Final Report

Developement and Introduction of Conservation Agriculture

at the proposed Lake Tana Biosphere Reserve

Submitted to

The Nature and Biodiversity Conservation Union (NABU)

March 2014, Bahir Dar

Melesse Temesgen (PhD)

Birhanu Biazin (PhD)

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Abbreviations / Acronyms

ATNESA	Animal Traction Network for Eastern and Southern Africa
BBM	Broad Bed & Furrow Maker
CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIRAD	Agricultural Research for Development (French)
CT	Conservation Tillage
FAO	Food and Agricultural Organization of the United Nations
FGD	Focus Group Discussion
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
NABU	The Nature and Biodiversity Conservation Union
SCS	Soil Conservation Structure
SG2000	Sasakawa Global 2000
SSA	Sub Sahara Africa
SPSS	Statistical Software for Social Sciences
WBISPP	Woody Biomass Inventory and Strategic Planning Project

1. Introduction

1.1 Overview of Conservation Agriculture

By 2050, the global food demand will increase by 70% (Bruinsma, 2009). There will be more demand for nutritious (high protein) food. Yet more efficient use of natural resources is required. Conservation Agriculture (CA) is considered as one of the most important agricultural practices that would enable sustained and improved crop yields under diverse agro-ecological conditions. The three major principles of conservation agriculture are minimum tillage, crop rotation and maintaining soil cover. Hence, the main benefits of CA encompass reduction of soil erosion, conservation of soil moisture in dry land areas, improvement of soil structure and nutrients, reducing labour and energy, carbon sequestration and mitigation of climate change. Many studies claim better crop yields even in the short-term (Derpsch, 2003; FAO, 2008; Hobbs, 2007). However, the global distribution of Conservation agriculture showed that it is widely applied in South America, North America and Australia. These three continents cover about 96% of the CA practices applied in the globe. Asia (2.3%), Europe (1.1%) and Africa (0.3%) share the smallest proportion of the CA coverage.

Although Africa covers 20.2% of the global land & 15% of population, it constitutes only 0.3% of the CA in the world. A wide variety of international organizations (e.g. FAO, CIRAD, CIMMYT, ICRISAT, the African Conservation Tillage Network, etc.) actively promoted CA with smallholder farmers in Africa. However, the adoption of CA by smallholder farmers has been very low in Africa. Giller et al. (2009) argued that several of the previously introduced CA techniques do not ‘fit’ within the majority of current smallholder farming systems in Africa. Mulching can be difficult for smallholders as crop residue is desperately needed as source of livestock feed (Erenstein, 2002, 2003). Hence, alternative sources of livestock feed should be introduced to promote crop residue mulching. In dry areas, there is insufficient amounts of residues due to water shortage and degraded nature of soil resources (Jat et al., 2012). Apart from that, herbicides and fertilizers are often needed to realize the benefits of CA. Yet they are not available to smallholders in Africa (Gowing and Palmer, 2008). Smallholders are reluctant to adopt CA practices if they face increased demands for labour to remove weeds during the first years of introduction (Affholder et al., 2010). These all scenarios indicate that site-adapted and acceptable conservation agriculture technologies are required.

Recently, researchers have paid increasing attention to the development of appropriate conservation tillage (CT) practices suitable for dry land farming systems in SSA (ATNESA, 2010; Rockstrom et al., 2009). CT encompasses a wide range of tillage techniques that have been tested and developed in many different places (Biamah et al., 1993; Fowler and Rockström, 2001; Temesgen, 2007). It covers a spectrum of non-inversion practices, from zero-tillage to reduced tillage, aiming at maximizing infiltration and soil productivity, and minimizing water losses while simultaneously conserving energy and labor.

1.2 Conservation Agriculture in Ethiopia

The previous efforts of promoting CA techniques in Ethiopia focused on introducing minimum tillage and zero tillage in association with herbicides (mainly Roundup glyphosate) through mainly non-governmental organizations like SG2000. With intensive applications of fertilizers and roundup, substantial crop yields were obtained from implementations of CA for teff and wheat in mid and high altitude areas of Ethiopia like Debrezeit and Gojjam. Long-term field experiments in Northern Ethiopia revealed that significant improvements in crop yield could be observed after about three years of cropping with CA (Araya et al., 2011). The performance of the CA techniques, however, depends on the fertility status of the soils and climate situations. Field experiments carried out over 6 years period showed that zero-tillage with application of herbicides gave no or marginal improvement in yield of teff (Eragrostistef [Zucc.] Trotter), wheat (Triticumaestivum L.) and lentils (Lens culinaris Medikus) (Erkossa et al., 2006).Those CA packages that have been promoted in association with intensive fertilizer and herbicides uses could not be adopted by the farmers in the absence of external funds as the prices of herbicides and fertilizers are not affordable by the smallholder farmers. On the other hand, there is a growing concern on the environmental and human health implications of herbicides such as Roundup in many parts of the World. Particularly, in biosphere reserve areas where sustainable management and utilization of natural resources is a prime concern, there is a need to develop appropriate CA techniques that can be implemented without the application of herbicides. There were successful experiences of promoting appropriate conservation tillage techniques by synergizing indigenous knowledge of tillage and land management with improved technologies in Ethiopia (Nyssen et al., 2011; Temesgen, 2007)

Other experiences showed that planning of appropriate CA techniques requires a closer scrutiny of the socio-economic, institutional and agro-ecological conditions of the target areas. Farmers adapt and implement new technologies of CA with their own understanding and interpretation of the underlying principles and rationale, their own priorities and the possibilities to integrate new approaches into their farming systems (Giller et al., 2011).

1.3. Objectives of the study

The overall objective of this project was to develop a soil-friendly agricultural system in the Lake Tana area based on the multiple-benefit approaches of conservation agriculture. Hence, there are two specific objectives posed to this study: 1) to assess and develop site-adapted conservation agriculture technologies and implementation schemes that are compatible to the Lake Tana environment (package development); and 2) to develop a locally appropriate communication and practical training strategy (training manual) for implementation of the proposed technologies (outreach).

1.3 Description of the Study Area

This study was undertaken in the proposed Lake Tana Biosphere Reserve area that encompasses the terrestrial land area around the Lake Tana. Although the total area of Lake Tana watershed encompasses about 21 districts with a total area of 15,096 km^2, the lake Tana BR includes only some part of the ten districts around the lake with strong ecological, environmental and socio-economic linkages to the lake itself (Heide, 2012; Teshome et al., 2009). The ten districts that are included in the proposed Lake Tana BR are Derra, Fogera, Libo Kemkem, Gondar Zuria, Dembia, Takusa, Alefa, North Achefer, Bahirdar Zuria and Bahir Dar city.

Lake Tana being the largest lake in Ethiopia, it has a surface area of 3156 km^2 at an elevation of 1840 masl. The lake is the main source of the Blue Nile River which is also the main contributor of the Nile River, the longest river in the world. Cultivated lands cover more than 55% of the Lake Tana watershed area (WBISPP, 2002). The agricultural system in the area is dominated by cereal-based system, with an insignificant share by perennials. In association with continued conversion from natural forests and grasslands to crop lands, there is currently an acute shortage of biomass for household energy and feed for livestock. As a consequence, the farmers are using the crop residues as sources of household energy and livestock feed. This has triggered soil fertility decline and soil erosion. In the rugged topographic settings of the Lake Tana watershed area, soil erosion and land degradation are the major challenges that affect both agricultural productivity, wetland sustainability and the lake hydrology. Most of the wetlands are being converted in to croplands.

2. Methods and approaches

A combination of methods has been employed to examine the existing farming system and land management practices, identify the major challenges and opportunities for introduction of new CA packages. Hence, review of secondary sources, reconnaissance field surveys, key informant interviews, focus group discussions and questionnaire survey were undertaken. Moreover, soil sampling and analysis is being undertaken. The different methods and approaches that were employed during this study are presented herein.

2.1 Review of secondary sources, reconnaissance survey and key informant interviews

A review of secondary sources was undertaken to examine the global, regional and national experiences of conservation agriculture development efforts. Hence, scientific articles, conference proceedings and development reports were reviewed. Moreover, relevant information about the Lake Tana basin area and the biosphere reserve was assessed to examine the land-use and land cover changes, farming systems, indigenous tillage and land management practices and challenges and opportunities for further developments. An interdisciplinary team of experts made a round trip to observe the existing farming system and biophysical characteristics. Hence, the experts had made several stops in all the 10 districts that are included in the proposed Biosphere Reserve area and discussed with key informants. The key informant interviewees encompassed farmers, development agents, regional experts at the bureau of agriculture and staffs from the regional agricultural research institute (Figure 1). Based on reconnaissance field visits, identification of potential sites for in-depth study through focus group discussions and questionnaire survey were selected.

Figure 1. Key informant discussion with individual farmers in Gondar Zuria district (left) and North Achefer district (right)

2.2 Focus group discussions

Based on prior selection of the three representative districts where an in-depth study could be undertaken, focus group discussions (FGDs) were held at North Achefer (figure 2), Bahirdar zuria and Gondar Zuria districts. The people included in the FGDs encompassed household heads from both the upstream and downstream areas in the study area. Hence, thorough discussions were undertaken on issues related to cropping patterns, crop rotation, crop residue management, livestock keeping and feed sources, existing land management and tillage practices, etc. The outcome of the FGDs was used to develop a full-blown questionnaire.

Figure 2. Focus group discussion with farmers in North Achefer district

2.3 Questionnaire survey

Based on the outcomes of the key informants interviews and FGDs, a well-thought out questionnaire was developed for formal surveying. The issues examined through the questionnaire survey included socio-economic characteristics, existing cropping patterns, livestock production and feeding systems, indigenous tillage and other land management systems, challenges and opportunities for further introduction and development of CA techniques. Therefore, sixty households were randomly selected for interview from three districts (Gondar Zuria, North Achefer and Bahir Dar Zuria) in the Lake Tana BR area. Hence, there were twenty interviewees from each of the aforementioned districts. Enumerators were trained intensively on the sampling and interview techniques. The result of the survey was analyzed using Statistical Software for Social Sciences (SPSS version 17).

2.4 Soil Sampling and analysis

During the field visits and reconnaissance surveys, it was observed that the dominant types of soils in the Lake Tana biosphere reserve area are black soils and red soils. The red soils are taxonomically the Nitisols while the black soils are Vertisols (Figure 3). The black soils are mainly located in the downstream flood plains. The majority of the areas that are close to the Lake are covered by black soils. The red soils are dominantly found in the hilly slopes and middle stream areas of the ten districts. Accordingly, soil samples were taken from representative sites for both red soils and black soils. Hence, two types of soil samples (disturbed and undisturbed) were taken to analyze selected physico-chemical soil properties. The disturbed soil samples were used to analyze soil organic carbon, Cation Exchange Capacity (CEC) and PH. The undisturbed soil samples were taken to determine soil bulk density. All the soil samples were taken from two soil depths (0-15cm and 16-30cm depths). The top 0-15 cm soil layer is considered as the plough layer by the traditional Maresha plough. The next depth is considered as either the plow pan layer in case it occurs or the layer where leached materials could accumulate. Accordingly, the aforementioned physico-chemical soil properties were analyzed at the laboratory of Adet Agricultural Research Center..

Figure 3. The red soils (Nitisols) and black soils (Vertisols) in the Lake Tana basin

The outcome of the soil analysis revealed that the soil organic carbon status is generally low for both the Nitisols and Vertisols of the study areas. While the surface soil of the Nitisols is moderately acidic, the surface layer of the Vertisols is neutral. Although the fertility status of the sampled soils was not very poor, there is a need to maintain and improve the nutrient status through improved soil amendment techniques.

Table 1. Selected physic-chemical soil properties under Nitisols (red soils) and Vertisols (black soils) in the Lake Tana basin, Northern Achefer, Dembola Mariam

Type of Soil	Depth	%OC	%OM	CEC(meq/100g)	BD (g/cm3)	pH
	0-15	1.04 (0.20)	1.79(0.34)	24.88(6.25)	1.22(0.08)	5.52(0.25)
Nitisols	***16-30***	0.84(0.19)	1.46(0.33)	25.40(8.84)	1.19(0.12)	5.67(0.24)
	0-15	0.90(0.09)	1.56(0.16)	49.69(6.17)	1.42(0.12)	6.67(0.32)
Vertisols	***16-30***	0.71(0.11)	1.22(0.19)	50.49(4.94)	1.50(0.06)	6.85(0.38)

3. Results and discussions

3.1Socio-economic characteristics, farming systems and land management

The outcome of the focus group discussions and questionnaire survey revealed that rain-fed cereal crop farming and livestock rearing are the major sources of livelihood for the farm households in the proposed Lake Tana biosphere reserve area. The most important crops grown in the red soils encompass sorghum, finger millet, maize, teff, niger seed and faba beans. On the other hand, the most important crops grown in the black soils encompass finger millet, Sorghum, teff, chickpea, grass pea, rice, sorghum and sun flower (Figure 5). All of the respondents (N = 60) own more than one cattle. All of the respondents said that livestock feed is a major problem for livestock rearing and they use crop residues as a sources of feed during the dry season.

Soil erosion and fertility decline, water logging problems in black soils and water scarcity during the growing season in red soils were mentioned as the major challenges that affect their improved and sustained agricultural productivity in the area. Moreover, shortage of farmland, shortage of capital to invest on inputs, market problem and labor shortage were also described as causes against increasing productivity and ensuring household food security. All the respondents believed that soil erosion has increased over the years in the Lake Tana watershed.

All the respondents believed that tillage is a very important land management practice without which crop production is impossible. Generally, the traditional *Maresha* plough is used in the area. They apply the consecutive cross-plowing by the traditional Maresha to complete the untilled soils due to the 'V'-shaped incomplete furrows (Figure 4). The questionnaire survey revealed that the frequency of tillage varies with the types of soils and crops (Table 2). The lower number of tillage frequency for Chick pea and grass pea could be explained by the fact that these crops are mostly considered as secondary crops grown during the dry season.

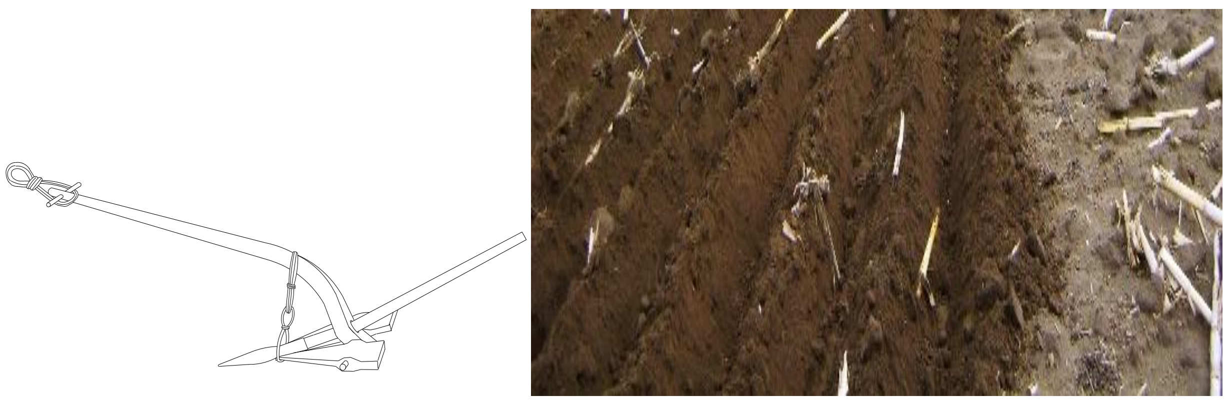

Figure 4. Pictorial representation of the traditional Maresha implement (left) and the 'V'-shaped furrow made by the Maresha tillage

Figure 5. Sorghum and finger millet as a dominant cereal crops in much of the districts around the Lake Tana

In all the surveyed districts, all the respondents believed that leaving crop residues on the farm enhances crop yields. However, only 19% of the respondents leave all or part of the crop residue on the farm to enhance the fertility of their land. In Bahr Dar Zuria district farmers leave crop residues of nigger seed in the field especially if the next crop is maize. They believe that the residue of nigger seed improves soil fertility and maize seedlings can still emerge in the presence of the crop residues. Farmers believe that it is not possible to plant finger millet in fields where maize stocks are left due to various reasons. Seeds of finger millet can fall on maize stocks and hence fail to germinate. Maize stocks harbor pests such as stock borers. It is difficult to prepare seedbed for finger millet in the presence of maize stocks as the latter requires well prepared seedbed like teff. There is a low level of intercropping in the Lake Tana watershed area. Intercropping of maize with kale seed was mentioned by 8% of the respondents.

Table 2. Mean frequency of tillage for different types of crops and soil types in the Lake Tana BR

Crop type	***Mean Tillage frequency***	
	Red soils	***Black soils***
Maize	5	4
Teff	5	4

Finger Millet	5	4
Chick pea and grass pea	2	1

3.2Challenges and opportunities for the development of Site-adapted CA techniques

Potential challenges and opportunities for possible developments of CA techniques were identified through focus group discussions and questionnaire survey in the Lake Tana watershed areas (Table 3).

Table 3. Potential CA technologies against the potential challenges and opportunities for development in the Lake Tana watershed areas

Potential CA technologies	***Challenges and constraints***	***Opportunities***
Reduced/minimum tillage	The traditional tillage implement, *Maresha*, creates V-shaped furrows that leave unplowed strips of land between furrows. As a result, farmers are forced to orient their next plowing direction perpendicular to the first, i.e., cross plowing. Cross plowing forces farmers to increase tillage frequency. It also leads to orientation of furrows along or nearly along the slope thereby aggravating rill formation and hence soil erosion due to increased flow momentum.	A recently developed plow called *Arashogel* makes it possible to avoid cross plowing thereby reducing tillage frequency. Arashogel is equipped with sharp wings that cut the strips of land left by Maresha and creates invisible barriers that control water flow along the slope leading to reduced surface runoff and soil erosion.
Crop rotation	In waterlogged fields Vertisols farmers find it difficult to practice	Farmers can drain excess water using BBM technology, which

	double cropping (e.g. wheat – chickpea) as they have to wait until the excess water is drained, which means losing the main cropping season during which they could grow cereals to be followed by legumes.	enables them to plant cereals early in the season. The cereal crop can then be harvested and legumes can be grown using the residual moisture. Extended period of soil cover reduces soil erosion and increases carbon sequestration
Maintaining soil cover	Use of crop residues for livestock feed and household energy coupled with communal grazing after harvest makes leaving crop residues difficult in the field to maintain soil cover. Moreover, water logging problem in black soils forces farmers to wait until September to plant chickpea. The soil is exposed to erosion during July and August as farmers keep on plowing. On the other hand, leaving crop residues may enhance pest and disease prevalence.	In areas close to the lake, farmers can plant agro ecology specific multi-purpose trees (MPTs) such as pigeon pea to maintain soil cover during the dry season and use the leaf as protein supplement for livestock. In black soils, use of BBM technology to drain excess water thereby allowing early planting of cereals can increase the length of time when the soil is covered with crop. If the farmers grow improved fodder (grasses and legumes), they can leave some part of the crop residue, especially stubble, to maintain the soil fertility and reduce its susceptibility to erosion. To reduce the prevalence of pest and diseases, both the cereals and legumes can be rotated. For instance, Teff and Chick pea in the first year and wheat and grass pea in the next year.

Soil conservation structures (SCS)	Many farmers destroy SCS because they think their crop land is wasted and also because it is difficult to undertake traditional cross plowing between SCS using the traditional Maresha implement.	Forage cops can be grown on SCS to improve productivity of "lost" cropland. The recently developed plow, Arashogel, enables farmers to effectively undertake tillage parallel to the SCS. By leaving invisible barriers and hence retarding water movement along the slope, Arashogel, reduces water flow to the SCS thereby increasing their life span. Growing fodder grasses and legumes on the SCS like bunds and terraces will also increase availability of livestock feed.

In red soils with moderate and steep slopes, the main concern is soil erosion. Farmers practice repeated cross plowing in these soils depending on the type of crop to be grown. Although farmers are aware of the disadvantages of cross plowing which aggravates soil erosion, they cannot avoid it. The use of the traditional farm implement, "*Maresha*" leaves strips of unplowed land between consecutive passes. Farmers cannot easily access the unplowed strips without resorting to cross plowing.

On moderately sloped to steep slopes, much of the land in this classification is treated with soil conservation structures. However, farmers reported that they usually destroy the soil conservation structures due to the difficulty of conducting cross plowing between the structures which are usually constructed in short intervals. They try to plow the field parallel to the structures but they have to employ another labor to manually dig the strips of land left between two consecutive passes. It was also observed that the waterways constructed in these areas are not grassed and there are no drop structures. Farmers reported that the waterways in most cases grow to gullies.

In light of this, in red soils with moderate to steep slopes, the strategy should primarily focus on reduction of tillage frequency and improvement of tillage between soil conservation structures. Farmers carry out repeated tillage with cross plowing because the traditional tillage implement, *Maresha*, does not permit efficient contour plowing as described above. However, an improved implement that can enable farmers to undertake contour plowing is available. Use of *Arashogel* allows farmers to cut the strips left between consecutive passes of Maresha. Moreover, field research has shown that the use of *Arashogel* retards surface runoff thereby minimizing soil erosion (Temesgen, et al., 2010; Kebede et al ###, unpublished data). The tillage system makes it more convenient to plow between soil conservation structures. The invisible barriers left between passes allow more infiltration by reducing surface runoff towards the soil conservation structures. It also prevents water logging behind the soil conservation structures and possible breaking of the soil conservation structures that would have had detrimental effects downstream. Research has shown that crop yields and life span of the soil conservation structures can be increased by the application of such a tillage system. Use of composting is also recommended to improve soil structure and fertility.

In Bahrdar zuria where red soils dominate with relatively flat topography and access to water for irrigation, it is recommended to have longer period of soil cover. Soil cover can be achieved through leaving crop residues on the surface, particularly after harvesting niger seed. The crop residue of nigger seed is more convenient to use as soil cover. The crop to be planted in the crop residues should be maize, to start with. A direct seeder can be used to place maize seeds and fertilizer while pressing down the crop residue. Pressing the crop residue helps in facilitating management of the maize crop and in suppressing weeds as the surface area of the soil covers increases when it is laid down rather than remaining vertical. Maize is expected to perform better than any other crop under crop residue. At the moment, leaving maize stocks in the field is not recommended until appropriate technologies are developed.

In vertisols, the frequency of tillage is slightly less than that of red soils. This is because black soils are difficult to work when they are dry thus delaying commencement of tillage. Besides, black soils are considered self-loosening soils as the swelling and cracking cycle in these soils reduce compaction. One of the major problems associated with these soils is water erosion due to the long period of time left with no crop cover. In Gonder zuria, Dembia, Alefa, Takusa and North Achefer districts, sorghum and finger millet are very important crops in the predominantly black soils (Figure 3). It was learnt that after harvesting finger millet in February-March, farmers leave the soil bare during much of the main season. Farmers keep on plowing the soil until September, which is the sowing time of chickpea. Keeping the soil bare while plowing it during the high rainfall months of July and August can lead to higher soil erosion by water. Moreover, waterlogged condition followed by drying is the main cause of emission of methane, which is a more potent greenhouse gas than carbon dioxide.

In relatively flat areas close to the Lake where vertisols are dominating, crop residues obtained from finger millet, teff and rice are sold with a considerably high price. In the Fogera area, the majorities of the farmers collect the rice Stover around the homestead and feed that all their livestock (Figure 4). The crop residues are sold to households who either have dairy cows at Bahir Dar and other district towns like woreta or for construction of muddy houses. Based on a survey of 20 households at Bahir Dar Zuria district, the prices of crop residues of finger millet and teff is 1500 Birr per hectare, with a maximum value of 3000 Birr.

The area covered by black soils around the lake could be suitable to implement ideal CA practices. However, in most areas (Gondar Zuria, Dembia, Alefa, Takusa, North Achefer, Bahir Dar Zuria and Dara) except in the Fogera plains, the black soils are being used to grow mainly finger millet and to a lesser extent teff. The soil is exposed to erosion by water due to the fact that there is a long period of time when the soil remains without cover. In particular, when farmers continue plowing the soil between the harvest of Finger millet during February-March and chickpea planting in September, the soil is exposed to erosion by water due to little or no soil cover during the high rainfall months of July and August. One way of achieving this is planting of improved wheat varieties in June. This needs a surface drainage technology. Drainage of Vertisols has been recommended in order to address the problem of water logging that made it difficult to use these highly fertile soils. Research has shown that wheat can be planted in June and harvested in September followed by planting of chickpea or other legumes, thus enabling double cropping per year. Therefore, we recommend that soil cover is maintained during the season by applying Broad Bed and furrow Maker (BBM) technology. The other way of improving soil cover is to plant pigeon pea as a soil cover. Since the crop has deep penetrating roots, it can improve soil structure so as to improve infiltration. The pigeon pea can be planted using irrigation as water for irrigation in the areas close to the lake is not a serious constraint. The cover crop can be pressed down using a mechanical device. Composting can also be practiced in these areas. Composting improves the soil structure and its water holding capacity. Higher infiltration in well structured soils reduces soil erosion. Moreover, higher biomass production due to the application of compost will further improve the soil organic carbon content. Exceptionally, in the Fogera plains, farmers practice recession farming. They grow rice and chickpea in rotation. The flat topography of the area implies little or no runoff generation. The threat to soil erosion is minimal in this area. The soil remains saturated in most cases and the likelihood of loss of organic carbon through oxidation is relatively low in these areas. The residue of rice is collected and piled around the homesteads to be used as livestock feed during the dry season (Figure 6).

Figure 6. Rice straw being pilled at the courtyard to be used as livestock feed during the dry season at Fogera area, Abuana Hokit PA (Photo by Birhanu Biazin).

3.3 Recommended Conservation Agriculture packages and their modes of implementations at the proposed Lake Tana BR

3.3.1 Recommended site-adapted conservation agriculture packages

Three site-adapted CA packages have been recommended based on the outcomes of field observations, key informant discussions, focus group discussions and survey results. Provided that the challenges for poor acceptance of CA techniques in previous efforts are multifaceted, each of the site-adapted CA practices could be planned in packages as described herein.

1. ***CA package for black soils (Vertisols)***

Interventions

- ***Early planting of the cereal crop followed by planting of legumes using the residual moisture after surface drainage using Aybar BBM***

The most important challenges in the black soils encompass water logging during the rainy season, soil erosion and fertility decline due to crop residue harvest and minimum level of rotation between cereals and legumes. Much of the black soils in the proposed Lake Tana BR are used for finger millet. When the black soils are used for the production of finger millet, rotation with legumes cannot be undertaken in one year. It happens in two consecutive years. This reduces the length of soil cover and benefit of the farmers. In few areas, crop rotation between cereals (teff and rarely wheat) and legumes (chick pea and grass pea) is being practiced in one year. However, the mode and extent of this practice is not effective at present. This is mainly due to the lack of proper surface water draining technique in the black soils. Rotation of cereals with legumes in one year is possible if the farmers are shifting from finger millet to teff and wheat by applying surface drainage of the black soils using proper drainage implements. Surface drainage of the black soils using proper implements like BBM (Figure 7) will enable to apply early planting of teff or wheat thus giving enough time to grow legumes (chickpea and grass peas) within the same year. This will enable to have a longer period of time when the soil will have a cover crop. The presence of a crop cover during both the rainy and dry seasons will reduce the susceptibility of the soils to erosion. In this package, part of the legumes residue can be retained on the farm to reclaim the soil fertility. Currently, the farmers harvest all the biomass of the legumes (grass pea and chick pea) except the roots (Figure 8). Hence, the farmers will be initiated to harvest all the crop residues of the cereals and some portion of the residues from the legumes to mix and feed their livestock. Thus the livestock will get both carbohydrate and protein sources. The rest of the legume Stover will be distributed on the farm to enhance the fertility of the soil by improving the nitrogen content. It was learnt that continuous growing of grass peas without rotation causes pest and disease prevalence. Thus to reduce this problem, rotational cropping is recommended in this package. Accordingly, both the cereals (teff and wheat) and legumes (chickpea and grass pea) will be rotated during the consecutive years. For instance, a farmer may grow Teff (during June/July-September/October) and Chickpea (during October- February) in year 1. In year 2, he/she will grow wheat (during June-September/October) and grass pea (during October-September). Accordingly, both the cereal and the legume are rotated during the consecutive years thus reducing the susceptibility to pest and diseases in one hand and enhancing the soil fertility in the other. Weed removal can be practiced manually.

Figure 7.The newly developed Ayibar BBM (Broad Bed and furrow Maker) that has been testified as easy to be adapted to the existing Maresha ploughing using oxen traction

Figure 8.Grass pea as an important crop in the black soils of North Achefer although the potential of rotation has never been exploited. The farmers harvest all the legume biomass except the roots (Picture from Kunzila Zuria PA, by Birhanu Biazin)

2. ***CA package for Red soils (Nitisols)***
   Intervention

- ***Reduced tillage using Arashogel and leaving some portion of the cereal Stover in red soils where physical soil and water conservation measures are applied***

The main reason behind the application of cross-ploughing and repeated tillage using the traditional Maresha plough is to complete the unfinished 'V' shaped furrows by applying perpendicular plough during the next ploughs. The practice for cross-ploughing using the Maresha has also affected the adoption of the soil and water conservation measures like bunds and terraces as they obstruct cross-ploughing. The newly developed *Arashogel* has been designed to avoid cross-ploughing. It was designed in such a way that it can remove the weeds and grasses by its sharp wings in one pass (Figure 9). Hence, the application of the Arashogel can reduce the frequency of tillage and hence reduce the soil's susceptibility to erosion by water.

It will be an opportunity to promote contour plowing and enhance the adoption of physical soil conservation structures under sloping lands. This is in line with the current government-led watershed development mainly through the promotion of physical soil and water conservation measures like bunds and terraces. Moreover, the Arashogel can also contribute to reduced oxidation of organic matter due to reduced tillage frequency. The number of tillage before sowing of the cereals will not be more than two at a maximum.

Figure 9. The Arashogel designed to avoid the traditional cross-ploughing during consecutive tillage operations due to its wings, which cut the grasses and other weeds left by Maresha. Unlike the traditional Maresha, this tillage implement enables to farmers to effectively plough parallel to bunds and terraces.

3. ***CA package around the lake***

Intervention

Crop stover/residue mulching integrated with improved forage grasses /legumes around the farm boundaries near to the lake

Leaving the Stover and residues of finger millet, teff, rice and wheat crops would be important to cover the soil and reduce soil erosion thus also enhancing the soil fertility. However, traditionally, most of the farmers harvest the whole biomass of the aforementioned crops except the roots as they desperately need the crop residues as sources of livestock feed. Therefore, to make the farmers harvest part of the crop residues of the aforementioned crops and leave as much residue as possible on the ground, an alternative source of livestock feed must be availed. Hence, the production of improved forage grasses like Desho and Elephant grass and legumes like pigeon pea, sesbania and Desmodium are recommended either around the soil bunds and terrace or at farm boundaries. Leaving the crop residues will be integrated with reduced tillage (1-2 times) in the red soils and use of BBM in the black soils. The growing of fodder grasses and legumes around the lakes will buffer the lakes from siltation coming from the upstream areas. While weed control is made manually, pest and diseases can be prevented by applying rotation of the crops during the consecutive growing seasons.

3.3.2 Modes of implementations of the selected packages

Nine pilot households (3 from Bahir Dar Zuria district, 3 from North Achefer, and 3 from Gonder Zuria) will be selected depending on their appropriateness to represent the types of soils and cropping patterns for the demonstration of the selected CA packages. Moreover, one FTC will be selected from Bahir Dar zuria district for the demonstration of the package 3. The three districts were selected based on their representativeness of the other 7 districts and accessibility during demonstration. Accordingly, half of the pilot households will be selected from areas where there are dominantly red soils and the other half will be selected from areas where there are dominantly black soils. Compensations will be arranged to cover the opportunity costs of the pilot households. Or instance, in case the farmers have been using herbicides to remove weeds, compensatory mechanisms will be arranged as they should pay more for labor during manual weeding. The compensation will be calculated based on the current price of the crop under consideration and amount of yield declined or lost.

Participatory evaluation of the effects of the aforementioned CA packages will be undertaken for two consecutive years. Scientists, farmers and extension staffs will be involved in the evaluation of the CA packages on minimizing soil erosion, soil fertility maintenance, improving crop yields and minimizing energy and labor requirements. The effect of the CA packages on reducing the soil erosion will be undertaken by installing runoff (Gerlach) troughs at the tail ends of six of the demonstration plots. Three of the runoff troughs will be installed with the CA package for the red soil using Arashogel and the other three will be installed with the CA package for the black soil using Ayibar BBM. Moreover, the effect of the improving the soil fertility will be evaluated by taking soil samples before the introduction and two years after the introduction of the package sat the pilot farms. Hence, the soil organic matter content, total nitrogen and bulk density will be analyzed. The role of the selected CA packages on carbon sequestration can also be implied. Moreover, the major challenges that will affect the wider adoption of the packages will be identified through participatory evaluation of the CA packages. The packages could be further modified upon evaluations for proper dissemination. On top of coaching of the ten pilot households, one model CA demonstration site need to be established at a Farmers' Training Center (FTC) in BahirDar Zuria district. This site will enable to demonstrate the biophysical and socioeconomic impacts of CA in the proposed Lake Tana BR. BahirDar zuria district being near to the BahirDar city where the various stakeholders and decision makers are quartered, it will be easier to organize field days and influence the main actors and extension staff for possible dissemination of CA packages at a wider scale.

5. References

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