A Training Manual for Training of Trainers on Conservation Agriculture (CA) and Climate Smart Agriculture (CSA)

Volume 6

By

Agere Lupi

Training Organized by
Ministry of Agriculture and Livestock Resources (MoALR),
Participatory Small-Scale Irrigation Development Program (PASIDP) and
Ethiopian Institute of Agriculture Research,
Melkassa Agricultural Research Center

08─14 Oct 2018

Melkassa, Ethiopia

Table of Contents

Conservation Agriculture (CA)

Agare Lupi, Email: agere97@gmail.com; Cellphone: 0913484555
Ethiopian Institute of Agricultural Research, Melkassa Agricultural Research Center, P.O. Box 436, Tel. 251-022 2250210, Fax: 251-022225 0213

1. Basic Concepts of Conservation Agriculture (CA)

Conservation agriculture was introduced by the FAO (2008) as a concept for resource-efficient agricultural crop production based on integrated management of **soil, water, and biological resources combined with external inputs**. It has been promoted by institutions and organizations with the expectation that it can contribute to sustainable intensification (Hobbs 2007).

The definition of CA incorporates system concepts based on three key principles:

- continuous residue cover on the soil surface;
- continuous minimum soil disturbance (no-tillage, Reduced tillage); and
- diverse crop rotations and cover crop mixes

Conservation agriculture (CA) is a set of cropping principles aimed at sustaining high crop yields with minimum negative consequences on the environment. In practice, CA includes the simultaneous application of minimal soil disturbance, permanent soil cover through a mulch of crop residues or living plants, and crop rotations (Food and Agriculture Organization, 2014).

Benefits of CA systems in various countries have been widely published (Bolliger et al., 2006; Derpsch,2008; Hobbs, 2007; Reicosky and Saxton, 2007; Wall,2007). Comparing conventionally ploughed and CA systems, CA has exhibited higher infiltration and higher available soil moisture especially during critical crop development stages, which ultimately resulted in higher grain yield and therefore higher rainfall-use efficiency (Roth et al., 1988; Thierfelder, 2003). Results from East Africa and Colombia show that between 10 and 22% of rain water may be lost from an uncovered, ploughed soil surface (Thierfelder, 2003; Rockstrom et al., 2001). Higher infiltration rates, which may be observed in CA fields, prevent losses of surface water and soil (Lal,1977; Shaxson and Barber, 2003). As a consequence of higher infiltration rates and reduced evaporation, general improvements in soil water status and water holding capacity in CA systems can be observed (Bescansa et al., 2006; Derpsch et al., 1986). Other findings showed that higher infiltration rates, higher soil moisture contents (Derpsch et al., 1986; Roth et al., 1988; Roth, 1992), and absence of surface crusting (Shaxson and Barber, 2003) resulted from zero tillage combined with surface mulch. Retention of crop residue translates to lower losses of moisture to evaporation in untilled soils covered with mulch compared to tilled soils (Dardanelli et al., 1994; Lal,1990).

1. The state of Conservation Agriculture in Ethiopia

In Ethiopia, soil conservation practices such as reduced tillage have long been undertaken by farmers; however, the promotion of conservation agriculture technology began in earnest in 1998 through the joint promotion and demonstration of the technology on the plots of 77 farmers by Sasakawa Global (SG2000), Makobu and regional agricultural development bureaus

On average, the yields of the 1998/99 conservation agriculture demonstration plots were similar to the average yield of conventional tillage plots. During this initial introduction period of conservation agriculture, further trials were carried out between 1999 and 2003 at the Jima, Bako and Melkasa research centres on maize, sorghum and teff. These trials indicated that conservation tillage plots gave higher yields compared with the conventional tillage (Tesfa, 2001; Worku, 2001; Tolesa, 2001). The studies also indicated lower production costs for conservation agriculture fields. The general pattern emerging from these data is that yields increase both in the short and long term as a result of conservation agriculture. This is consistent with reviews of research in Latin America, Africa and Asia that conclude that conservation agriculture yields are between 20 to 120 percent higher than those in conventional agriculture (Kassam *et al*., 2009; Derpsch *et al*., 2010).

There are several mechanisms by which conservation agriculture can improve yields. Mulching and residue management can increase soil fertility and the availability of nutrients to plants. Improved water availability throughout the cropping cycle is another key mechanism of yield improvement or stabilization

Since the initial trials and introduction, conservation agriculture has been promoted by different organizations including FAO, the Agricultural Transformation Agency (ATA), the International Maize and Wheat Improvement Center (CIMMYT) and a number of NGOs such as Ethiopia Wetland, FH Ethiopia, Self Help Africa, AGRA, Canadian Foodgrains Bank and Wolayita Terepeza Development Association, among others. In 2010 FAO, in collaboration with the Federal and Regional Agricultural Offices, provided technical and financial support for conservation agriculture promotion in Ethiopia. Accordingly, 24 conservation agriculture demonstration plots were established, involving 600 smallholder farmers in 12 woredas of the Amhara, Oromia and Tigray regions. FAO also introduced a range of conservation agriculture equipment including jab planters and oxen-drawn seed and fertilizer planters in those same woredas in 2010 and supported the training of 72 extension agents to conduct conservation agriculture farmer field schools, of which 32 were also trained in the assembly and operation of conservation agriculture equipment.

In 2012 and 2013, ATA supported 6 000 farmers in seven woredas to practice conservation agriculture as well as training 327 experts and 750 development agents in conservation agriculture in selected woredas in the country. ATA's target for 2014 was to have 50 000 farmers practicing conservation agriculture in 57 woredas across the country. CIMMYT, in collaboration with national and regional research organizations (for example the Ethiopian Institute of Agricultural Research [EIAR]), has been conducting conservation agriculture trials and demonstrations in different parts of the country through a program known as Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA).

It has also been reported that in areas where weed problems are prevalent, most farmers will easily adopt herbicide use as part of their farming practice. In Adaa District, where teff crop is important, farmers practice minimum ploughing, which is much more affordable since teff requires frequent ploughing. Conservation agriculture saves more labor on teff, which requires intensive ploughing four to six times before planting. Minimum tillage also represents an important economic appeal to farmers in terms of reducing production costs, particularly expenditure on labor, seeds and other yield-improving inputs.

In general, however, adequate data on the adoption of conservation agriculture in Ethiopia are not well documented and available at all levels.

2. Food security

Sustained and stable food production generated by conservation agriculture systems can significantly improve the food security and nutritional status of vulnerable households and communities. Conservation agriculture can help stabilize yields in the face of climate shocks such as droughts by reducing evapotranspiration and regulating soil temperatures as well as supporting the management of pests and diseases in crop production if appropriate crop rotations and combinations are used. These benefits are especially important for poor and vulnerable smallholder farming households

In the past, soil tillage has been associated with increased soil fertility. It has recently been recognized that, in the long term, this process leads to a reduction of soil organic matter. Soil organic matter not only provides nutrients for the crop, but is also a crucial element for the stabilization of soil structure. Therefore, most soils degrade under prolonged intensive arable agriculture. This structural degradation of the soils results in the formation of crusts and compaction, ultimately leading to soil erosion and reduced agricultural productivity. As a result, the conservation agriculture components that are currently being promoted include:

2.1. Reduced tillagE

In Ethiopia, land preparation is mainly carried out with a view of getting rid of weeds, but it also helps in breaking compacted soils and improves moisture infiltration. However, moisture infiltration is much better in soils that are less tilled but not compacted by the effect of overgrazing. Conservation agriculture using reduced tillage in Ethiopia has been demonstrated on maize, wheat, teff, sorghum, faba bean and onion and has shown successful results. Upscaling of conservation technology is currently under way.

2.2. Crop residue management

The success of conservation agriculture in Ethiopia is highly dependent on crop residue management. Crop residues provide protective cover for the soil and increase soil infiltration. Research has shown that when 35 percent of the soil surface is covered with uniformly distributed residues, splash erosion will be reduced by up to 85 percent. Approximately two tons of maize residues per hectare are necessary to obtain 35 percent soil cover, which has been established as the minimum amount required for achieving a substantial reduction in relative soil erosion (Tolesa, 2001). In many parts of the country, however, crop residues have traditionally been used for multiple purposes including fuel, building materials and animal feed, which conflict with their use in conservation agriculture. Among these, livestock-related use (feed) is probably the most widespread in the country.

2.3. Crop rotation and intercropping

In a system with reduced mechanical tillage based on mulch cover and biological tillage, alternatives have to be developed to control pests and weeds. Practicing crop rotation and intercropping has many advantages, which include reduced risk of pest and weed infestations; better distribution of water and nutrients through the soil profile; exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species, resulting in a greater use of the available nutrients and water; increased nitrogen fixation through certain plant-soil biota; improved balance of nitrogen, phosphorus and potassium (N-P-K) from both organic and mineral sources; and increased formation of organic matter. Better nutrient management through crop rotation can decrease nitrogen fertilizer use by up to 100 kg N per hectare per year, substantially lowering related greenhouse gas (GHG) emissions (nitrous oxide has a global warming potential 310 times greater than CO2) as well as reducing the costs of production. Reduced synthetic fertilizer use also leads to reduced greenhouse gas emissions from the manufacturing process and transportation (PANW, 2012). However, in most parts of the Ethiopian farming system farmers hardly practice crop rotation and mono-cropping is the dominant cropping system.

Fig 1 Intercropping and crop rotation

3. Environment, biodiversity and soils

Conservation agriculture has a significant impact in reducing soil erosion through increased rainwater infiltration and buildup of soil organic matter for increased soil moisture storage. Conservation agriculture can improve biodiversity at farm and community level and support improved ecosystem services such as water and nutrient cycling. It can also support flood control through improved water infiltration in agricultural fields.

4. Water management

Conservation agriculture has been found to have beneficial effects on water management and water-use efficiency. With an increase in soil organic matter and root density under conservation agriculture, water infiltration and water holding capacity are improved, making water more available throughout the farming cycle. Kassam *et al*. (2009) reported that for each percent increase in soil organic matter, an additional 150 m3/ha of water can be stored in the soil (in Sintayehu, 2011). Surface mulches and improved soil pore structure also increase infiltration and absorption capacity, while reducing evaporation. These benefits help reduce the risk of erosion and flooding during heavy rains, contribute to aquifer recharge and make more water available for crops

4.1. In-situ or within-field water harvesting

For the insitu, rainwater would be collected where it falls, to be captured more efficiently on the same surface (often referred to as in-situ or micro-catchment or green water). This is allowing rainwater to infiltrate and percolate down to the water table, given an appropriate time of concentration. The in-situ systems do not cover a distance of more than 5-10m from the point of water intake to the point of infiltration into the storage medium (mostly the soil). Often, in-situ RWH is based on a range of soil conservation measures, such as terracing, pitting, mulching (orgaic and stone) and conservation tillage practices which are commonly implemented to counter soil erosion.

The recommended rainwater harvesting techniques vary according to:-

- Available natural resources (land, rainfall and soil),
- Human resources (labour, capital and skills) and.
- Produce (crops, trees, livestock etc)

However,

- few techniques have been subjected to economic analysis.
- Because of their higher inputs (especially labour), water harvesting techniques are most appropriate for high-value crops.

4.1.1. Contour bund

Contour bunds are earth banks, 1.5–2m wide, thrown across the slope to act as a barrier to runoff, to form a water storage area on their upslope side and to break up a slope into segments shorter in length than is required to generate overland flow. They are suitable for slopes of 1–7° and are frequently used on smallholdings in the tropics where they form permanent buffers in cropping system, being planted with grasses or trees. The banks that are spaced at 10–20m intervals, are generally hand- constructed. There are no precise specifications for their design and deviations in their alignment of up to 10 per cent from the contour are permissible. In Wello Province, Ethiopia, Hurni (1984) found that earth bunds were only effective on slopes up to 6°. An alternative technique on stony soils is to construct stone bunds, 250–300mm high, set in a shallow trench on the contour. In order to enhance their ability to filter runoff and trap sediment, smaller stones should be placed on the upslope side and, if possible, gravels upslope of them (Hudson 1987).

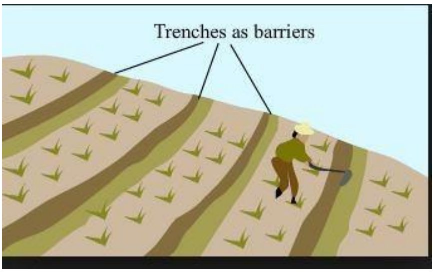


Fig 2. soil bund for moisture retention

Contour plowing or contour farming or Contour ploughing is the farming practice of plowing and or planting across a slope following it elevation contourlines. These contour lines create a water break which reduces the formation of rills and gullies during times of heavy water run-off; which is a major cause of soil erosion. The water break also allows

4.1.2. Terrace

Terraces are earth embankments constructed across the slope to intercept surface runoff, convey it to a stable outlet at a non-erosive velocity and shorten slope length. Terraces therefore perform similar functions to contour bunds. The two are different in a sense that terraces are designed with more conservative specifications. Decisions are required on the spacing and length of the terraces, the location of outlets, the gradient and dimensions of the terrace channel and the layout of the terrace system

Terrace Farming: In Steep slope region when farming is done on flat surface. So, where does this flat surface come from? You made it available for yourself by using machines or manually. :) Just Think of Steps of your house. Your Dearest child (or Bewafaa GIRL FRIEND) insists to plant something on Every step. Terrace Farming it is somewhat bigger in size. You can visualize it

Fig 3. terrace farming

Terraces can be classified into three main types: diversion, retention and bench. The primary aim of diversion terraces is to intercept runoff and channel it across the slope to a suitable outlet. They therefore run at a slight grade, usually 1: 250, to the contour. There are several varieties of diversion terrace.

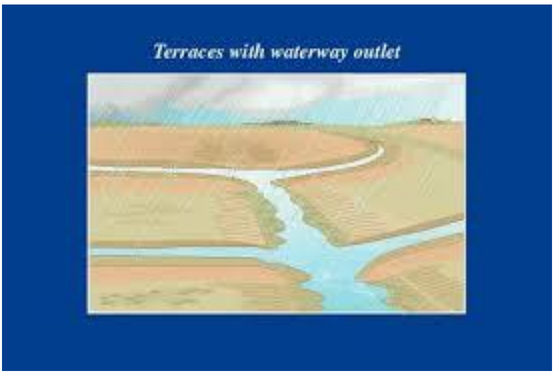


Fig 4; diversion terrace

Diversion terraces are not suitable for agricultural use on ground slopes greater than 7° because of the expense of construction and the close spacing that would be required. Closer spacing is feasible, however, on steeper slopes on road banks, mining spoil and along pipeline corridors.

4.1.3. Retention terrace

Retention ditches are large ditches, designed to catch and retain all incoming runoff and hold it until it infiltrated into the ground. They are sometimes also called infiltration ditches. In semi-arid areas retention ditches are commonly used for trapping rainwater and for growing crops that have high water requirements, such as bananas. These crops can be planted in the ditch and thereby get increased supply of moisture. The design of retention ditches is usually determined by trial and error. Often the ditch is about 0.3-0.6 m deep and 0.5-1 m wide. In very stable soils it is possible to make the sides nearly vertical, but in most cases the top width of the ditch needs to be wider than the bottom width. The spacing between the ditches varies according to slope. On flat land the ditches are usually spaced at 20 m and have close ends so that all rainwater is trapped. On sloping land, the spacing is between 10-15m and the ditches might have open ends so that excess water can exit. Retention ditches can also be made for the purpose of harvesting water from roads or tracks. The location of such ditches will be specific to the site.

Conditions

Retention ditches are particularly beneficial in semi-arid areas where lack of soil moisture is a problem. They should be constructed on flat or gentle sloping land and soils should be permeable, deep and stable. Retention ditches are not suitable on shallow soils or in areas prone to landslides.

Advantages

- Retains runoff and improves soil moisture.
- Reduces soil erosion.
- Makes it possible to grow water demanding crops in dry areas.

Limitations

- When heavy rainfall occurs, the ditches might overflow and brake.
- Labor demanding to construct.
- Need to be maintained and de-silted regularly.

- On unstable land there might be risk of landslides

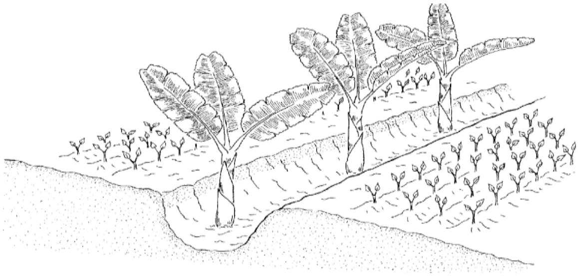


Fig 5. retention ditch planted with banana trees.

4.1.4. Fanya juu terraces

***Fanya juu* terraces** are used in many parts of East Africa as an alternative to bench terraces. They consist of narrow shelves constructed by digging a ditch on the contour and throwing the soil upslope to form an embankment, which is later stabilized by planting grass (Thomas & Biamah, 1989). During cultivation, vegetation and crop residues are spread over the shelves. Over time, redistribution of the soil within the inter-terrace area causes the inter-terrace slope to decline in angle and bench-like features to develop. Since this decreases the storage area for runoff behind the embankment, maintenance is required to raise the height of the bank to prevent overtopping.

Fig 8 fayna juu for soil erosion reducing

4.1.5. Semi circular bunds

Semi-circular bunds are earth bunds in the shape of a semi-circle with the tip of the bunds on the contour. The size of the bunds varies, from small structures with a radius of 2 m to very large structures with a radius of 30 m. They are often used to harvest water for fruit trees and are especially useful for seedlings. Large structures are used for rangeland rehabilitation and fodder production. The entire enclosed area is planted. When used for tree growing, the runoff water is collected in an infiltration pit, at the lowest point of the bund, where the tree seedlings also are planted. The bunds are laid out in a staggered arrangement so that the water which spills round the ends of the upper hill will be caught by those lower down.

Conditions

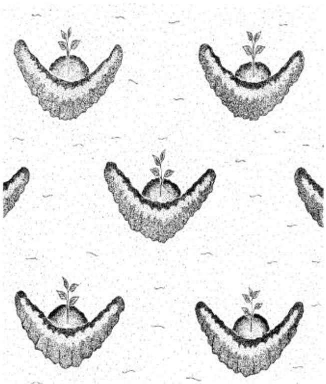
Semi-circular bunds are suitable on gentle slopes (normally below 2%) in areas with annual rainfall of 200-750 mm. The soils should not be too shallow or saline.

Advantages

- Easy to construct.
- Suitable for uneven terrain.
- Increases soil moisture.
- Reduces erosion.

Limitations

- Difficult to construct with animal draft.
- Requires regular maintenance.



Semi-circular bunds: Constructed in series in staggered formation.
---Runoff water is collected from area above it and impounded by the depth decided by the height of the bund.
--Excess water is discharged around the tips and is intercepted by the second row and so on.
--Normally the semi-circles are of 4-12 m radius with height of 30 cm, base width of 80 cm, side slopes 1:1.5 and crest width of 20 cm

Fig 9 semi-circular bunds for fruit production

4.1.6. Stone countour bunds

Stone lines along the contour are a popular technology in dry stony areas. Since the lines are permeable they do not pond runoff water, but slow down the speed, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion. The lines are constructed by making a shallow foundation trench along the contour. Larger stones are then put on the downslope side of the trench. Smaller stones are used to build the rest of the bund. The stone lines can be reinforced with earth, or crop residues to make them more stable. When it rains, soil will start to build up on the upslope side of the stone line, and over time a natural terrace is formed. The stone lines are spaced 15-30 m apart, a shorter distance being used for the steeper slopes

Conditions

Stone lines are suitable on gentle slopes in areas with annual rainfall of 200-750 mm. They are often used to rehabilitate eroded and abandoned land. Plenty of stones should be locally available. Most agricultural soils are suitable.

Advantages

- Slows down runoff and thereby increases infiltration and soil moisture.
- Induces a natural process of terracing.
- Reduces erosion and rehabilitates eroded lands by trapping silt.
- Are easy to design and construct.
- Since the structure is permeable, there is no need for spillways to drain excess runoff water.

Limitations

- Stones might not always be locally available.
- The stone lines might serve as a refuge for rodents and reptiles.
- Construction is labor demanding.

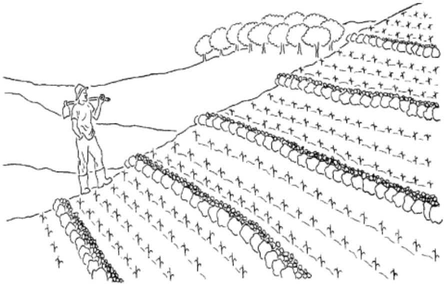
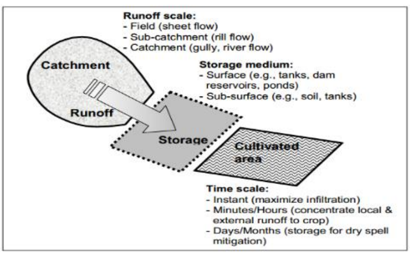
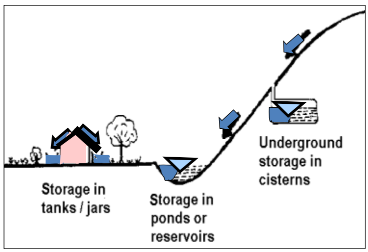


Fig 10 stone line along the counter

4.2. Ex-siu: Macro rainwater harvesting structures

Ex-situ water harvesting is an external i.e the collection of rainfall and runoff from large areas, which are at an appreciable distance from where it is being used; often referred to as runoff farming or on farm pond. This system includes catchment areas with usually low or little infiltration capacities like, rooftops, roads or pavements; yet also bits of ground or rocks. These catchment areas allow for a fairly easy collection of substantial amounts of water. This is then stored in wells, dams, ponds or cisterns and, when needed, abstracted and distributed for irrigation or domestic, public and commercial uses.





How to identify Suitable Water Harvesting Areas

- Field visit
- Experiemgtal plot (eg; using simulator)
- Aerial surveys and evaluation of aerial photographs
- Satellite images and their classification and evaluation
- Hydrological simulation models (predict runoff from rainfall data)

- Models of plant-soil-water-continuum

Fig 11: EX-situ water harvesting (Soure: Kibret, 2014)

5. Climate change mitigation:

Evidence on conservation agriculture, greenhouse gas (GHG) emissions and carbon sequestration indicates that conservation agriculture can help mitigate climate change by reducing existing emission sources and sequestering carbon in soils and plant biomass. Baker *et al*. (2007) estimate that the conversion of all croplands to conservation tillage globally could sequester 25 Gt C over the next 50 years. This is equivalent to 1 833 Mt CO2-eq/yr, making conservation tillage among the most significant opportunities from all sectors for stabilizing global GHG concentrations. Scaling down these global estimates to the continental, landscape or plot scale to estimate the mitigation potential of conservation agriculture in sub-Saharan Africa entails considerable challenges. Overall there is insufficient information on the GHG impacts of conservation agriculture practices, especially for developing countries in the tropics and subtropics (Milder *et al*., 2011)

Fig 12. tillage practice

6. Soil fertility Managements:

The declining per capita food production in Africa is associated with declining soil fertility in smallholder farms. This is because nutrient capital is gradually depleted by:

- Crop harvest removal,
- Leaching, and
- Soil erosion.

The use of crop residues by farmers as fodder and shorter or no fallow periods, due to a shrinking land resource base, can be balanced by the addition of organic manure and chemical fertilizers, which most smallholder farmers in the region cannot afford. There is, therefore, a need to develop appropriate soil nutrient and cropping systems that minimize the need for chemical fertilizers and also find ways to integrate livestock into the farming system. The focus of any soil fertility replenishment should be integrated nutrient management involving the application of leguminous mulches, agroforestry, and composting as well as technologies that reduce the risks of acidification and salinization.

In terms of soil fertility, the improved soil structure resulting from conservation agriculture enhances aeration and other conditions required for efficient nutrient cycling. Soil organic matter has been found to increase

significantly over time in conservation agriculture systems, primarily due to the introduction of additional organic matter as crop residues or mulch and to the reduction or elimination of tillage, which tends to accelerate the oxidation of soil organic matter (Hobbs *et al*., 2008; Kassam *et al*., 2009). Zero tillage systems are also associated with increased levels of available phosphorus in the upper soil layer (e.g. 0-5 cm),
due largely to the role of biological processes in phosphorus cycling (Milder *et al*., 2011).

Soil fertility depletion results from an imbalance of nutrient inputs and harvest removals and other losses, and it is reaching critical levels among smallholder famers (with depletion of soil organic matter being a contributory factor).

6.1. Soil organic matter

Soil organic matter includes all organic (or carbon-containing) substances within the soil. Soil organic matter not only stores nutrients in the soil, but it is also a direct source of nutrients. Some of the world's most fertile soils tend to contain high amounts of organic matter. Soil organic matter includes:

- Living organisms (soil biomass);
- The remains of microorganisms that once inhabited the soil;
- The remains of plants and animals; and
- Organic compounds that have been decomposed within the

soil and, over thousands of years, reduced to complex and relatively stable substances commonly called humus.

As organic matter decomposes in the soil, it may be lost through several avenues. Since organic matter performs many functions in the soil, it is important to maintain soil organic matter by adding fresh sources of animal and plant residues, especially in the tropics where the decomposition of organic residues is continuous throughout the year

Although surface soils usually contain only 1-6 % organic matter, soil organic matter performs very important functions in the soil. Soil organic matter:

- Acts as a binding agent for mineral particles;
- Is responsible for producing friable (easily crumbled) surface

Soils;

- Increases the amount of water that a soil may hold; and
- Provides food for organisms that inhabit the soil.

Humus is an integral component of organic matter because it is fairly stable and resistant to further decomposition. Humus is brown or black and gives soils its dark color. Like clay particles, humus is an important source of plant nutrients

6.2. Manure management

Manure management activities involve the handling of animal dung and urine (farmyard manure) predominately in the solid form when applying it to croplands

Applications of manure in the croplands enable achieving and maintaining a fertile soil, which can increase crop yields. The application of manure can improve productivity and produce greater crop yield which is important for adapting to climate change.

Methane emissions from animal waste strongly depend on the specific manure management system and on the conditions and manner in which the system operates. However, generally handling manure in the solid form instead of the liquid form will suppress CH4 emissions. Covering liquid manure also reduces N2O emissions. GHG mitigation potential of manure management is **0**.02-1.42 t CO2-eq/ha/yr.

How do you do it?

- Handle manure in the solid form instead of the liquid form when applying it to croplands.
- Cover liquid manure

6.3. Composting

Composting is the controlled biological and chemical decomposition and conversion of animal and plant wastes with the aim of producing humus. Humus is the dark organic material in soils, produced by the decomposition of vegetable or animal matter and is essential to the fertility of the soil

How is it helpful for livelihoods?

- Compost functions as a form of organic fertilizer made from leaves, weeds, manure, household waste and other organic materials, thus it can reduce the cost of fertilizer from other sources.
- Proper compost management leads to an increased proportion of humic substances in the soil due to high micro-organic activity, and therefore applying compost leads to quantitative and qualitative improvements of the humus content of the soil, which leads to an increase in crop yields

How is it helpful for adaptation to climate change?

- Composting helps to improve soil fertility which is helpful in reducing the impacts of climate change.
- Composting helps increase soil moisture and soil cover, as well as reduce soil loss.

How is it helpful for climate change mitigation?

Composting helps reduce the need for fertilizer which decreases greenhouse gas emissions. GHG mitigation potential of composting is 0.02-1.42 tCO_2-eq/ha/yr.

6.4. Improved fertilizer use efficiency

Improved fertilizer use efficiency involves various techniques for reducing the amount of fertilizer required for plants to grow effectively.

How is it helpful for livelihoods?

- By improving efficiency, it reduces the amount of fertilizer needed, which reduces the cost of fertilizer inputs.

How is it helpful for adaptation to climate change?

- Precision agriculture techniques can also help to retain water and nutrients in the root zone, which are important for adapting to climate change.
- How is it helpful for climate change mitigation?
- By reducing the amount of fertilizer required for plants to grow effectively,
- the GHG emissions from fertilizer usage decrease.
- GHG mitigation potential of improved fertilizer use efficiency is 0.02-1.42 tCO_2-eq/ha/yr.

How do you do it?

- Use recommended rates of suitable organic and inorganic fertilizers. (These rates can be found in the Farm Management Handbook of Kenya.)
- Place the nitrogen more precisely into the root zone to make it more accessible by crops.
- If possible, use precision agriculture techniques to improve fertilizer application by helping determine exactly where to place nutrients, how much to apply, and when to apply.

Three techniques can help achieve this objective:

- The collection of spatial data from pre-existing conditions in the field (e.g., remote sensing, canopy size, or yield measurement);
- The application of precise fertilizer amounts to the crop when and where needed; a
- The recording of detailed logs of all fertilizer applications for spatial and temporal mapping

7. Climate Smart Agriculture (CSA) and Conservation Agriculture (CA)

Introduction

Africa's climate is changing. Across the continent rainfall patterns are set to alter. In many areas, droughts will become more frequent, more intense, and last longer. In others, new patterns of rainfall will cause flooding and soil erosion. Climate change is emerging as one of the major threats to development across the continent. At the same time, Africa's population continues to grow. Annual growth is estimated at 2.4% and the population is predicted to double from its current 0.9 billion people by 2050. According to the Food and Agriculture Organization of the United Nations (FAO), more than a quarter of sub-Saharan Africa's people are currently undernourished. Crop production will need to increase by 260% by 2050 to feed the continent's projected population growth.

Africa's agriculture must undergo a significant transformation to meet the simultaneous challenges of climate change, food insecurity, poverty and environmental degradation

- What is climate and change?
- Climate change and Agricultural in Ethiopia
- Past and future Trend and Variability of Climate Change in Ethiopia

Temperature and rainfall vary across the main regions of Ethiopia. There is a trend of decreasing temperatures and increasing rainfall from the lowlands in the south- and north-east to the central and upper highlands; with rainfall reaching over 2000 mm annually in the southwestern highlands compared to as low as 300 mm in the lowlands. The regions also experience very different seasonal regimes: while the June–September wet season (also known as the *Kiremt* season, with rainfall reaching as high as 350 mm/month) is common throughout most of the country, farmers and pastoralists in the North and the Centre rely yearly on an additional short wet season from February–May known as the *Belg* season. The South is exposed to rains between February–

May and October–December (the Bega season), while rains are very scarce in the far eastern parts of the country [41].

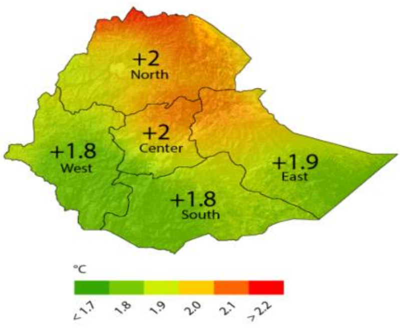
Analyses of historic climate data (1981–2014) revealed the occurrence of more frequent droughts, increases in mean temperatures, more erratic rainfall, and more frequent heavy rains [42, 43]. These changes have had an impact on farmer livelihoods as well as on national economic performance. For example, studies have shown a close relationship between annual rainfall variability and agricultural

GDP as well as affecting overall GDP growth.12 Droughts in particular have had great impact on farmers' livelihoods. In terms of impact on livelihoods, the 1984 and 2003 droughts affected 7.5 and
12.6 million people respectively [43]. Losses from the 2006 floods amounted to US$3 million, 800 human lives, and 20,000 homes [44]. More recently, the El Niño event in 2015/16 resulted in Ethiopia
experiencing one of the worst droughts in decades, with over 10.2 million people estimated to need food aid [45]. These events led to crop damage, animal loss, loss of livelihoods, migration to urban areas and increases in malnutrition

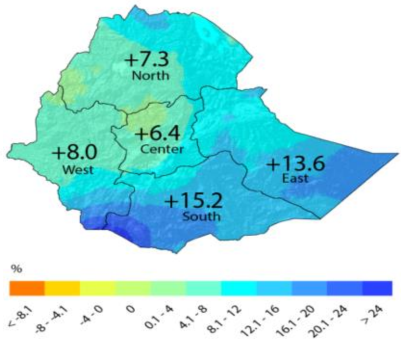
In terms of future trends, projections using any of the four main GHG emissions scenarios used by the IPCC indicate a continued increase in mean temperature throughout the entire country, with the greatest increases expected to be experienced in the northern parts of the country. Higher variability of rainfall is also expected, with rains becoming more unpredictable, more unreliable, and more intense [46]. Future climate projections indicate increases in annual rainfall for Ethiopia as a whole, with these increases being greatest in the southern and south-eastern parts of the country and least in the central and northern parts of the country. These increases are largely a result of increasing rainfall during the short rainfall season (October–December) in southern Ethiopia; however, changes in precipitation were found to be variable, with some scenarios and time lines indicating decreases in rainfall. Intra- and inter-seasonal rainfall variability are also expected to increase

Projected changes in temperature and precipitation in Ethiopia by 2050 [49, 50, 51]

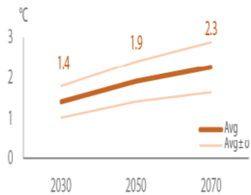
Changes in annual mean temperature (°C)



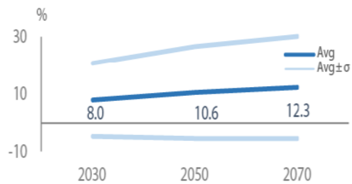
Changes in total precipitation (%)



Average temperature (°C)



Average precipitation (%)



Climate change impact on Agriculture in Ethiopia

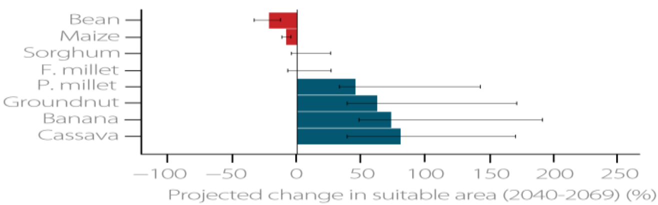
The agricultural sector in Ethiopia is faced by a number of challenges, centred largely on increased pressure over natural resources (driven by a rapidly growing population and demand for food), which has led to land degradation on over 40million hectares of land [21], declines in soil fertility and high rates of soil erosion, particularly in the highlands In addition, low agricultural yields have been associated with unfavourable climate conditions in some parts of the country (including climate shocks such as droughts and floods), which have had adverse effects on the natural resource base (e.g. soil erosion caused by intense rains) as well as on the livelihoods of rural populations who have limited resources ability to invest in resilience building and adaptation strategies

Asked about the causes of crop damage in the 2015/16 crop survey, most farmers reported shortage of rain (57% of all farmers reporting crop damage), diseases and pests (18%), frost or floods (9%), weeds (7%), hailstone (7%), excessive rain (5%), wild animals (5%), and other factors (20%) as the main contributors to crop damage and even loss. Shortage of rain mostly affected cereals [4] but is also a significant factor in livestock production; affecting the availability of water, fodder and pasture with impacts on animal health and the nutrition and food security of pastoralists and agro-pastoralists

The possible impacts of these changes on agricultural production in the country include, among others, the following:

- Changes in water availability for crop and livestock production.
- Increased competition and conflicts over pasture and water for livestock.
- Geographical shifts and reductions in areas suitable for production of teff, maize, barley and sorghum [47].
- Shifts from livestock rearing to crop cultivation, from nomadic to sedentary livestock keeping, and/or from pastoralist to agro pastoralist [48].

Projected change in suitable area in Ethiopia (2040-2069)



Climate Smart Agriculture in Ethiopia

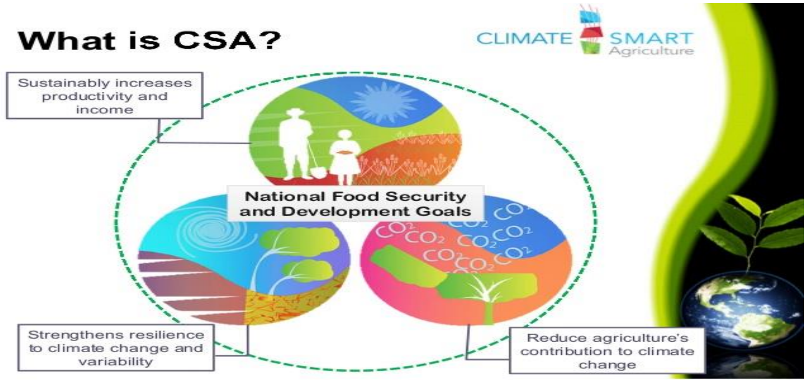
The agriculture sector is the backbone of Ethiopia's economy and livelihoods. Yet, heavy reliance on rain-fed systems has made the sector particularly vulnerable to variability in rainfall and temperature. Climate change may decrease national gross domestic product (GDP) by 8–10% by 2050, but adaptation action in agriculture could cut climate shock-related losses by half

Climate risk management interventions and long-term adaptation actions need to match localized vulnerabilities and impacts. The drought-prone highland areas are likely to experience more intense and irregular rainfall, affecting yields of slow maturing, long-cycle crops; however, the higher altitude moisture-sufficient parts of the highlands where cereal production is dominant are expected to increase in suitability and productivity of some cereals. Increased temperatures and extended drought periods are likely to negatively affect the lowlands, posing particular challenges to already vulnerable pastoral-and agro pastoral populations.

What is climate-smart agriculture?

Climate-smart agriculture (CSA) may be defined as an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper et al. 2014).The most commonly used definition is provided by the Food and Agricultural Organization of the United Nations (FAO), which defines CSA as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals". In this definition, the principal goal of CSA is identified as food security and development (FAO 2013a; 2 Lipper et al. 2014 1); while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address trade-offs and synergies between these three pillars: **productivity, adaptation,** and **mitigation** [1



The three pillars of CSA

- **Productivity:** CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish, without having a negative impact on the environment. This, in turn, will raise food and nutritional security. A key concept related to raising productivity is sustainable intensification
- **Adaptation:** CSA aims to reduce the exposure of farmers to short-term risks, while also strengthening their resilience by building their capacity to adapt and prosper in the face of shocks and longer-term stresses. Particular attention is given to protecting the ecosystem services which ecosystems provide to farmers and others. These services are essential for maintaining productivity and our ability to adapt to climate changes.

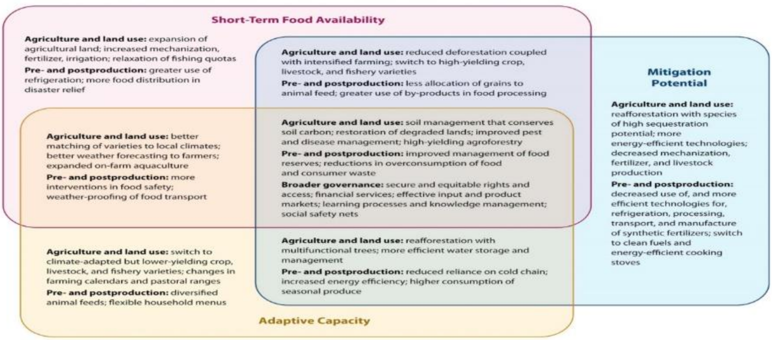
Mitigation: Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions. This implies that we reduce emissions for each calorie or kilo of food, fibre and fuel that we produce. That we avoid deforestation from agriculture. And that we manage soils and trees in ways that maximizes their potential to acts as carbon sinks and absorb CO2 from the atmosphere.

Major characteristics of CSA

- **CSA addresses climate change:** Contrary to conventional agricultural development, CSA systematically integrates climate change into the planning and development of sustainable agricultural systems (Lipper et al. 2014). 1
- **CSA integrates multiple goals and manages trade-offs:** Ideally, CSA produces triple-win outcomes: increased productivity, enhanced resilience and reduced emissions. But often it is not possible to achieve all three. Frequently, when it comes time to implement CSA, trade-offs must be made. This requires us to identify synergies and weigh the costs and benefits of different options based on stakeholder objectives identified through participatory approaches (see figure 1).
- **Ecosystems services:** Ecosystems provide farmers with essential services, including clean air, water, food and materials. It is imperative that CSA interventions do not contribute to their degradation. Thus, CSA adopts a landscape approach that builds upon the principles of sustainable agriculture but goes beyond the narrow sectoral approaches that result in uncoordinated and competing land uses, to integrated planning and management (FAO 2012b; 5 FAO 2013a 2).
- **CSA has multiple entry points at different levels:** CSA should not be perceived as a set of practices and technologies. It has multiple entry points, ranging from the development of technologies and practices to the elaboration of climate change models and scenarios, information technologies, insurance schemes, value chains and the strengthening of institutional and political enabling environments. As such, it goes beyond single technologies at the farm level and includes the integration of multiple interventions at the food system, landscape, value chain or policy level.
- **CSA is context specific:** What is climate-smart in one-place may not be climate-smart in another, and no interventions are climate-smart everywhere or every time. Interventions must consider how different elements interact at the landscape level, within or among ecosystems and as a part of different institutional arrangements and political realities. The

fact that CSA often strives to reach multiple objectives at the system level makes it particularly difficult to transfer experiences from one context to another.

- **CSA engages women and marginalized groups:** To achieve food security goals and enhance resilience, CSA approaches must involve the poorest and most vulnerable groups. These groups often live on marginal lands which are most vulnerable to climate events like drought and floods. They are, thus, most likely to be affected by climate change. Gender is another central aspect of CSA. Women typically have less access and legal right to the land which they farm, or to other productive and economic resources which could help build their adaptive capacity to cope with events like droughts and floods (Huyer et al. 2015). 6 CSA strives to involve all local, regional and national stakeholders in decision-making. Only by doing so, is it possible to identify the most appropriate interventions and form the partnerships and alliances needed to enable sustainable development.



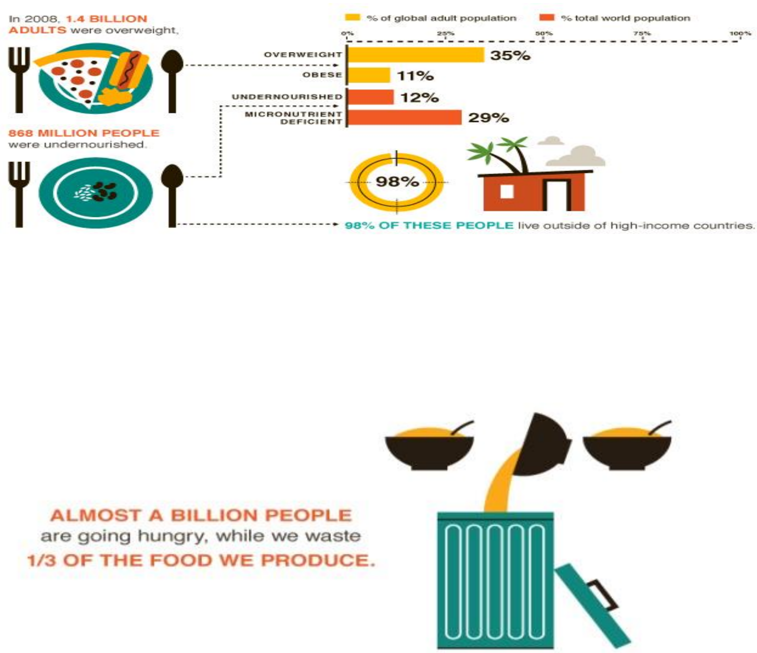
AR Vermeulen SJ, et al. 2012.
Annu. Rev. Environ. Resour. 37:195–222

- **Why climate-smart agriculture?**

1. CSA addresses food security, misdistribution and malnutrition

Despite the attention paid to agricultural development and food security over the past decades, there are still about 800 million undernourished and 1 billion malnourished people in the world. At the same time, more than 1.4 billion adults are overweight and one third of all food produced is wasted. Before 2050, the global population is expected to swell to more than 9.7 billion people (United Nations 2015). 1 At the same time, global food consumption trends are changing drastically, for example, increasing affluence is driving demand for meat-rich diets. If the current trends in consumption patterns and food waste continue, it is estimated we will require 60% more food production by 2050 (Alexandratos and Bruinsma 2012). 2 CSA helps to improve food security for the poor and marginalised groups while also reducing food waste globally (CCAFS 2013). 3

Figure 1: Food security, malnutrition and misdistribution



2. CSA addresses the relationship between agriculture and poverty

Agriculture continues to be the main source of food, employment and income for many people living in developing countries. Indeed, it is estimated that about 75% of the world's poor live in rural areas, with agriculture being their most important income source (Lipper et al. 2014). 4 As such, agriculture is uniquely placed to propel people out of poverty. Agricultural growth is often the most effective and equitable strategy for both reducing poverty and increasing food security (CCAFS and FAO 2014). 5

3. CSA addresses the relation between climate change and agriculture

Climate change is already increasing average temperatures around the globe and, in the future, temperatures are projected to be not only hotter but more volatile too. This, in turn, will alter how much precipitation falls, where and when. Combined, these changes will increase the frequency and intensity of extreme weather events such as hurricanes, floods, heat waves, snowstorms and droughts. They may cause sea level rise and salinization, as well as perturbations across entire ecosystems. All of these changes will have profound impacts on agriculture, forestry and fisheries (FAO 2013a). 6 Figure 2. Observed and projected changes in annual

- How is it different?
- Conservation agriculture

Component of Conservation agriculture
Principles of conservation agriculture
Conservation agriculture and crop production
Conservation agriculture for climate change adaption options
Conservation agriculture and conservation tillage

8. Reference

Aklilu, A. and Alebachew, A. 2009. Assessment of climate change-induced hazards, impacts and responses in the southern lowlands of Ethiopia. Forum for Social Studies, Addis Ababa.

Woodfine, A. 2009. The Potential of Sustainable Land Management Practices for Climate Change Mitigation andAdaptation in Sub-Saharan Africa. Technical Report for TerrAfrica.

Baker, J.M., Ochsner, T.E., Venterea, R.T. & Griffis, T.J. 2007.Tillage and soil carbon sequestration - what do we really know? Agriculture, Ecosystems & Environment, 118: 1–5.

Befekadu, D. and Berhanu, N. 2000. Annual Report on the Ethiopian Economy, Vol. I. The

Ethiopian Economic Association.
Central Statistical Agency of Ethiopia. 2011. Large and medium scale commercial farm survey 2010/11. Results at country and regional levels. V-Viii. Addis Ababa.
Central Statistical Agency of Ethiopia. 2012. Report on area and production of major crops. Private peasant holding, meher season. V-1. Addis Ababa.
Derpsch, R., Friedrich, T., Kassam, A. and Li, H.W. 2010.Current status of adoption of no till farming in the world and some of its main benefits. Int. J. Agric. and Biol. Eng. Vol. 3. No 1.
Ethiopia Climate Resilient Green Economy Strategy. 2011. Ethiopia National Adaptation Programmes of Action (NAPA).2007.
FAO. 2010. "Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation.Paper prepared for Hague Conference on Agriculture, Food Security and Climate Change.
FDRE. 2011. Agriculture Sector Programme of Plan on Adaptation to Climate Change. Addis Ababa, Ethiopia. Hobbs, N.T., Galvin, K.A., Stokes, C.J., Lackett, J.M., Ash, A.J.,
Boone, R.B. 2008. Fragmentation of rangelands: implications for humans, animals, and landscapes. Global Enivron. Change, 18, 776 -785.
Milder, J.C., Majanen, T. and Scherr, S.J. 2011. Performance and Potential of Conservation Agriculture for Climate
Change Adaptation and Mitigation in Sub-Saharan Africa.An assessment of WWF and CARE projects in support of the
WWF-CARE Alliance's Rural Futures Initiative. JVP. 2000. The Joint Vertisol Management Project: Summary of Achievements and Lessons learnt. Addis Ababa.
Kassam A. H., Friedrich T., Shaxson T. F. and Pretty J. N.2009. The spread of Conservation Agriculture: Justification, sustainability and uptake. International Journal of Agriculture Sustainability 7: 292-320.
Kitalyi, A., Nyadzi, G., Lutkamu, M., Swai, R. and Gama, B. 2011. New climate, new agriculture: how Agroforestry contributes to meeting the challenges of Agricultural development in Tanzania.Tanzanian Journal of Agricultural Sciences, 10 (1): 1 – 7.
Lamourdia, T. 2010. Upscaling Conservation Agriculture.Proceedings of the workshop on Conservation Agriculture in Ethiopia. Addis Ababa, Ethiopia.
Liben, F.M., C.S. Wortmann, and K. Tesfaye. 2015. Dry soil planting of maize for variable onset of rainfall in Ethiopia. Agron. J. 107:1618– 1625. doi:10.2134/agronj14.0621
Liben, F.M., S.J. Hassan, B.T. Weyesa, C.S. Wortmann, H.K. Kim, M.SKidane, G.G. Yeda, and B. Beshir. 2017. Conservation agriculture for maize and bean production in the Central Rift Valley of Ethiopia.Agron. J. 109:2988–2997. doi:10.2134/agronj2017.02.0072
Liben, F. M., B. Tadesse, Y. T. Tola, C. S. Wortmann, H. K. Kim, and W. Mupangwa 2018, Conservation Agriculture Effects on Crop Productivity and Soil Properties in Ethiopia. Agronomy Journal • Volume 110, Issue 2•2018
MoA. 2014. Natural resource activities implemented in the GTP.
MOFED. 2003. Rural Development Policy and Strategy Document.
MOFED. 2010. Growth and Transformation Plan 2010/11-2014/15. Volume 1: main text. Addis Ababa.
PANW. 2012. Crop rotation benefiting farmers, the environment and economy. Friends of the Earth Europe, EU group and APRODEV.
Senay, H. 2012. United Nations Development Programme. 304 East 45th Street, New York, NY 10017, USA. www.undp. org/gender.
Shimeles, A. 2014. Selected CA case studies in Ethiopia. EIAR/ NARS. Presentation made at the

Eastern Africa Sub-regional CSA Workshop held in Nairobi, Kenya. 29 September 2014.
Sintayehu, W. 2011. Presentation made at the National Policy Workshop on Climate Change Adaptation and Mitigation. Climate Change Forum and CCAFS, 2011. Sustainable Land Management Project Document. 2013.
Tekalign, M., Mohamed-Saleem, A. and Abate, T. 1993.Development of coordinated efforts. In: Tekalign Mamo, Abiye Astatke, K.L. Srivastava and Asgelil Dibabe (Eds.)
Tesfa, B. 2001. Report of research on maize tillage system atJima Research Centre. In: Proceedings of the workshop on conservation tillage. February 28 to March 1, 2001, Melkasa Research Centre, Nazreth.
Tolesa, D. 2001. Conservation tillage experiments at BakoResearch Centre. West Showa Zone. In: Proceeding of the workshop on conservation tillage. February 28 to March 1,2001, Melkasa Research Centre, Nazreth.WABEKBON. 2006. Ethiopia. Country Gender Profile.Wabekbon Development Consultants, Addis Ababa.
Wondwossen, T., Dejene A., La Rovere, R., Mwangi, W. Mwabu, G., and Tesfahun, G. 2008. Does Partial Adoption of Conservation Agriculture Affect Crop Yields and Labour Use? Evidence from Two Districts in Ethiopia. CIMMYT/SG 2000.
Worku, B. 2001. In: Proceedings of the national workshop on conservation agriculture at Melkasa. Organized by SG2000. Melkasa, Nazreth.
World Vision. 2006. Humbo/Soddo Community Based Forest Management Project. South Branch Office, Humbo ADP.World Vision. 2009. Humbo Community managed forestry project, Ethiopia. Climate change, community forest and development.