A monitoring and evaluation report of the conservation agriculture project (CAP1) in Zambia

by Jens B. Aune, Progress Nyanga and Fred H. Johnsen

Noragric Report No. 68, October 2012
Department of International Environment and Development Studies
Noragric

Norwegian University of Life Sciences
MDCCCLIX

A Monitoring and Evaluation Report of the Conservation Agriculture Project 1 (CAP1) in Zambia

By

Jens B. Aune, Progress Nyanga and
Fred H. Johnsen

Noragric Report No. 68
October 2012

**Department of International Environment and Development Studies,
Noragric
Norwegian University of Life Sciences**

Noragric is the Department of International Environment and Development Studies at the Norwegian University of Life Sciences (UMB). Noragric's activities include research, education and assignments, focusing particularly, but not exclusively, on developing countries and countries with economies in transition.

Noragric Reports present findings from various studies and assignments, including programme appraisals and evaluations.

This Noragric Report is the result of an assignment under the agreement between the Conservation Farming Unit (CFU) and Noragric. The project was funded through the Norwegian Embassy in Zambia.

Aune, Jens B., Progress Nyanga and Fred H. Johnsen. A Monitoring and Evaluation Report of the Conservation Agriculture Project 1 (CAP1) in Zambia.
Noragric Report No. 68 (October 2012)
Department of International Environment and Development Studies, Noragric
Norwegian University of Life Sciences (UMB)
P.O. Box 5003
N-1432 Aas
Norway
Tel.: +47 64 96 52 00
Fax: +47 64 96 52 01
Internet: http://www.umb.no/noragric

ISSN (printed version): 1502-8127
ISSN (online version): 1892-8102
Photo credits: Josie Teurlings (cover)
Cover design: Åslaug Borgan/UMB
Printed at: Elanders Novum

TABLE OF CONTENTS

ABSTRACT

The Conservation Agriculture Project 1 (CAP1) was a project implemented by the Conservation Farming Unit (CFU) of the Zambian National Farmers Union (ZNFU) from 2006 to 2011. The project focused on the Eastern, Southern and Central regions and had a target to reach 120,000 farm households. Project activities included promotion of different tillage methods like basins (30cm long, 15 wide and 20cm deep) and ripping, promotion of tuber and grain legumes through distribution of plant material and promotion of tree planting of *Faidherbida albida* and *Jatropha curcas*. The project has built up an extension system based on regional coordinators (CFU staff), farm coordinators, contact farmers and associate farmers. Noragric was given the role to monitor the project. Household surveys, field measurements and field visits were undertaken by two PhD students from Zambia, Norwegian M.Sc students and staff from Noragric.

IMPACTS

The project has partly fulfilled the development objective and immediate objectives established at the beginning of the project. There is a slight improvement in food security. Among households experiencing food shortages, the average number of months with food shortage was reduced from 4.4 months in the baseline year (2007) to 3.2 months in 2010. Farmers have increased the income from crops by 32 % during this period. Farmers have furthermore increased their expenditures during the period and invested in improved housing and more livestock during this period. The total welfare of farmers may therefore have been improved.

Conservation agriculture (CA) was practiced on 26% of the cropped land of surveyed farmers in the 2009/2010 season while the rest is under conventional tillage. This shows that there is yet only a partial uptake of CA. For those that had adopted basins, the average area under this method was 0.71 hectares per farm whereas for farmers practicing ripping the average area under ripping was 1.21 hectares per farm. Planting basins were adopted by 58% of the farmers in the 2009/2010 season while 18% practiced ripping this year. Still 58% of the farmers practiced ploughing in the 2009/2010 season. Further upscaling of ripping is dependent on improved availability of rippers. It appears that there is higher adoption among households with low income and few animals. Previous participation in the CA projects had a very positive influence on the uptake of CA in the CAP1.

CAP1 has stimulated the production of crops like cassava, sweet potato, groundnuts and cowpea. Cassava production increased in the 2006/2008 to 2007/2008 period from 169 to 461 kg per household respectively and total tuber production is now more than one ton per household. Legume production has also increased considerably. There is no clear trend with regard to total maize production per household. The reason is probably that the area under CA is still quite low per household.

The objective to increase soil organic carbon content is not fulfilled. The reason is that the farmers are not able to retain crop residues since cattle are roaming freely in the dry season. Use of mulching is one of the principles of conservation agriculture, but it appears farmers do not adhere to this principle. Only two of the three principles of CA are respected in the project and

this explains why there is no effect on soil organic matter. There is therefore a need to establish local institutions that can ensure improved grazing management.

The establishment of *Faidherbia albida* on farmers fields has been much slower than planned. The plan was to establish 200 *Faidherbia albida* trees per farm, but standing stock in 2009 was only 9 trees per farm. Survival of the trees is one of the factors that have slowed down tree establishment.

OUTPUTS

Surveys and field observations showed that there are considerable differences in yield level and labour demand both within CA systems and between different cultivation methods. The survey results of 129 farmers showed yield levels of 1.8, 5.2, 2.3 and 3.8 tons per ha respectively for hand-hoeing, planting basins, ripping and ploughing. Field observations showed that total labour use during the whole season was 124, 145, 61 and 83 person-days per hectare for planting basins, hand hoeing, ploughing and ripping respectively. Land preparation of basins took 24 hours per hectare while general use of a hand hoe took 21 hours per hectare. Labour demand of ploughing was 3.8 hours per hectare while ripping only took 0.8 hours per hectare. The tillage system that gave the highest gross margin was planting basins followed by ripping, hoe tillage and ploughing. The reason why basins give a higher gross margin is related to higher yields.

There has been a gradual increase in the use of herbicides. In the 2006/2007 season 1.1% of the farmers used herbicides whereas in the 2009/2010 season 8.2% of the farmers used herbicides. There is an increasing need to use herbicides as the cultivated area increases. The monitoring team observed that outdated herbicides like atrazine and paraquat were used in project areas.

Farmers practicing basin planting, general hoe tillage and ripping, start sowing in general 12 -15 days earlier than farmers who practice ploughing. Basins therefore do not lead to earlier sowing than general hoe agriculture. For many farmers, planting time is also determined by the availability of improved seeds.

The research component of the project has been weak. Many experiments have been conducted, but there is no publication from the experiments in national or international journals. The coordination between CAP1 and other projects on CA has been insufficient resulting in inefficient use of resources and in some areas there has been an overlap between projects working on CA. CA does not seem to be well mainstreamed into the policies of the Ministry of Agriculture yet as the Ministry is not allocating funds to CA.

OVERALL ASSESSMENT

Despite these difficulties, there is an overall positive effect of the project. CA is gradually expanding and the agronomic and economic effects of CA are positive. The cropping system is also more diversified which makes agriculture less vulnerable to shocks like drought and flooding.

1. INTRODUCTION

The first forms of agriculture practiced were characterized by opening a hole in the soil with a planting stick and sowing in the planting hole. This way of farming is a method close to the principles of conservation agriculture. However, farmers gradually started to use the plough. The first ploughs developed (the ard) did not invert the soil as do the mouldboard ploughs, but rather opened a shallow furrow. This type of tillage is still practiced for example in Ethiopia. Gradually the plough became the symbol of agriculture. The plough became popular because when combined with the harrow it makes a nice seed bed, improving the soil's physical properties and contributing to weed control. However, during the 20th century farmers and scientists started to realize the negative environmental consequences related to the use of the plough such as high rates of soil erosion (the US dust bowl), high energy demand in ploughing, reduced soil organic matter content, reduction in soil life and emission of CO_2 (Aune 2012). One of the first critics of ploughing was William Faulkner who in 1943 published the book "Plowman's Folly". CA was developed as a response to these environmental problems. CA is now rapidly spreading in the world and the area under CA in 2009 was over 100 million hectares (Aune 2012).

Conservation agriculture was developed to address the negative consequences of ploughing, particularly soil erosion. The development of conservation agriculture started in the USA, but later expanded greatly in South America.

Conservation agriculture is based on three major principles (FAO 2011):

1. Continuous minimum mechanical soil disturbance (minimum tillage)
2. Permanent organic soil cover (surface mulch)
3. Diversification of crop species grown in sequences and/or associations

Conservation agriculture takes many forms and can be practiced by smallholder-farmers using the hoe as well as by highly mechanized big farms. Technological advances have made large-scale conservation agriculture possible since direct drillers have allowed for direct sowing into an unploughed seed bed and herbicides have reduced the need for tillage to control weeds. Biological activity by earthworms and other soil fauna improves the soil's physical structure in conservation agriculture thereby reducing the need to plough to improve physical properties.

If only the principle of direct sowing is practiced while the principles of residue retention and crop rotation are not adhered to, it is more appropriate to use the term no-till agriculture. Other terms used are conservation tillage or conservation farming.

CA has in recent years increasingly become part of the political agenda. One example is that CA is one of the activities of Pillar 1 (land and & water management) under the Comprehensive Africa Agriculture Development Programme (CAADP 2012). CA can be considered as part of Climate Smart Agriculture (CSA). CSA is defined as agricultural systems that increase productivity in a sustainable way, increases adaption in agriculture toward climate change and contributes to mitigation of greenhouse gases (FAO 2012). Integration of CSA in a new climate agreement was discussed under the COP 17 of UNFCC in Durban in December 2011.

2. AGRICULTURE IN ZAMBIA

The Conservation Agriculture Project 1 (CAP1) of the Conservation Farming Unit (CFU) in Zambia was implemented in Southern, Eastern and Central regions of the country. The Agro-Ecological Regions (AER) covered were region AER1, AER IIa and AER IIb. Annual rainfall in these areas is from below 800 mm (AER 1) to 800-1,000 mm (AER IIa) (Umar et al. 2011). Fewer activities have been undertaken in AER1. Sinezeze in region AER1 was originally part of CAP1 but the project pulled out of this site. The altitudes of AER 1 and AER IIA are respectively from 400 to 900 m.a.s.l. and 900-1300 m.a.s.l. (or metres a.s.l.). AER I is therefore a more arid zone than AER IIa. The mean annual temperature ranges from 23 to 32^{o}C.

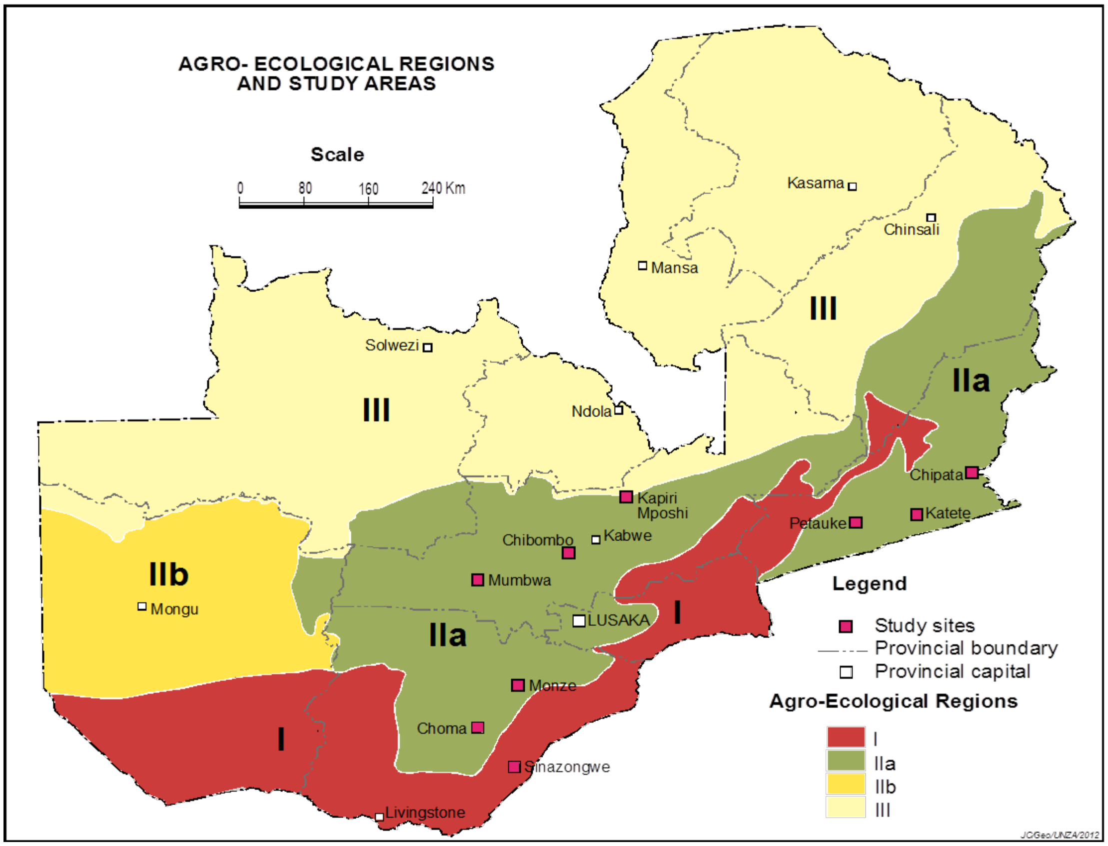

Figure 1. Agroecological zones in Zambia

Maize is the dominant crop in the farming system in these agro-ecological zones. Farmers use the production for own consumption and the surplus is sold. Other crops grown include cotton, soybean, cowpea, groundnut, sweet potato, cassava and cucurbit. 92% of smallholder farmers in Zambia cultivate an area less than 5 hectares (Weber 2012). Farmers in Zambia are not generally land constrained as only 14% of Zambia's land with agricultural potential is actually being cultivated (Mulemba 2009). Zambian farmers are more constrained by labour, seeds and input.

The FAO statistics for Zambia show that the area under maize has remained fairly stable during the last 20 years, but there has been a dramatic increase in area under maize in the 2009 and 2010 harvesting seasons. The yield of maize has been about 1.5 tons/ha for the last 20 years, but increasing yields are observed from 2003. In 2010, the average yield was about 2.5 tons/ha. Fertiliser use expressed in kg nitrogen fertiliser has increased by 60% in the period from 2002 to 2009 (FAOstat). This increase in maize production is therefore likely to be partly related to increased fertiliser use. The number of cattle was about 2.9 million in 1990 and 3 million in 2010 (FAOstat).

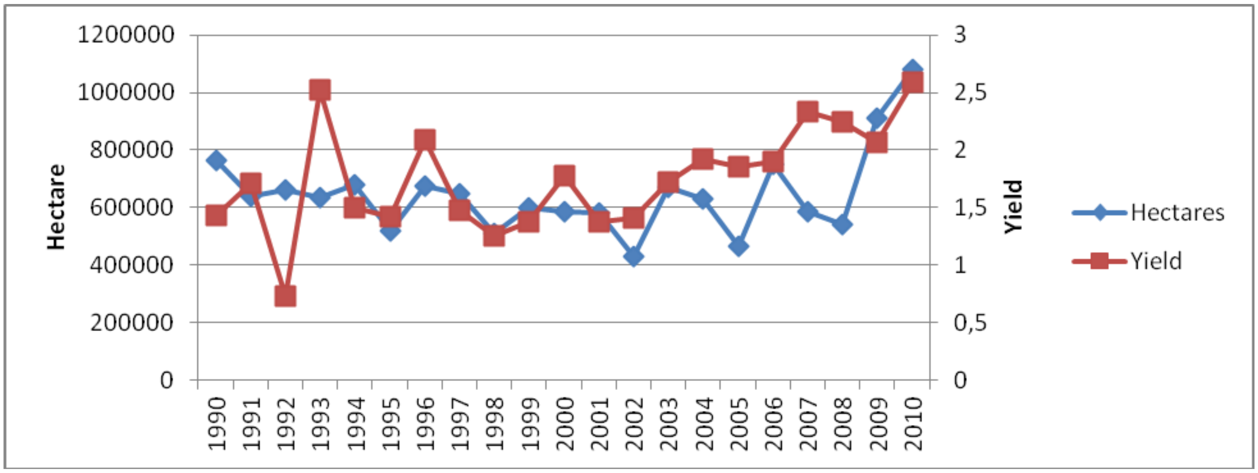

Figure 2. Development of area under maize and maize yield in Zambia in the period 1990-2010 (FAO statistics)

Zambia initiated a Fertiliser Support Programme (FSP) in 2002. The FSP package consists of 20 kg of hybrid maize seed, 200 kg of compound D fertiliser and 200 kg of urea (World Bank 2010). This is sufficient for one hectare of maize. The farmers have paid 40% of the input cost from 2006/2007. However, the quantities delivered to the farmers have often been less than what is described in the package and late distribution of fertilizer has been common. The fertiliser is provided to farmers that are members of cooperatives. Research by Michigan State University shows that it is the household with the largest landholdings that benefits the most from this input supply as farmers with farm size of 0-1 hectare, 1-2 hectare and 3-5 hectare received respectively 24, 69 and 139 kg fertiliser in 2011 (Mason 2011).

The Food Reserve Agency purchases the maize harvest at a price that is higher than the price at the regional market. This contributes to stimulating maize production, likely at the expense of other crops. The maize harvest in Zambia in recent years has been excellent and a part of the harvest is exported through the use of an export subsidy. Without this subsidy maize from Zambia cannot compete in the regional market.

3. CONSERVATION AGRICULTURE IN ZAMBIA

The conventional tillage system in the smallholder sector is characterized by either hoe cultivation or ploughing using animal traction. The first rains in November are typically used to till the soil. Many farmers have lost their oxen in Zambia due to the corridor disease (CFU 2007). Availability of oxen for ploughing is therefore often a problem resulting in late planting with serious consequences for yield. After harvesting, crop residues are not retained in the fields because of communal grazing and burning. Maize yields in the conventional farming system are often below 2 tons/ha due to late sowing, infestation of weeds, low soil fertility and limited use of soil fertility management practices including the use of mineral fertilizer.

The Conservation Farming Unit has been instrumental in developing CA in Zambia. CFU was formed in 1995 and is an independent organization having a collaborative agreement with the Zambian National Farmers Union. The CFU has received funding for promoting CA in Zambia from the World Bank, EU, CIDA, and the governments of Norway and Finland. Since 2006 Norway has funded a large programme implemented by CFU. Norway has in addition from 2007 funded the Conservation Agriculture Scaling Up Project (CASPP). This programme is implemented by the Ministry of Agriculture and Cooperatives (MACO). Training of MACO staff has been provided by CFU.

CFU uses the terms minimum tillage (MT), conservation tillage (CT), conservation farming (CF) and conservation agriculture (CA). Minimum tillage is a term used for minimum tillage or zero tillage; CT is MT plus the retention of crop residues to the extent possible; CF is CT plus the incorporation of legumes; and CA is CF plus the establishment of *Faidherbia albida* (CFU 2011). CFU proposes three different types of CA/CF: planting basins, ripping with oxen and ripping with tractor. The size of the basins is 30cm long, 15cm wide and 20cm deep and the planting distance in maize is 70 x 90cm (see photo front page). This is equivalent to tilling 7% of the land (Umar et al. 2012). Farmers with access to oxen are stimulated to use ripping either by oxen or tractor. The furrows are 15-20cm deep and spaced at 90cm. This corresponds to tilling 10-12% of the land (CFU, 2009a:10). The term CA in this report covers all forms of minimum tillage methods.

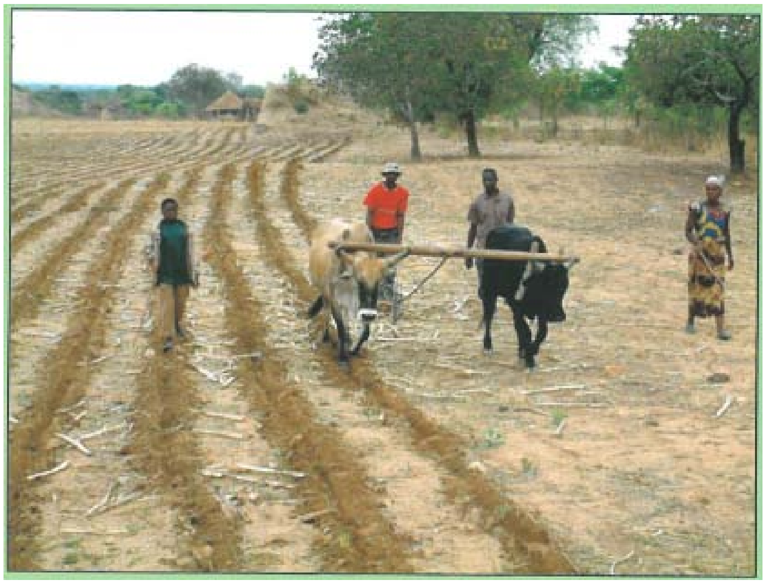

Figure 3. Farmers practicing ripping with oxen. Photo: B.B. Umar

As part of the project, CFU has also been giving advice on timely planting, correct application of mineral fertiliser, lime and manure, the safe and effective use of herbicides, crop rotations, introduction of tuber crops (particularly improved cassava and sweet potato) and trees like *Faidherbia albida*, *Jatropha curcas* and *Moringa oleifera*. Jatropha has not been promoted since 2008 due to the collapse of the Jatropha oil industry.

4. PROJECT OPERATIONS

The project document "Reversing food security and environmental degradation in Zambia through conservation agriculture" defined the development objectives, immediate objectives and outputs of the project and described how the project would operate. The overall development goal was "to increase food security and profitability, enable appropriate responses to emerging economic opportunities and encourage regeneration and reforestation". The project aims to target 120,000 farmers. The project would select 400 farm coordinators who would be trained by CFU field officers. Each farm coordinator would train 10 contact farmers and each contact farmer would train 15 associate farmers and 15 additional farmers or non-associated farmers. There would thus be a total of 4,000 contact farmers, 60,000 associated farmers and 60,000 additional or non-associated farmers. The training will be open to any farmer and it is therefore expected that the project would reach out to approximately 120,000 farmers. The honorarium to the farm coordinators would be in the form of a bicycle, 2 lima CF demo packs at 65% subsidy and a magoye ripper. Contact farmers would receive *chaka* hoes or magoye rippers and 2 lima (0.5 hectare) CF packs on loan. Electronic vouchers for purchasing of farm inputs have been provided since 2008 to farm coordinators and contact farmers. Participating farmers would receive starter packs of cassava cuttings, jatropha seedlings and *Faidherbia albida* seedlings. The CAP1 would in addition develop information material in the form of leaflets and a radio programme. CA associations would also be established.

5. METHODS USED IN THE NORAGRIC STUDY

Noragric was asked to carry out the monitoring of the project. A monitoring system was developed through the establishment of a household survey. Noragric recruited two PhD students who collected most of the data. The largest survey focused on socio-economic factors in CA adoption and included 640, 535, 486 and 440 farmers in 2007, 2008, 2009 and 2010 respectively. The farmers were randomly selected from a list provided by CFU and included farmers that were associated with the project as well as non-associated farmers. The reasons why the sample was reduced over the years included deaths, migration, sickness, refusals and absenteeism. The other survey focused on the agronomic practice and labour use and involved 129 households (random selection). The areas covered were the Eastern, Central and Southern regions. Focus group discussions were in addition undertaken. A time use study of the operations related to cropping was also conducted. Field observation and group discussion with the farmers were in addition used to collect data. The two Norwegian M.Sc. students, Freim (2008) and Borge (2010), also collected data for the project for their thesis. Borge undertook a household survey including 154 farmers.

A total of 73 paired soil samples were taken to assess the impact of CA on soil properties. The samples were analyzed in the soil laboratory at the University of Zambia. The analysis included total carbon, total N, available phosphorous, exchangeable potassium, pH, bulk density and plant available water. Soil samples were also undertaken below, in- and outside canopies of 102 *Faidherbia albida* trees to assess the contribution of the tree to soil fertility.

6. RESULTS

6.1. EFFECTS ON SOIL PROPERTIES

Tillage and residue management is known to affect soil properties. Conservation agriculture can increase the soil organic matter content because oxidation of soil organic matter is reduced when the soil is undisturbed and retention of crop residues will contribute to build soil organic matter. However, it takes time before any changes in soil properties can be seen regardless of which system is practiced.

Soil samples taken at 73 locations where CA and conventional agriculture (CV) were found adjacent to each other and where CA had been practiced for at least 5 years, showed no clear difference in soil chemical properties between CA and CV plots (Umar et al. 2011). The soil samples in CA plots were randomly taken from both inside the basins and from the inter-rows. The reason why no clear difference was found was probably that the crop residues were not retained either in the CA plots or in the CV plots. If crop residues are retained, it will lead to build up of soil organic matter and increased recycling of other plant nutrients. It will probably take more time before the effects of zero tillage can be seen. This result shows that there is no general improvement in soil fertility if CA is practiced without mulching. However, within the planting basins there is a possibility that there is a localized effect on soil fertility as nutrients are applied to the basins.

The nitrogen content of the soil samples was low whereas the phosphorous and potassium levels were high. This is an indication that for these soils, the emphasis should be given on nitrogen fertiliser. There was no difference in bulk density between CA plots and non CA plots (Umar et al. 2011). Therefore, no evidence for formation of hard pans in the 0-20 cm was found. Breaking of the hard pan has been one of the reasons given by CFU why it is necessary to establish basins or to rip the soil.

Plants established in basins were generally more drought resistant than maize planted in the traditional soil tillage, but this effect is likely related to improved storage of water in the basins and may not be a result of breaking the hard pan. However, these are issues that should be further studied. In Zimbabwe it has been reported that a CA system (basins) can either increase or maintain soil organic carbon whereas conventional tillage reduces the soil organic carbon content. The increase in the soil organ carbon content during a 3-year period was up to 9,4% in conservation tillage while the decrease in conventional tillage was 7.3% (Marongwe et al. 2011).

6.2. CA AND PLANTING TIME

One of the advantages of conservation agriculture is that it allows farmers to sow on time. Farmers in Zambia traditionally use the first rains in November to till the land either by hoe or by oxen. Sowing is often delayed due to limited access to oxen, particularly for non-oxen holders. The recommendation for CA farmers is to sow following the first heavy rains after 15 November. CFU has recommended the farmers to till the land in the dry season in order to have sufficient time for the operation. The survey found that the average starting time for planting maize was respectively 9, 12, 12 and 23 November for basins, hand hoeing, ripping and ploughing respectively. Farmers practicing ploughing are therefore sowing 12-15 days later than the farmers practicing the other tillage method. This result indicates that farmers only plant a few days earlier if they change from hand hoeing to basins. The labour data partly explain these results. There is no clear difference in labour use in land preparation between hand hoeing and planting basins. For the animal traction based operations, ripping is less labour demanding than ploughing (Bwalya et al. 2011). This can explain why farmers practicing ripping sow earlier than those practicing ploughing.

Farmers who practice ploughing and who own oxen are less likely to change to basins on a substantial part of their land. However, many farmers will have to hire oxen and for this reason sow late. For these farmers it is an alternative to establish basins, particularly for smaller parts of the land. The survey data also show that many farmers practice several tillage methods on their farm.

6.3. CA AND WEED CONTROL

The main weed control measure in CA is mechanical weeding as 99% of the farmers use hand hoeing as a weed control measure. Labour use in weeding is 16% higher in basin tillage as compared to general hoe cultivation (Umar et al. 2011). Manual weeding is mostly done by women and children (Nyanga et al. 2012).Weeding is a very time demanding task and use of herbicides can contribute to free the women and children from this burden.

There has been an increased use of herbicides since the start of the project. In the 2006/2007 season 1.1% of the farmers used herbicides whereas in the 2009/2010 season 8.2% of the farmers used herbicides (Nyanga et al. 2012). The survey by Umar et al. (2011) also showed that 8.2% of farmers used herbicides. The most commonly used herbicides are atrazine and glyphoshate. Glyphoshate is applied prior to sowing to control weeds that have germinated. Atrazine is used as a pre- and post emergence herbicide. Women expressed concern that the use of herbicides would make it more difficult for them to practice mixed cropping as it is difficult to combine use of atrazine and cultivation of legume crops like cowpea.

It was found that households are hand-weeding on average only 3 times in the season resulting in insufficient weed control. Herbicide application is costly and farmers spend 4.30 US$ per hectare on herbicides annually. The survey result showed that farmers were using only 0.55 litres glyphosphate/ha while the recommendation is 4-5 litres per hectare (Umar et al. 2011). About 39% of the farmers have difficulties in following the application instructions for the herbicides. Farmers are, in addition, often using muddy water which further reduces the efficiency of glyphophate as it deactivates on contact with soil.

Atrazine is an important herbicide for weed control in maize in Zambia and is used in different formulations. However, this is an herbicide that is banned in the EU (and also in Norway), but is still allowed to be used in the USA. Atrazine breaks down slowly in the soil and will inhibit germination of crops that are sown together with maize. It is therefore not possible to use this herbicide together with intercropping. Negative health effects of this herbicide have also been reported related to reproduction. CFU recommends Blazine which contains 25% atrazine and 25% cyanazine. However, even though the concentration is lower, there is still a considerable amount of atrazine spread in the environment. There is therefore a need to find alternatives to this herbicide.

The Noragric team has also observed the use of Gramoxone (paraquat). This is an extremely poisonous herbicide that is banned in many countries. Farmers have received training in the use of this herbicide in CAP1. The extent of the use of this herbicide is not known.

CFU has also developed the ZAMwipe as a low cost method for applying herbicides. However, it has not been very popular among farmers because it is 3 to 4 times more labour demanding than the knapsack sprayer (Mazvimavi 2011). It can be used for treating weed infested spots.

Herbicide use is expected to increase in CA project areas. The reasons are that herbicides have become more easily available in rural areas and that the electronic voucher system has enlisted herbicides. There is an increasing need for training in the correct use of herbicides in project areas.

6.4. CA, FERTILIZATION AND RESIDUE MANAGEMENT

CFU recommends farmers practicing basins and aiming at a yield level of 3.5 to 4.5 tons/ha to use 125 kg fertilizer (compound D)/ha as basal dressing and 200 kg urea per ha as top-dressing (CFU handbook 2011). For farmers aiming at 5.0 to 6.5 tons/ha CFU recommends 250kg fertiliser/ha as basal dressing and 300kg/ha as top-dressing. The recommendation in conventional agriculture is 200 kg fertilizer/ha as basal dressing and 200 kg/ha as top dressing. The Noragric survey showed that farmers in general have increased the application of organic and mineral fertiliser during the project period (Nyanga et al. 2011). In the 2006/2007 season the farmers used 66 kg basal dressing per farm while in 2009/2010 farmers used 128 kg per farm. Top dressing of urea increased during this period from 70 kg to 137 kg per farm and the number of oxcarts of manure used increased from 1.24 to 2.21. This study revealed no difference between the associated farmers and the non-associated farmers in the use of mineral fertiliser.

A more detailed study by Umar et al. (2011) also found no differences in fertilizer application rates between CA and CV plots. Average fertiliser use was about 30 kg/ha, much less than the recommended level. However, 70% of farmers claimed that they had reduced the use of mineral fertiliser in CA plots. 92% of the farmers stated that high cost was a problem related to the use of mineral fertiliser. Farmers apply organic fertiliser on 44% and 31% of their fields under CA and CV respectively.

Residue retention is one of the principles of CA, but this is a principle not much adhered to in Zambia by CA farmers. In southern and central Zambia most of the crop residues are usually fed to livestock. In the Eastern province the crop residues are often burned in connection with hunting of rodents. The effect of mulching is not always immediate. It takes several years before effects can be seen and this makes farmers unwilling to practice mulching.

Figure 4. Crop residue retention as mulch is seldom practiced. Photo: B.B. Umar

6.5. YIELD IN CONSERVATION AGRICULTURE

CA and particularly the use of planting basins give a better yield than CV. The reasons why CA gives a better yield than CV under real farming conditions includes more timely sowing, more efficient utilization of fertilizers as nutrients are placed adjacent to the plant, water harvesting in basins, better water infiltration in the ripped lines, and improved water infiltration.

The survey results of 129 farmers showed yield levels of 1.8, 5.2, 2.3 and 3.8 tons per ha respectively for hand-hoeing, planting basins, ripping and ploughing (Umar et al. 2011). On-station experiments by Golden Valley Agriculture Research Trust (GART) showed yield levels of 4.0, 6.3, 5.3 and 5.5 tons per hectare for hoe tillage, basin tillage, ripping and ploughing respectively (Umar et al. 2011). This shows that yield levels in basins are consistently higher than yield levels in other tillage system. Ripping does not give any increase in yield as compared to ploughing. In years of flooding like in the 2007/2008 season, farmers under the CFU project had to backfill the basins in order to prevent the basins from being waterlogged. The reasons why yields are higher in basins are probably related to earlier sowing in CA, water harvesting effects and improved infiltration of water in the basins, and more efficient use of nutrients as the nutrients are concentrated adjacent to the plants.

A survey of CA farmers in Zambia confirmed that CA increases yield (Borge 2010). About 55% of the farmers experienced yield increase when switching to CA while only about 10% experienced a yield decrease.

Farmers in Zambia do not adopt CA as adaptation to climate change. However, farmers pointed out during discussions that maize yields were higher in CA plots than CV plots in seasons with low rainfall (Nyanga et al. 2011). Farmers attribute this to the water harvesting effects of the basins.

Increased yield has also been one major reason for the farmers to adopt the use of basins in Zimbabwe (Marongwe et al. 2011). Average yields from 15 regions across Zimbabwe showed an increase from 970 kg per hectare for non-CA farmers to 1,546 kg per hectare for CA farmers (basins). From Zimbabwe it is reported that CA performs best under conditions of moisture stress. The study from Zimbabwe shows that good results can be achieved even though the size of the basin is only 50% of the size of basins in Zambia. Whiteside (2011) reports that common yield increase in Southern Africa in CA over traditional tillage is 20-75%.

6.6. LABOUR USE AND GENDER RELATIONS IN CONSERVATION AGRICULTURE

A change to conservation agriculture will change the total workload as well as the distribution of the workload during the season. A comparison of the systems using field observations showed that total labour use during the whole season was 124, 145, 61 and 83 person-days per hectare for planting basins, hand hoeing, ploughing and ripping respectively (Umar et al. 2012). Hand hoeing is here represented as overall digging of a wet soil. Another study on labour use in Zambia found that labour use was 148, 70 and 63 person-days per hectare for basins, ploughing and ripping respectively (FAO 2011). In Zimbabwe, CA (basins) was found to require 109 person-days per hectare compared to 69 person-days per hectare for hoe tillage (Mazvimavi and Twomlow 2009). The distribution of labour also differs depending on the tillage method practiced. Time use for land preparation was 24, 21, 3.8 and 0.8 man-days per hectare for basins, hoe tillage, plouging and ripping respectively (Umar et al. 2012) This is equivalent to the results given in the handbook by the Conservation Farming Union and similar to a study by ICRISAT in Zimbabwe that showed that the establishment of basins requires at least 21 man-days per hectare (Mazvimavi and Twomlow 2009). The weeding requirement in ripping is much higher than in ploughing as 53 person-days per hectare for weeding are used in the ripping system while 32 person-days for weeding in ploughing (Umar et al. 2012) . This result indicates that more time was spent on weeding in CA plots as compared to ploughed plots. However, this difference was not statistically significant. Farmers' own assessment shows that it is more labour demanding to establish basins than to do conventional cultivation by hoe (Umar et al. 2011).

Basin digging is hard work and CFU recommends that 3 persons do not dig more than 500 basins per day equivalent to 3 hours of work each. This high labour requirement explains why the average area under basins is only 0.5 hectare per farmer (average of all farmers). Basin digging is normally undertaken by the family members alone. This is contrary to ploughing where hired labour represents 38% of the labour use.

A change to conservation agriculture will also change the gender relations in the farming operation. In conventional agriculture the women are often removing vegetation and crop residues through cutting, raking and heaping prior to ploughing. In CA this operation is not done, saving the women from undertaking this pre-tillage work.

Hoe tillage is usually a woman's domain in Zambia, but in the Eastern province men have a tradition for taking part in manual soil cultivation. CFU has been promoting the *chaka* hoe as a tool to be used for basin digging. This hoe is stronger and heavier, with a narrower blade than the traditional hoe. The shaft is also longer than the traditional hoe. It is possible to dig the basin faster and with more precision using the *chaka* hoe. This hoe has been distributed by CFU through their training. However, use of the *chaka* hoe makes the work heavier. When the *chaka* hoe is used, the hoe has to be swung from behind the shoulders. This makes it very hard for the women to work for a long time. Other studies confirm the difficulty for female farmers to use the *chaka* hoe (Mazvimavi 2011).

Figure 5. The chaka hoe. Photo: B.B. Umar

6.7. ECONOMICS OF CONSERVATION AGRICULTURE

The economic assessment was based on a survey of 120 farmers (Umar et al. 2012). This assessment was based on yield levels, field assessment, recording of labour use, and prices of in- and output. The gross margin found for the four systems was 2,212, 34, -270 and 503 thousand Zambian Kwacha (ZMK) per hectare for basin digging, hand hoeing, ploughing and ripping respectively. Both CA methods therefore outperformed the CV systems. Basin digging gave by far the highest gross margin because the yield was 4.4 tons/ha as compared to 1.7, 2.4 and 2.8 in hand hoeing, ploughing and ripping respectively. Labour cost was higher in basin digging as compared to other tillage systems, but the high yield more than compensated for this cost. The cost of mineral fertiliser was on the other hand higher under ploughing and ripping. Return to labour was 23,000, 4,112, 4,172 and 14,641 ZMK per working day for basins, hand hoeing, ploughing and ripping respectively. Basin tillage has therefore nearly 6 times higher return to labour per day than hoe tillage and ploughing. The studies in Zimbabwe confirmed that the gross margin was higher in basin tillage and ripping compared to ploughing (Mazvimavi 2011). The gross margin from CA (basins) was 5 times greater than the gross margin in hoe tillage (Mazvimavi and Twomlow 2009). Return to labour was higher in the CA basin system compared to ploughing in Zimbabwe (Mazvimavi 2011).

6.8. THE EFFECT OF *FAIDHERBIA ALBIDA* ON CONSERVATION AGRICULTURE

Planting of *Faidherbia albida* (F. albida) has been included as a component of the CAP1 in Zambia. This is a tree that sheds its leaves in the rainy season. As compared to most other trees, the shading effect of this tree on crops will therefore be much less. In addition, the tree fixes nitrogen and leaf droppings will enrich the soil with nitrogen and other nutrients taken up through the root system. CFU recommends planting the trees 10 x 10 metres corresponding to 100 trees per hectare. In order to study the effect of this tree on soil properties, soil samples were taken under 102 trees. Samples were taken at a depth of 0-20 cm in the inner canopy, middle canopy and outside the canopy (5 metres outside the canopy). The distance varied according to the diameter of the trees. The results showed that soil carbon, nitrogen and the potassium content were significantly higher in the inner radius than in the outer radius. The increase from the inner to the outer radius was 31%, 42% and 25 % for soil organic carbon, nitrogen and potassium content respectively (Umar et al. 2012). For pH and available phosphorus no changes could be observed. However, the levels of available phosphorous in the soil indicate that this element is sufficient for crop production. The difference in nitrogen was 1,300 kg/ha between the inner circle and the outer radius. This corresponds to an annual release of 39 kg/ha assuming a mineralization constant of 3% (Umar et al. 2012). This improvement in soil chemical properties is probably related to droppings of leaves, as GART has reported that the leaves of *F. albida* contain 3.6% nitrogen. Presence of dung was low in this study and could not explain the changes in soil properties. GART has reported that the yield under *F. albida* is 3 tons per hectare under the canopy whereas it is 2 tons per hectare outside. From Niger it is reported that maize, sorghum and millet yields are higher under the canopy of *F. albida* than outside (Payne et al. 1998).

Figure 5. Faidherbia albida tree

6.9. JATROPHA

Planting of the oil producing tree *Jatropha curcas* has been promoted in the CAP1. At the onset of the project there was a strong interest in the tree for its oil producing abilities. International oil prices were very high in 2006-2007 and this created a lot of interest in this tree. The tree is mainly planted in hedges. The tree can be planted both for the purpose of delineating a plot and for oil production. The Noragric survey showed that there was an average of 4 and 50 trees per farmer respectively in the 2007 and 2009 seasons. The M.Sc thesis by Freim (2008) showed that the income from Jatropha can be equal to other cash crops depending on the yields, oil and labour price. The activity calendar for Jatropha production does not interfere with the activity calendar for food crops. There is therefore no direct competition between using labour for food and Jatropha production. However, the future prospects for Jatropha production will depend on the price of Jatropha oil (reflecting international oil prices) and the development of an oil producing industry based on Jatropha in Zambia. The drop in oil prices in Zambia after 2007 has led to reduced interest in oil production based on Jatropha.

6.10. ADOPTION OF CA IN ZAMBIA

CFU aimed at targeting 120,000 farmers in the CAP1 project. The survey showed that about 71% of the farmers in 2009/2010 practiced CA. The average area under CA among all the sampled farmers is 0.52 hectares representing about 26% of their cropped land (Nyanga 2012). For those practicing CA the average area under CA is 0.78 hectares. The area under basins is 0.52 hectares for farmers practicing this method whereas ripping is practiced on 1.21 hectares for farmers using this method. The number of farmers practicing basins has increased from 22% in 2006/2007 to 58% in 2009/2010. The corresponding numbers for ripping are 3% and 21%. The average cultivated area is about 2 hectares per household and there is no significant difference between CA and non-CA farmers in the total size of land area. It appears that it is the poorer farmers that have adopted CA as the CA adopters have 24% less income than the non-CA adopters. In addition, CA adopters have 20% fewer animals per household and 34% fewer oxen per household. Those who possess oxen seem therefore more likely to continue with conventional tillage. Farmers who rely on ox ploughing without owning oxen often have to sow late. CA is therefore an approach that can allow the farmers to sow on time.

The M.Sc. thesis by Elli Borge (2010) confirmed that it is the poorer households that turn to conservation agriculture. She found that CA farmers in the Southern province in Zambia had fewer cattle, cultivated less land and possessed fewer TVs than non-CA farmers. The CA farmers also used less mineral fertiliser and commercial seeds.

Access to labour also has a role in the adoption of CA. CA farmers have 54% more access to labour per hectare (Nyanga 2012a). It also appeared that previous participation in CA programmes had a positive influence on the uptake of CA. CA adopters with previous experience in minimum tillage before CAP1 accounted for 38% of households while non-adopters with previous experience before CAP1 in minimum tillage accounted for 8% (Nyanga 2012a). CA adopters also seem to be better organized than non-CA farmers as they are members of more agricultural organizations. The access to credit to farmers has been reduced over the period.

CA farmers attend nearly twice as many CA trainings as non-CA farmers, but even non-CA farmers attend on average 1.6 trainings per year. It seems therefore that many attend CA training without necessarily making use of the technology. CA farmers consider the training as the most important source of information on CA.

Farmers are advised through the CAP1 to space the basin 70 cm within the row and 90 cm between the rows. However, it was found that the farmers used a within row spacing of 46 cm whereas the recommended intra-row spacing was respected (Umar et al. 2012).

The major reasons given by the farmers why they find it difficult to use CA are lack of labour (39%), lack of land (30%) and no timely access to seeds (9%) (Umar et al. 2011). CA farmers in Zimbabwe also cite labour constraints related to basin digging and weeding (Marongwe et al. 2011).

The qualitative assessment of CA gave additional valuable information on how CA is adopted. Farmers expressed that a good relationship with the extension agent was important. However, it appears that CA farming is contrary to the conceived idea how farming should be practiced. Farmers are used to prepare a clean seed bed, and crop residues are burned for that purpose. Use of oxen during the dry season is considered a practice hostile to the well-being of the animals as the soil is hard and the animals are not well fed during this season. Farmers claim that the animals become susceptible to diseases if they are used for tillage in the dry season. There is also prestige attached to using the plough and cultivating a large area. It can therefore be more culturally acceptable to use ripping as this allows the farmers to make use of traction animals and cultivate large areas. The gender relations also play a role in the adoption of the different CA technologies. For women farmers, it will be easier to adopt basins as they are already used to working with the hoe and men can easily accept ripping as use of traction animals is within their domain. Basins can also be established for food security reasons as the yield in the basins is high. Basins also have a low capital requirement which makes them interesting for the poorer segments of the population. The richer farmers may use animal traction based ripping or ripping with tractor. Labour sharing mechanisms were found to have a positive effect on the uptake of CA. Some farmers organize themselves and work as a group. They work for one day on each of the members' farms. It was particularly the female farmers that organized part of the work this way.

CA can also be a useful approach for households with limited access to labour and for households that suffer from HIV/AIDS. These households may not opt for the basin system but rather focus on the use of ripping and herbicides for weed control. This is a form of CA with a low labour demand.

In some areas CA has been met by resistance from influential persons. In these areas it has been more difficult to promote the ideas of CA. The social context can therefore play a key role in the adoption of CA practices.

Discussions with farmers revealed that some asked what they would get in return if they adopted CA (Nyanga et al. 2011). This attitude is the result of donations in relation to development projects including projects on conservation agriculture. In the case of CAP1 farmers have been given cassava cuttings and sweet potato vines. It is therefore still early to judge whether the adoption that is seen is true adoption or the results of incentives provided through CAP1.

6.11. EFFECT OF CA ON LIVELIHOOD SECURITY

It is not easy to assess the effect of the project on livelihood security as there are many factors that influence the food security situation in the households.

Farmers have to a large extent diversified their cropping systems in the period from 2006/2007 to 2009/2010 (Nyanga et al. 2011). There has been a considerable variation in maize production per household during the period, but there is no clear trend. The effect of CAP1 on maize production is therefore not clear. The crop that has increased the most is cassava. In the beginning of the project period less than 5% of the sampled households cultivated cassava, but in 2009/2010 more than 30% of the households produced this crop. The cassava production per household increased from 169 to 461 kg during this period. Cassava was able to produce a good yield also in the flooding year of 2007/2008. The crop is also very resistant to drought and may produce an acceptable yield even in years when maize fails. Sweet potato, groundnuts and soybean production per household increased by respectively 30%, 35%, and 37% (Nyanga et al. 2011). The cumulative production of grain legumes is nearly 1,300 kg per household which represents a valuable addition in protein production. Tuber production is also more than 1 ton per household. The number of farmers growing cowpeas has increased 22-46% during the project period while the corresponding numbers for groundnut was from 63 to 88% (Nyanga 2012). This shows that CAP1 has diversified crop production. This has also diversified nutrition as a study using “24 hour of recall of food items” consumed showed that the number of meals including a pulse per day increased from 0.6 in 2007 to 1 in 2010 (Nyanga 2012). A more diversified crop production will also be a more stable production because if one crop fails other crops may compensate for the loss.

The mean household cash income has increased by 62% from 2006/2007 to 2009/2010. However, this increase has mainly been achieved in the last year of the survey. Crop production is the main source of income for farmers. Household income from crop production, livestock production, wage for agricultural work and non-farm income represents 62, 11, 2, and 25% of the total income respectively (Nyanga et al. 2011). There was a decrease in the income during the 2007/2008 year due to flooding.

Farmers normally sell the production soon after harvest to the Food Reserve Agency because there are few possibilities for storage. The supply of maize to the market is high at this time and the maize price is therefore low. Farmers could be able to make more profit if they could store the maize until the price was higher.

Farmers practicing CA also sow earlier, thereby getting an early harvest. This is particularly important in relation to food security as the harvest will be available at a time when there is limited availability of food in the households (Nyanga 2012).

Another indicator of the food security situation is the ability of the household to give out remittances (Nyanga et al. 2011). In the 2006/2007 season 38% of the families gave remittances while in 2009/2010 about 68% of the families gave remittances. The average amount of remittances was 25 US$ per household in 2009/2010, a tripling from the amount in 2006/2007. The remittances are still low in 2009/2010, but the increase over time can be used as an indicator of improved economic conditions.

Farmers have furthermore been able to accumulate capital in the form of own farming equipment, livestock and improved houses during the period. Such capital is important in times of economical shocks for the farmers. In 2006/2007 about 8% of the households owned a *chaka* hoe whereas in 2009/2010 about 32% owned one (Nyanga et al. 2011). The ownership of a ripper increased from 3 to 13% during the same period (Nyanga et al. 2011). It is therefore clear that the households are better equipped for practicing CA now compared to the beginning of the period, but still the majority of the households lack important equipment. However, CA farming can also be practiced using the traditional hoe.

There is a slight increase in farmers' ownership of cattle during the project period. 41% of the households owned cattle at the beginning of the period while 49% owned cattle at the end of the period (Nyanga et al. 2012). The number of heads of cattle per household increased from 3.0 to 4.1. Livestock is important for food security through provision of milk, meat, manure, animal traction and income. Animal pests continue to represent a major threat to livestock production in Zambia and veterinary services are inadequate. Important diseases are corridor disease, contagious bovine pleura-pneumonia, African swine fever and Newcastle disease.

The households have also improved their houses during the period. Households having a roof with corrugated iron sheets increased from 23% to 34% and a similar trend was observed for having a cement floor. The number of households owning a mobile phone increased from 19% to 62% and ownership of a TV increased from 16-26 % (Nyanga et al. 2011).

The results show that over the years there has been a positive development with regard to farmer's income, amount of remittances released, ownership of cattle, standard of housing and access to consumer goods such as mobile telephones and TV. It is difficult to pinpoint the factors that can explain these improvements in welfare and CA is probably only one of the contributing factors. The contribution from CAP1 can be been seen in the increased yield and income from crop production.

6.12. FULFILMENT OF DEVELOPMENT OBJECTIVES

The development objective established for the project was “to increase food security and profitability, enable appropriate responses to emerging economic opportunities and encourage environmental regeneration and reforestation”. Several indicators were defined by the project to assess this indicator.

The first indicator is that “within 5 years 20% of the farming families in project areas have sufficient farm-food available of adequate nutritive value to satisfy the household needs between October 1 and April 30”. Among households experiencing food shortages, the average number of months with food shortage reduced from 4.4 months in the baseline year (2007) to 3.2 months in 2010 (Nyanga et al. 2011). The reduction was statistically significant ($T=5.48$, $p\text{-value} < 0.001$). Focus group discussants often reported experiencing a reduction in the intensity of food shortage during the common hunger peak period because of green harvest arising from early planting on conservation agricultural fields. There has practically been no change in the amount of food aid received during these four years. There is also an indication that the quality of food has increased. From 24 hour recalls, the percentage of households having a diet with pulses steadily increased from a baseline 46% to 62% in 2010 (Nyanga 2012)

The production data also show that except for maize, there has been a substantial increase in crop production. It seems that the households have rather prioritized increasing expenditures on medicines, remittances, groceries and other items which have increased by 42%, 41%, 61% and 78% respectively. In the baseline, 38% of the families gave remittances while in 2010 about 68% of the families did so. The average amount of remittances given has tripled to about 25 US$ over the same period. The total expenditures on these items have increased by ZMK 244,000 (47 US$) on average per farm family during the four year period. The farmers have in addition invested in livestock and improved the conditions of the houses.

The second indicator is that “20% of the 330,000 farming families (equivalent to 66,000 families) in project areas receive a 40% increase in income through the sale of crops after 5 seasons, whilst still satisfying the households’ food needs”. The objective is difficult to assess. The average production of the major crops has increased from 6,557 kg in the 2006/2007 season to 7,631 kg in the 2009/2010 season. The average income from the sale of crops increased from ZMK 2.5 million in 2007 to ZMK 3.3 million in 2010, equivalent to 32%. The goal states that 66,000 farmers have increased their income by 40%. The project is therefore not far from achieving this objective.

Another indicator is that after 5 years, 20% of the 330,000 farming families have more than 10% organic matter in the soil. It is not likely that this objective has been met. No changes could be observed in the soil organic carbon content between plots under CA and conventionally farmed plots. There is no difference in soil organic matter because the crop residues are not retained in the CA system and CA is practiced on small areas. The establishment of the Faidherbida tree in the farmers’ plots also takes time and the trees are not well attended to. It will take several years before any effect of the Faiherbida trees planted during the project can be seen. There are also too few trees planted per farm in order to achieve a 10% average increase in soil organic carbon on the farms. It seems like this indicator was too ambitious.

The project had at the beginning also established an indicator that "after 5 seasons 7,5% of the 330,000 farming families in the project areas hire labour to assist with land preparation, weeding or harvesting". This indicator seems also not to be well chosen as even at the onset of the project 27% of the families hired labour for weeding (Nyanga et al. 2011). However, there was a tendency during the project period that farmers increasingly hired labour. While 27% of the farmers hired labour in the 2006/2007 season, 36% hired in 2009/2010. The use of hired labour for harvesting also doubled. However, there was no change in hiring of labour with regard to tillage and planting.

The fourth indicator is that after 10 years, 20% of the 330,000 farming families are receiving income from sale of Jatropha seed. The project was initiated at a time when there was a strong interest in investing in Jatropha production. Oil prices were high in this period and there were high expectations of the Jatropha crop. The oil prices have fallen since the initiation of the project, and it has been realized that it is more difficult to earn an income from Jatropha oil production than expected. Harvesting of Jatropha is, for example, very time demanding and the production has not yet been mechanized. This objective is therefore no longer relevant.

The final objective is that abandonment of exhausted land in favour of new land is reduced by 20%. This is an indicator that is difficult to verify. We have observed that farmers who have been involved in the project have increased the cultivated area only from 1.90 hectares to 1.94 hectares whereas the non-associated farmers have increased the area from 2.02 to 2.37 hectares. We therefore see that for the associated farmers there is hardly any change in the cultivated area whereas there is an increase for non-associated farmers. This way of measuring changes in land-use does not measure land abandonment, but it appears that CA can save land from being cultivated.

It appears from this assessment that the CAP1 has partly fulfilled the overall objectives of the project. The food security has been improved and the households have built capital in the form of improved housing, farm implements and livestock. The households have also increased their expenditures and income from production. This indicates that the overall welfare of the population has been improved. The objectives related to reforestation and increasing carbon content have however not been achieved.

6.13. FULFILMENT OF IMMEDIATE OBJECTIVE

The immediate objective established at the beginning of the project period was that "an increasing number of small-holder farmers in 12 districts of Southern, Central and Eastern regions of Zambia have adopted Conservation Farming and Conservation Agriculture practices". The indicators developed specify what is to be achieved in relation to this objective.

The first indicator is that “60,000 smallholders of whom 30% are women in project areas practice CF on at least 50% of their annual cropped land within 5 seasons”. Our survey showed that by 2010 the average area under CA was 26%, whereas for farmers associated with CAP1 the average area under CA was 35%. A regression analysis showed that there was not any significant difference between female headed or male headed farmers in the adoption of CA. This objective is therefore only partly fulfilled.

The second objective is that 60,000 farmers have each established 200 Faidherbida trees in their field after 5 years. The standing stock was 9 trees per farmer in 2009, but 17 trees per farmer were planted on average in the 2009/2010 season. The survival rate for the trees has only been 33% (Umar and Nyanga 2011). Termites and fires have been important reasons for the low survival rate. The project is very far from achieving this objective.

The third objective is that 60,000 farmers grow 500 metres of Jatropha hedges after 5 years. The standing stock of Jatropha trees per farmer was 50 trees in 2009; 22 trees per farm were planted in the 2009/2010 season. Only 18% of the farmers planted Jatropha as a live fence around their farms. The interest to plant Jatropha has gone down since the initiation of the project. The project is far from achieving this objective, but the objective is no longer relevant.

The fourth objective states that after 5 seasons, 60,000 farmers, of whom 30% are women, have increased their overall farm productivity by 40%. The project is not very far from achieving this objective as the average income from crop production has increased by 32% from the 2006/20007 to the 2009/2010 season and income from livestock has increased by 42% (Nyanga et al. 2011). Off-farm income has, however, increased 2.56 times. The survey results show that there is no difference between men’s and women’s participation in the project.

The fifth objective states that after 5 years, 60,000 farmers, of whom 30% are women, produce 25% more cereals, legumes and cotton for sale while satisfying the household needs within 5 seasons. Income from crops has increased from 1.6 million ZMK in 2006/2007 to 2.47 million ZMK in 2009/2010 representing a 54% increase in income from crops. For non-associate farmers the income from crops increased from 3.31 to 4.10 million ZMK in the same period, representing a 23% increase in income from crops. The income increase is therefore clearly higher for CA farmers. Maize yields have increased for CA, but since the area under CA is still small this does not translate into higher total maize production at the farm level. However, there is a clear increase in production for sweet potato (+191%), cassava (+1100%), cowpeas (+102%), groundnuts (68%) and soybeans (+73%). The actual production increase was highest for groundnut which increased from 330 kg to 557 kg during the four-year period. These data indicate that this objective is likely to be fulfilled.

The sixth objective states that “within 5 seasons 60,000 farmers in the project areas have adopted a rotation system compromising of at least three crops, including one legume crop on their farms”. This objective is difficult to assess because the maize is often intercropped with other crops. The maize dominance in the cropping system has increased since the area under maize has increased from 57% in the 2006/2007 season to 61% in the 2009/2010 season. The maize dominance in the production system has increased despite the efforts by CFU to diversify the cropping system. Maize production seems therefore deeply rooted in the minds of the farmers and is a crop also promoted by the Ministry of Agriculture and Cooperatives. Only 16 percent of the cropped land is under legumes. Ideally, 1/3 of the land should be under legumes. However, farmers have increased the production of minor crops like sweet potato and cassava. Even though the project has failed to establish improved rotation, still it has contributed to diversifying crop production as farmers now grow more legumes and root crops.

The seventh objective states that 18,000 female farmers have their own food security garden. The survey does not have any data on this, but we are aware that many female farmers have initiated cultivating sweet potatoes and cassava.

Under the eighth objective it is stated that after 5 years 70% of organizations promoting CA in Zambia are members of Conservation Agriculture Associations. This specific objective has not been assessed, but a CA association has been formed at the national level. In general there has been a positive development with regard to institutional development in the project areas even though it is difficult to relate this directly to CAP1. At the beginning of the project, 22% of farmers were members of farmer cooperatives and ZNFU, whereas in 2009/2010 42% of farmers were member. Membership in women associations increased from 13 to 32% during the same period.

The ninth objective is that after five years CA association members have increased budget allocations for CA by 25%. This is an indicator that has not been assessed.

The tenth objective states that after 5 years CA technical guidelines between all Conservation Agriculture Association members are established. This objective is believed to be met. We are aware that the project has prepared technical guidelines and that these guidelines are widely distributed among members.

6.14. FULFILMENT OF OUTPUT INDICATORS

In the project document it is stated that 64,000 lead farmers are trained (4 trainings per year), 30% attendance (to be confirmed) are female and 400 demonstration plots established. This indicator seems to be partly fulfilled according to the survey results (Nyanga et al. 2011). The average farmer in the survey area attended about 2.5 sessions per year.

Another set of output indicators is related to the incentive scheme. The indicators here were that 400 farm coordinators received specified input and 400 contact farmers accessed a seasonal revolving fund. The survey has not assessed this but we are aware that vouchers are extensively distributed in project areas.

Development of CA starter packs consisting of planting material of cassava, sweet potato and other species was another output indicator. The indicator states that “19,500 farmers have received elite cassava cutting, 19,500 farmers received Jatropha seeds, 120,000 farmers received *Faidherbida albida* seeds and sleeves, and the establishment of nurseries for cassava, sweet potato and fruit trees." The distribution of seedlings has been carried out according to the plans. The survey results showed that 20.7% of farmers received elite cassava cuttings in the 2009/2010 season (Nyanga et al. 2011). This corresponds to about 25,000 farmers which is well above the target. CFU's own data indicate that 28,000 farmers have received cassava seedlings (ORGUT 2011). The numbers of farmers who have received cassava planting materials has increased over the years. The number of cassava cuttings planted per farmer was 108, 27 and 201 respectively for 2007/2008, 2008/2009 and 2009/2010 (Nyanga et al. 2011). Percentage farmers that received *F. albida* seeds were 5.6, 28.6, 31.1 and 34.5 % for the years 2006/2007, 2007/2008, 2008/2009 and 2009/2010 respectively. When summing this up over the years, it is likely that close to all farmers in the sample areas have received plant materials. The standing trees of *F. albida* per farmer were 9 in the 2008/2009 season and an average of 17 trees per farm were planted in the 2009/2010 season. Jatropha seeds have been received by less than 15% of farmers every year. CFU has not established nurseries in the villages but rather purchased from private nurseries. This approach may not be as sustainable as building competence locally in running nurseries. Long term supply of plant materials will also be more costly.

Another indicator is related to training of MACO staff. According to our information these trainings have been undertaken.

CAP1 has also planned to implement 51 on-farm and on-station trials. This research has been conducted by GART in collaboration with CFU. The results have been published in GART yearbooks, but GART has not published these data in national, regional or international scientific journals. More work should be done to make the research more visible through presentations in international journals and at conferences.

The production and distribution of technical handbooks (130,000) seems to have been undertaken and a CA association has been established. The technical handbooks have not been translated into local languages. Field days have also been held.

6.15. POSSIBLE AREAS FOR IMPROVEMENTS OF THE CFU PROGRAMME

Many positive effects have been achieved through CAP1. Farmers have started to use the technologies and there is a positive economic development in the project areas. Despite this, the monitoring undertaken by Noragric has shown that there are possibilities for improving the quality of the project. This relates to how CA agriculture is practiced in the project areas, adoption rates, sustainability of the project, extension messages, limited recognition of cultural factors, and a lack of mainstreaming into national policies.

Conservation agriculture is based on the principle of continuous minimum mechanical soil disturbance (1), retention of crop residues (2) and improved crop rotations (3). Much has been achieved in CAP1 with regard to tillage methods and improved rotation, but still very few farmers in the project areas retain crop residues as mulch. Many of the ecological benefits related to CA are connected to retention of crop residues (Buerkert et al. 2000). Mulching is important with regard to building soil organic carbon, increasing the infiltration of water into soil, improvement of the water holding capacity of the soil, regulating oil temperatures, improving exchange capacity (ability to retain nutrients), and controlling build-up of soil acidity. In Zimbabwe it has been found that mulching is particularly important in order to increase soil organic carbon content in sandy soils (Chivenge et al. 2007) whereas reduced tillage will contribute to increased soil carbon content in fine textured soils (clay). Changes in tillage method and crops grown are easier for the farmers to accept than mulching because tillage and crop choice do not require any fundamental changes in the farming system. Retention of crop residues requires changes in the grazing system and is therefore a change in the farming system that is more difficult to achieve. The livestock in Zambia roam freely after the cultivation season and very limited quantities of crop residues are left when the new season starts. It will therefore only be possible to practice CA in Zambia correctly if the grazing system is changed. This will require the establishment of land-use plans or a plan for grazing management. Increased focus on stabilization of animals and fodder production can be part of such a plan. Increased use of herding is also a measure to ensure that livestock do not not graze on crop residues. It appears that CAP1 has not given sufficient attention to this. Unless this issue is addressed, no real improvements in soil properties can be expected.

The size of the basins promoted by CFU to farmers is 15 cm wide, 30 cm long and 20 cm deep. In Zimbabwe where CA is promoted by CIMMYT the recommended size of the basins is 15 cm wide, 15 cm long and 15 cm deep (Mupangwa et al. 2006)**.** This implies that the workload of constructing the basins has more than doubled in Zambia compared to Zimbabwe (in theory). This can be a critical factor for adopting basins in Zambia. However, it is difficult to know which of these dimensions the optimum one is. The average area under CA basins for those practising basins was 0.71 hectares while the average size for those practicing ripping is 1.21 hectares (Nyanga et al. 2011). It therefore appears that it is easier to upscale ripping than basin. The new project will also give more emphasis to ripping. Basins may be a good choice in more heavy soil where infiltration of water is a problem, but basins may not be needed on lighter soils. Under such conditions it may be sufficient to hill place seeds and fertilizer in combination with mulching in a zero tillage system. Mulching can improve moisture conditions in the soil to the same extent as the basins, but the labour requirement will be much lower. The research component in CAP1 has not efficiently addressed this issue.

Digging of basins and ripping in the dry season has not been easy to introduce. In the dry season, households are engaged in other activities than farming and there is no tradition for tilling the soil. The soil is also hard and difficult to work during this period (Umar et al. 2011). It has also been difficult to convince farmers to use traction animals in the dry season. The soil is hard and there is not much fodder available for the animals. It is against the cultural tradition to use traction animals during this season.

Access to CA equipment is a constraint related to further expansion of conservation agriculture. Only 13% of the farmers have access to a ripper and there is a need for closer engagement with the private sector to improve access to this equipment (Nyanga et al. 2011). Further expansion of CA in Zambia will seriously be affected if this issue is not addressed.

Sowing in basins and along ripping lines will make it possible to place fertiliser adjacent to the seed allowing for more efficient utilization of fertilizer. The recommendation in Zambia in conventional agriculture is to apply 200 kg Compound D per hectare as basal dressing and 200 kg urea per hectare applied as top-dressing at knee high stage of maize. It appears that some CA farmers are following the same recommendation for fertiliser application as in conventional agriculture. This probably results in inefficient use of fertiliser. CFU recommends 125 kg Compound D as basal fertiliser equivalent to 12.5 kg N per hectare. ICRISAT in Zimbabwe has found that rates as low as 8.5 kg N per hectare applied as microdoses gives a good response (Twomlow et al. 2010). In Zimbabwe these results have been used with ammonium nitrate, a fertiliser type that only contains nitrogen. There is a need for research that can determine appropriate fertilizer rates and fertiliser types in CA systems. However, the fundamental problem for CA farmers in Zambia is that they are not using sufficient quantities of fertilizers (organic and mineral).

For further upscaling of the CA technologies on large areas it is important to give more emphasis to the correct use of herbicides. The handling of herbicides in households is often dangerous and the herbicides are not applied in correct rates. As a large actor in agricultural development in Zambia, we also think CAP1 should have given more attention to the type of herbicides distributed to the farmers. Outdated herbicides like atrazine and paraquat are still in use.

The project has developed information materials of very good quality but this material is only available in English. This has the consequence that many farmers are not able to understand the material but have to rely on what is explained at the meetings.

The scientific community has lamented over the lack of sound scientific evidence which proves that CA techniques are efficient. Giller et al. (2009, 2011) posed several questions and concluded that there is an urgent need for a critical assessment of the ecological and socio-economic conditions under which CA is best suited for smallholder farming in Sub-Sahara-Africa. There is a need for more scientific information about the yield effects of CA, the effects of CA on soil properties and water balance, and the labour and socio-economic implications of CA. The effect of gender should be assessed as CA will change labour requirements of different farm operations. The research component of CAP1 has not properly assessed these questions. The collaboration between GART and CFU has not been optimal. It appears that the research questions and research design have to a large extent been defined by CFU and that there is limited involvement of GART in this phase. The experiments are conducted partly by GART and partly by CFU. The research results seem mainly to be published in annual reports by GART and there is no publication of the results in national, regional or international journals. This has the consequences that the impact of the results beyond Zambia is very limited. Stakeholders (policy makers, farmers, donor community) need to be convinced of the positive effects of CA/CF. If major policy makers on agricultural development are not convinced about the merits of the system, they are not likely to invest in scaling up CA. More research is therefore needed not only to document what has been achieved, but also to continue development of CA systems that are suitable for the different agro-ecological and socio-economical conditions.

The CFU agents have quota that they have to fulfil with regard to adoption of CA. This has the consequence that the extension message may be too favourable with regard to the impact of CA and that negative aspects or particular challenges with regard to CA are not given sufficient attention. There are reports that farmers think they have not be given correct advice from the CFU extension agents.

CFU is not the only organization promoting CA/CF in Zambia. The Ministry of Agriculture had a large programme on CA supported by Norwegian funding (CASPP). It was observed that there were locations where both CFU and CASPP were operating. It was obvious that there was a lack of coordination between the two programmes. The incentive structure was also not the same in the two programmes which led to farmers selecting the programme which can give the best incentives, or they benefited from the incentives of both programmes. This has led to an inefficient use of resources.

The way the CAP1 has been planned and implemented is to some extent contrary to current development thinking and participatory development approaches advocated by leading development think tanks like the Institute of Development Studies in Brighton, U.K.. However, this is not necessarily wrong as long as the project gives positive results. The extension approach is to some extent similar to training and visit programmes in World Bank projects in the 1980s and 1990s. CF/CA has been presented to the farmers as a package with a detailed description how it should be practiced. This gives the farmers little room for adaptation to local conditions. There has been little or no involvement of the farmers in the development of the extension message. The advantage of such an approach is that it has been possible to reach out to many farmers and villages through the use of farmers as extension agents. It would have been difficult for CFU to reach as many farmers if a participatory approach had been adopted. A participatory approach will often involve in-depth discussions with farmers on priorities and choice of technologies. Since the aim of CFU is to have regional impact and reach a high number of farmers it may not be reasonable to criticize CFU for the approach chosen. However, CFU should probably still have paid more attention to adoption to local conditions. In the Southern region there is a stronger tradition for use of animal traction and ploughing since the Tonga people are known as cattle keepers. CFU should here probably have been giving more emphasis on using ripping by oxen. In th Eastern province, the hoe culture is stronger. This is the area where it is most easy to introduce basins.

Supply of mineral fertiliser, improved seeds, herbicides, pesticides and credit has not been the role of CAP, but the supply of these inputs can have a decisive role with regard to the uptake of CA in Zambia. CA can be practiced without access to these inputs, but the agronomic effect of CA on yield and labour productivity may be limited without these inputs. Fertiliser in Zambia is often distributed late and the effect of early sowing in CA may well disappear if the crops are not well fertilized. Fertiliser is also necessary in order to produce more straw that partly is used for fodder and partly as mulch. If no fertiliser is used, it is very unlikely that it will be possible to recycle much of the straw as no surplus straw production that can be recycled is available. Access to herbicides is also crucial, particularly for practicing ripping on large areas.

In terms of trees, CAP1 has only focused on the promotion of *Faidherbida albida, Moringa oleifera* and *Jatropha curcas*. In reality the focus has only been on promotion of *Faidherbida albida*. This approach may be too limited in scope as there are also other trees that can improve soil fertility in Zambia. ICRAF has for many years been promoting different types of agroforestry systems like alley cropping, relay planting and improved fallows. Trees that have been tested include *Gliricidium sepium, Sesbania sesbane* and Tephrosia. An analysis of profitability of agroforestry systems compared to maize with and without fertiliser showed the Net Present Value over a five-year period was highest for maize receiving only mineral fertiliser, but the agroforestry system also clearly gave a better profitability than unfertilized maize (Ajayi et al. 2009). However, the value cost ratio was higher for the agroforestry system (*Sesbania sesbane* maize rotation or Gliridia maize intercropping) than in fertilised maize. Labour requirement was not higher in these agroforestry systems than for fertilized maize. Farmers have not given much attention to the Faidherbida seedlings that have been planted in CAP1. Poor farmers generally have a short planning horizon and many farmers cannot wait for benefits that will come in 5 to 10 years. Planting faster growing trees like *Gliricida sepium* or *Sesbania sesbane* in combination with *Faidherbida albida* could have addressed this problem.

CA in Zambia has up to now been mainly promoted through projects. CA is part of the policies on agricultural development but it seems that promotion of CA is not mainstreamed within the Ministry. Most of the Ministry's resources are used on subsidizing mineral fertilizers and the purchase of maize, and there is no particular financial push to promote CA.

6.16. POSITIVE IMPACT OF CAP1

Much has been achieved during the first phase of CAP1. More than 120,000 farm households have been reached through the project and uptake is around 70% (Nyanga 2012a). Technically the promoted technology works well, but it appears that ripping using different types of traction has the biggest potential for upscaling. CA has provided some options for the less endowed households to plant early in basins thus reducing food insecurity during the hunger peak period because of early harvest CA has led to earlier sowing as the farmers are encouraged to prepare the land in the dry season.

The CAP1 has furthermore addressed the issue of maize dominance in the farming system by emphasizing the use of crops like groundnut, cowpea, cotton, cassava and sweet potato in the farming system. Improved rotation may reduce the pressure from pest and diseases and N-fixation crops will in addition provide nitrogen. Cassava and sweet potato will give a yield also in dry years and can resist dry spells. Cassava was also able to give a good yield in the flooding year of 2007/2008 (Umar & Nyanga 2011). A harvest of cassava and sweet potato is also available during the time of the year when there is food shortage. These crops can therefore have a vital role in improving food security.

Non-CA farmers also attend CA trainings. They continue to plough, but they have diversified their production and practice more crop rotation (Nyanga et al. 2011). This shows that the non-CA farmers have also benefited from CA training.

The CAP project has furthermore contributed to training of farmers in good farming methods and the farmers have been followed up over many years. This has contributed to increased knowledge of CA farming.

6.17. SUSTAINABILITY OF THE PROJECT

A true test of the sustainability of the project can only be undertaken some years after its completion. However, it is likely that some of the results that were achieved during the project period will have a lasting effect on agriculture in the project areas. One of the changes that will have a persistent effect is the cultivation of cassava and sweet potato. These crops give an important contribution to food security and are easy to grow. It will also be possible to grow these crops in a harsher environment. The impact on the tillage system could also be a lasting effect. We believe that many smallholders will continue to establish small plots with basins around their homestead for food security reason. We also think ripping will grow, but this is very much dependent on the supply of rippers and herbicides for weed control.

The increased focus on CA by the donor community, regional political bodies, national government, and private sectors is also likely to contribute positively on the sustainability of CA practices in Zambia.

CA can be practiced by subsistence farmers without any use of input or credit support, but CA will be more sustainable if the input supply system functions properly. The reason is that there is a stronger effect of fertilization in the CA system as compared to the CV system and herbicides are important if CA is to be practiced on larger areas. A favourable relationship between the price of products (maize price) and input prices will make it more attractive to practice CA.

Institutional collaboration that includes local and international universities, research institutions, the National Farmers Union, CFU and other private sectors is furthermore essential for the sustainability of CA practice in Zambia.

To enhance sustainability at the household level, we strongly feel that translation of extension materials such as leaflets into local languages and increasing their availability could enhance the competence of individual farmers in sustainable agronomic practices.

Farmers' competence in sound agricultural methods has been increasing during the project period. This competence will remain even though the project will phase out. This is competence related to tillage method, the importance of crop rotation, new crops, the importance of trees in the farming system, weed control, institutional development and market integration.

6.18. NETWORKING, MONITORING AND EVALUATION OF THE PROJECT

CFU has not given much emphasis to networking in CA. CFU has been good in training its own staff and collaborative farmers. Extension personnel of the Ministry of Agriculture have also been trained. A national organization on CA has also been established. It is however difficult to assess the strength of this organization.

Noragric was given a role at the beginning of the project in relation to design, establishment and implementation of a comprehensive monitoring and evaluation system. Noragric selected about 540 farmers in the first season (later reduced to 440 due to drop-outs) and these farmers were followed through 4 seasons. In addition to a large survey, more specialized surveys were undertaken on labour use, the economics of CA, CA and soil quality, yields in CA and the effect of the *Faidherbia albida* tree on soil properties. CFU also hired a Zambian consultancy firm (IMSC) in order to include a larger number of farmers. Noragric has met with CFU in an annual meeting to discuss the output from the project and the implications of the findings for project implementation. It is difficult to assess to which degree these recommendations have been taken on board by CFU.

7. LESSONS LEARNED

1. CA has been found to be a useful approach for stallholders farmers in Zambia
2. There is a clear yield benefit of planting basins as compared to other tillage systems.
3. CA has led to earlier planting.
4. Farmers have expanded the use of CA, but farmers continue to plough the land in addition to using CA practices. Ripping has expanded faster than the use of basins.
5. The labour demand in establishing basins is not much different from practicing hoe cultivation.
6. The *chaka* hoe may not be an appropriate tool to practice CA particularly for women because it is too heavy.
7. Farmers have benefitted from distribution of planting materials of cassava and sweet potato.
8. The way farmers practice CA in Zambia does not lead to improvements in soil properties. The reason is that crop residues are not retained as mulch. It is therefore difficult to claim that the farmers are practicing CA as mulching is a key principle of CA. They rather practice reduced tillage.
9. The new phase of the project should give more emphasis on how livestock can become an integrated part of CA.
10. *Faidherbida albida* improves soil properties and maize yield, but the farmers show limited interest in protecting the trees after they have been established.
11. Farmers' use of herbicides has increased, but many farmers lack the competence in how to use the herbicides.
12. Introduction of CA has changed women farmers' labour demand. The labour demand has been reduced for clearing the land, but the labour demand for weeding has increased.

8. CONCLUSIONS

The overall effect of CAP1 is positive. Farmers in project areas are gradually changing to conservation agriculture, but it appears that cultivation by ripping has the potential for further up-scaling. The reason is that the labour requirement for basin cultivation is high compared to ripping. However, cultivation using basins can still be important for food security reasons as it ensures higher yields than any of the other tillage methods. Maize production has not increased at the farm level. The reason is probably that CA is still practiced on only 26% of the land. However, one of the major benefits of the project has been that it has contributed to an increased production of tuber crops like cassava and sweet potato through provision of planting materials. Production of grain legumes has also increased. These production increases have contributed to augmenting farmers' income from crop production. The food security was improved and farmers have increased the number of livestock, invested in improved housing and increased consumption of consumer goods like medicines and groceries.

Despite these efforts to diversify production, maize is still cultivated on nearly 60% of the land. A positive effect of the project is that it appears that the poorer segments of the population are those who so far have benefitted most from CAP1. Agricultural policies in Zambia stimulate maize production through input subsidies and purchasing maize at a higher price than given at the regional market.

The environmental impacts of the project have been less convincing. The project has not contributed to increased soil organic carbon content. The reason is that the principle of CA of retention of crop residues is not respected. Livestock is roaming freely in the dry season making crop residue retention impossible. The project has distributed many seedlings of *Faidherbidia albida* but it appears that the farmers give little attention to the planted trees. A positive effect of the project was that the CA farmers do not expand the cultivated area whereas there is a tendency for non-CA farmers to expand the cultivated area.

There is a need to strengthen research on CA in Africa. CA is still new on the continent and CA is practiced under highly variable agro-ecological and socio-economic conditions.

The project has shown that conservation agriculture deserves to be labelled under the term climate smart agriculture. The productivity gains of CA are convincing and CA will also make agriculture more resistant to climate change as a result of better moisture retention and because agriculture has become more diversified (more tuber crops, legumes and trees). However, it will take many years before any effect of CA on the mitigation of Green House Gases can be seen.

The Norwegian embassy and CFU has initiated a new project on conservation agriculture in Zambia. We think this can be justified as there is a need to consolidate and further expand CA in Zambia.

9. REFERENCES

Ajayi, OC, Akinnifesi, FK, G. Sileshi and W Kanjipite 2009. Labour inputs and financial profitability of conventional and agroforestry-based soil fertility management practices in Zambia. Agrekon 48: 276- 292.

Aune, J.B. 2012. Conventional, organic and conservation agriculture: Production and environmental impact. In E. Lichtfouse (eds). Agroecology and strategies for climate change. Sustainable Agriculture Reviews 8: 149-166.

Borge, E.S. 2010. Conservation farming in the central and southern provinces of Zambia - a study of the characteristics of CF and the reasons for adoption. M.Sc thesis, Noragric, Norwegain University of Life Sciences, 70 pp.

Buerkert A; Bationo A; Dossa K 2000. Mechanisms of residue mulch-induced cereal growth increases in West Africa. Soil Science Society of America Journal 64: 346-358.

CAADP 2011. Pillar 1: Land & water management. http://www.nepad-caadp.net/pillar-1.php

CFU 2007. Conservation farming & conservation agriculture. Handbook for ox farmers in agro-ecological regions I and IIa, 2007 edition. http://alturl.com/v9mhs

CFU 2011. The practice of conventional and conservation agriculture in east and southern Africa. Conservation Farming Unit, 80 pp.

Chivenge P.P. Murwira, H.K., K.E. Giller, P. Mapfumo, J. Six 2007. Long-term impact of reduced tillage and residue management on soil carbon stabilization: Implications for conservation agriculture on contrasting soils.

FAO 2011. The main principles of conservation agriculture. http://www.fao.org/ag/ca/1b.html

FAO 2011. What is conservation agriculture. http://www.fao.org/ag/ca/1a.html

FAO 2012. Climate smart agriculture for development. http://www.fao.org/climatechange/climatesmart/en/0

Freim, L.O. 2008. How will small scale farmers in Zambia benefit from growing of Jatropha?. M.SC thesis, Noragric, NorwegianUniversity of Life Sciences, Norway, 90 pp.

Marongwe, LS, K. Kwazira, M. Jenrich, C. Thierfelder, A. Kassam and T. Friedrich 2011. An African success: the case of conservation agriculture in Zimbabwe. International Journal of Agricultural Sustainability 9: 153-161.

Mason,M.N., Burke, WJ, Shipekesa A and Jayne TS. The 2001 surplus in smallholder maize production in Zambia: drivers, beneficiaries and implications for agricultural and poverty reduction policies . Working Paper no.58. Food Security Research Projects, Lusaka, Zambia, 35p.

Mazvimavi K. and S. Twomlow 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agricultural Systems 101: 20-29.

Mazvimavi Kizito 2011. Socio-economic analysis of conservation agriculture in Southern Africa. Network Paper 02. FAO, Rome. http://www.fao.org/docrep/013/i2016e/i2016e00.pdf

Mupangwa W., Love D., Twomlow S. 2006. Soil–water conservation and rainwater harvesting strategies in the semi-arid Mzingwane Catchment, Limpopo Basin, Zimbabwe. Physics and chemistry of the Earth, Parts A/B/C 31: 893-900.

Mulemba H. 2009. The livestock sector in Zambia and rising food prices. Country briefing-Zambia. International Institute for Sustainable Development, Manitoba, Canada..

Nyanga, P. H., Johnsen, F. H. & Aune, J. B. (2011). *The Conservation Agriculture Project (CAP) implemented by the Conservation Farming Unit (CFU) of the Zambia Ntional Farmers Union (ZNFU), 2009/2010 Monitoring and Evaluation Report*.

Nyanga P., Johnsen F.H., Aune J.B. and Kalinda T.H. 2011. Smallholder perceptions of climate change and conservation agriculture: evidences from Zambia: Journal of Sustainable Development 4: 73- 85.

Nyanga, P. H. (2012a). Factors influencing adoption and area under conservation agriculture: A mixed methods approach. *Sustainable Agriculture Research*, 1 (2): *in press*.

Nyanga, P. H. (2012b). Food Security, Conservation Agriculture and Pulses: Evidence from Smallholder Farmers in Zambia. *Journal of Food Research*, 1 (2): 120-138.

Nyanga, P. H., Johnsen, F. H. & Kalinda, T. H. (2012). Gendered Impacts of Conservation Agriculture and Paradox of Herbicide use among Smallholder Farmers. *International Journal of Technology and Development Studies*, 3 (1): 1-24.

Nyanga P. 2011. Up-scaling conservation agriculture in Zambia: Some key practical barriers in practice of minimum tillage among smallholder farmers. WCCA.4 p.

Payne, WA, Williams, J.A, Moussa KAM, Stern RD 1998. Crop diversification in the Sahel through use of environmental changes near Faidherbia alida (Del) a Chew. Crop Science 38: 1585-1591

Siegel, P.B. and Alwang J. 2005. Poverty reduction potential of smallholder agriculture in Zambia: Opportunities and constraints. World Bank Africa Regional Working Paper Series no 85. Washington D.C., The World Bank.

Thierfelder, C. and P. Wall 2009. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. Soil and Tillage Research 105: 217-218.

Twomlow S, D. Rohrbach, J. Dimes, J. Rusike, W. Mupangwa, B. Ncube, L. Howe, M. Moyo, N. Mashingaidze and P. Mahposa 2010. Micro-dosing as a pathway to Africa's green revoloution: evidences from broad-scale on-farm trials. Nutrient Cycling in Agroecosystems 88: 3-15.

Umar, B.W., Aune J.B., Johnsen F.H. and Lungu O.I. 2011.Options for improving smallholder agriculture in Zambia. Journal of Agricultural Science, 3: 50-62.

Umar, B.W., Aune J.B., Johnsen F.H. and Lungu O.I. 2012. Are smallholder farmers economists? A dual-analysis of farmers' expenditure on conservation and conventional agriculture systems. Journal of Sustainable Agriculture (Forthcoming). DOI10.1080/10440046.2012.661700

Umar, B. B. & Nyanga, P. H. (2011). *Adapting Conservation Agriculture for smallholder farmers: potential of cassava (Manihot esculenta) in Zambia*. Available at: http://aciar.gov.au/files/node/14068/adapting_conservation_agriculture_for_smallholder__27713.pdf.

Umar, B. B., Nyanga, P.H (2011). Conservation Agriculture and Rainfall Variability in Zambia: Is CA a promising option for responding to droughts and floods? 5th World Congress on Conservation Agriculture. Brisbane Australia, WCCA/Farming Systems Design.

Umar, B. B., Nyanga, P.H (2011b). Conservation Agriculture with Trees: Trends and Possibilities among smallholder Zambian farmers. 5th World Congress on Conservation Agriculture. Brisbane, Australia, WCCA/Farming Systems Design.

Umar, B. B., Nyanga, P.H. (2011a). Integrating Conservation Agriculture with Trees: Trends and Possibilities among Smallholder Farmers. 5th World Congress of Conservation Agriculture incorporating 3rd Farming Systems Design Conference. Brisbane, Australia, WCCA/FSD Local Organizing Committee.

Umar, B.N., Aune, J.B., Lungu O.B. 2012. Effects of Faidherbidia albida on the fertility of small holders conservation agriuclture systems in Eastern and Southern Zambia. African Journal of Agricultural Resesarch (in press)

World Bank 2010. Zambia. Impact assessment of the fertilizer support program. Analysis of effectiveness and efficiency. Report No. 54864-ZM, 75 p.

Weber, MT 2012. Empirical information on smallholder maize production and fertilizer use in Zambia. Michigan State University and Central Statistics Office Zambia. http://www.aec.msu.edu/fs2/zambia/FSRP_WB_Fert_KickOff.pdf

Whiteside, M. 2011. Evidence base for climate resilient and productive agriculture in Southern Africa. DFID, 44p.

Publications from Noragric on CA in Zambia

Nyanga, P. H., Johnsen, F. H. & Aune, J. B. (2011). *The Conservation Agriculture Project (CAP) implemented by the Conservation Farming Unit (CFU) of the Zambia Ntional Farmers Union (ZNFU), 2009/2010 Monitoring and Evaluation Report*.

Nyanga P., Johnsen F.H., Aune J.B. and Kalinda T.H. 2011. Smallholder perceptions of climate change and conservation agriculture: evidences from Zambia: Journal of Sustainable Development 4: 73- 85.

Nyanga, P. H. (2012a). Factors influencing adoption and area under conservation agriculture: A mixed methods approach. *Sustainable Agriculture Research*, 1 (2): *in press*.

Nyanga, P. H. (2012b). Food Security, Conservation Agriculture and Pulses: Evidence from Smallholder Farmers in Zambia. *Journal of Food Research*, 1 (2): 120-138.

Nyanga, P. H., Johnsen, F. H. & Kalinda, T. H. (2012). Gendered Impacts of Conservation Agriculture and Paradox of Herbicide use among Smallholder Farmers. *International Journal of Technology and Development Studies*, 3 (1): 1-24.

Nyanga P. 2011. Up-scaling conservation agriculture in Zambia: Some key practical barriers in practice of minimum tillage among smallholder farmers. WCCA.4 p.

Umar, B.W., Aune J.B., Johnsen F.H. and Lungu O.I. 2011.Options for improving smallholder agriculture in Zambia. Journal of Agricultural Science, 3: 50-62.

Umar, B.W., Aune J.B., Johnsen F.H. and Lungu O.I. 2012. Are smallholder farmers economists? A dual-analysis of farmers' expenditure on conservation and conventional agriculture systems. Journal of Sustainable Agriculture (Forthcoming). DOI10.1080/10440046.2012.661700

Umar, B. B. & Nyanga, P. H. (2011). *Adapting Conservation Agriculture for smallholder farmers: potential of cassava (Manihot esculenta) in Zambia*. Available at: http://aciar.gov.au/files/node/14068/adapting_conservation_agriculture_for_smallholder__27713.pdf.

Umar, B. B., Nyanga, P.H (2011). Conservation Agriculture and Rainfall Variability in Zambia: Is CA a promising option for responding to droughts and floods? 5th World Congress on Conservation Agriculture. Brisbane Australia, WCCA/Farming Systems Design.

Umar, B. B., Nyanga, P.H (2011b). Conservation Agriculture with Trees: Trends and Possibilities among smallholder Zambian farmers. 5th World Congress on Conservation Agriculture. Brisbane, Australia, WCCA/Farming Systems Design.

Umar, B. B., Nyanga, P.H. (2011a). Integrating Conservation Agriculture with Trees: Trends and Possibilities among Smallholder Farmers. 5th World Congress of Conservation Agriculture incorporating 3rd Farming Systems Design Conference. Brisbane, Australia, WCCA/FSD Local Organizing Committee.

Umar, B.N., Aune, J.B., Lungu O.B. 2012. Effects of Faidherbidia albida on the fertility of small holders conservation agriuclture systems in Eastern and Southern Zambia. African Journal of Agricultural Resesarch (in press).

PhD theses:

Nyanga, P. 2012. Conservation agriculture among smallholders in Zambia: attitudes and social impacts. Philosophiae Doctor (PhD) thesis 2012: 39. UMB, Ås, Norway. Thesis accepted for defence.

Umar, B.B. 2012. From maize monocropping to conservation agriculture: a multiperspective analysis of smallholder conservation agriculture in Southern, Central and Eastern Zambia. Philosophiae Doctor (PhD) thesis 2012: 25. UMB, Ås Norway. Accepted PhD thesis.