in dry season to see how it works
74%	26%	I would have tried ripping if I had better access to a ripper
81%	19%	I am satisfied with my farming system as it is now
61%	39%	It is worth making basins on fields bigger than 4 Lima
64%	36%	I don't produce more because my storage is not good enough
51%	49%	Basins are for people without cattle for draft power
20%	80%	It does not pay to produce more because market is not good enough
93%	7%	Manure or compost is just as good as fertiliser
83%	17%	Ripping is good for extra food security
82%	18%	Basins are mainly for extra food security
73%	27%	Fertiliser can be harmful to the soil
91%	9%	It is only necessary to change the crop in the field when the yield go down
98%	2%	Legumes (beans, peas, sunnhemp) add more nutrients to the soil
95%	5%	Farming is a good way to make money
68%	32%	Basins can be made on fields bigger than 4 Lima
91%	9%	I would like to try other crops but cannot find seed
83%	18%	I sell locally because I cannot find transport to market
55%	45%	Making basins is effective for making money
60%	40%	Fertiliser is more important for a good yield than manure or compost
50%	50%	Only ripping is not good for growing crops on a big scale
59%	41%	Fertiliser cannot be replaced by compost and manure
20%	80%	Ploughing can makes the soil too hard for the crops
74%	26%	I have to extend farming land if I want to make more money
60%	40%	Weeding four times decreases the weeds next coming seasons
35%	65%	Using full crop rotation uses too much land

Appendix 9 – Statistical analysis of soil properties

The SAS System 09:22 Friday, October 1, 2004 11

treatment	pH	OM	Phos	MinN
Ripping A	6.46	3.46	.	13.1
R-B	5.35	3.58	6.907	3.5
R-C	4.76	1.07	5.723	20.4
R-D	4.82	0.72	5.450	9.6
Plough A	5.09	0.48	5.167	8.4
P-B	4.85	1.31	6.166	8.4
P-C	4.64	1.79	6.581	6.0
P-D	4.70	0.72	5.366	5.0
Inside basin-AB	5.47	2.40	5.256	8.4
IB-CD	4.86	1.31	5.336	6.7
IB-EF	5.21	1.76	6.009	3.6
IB-GH	5.49	2.27	5.885	4.5
Outside basin-AB	5.26	1.43	4.822	10.6
OB-CD	5.15	1.19	4.705	8.9
OB-EF	5.31	1.91	4.935	17.8
OB-GH	5.74	2.63	5.575	14.7

The SAS System 09:15 Friday, October 1, 2004 11

The GLM Procedure

Class Level Information

Class	Levels	Values
treat	4	1 2 3 4

Number of observations 16

Dependent Variables With Equivalent Missing Value Patterns

Pattern	Obs	Dependent Variables
1	16	pH OM
2	15	Phos

NOTE: Variables in each group are consistent with respect to the presence or absence of missing values.

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The GLM Procedure

Dependent Variable: pH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.78665000	0.26221667	1.29	0.3230
Error	12	2.44205000	0.20350417		
Corrected Total	15	3.22870000			

R-Square	Coeff Var	Root MSE	pH Mean
0.243643	8.679449	0.451114	5.197500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treat	3	0.78665000	0.26221667	1.29	0.3230

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	3	0.78665000	0.26221667	1.29	0.3230

The GLM Procedure

Dependent Variable: OM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2.80296875	0.93432292	1.13	0.3777
Error	12	9.96487500	0.83040625		
Corrected Total	15	12.76784375			

R-Square	*Coeff Var*	Root MSE	OM Mean
0.219533	*52.01663*	0.911266	1.751875

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treat	3	2.80296875	0.93432292	1.13	0.3777

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	3	2.80296875	0.93432292	1.13	0.3777

The GLM Procedure

t Tests (LSD) for pH

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.203504
Critical Value of t	2.17881
Least Significant Difference	*0.695*

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	5.3650	4	4
A			
A	5.3475	4	1
A			
A	5.2875	4	3
A			
A	4.8200	4	2

The GLM Procedure

t Tests (LSD) for OM

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	0.630406
Critical Value of t	2.17881
Least Significant Difference	*1.4039*

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	2.2075	4	1
A			
A	1.9350	4	3
A			
A	1.7900	4	4
A			
A	1.0750	4	2

The GLM Procedure

Class Level Information

Class	Levels	Values
treat	4	1 2 3 4

Number of observations 16

The GLM Procedure

Dependent Variable: MinN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	147.9000000	49.3000000	2.68	0.0941
Error	12	220.8000000	18.4000000		
Corrected Total	15	368.7000000			

R-Square	*Coeff Var*	Root MSE	MinN Mean
0.401139	*45.87724*	4.289522	9.350000

Comment: The CV for MinN is very large indicating high heterogeneity in the soils

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treat	3	147.9000000	49.3000000	2.68	0.0941

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	3	147.9000000	49.3000000	2.68	0.0941

The GLM Procedure

t Tests (LSD) for MinN

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	18.4
Critical Value of t	2.17881
Least Significant Difference	*6.6087*

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	13.000	4	4
A			
B A	11.650	4	1
B A			
B A	6.950	4	2
B			
B	5.800	4	3

Dependent Variable: Phos

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2.13661198	0.71220399	2.29	0.1348
Error	11	3.41901242	0.31081931		
Corrected Total	14	5.55562440			

R-Square	*Coeff Var*	Root MSE	Phos Mean
0.384585	*9.969452*	0.557512	5.592200

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treat	3	2.13661198	0.71220399	2.29	0.1348

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	3	2.13661198	0.71220399	2.29	0.1348

The GLM Procedure

t Tests (LSD) for Phos

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	11
Error Mean Square	0.310819
Critical Value of t	2.20099
Least Significant Difference	*0.9031*
Harmonic Mean of Cell Sizes	3.692308

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	6.0267	3	1
A			

```
B    A        5.8200      4    2
B    A
B    A        5.6215      4    3
B
B             5.0093      4    4
```

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Obs		treat	repl	infil
Ploguh	A	1	1	.
	A	1	2	.
	B	1	3	0.26
	B	1	4	0.27
	C	1	5	0.46
	C	1	6	0.39
	D	1	7	0.23
	D	1	8	0.28
On ripplne	A	2	1	0.43
	B	2	2	0.49
	C	2	3	0.37
	D	2	4	0.31
Betweeb ripplines	A	3	1	0.16
	B	3	2	0.17
	C	3	3	0.20
	D	3	4	0.19
In basins	AB	4	1	1.40
	AB	4	2	2.22
	CD	4	3	1.50
	CD	4	4	3.41
	EF	4	5	0.96
	EF	4	6	0.81
	GH	4	7	0.42
	GH	4	8	1.03
Outside basins	AB	5	1	1.11
	AB	5	2	0.34
	CD	5	3	0.86
	CD	5	4	1.15
	EF	5	5	0.29
	EF	5	6	0.70
	GH	5	7	0.23
	GH	5	8	0.67

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The GLM Procedure

Class Level Information

Class	Levels	Values
treat	5	1 2 3 4 5

Number of observations 32

NOTE: Due to missing values, only 30 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: infil

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	6.91260500	1.72815125	5.84	0.0018
Error	25	7.40122500	0.29604900		
Corrected Total	29	14.31383000			

R-Square	Coeff Var	Root MSE	infil Mean
0.482952	76.95953	0.544104	0.707000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treat	4	6.91260500	1.72815125	5.84	0.0018

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	4	6.91260500	1.72815125	5.84	0.0018

The GLM Procedure

t Tests (LSD) for infil

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	25
Error Mean Square	0.296049
Critical Value of t	2.05954
Least Significant Difference	0.6786
Harmonic Mean of Cell Sizes	5.454545

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

t Grouping	Mean	N	treat
A	1.4563	8	4
B	0.5688	8	5
B			
B	0.4000	4	2
B			
B	0.3150	6	1
B			
B	0.1800	4	3