

The Essentials of Conservation Agriculture for Soil Quality, Crop and Water Productivity in Ethiopian Agriculture: A Review

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Abstract

In fact food security can be increased through improved land use and land management practices. In Ethiopia much of the increase in crop production in the past decade has been due to increases in area of cultivated. To what extent expansion can continue remains a question, therefore obtaining higher yield rates is the challenge of Ethiopia's agricultural system. Conservation agriculture (mulching); which here refers to minimizing soil disturbance through no-till practice, application of organic mulch cover, and cropping in time; has the potential to improve soil quality, water, and crop productivity. The objectives of this critical review is to collect available information in similar production environments, indicators on the essential of CA contributions to soil quality, crop and water productivity both in dry and rainfall seasons of Ethiopian agriculture. Recently a study on the role of conservation agriculture indicates improve soil quality, crop yield and water productivity. In addition to this CA can be protect soil layer for erosions either wind or runoff, to optimize infiltration rate minimize runoff, to crate the path of soil it contributes micro nutrients move easily. So, reviewer concluded that conservation agriculture is potentially important to improve sustainable Ethiopian agricultural production and productivity. This agricultural practice (CA) should be able to adopt for irrigated and rain fed farms of Ethiopia.

Keywords: Conservation Agriculture, soil quality, crop productivity, water productivity and Ethiopia

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1. Introduction

Food security can be increased through improved land use and land management practices (Branca *et al.*, 2013; van der Molen, 2017; Ramankutty *et al.*, 2018), Agriculture in the next decade will have to produce more food on less land (Hobbs, 2007; Hobbs *et al.*, 2008; Govers *et al.*, 2017) and purchased production inputs by making more efficient use of natural and applied resources but with a minimal negative impact on the environment (Stagnari *et al.*, 2009; Meemken and Qaim, 2018; Baylis *et al.*, 2021). In Ethiopia much of the increase in crop production in the past decade has been due to increases in area cultivated. To what extent expansion can continue remains a question, therefore obtaining higher yield rates is the challenge of Ethiopia's agricultural system.

Conservation agriculture is the integration of ecological management with modern, scientific, agricultural production (Assefa *et al.*, 2020; Abebe *et al.*). According to Derpsch *et al.* (2010) Conservation Agriculture was started with concept of reduced tillage or no tillage practices in 1970s in USA. Conservation agriculture (CA), defined as minimal soil disturbance (no-till, NT) and permanent soil cover (mulch) combined with rotations, as a more sustainable cultivation system for the future (Hobbs, 2007). Conservation agriculture (CA) aims to conserve, improve, and make more efficient use of natural resources through integrated management of (Abebe *et al.*) soil, water, and biological resources combined with external inputs (Hobbs, 2007; Hobbs *et al.*, 2008; Leye, 2007; Stagnari *et al.*, 2009). It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource-efficient or resource effective agriculture (Govers *et al.*, 2017).

In recent times researchers are sound to deliver positive impacts of CA adoption on soil quality and crop yield improvement (Das *et al.*, 2014; Jat *et al.*, 2018; Nangia *et al.*, 2010; Assefa, 2018; Assefa *et al.*, 2020; Yimam *et al.*, 2020; Assefa *et al.*, 2021). The soil quality improvements are around enhancement of soil organic carbon (SOC) content (Yimam *et al.*, 2020), water infiltration capacity (Abera *et al.*, 2020), water holding capacity and microbial activities (Abera *et al.*, 2020), and thereby arresting decline in total factor productivity of applied inputs. Moreover, it was reported to have contributed to protection of the top fertile soil from wind and water erosion (Nangia *et al.*, 2010; Descheemaeker *et al.*, 2013; Fentahun Adamtie, 2020).

In Ethiopia, land degradation in the form of soil erosion, nutrient depletion, soil compaction, and increased salinization and acidity pose a serious threat to sustainable intensification and diversification of agricultural production systems. Ethiopian farmers have been practicing excessive soil tillage using animal traction for thousands of years (Goe, 1987) as cited by (Getnet *et al.*, 2015). Tillage is physical, chemical, or biological soil manipulation to optimize conditions for seed germination, emergence, and seedling establishment (Getnet *et al.*, 2015; Lal, 1976). Smallholder farmers in Ethiopia practice traditional tillage systems using an ard plow called Maresha (Nyssen *et al.*, 2011). Traditional tillage systems that involve repeated cultivations with the Maresha

plow have caused land degradation) and poor utilization of rain water that led to low crop productivity (Leye, 2007). Reports showed that Ethiopia loss 40–130 t ha⁻¹ year⁻¹ of soil from croplands that costs the country about 1.0-1.5 million tons loss of grain production per year (Abera *et al.*, 2020). Reduction in soil fertility and soil quality are among major factors contributing to low adaptability of agriculture to insufficient and erratic rainfall in many parts of the country (Alemu and Mengistu, 2019; Ariti *et al.*, 2015). Research on conservation agriculture in Ethiopia started early in 1980s (Georgis and Sinebo, 1993) with the focus of reducing heavy disturbance from frequent tillage operations by the traditional tillage implement, Maresha plow (Melesse *et al.*, 2007). Reports on crop performance and soil productivity improvements in most trials of zero and minimum tillage showed varying results in different soils and rainfall conditions (Assefa *et al.*, 2019; Assefa *et al.*, 2021; Belay *et al.*, 2020). In addition to this for irrigation seasons studies have examined drip irrigation in combination with CA is one of the best strategies for soil and water management that improves the cycles of vegetable production through increased water productivity (Yimam *et al.*, 2020; Assefa, 2018). Application of surface organic mulch cover has been used to improve soil water retention, reduce soil temperature and reduce wind velocity at the soil surface and arid lands (Yimam *et al.*, 2020; Bainbridge *et al.*, 2001). Surface organic mulch can also improve water penetration by impeding runoff and protecting the soil from raindrop splash and reducing soil crusting (Munshower, 1994). In recent studies, the effects of conservation agriculture with irrigation improves crop yield and also soil carbon and nitrogen were increased (Assefa *et al.*, 2019; Assefa *et al.*, 2020; Yimam *et al.*, 2020; Belay *et al.*, 2020). So, this review pepper was troubled to conservation agriculture (CA); which here refers to minimizing soil disturbance through no-till practice, application of organic mulch cover, and cropping in time; has the potential to improve soil quality, water, and crop productivity. Therefore the objectives of this review work is to collect available information in similar production environments, indicators on the essential of CA contributions to soil quality, crop and water productivity both in dry and rainfall seasons of Ethiopian agriculture.

2. History of Agricultural practice in Ethiopia

The history of tillage dates back many millennia when humans changed from hunting and gathering to more sedentary and settled agriculture mostly in the Tigris, Euphrates, Nile, Yangste and Indus river valleys (Hillel, 1991) as cited by (Hobbs *et al.*, 2008). From those Ethiopia is the source of Blue Nile the agriculture is generally dominated by smallholder, rain-fed, low-input-low-output mode of production (Agerie, 2013) Since, Ethiopian farmers have been practicing excessive soil tillage using animal traction for thousands of years (Goe, 1987) as cited by (Getnet *et al.*, 2015). Tillage is physical, chemical, or biological soil manipulation to optimize conditions for seed germination, emergence, and seedling establishment (Getnet *et al.*, 2015; Lal, 1976). Smallholder farmers in Ethiopia practice traditional tillage systems using an ard plow called Maresha (Nyssen *et al.*, 2011; Leye, 2007). Traditional tillage systems that involve repeated cultivations with the Maresha plow have caused land degradation) and poor utilization of rainwater that led to low crop productivity (Leye, 2007). Much of the increase in crop production in the past decade has been due to increases in area cultivated. To what extent expansion can continue remains a question, therefore obtaining higher yield rates is the challenge of Ethiopia's agricultural system.

3. Conservational Agricultural practice in Ethiopia

Soil and Water Conservation in Ethiopia has a long history. According to Beshah (2003) the traditional terraces in Konso constitute a spectacular example of a living cultural tradition stretching back to more than 400 years. The soil conservation practices, including minimum or no tillage have long been practiced by farmers with different approaches or systems in Ethiopia (Rockström *et al.*, 2009). From the observation indigenously Ethiopian farmers were applied plant residue (mulching) for nursery and perennial crops like hop and coffee. This applied residue (CA) is used to protect sun light and conserve soil moisture for long time. Conservation agriculture and its associated package of best practices were introduced in 1980 (Abera *et al.*, 2020). with the focus of reducing heavy disturbance from frequent tillage operations by the traditional tillage implement, Maresha plow (Leye, 2007). Whereas the adoption and expansion of conservation agriculture for Ethiopian farmers is still under expected. Agricultural policies input subsidy policies, investments in agricultural extension and access to markets in predicting are challenges for CA adoption (Marenya *et al.*, 2015).

4. Crop production and productivity in Ethiopia

Both irrigated and rain-fed agriculture is important in the Ethiopian economy. Nevertheless, virtually all food crops (97 %) in Ethiopia come from rain fed agriculture, with the irrigation subsector accounting for only about (3 %) of the food crops (Awulachew and Merrey, 2007; Mendes and Paglietti, 2015). Cereals dominate Ethiopian crop production were grown on 73.4 % of the total area cultivated, by a total of 11.2 million farmers and obtained 12 million tons per year of cereals, which is 68 % of total agricultural production (Mebratu *et al.*, 2015). Irrigated crops in medium and large-scale commercial farms are mostly cash crops, in particular cotton and sugar

cane, but fruits and vegetables were also introduced (Girma and Seleshi, 2007). In small-scale irrigation schemes, irrigated crops are more diversified, but for the country as a whole, the main irrigated crops are cereals—maize, wheat, barley or teff, pulses, vegetables, root crops, fruits, and fiber crops (cotton) (Neelakantam and Naidu, 2016). Smallholder irrigators generally prefer subsistence crops rather than cash crops (Muhanji *et al.*, 2011) and use irrigation to complement rain fed agriculture, i.e. Supplementary irrigation rain-fed, during the dry season, they use full irrigation to get additional income (IWMI, 2009).

According to Central Statistical Agency Ethiopia (2011); CSA (2019), the agricultural Sample Survey report of Ethiopia on area and production of crops as categorized grain crops, vegetables, root crops, and fruit crops. Crop production farms are classified as private smallholder rain-fed farms, Private smallholder dry season irrigation farms, and Commercial farms (Table, 1). Those farms coverage and productivity of grain crop shows a total land area of 15,270,526 hectares and 342, 17454.3 ton. Vegetables, It covers 1.96% at the national level and contributes 2.17% of the total crop production. Root crops, it covers 1.62% of the area under all crops at the national level. Fruit crops, it covers 107,890.60 hectares and obtained more than 7, 923, 66.5 ton per year.

As compared to farm type's crop productivity showed that irrigated farm is good productivity while rain fed and commercial farms are less productivity of grain, cereals, pulses and oilseeds.

Table 1: source CSA (2019); Ethiopia (2011) crop coverage area and crop production for Ethiopia under irrigated, rain fed and commercial

Farm type Crop Category	Irrigated			Rain fed			Commercial		
	Area (ha) ×103	Production ton x103	Productivity ton ha ⁻¹	Area (ha) ×103	Production ton x103	Productivity ton ha ⁻¹	Area (ha) ×103	Production ton x103	Productivity ton ha ⁻¹
Grain Crops	85.3	287.52	3.4	14543	32605.5	2.2	641.	1324.34	2.1
Cereals	70.4	262.01	3.7	11610	28392.2	2.4	296.	970.23	3.3
Pulses	14.8	25.4	1.7	2053.	3353.48	1.6	58.8	111.17	1.9
Oilseeds	0.1	0.12	1.2	879.6	0.86	0.0	286.	242.95	0.8
Total	170.	575.05	3.4	29086	64352.1	2.2	1283	2648.69	2.1

N.B: Area of cultivated and productions of yield data taken from CSA for irrigated, rain fed and commercial while productivity of each was changed by researcher

5. Role of Conservation Agriculture for soil, crop and water productivity

There are numbers of soil and crop management practices that can increase the crop yields and water productivity (Yi *et al.*, 2010). CA (Mulching) is a cropping practice that entails placing organic or inorganic or synthetic materials on soil close to plants to provide a more favorable environment for the growth and development of crops (Ranjan *et al.*, 2017; Kumar and Lal, 2012). The application of mulching practices reduces soil evaporation, conserve soil moisture, suppresses weed growth, control soil structure and temperature, influences soil micro-organisms and increase crop productivity (Kader *et al.*, 2017) and reduction of runoff and erosion (Ranjan *et al.*, 2017). It dampens the influence of the environmental factor on the soil by controlling seasonal fluctuations in soil temperature (Ghosh *et al.*, 2006). Especially, using a sufficient mulching layer could control both weed growth and soil temperature fluctuations (Ji and Unger, 2001). Moreover, the water holding capacity of soil is improved through mulch decomposition and humus formation (Liu *et al.*, 2013).

Agricultural production increase under CA by improving soil physical properties and fertility (Bandyopadhyay *et al.*, 2009). Mulching is very useful in protecting the roots of the plants from heat, cold, or drought or to keep fruit clean (Kumar and Lal, 2012). Mulching have also effective change in increasing horticultural crop production in water scarcity regions (Lal Bhardwaj, 2013). Additionally, organic mulch protect the crop from soil born disease and provided plant nutrition (Stirling and Eden, 2008) and nutrients leaching loses can also be minimized (Zibilske and Makus, 2009) and improve crop production through increasing soil quality by conserving soil moisture (Ranjan *et al.*, 2017), enhancing soil biological activities, and improving the chemical and physical properties of soil (Bandyopadhyay *et al.*, 2009).

Conservation Agriculture with Drip Irrigation for Water Productivity in Sub-Saharan Africa including Ethiopia studied by Assefa *et al.* (2019) suggested that irrigation water use was substantially lower under CA, 18% to 45.6%, with a substantial increase in crop yields, 9% to about two-fold, when compared with CT practice for the various vegetables.

5.1. Essentials of CA for Soil quality

Mulching with agricultural waste such as straw, compost, grass clippings, and leaves, and others had increased water retention and prevented the soil evaporation (Kar and Singh, 2004). Straw is the most commonly used material for ground covering in the crop and vegetable production because of its good thermal insulation properties. The temperature of the soil under the straw can be 5-80C lower than the temperature of bare soil which is especially important in the summer (OLJAČA *et al.*, 2018). Straw mulching increase WUE, crop

growth, and grain yield over none mulch (Kar and Singh, 2004). Straw mulching has the ability to improving the soil structure, water-holding capacity, and increase the soil moisture content of the soil, and the amount of water stored in soil increased as the application of mulching rate increases (Liu *et al.*, 2013).

Organic mulches preserve more soil moisture (Ghosh *et al.*, 2006) and (Teame *et al.*, 2017). Mulch played a dominant role in the conservation of soil water even if in the condition of moderate stress (Mukherjee *et al.*, 2012). Organic mulch consistently helped in retaining higher soil water than without mulch and reduced soil temperature by 2-3oc (Ghosh *et al.*, 2006).

Moisture contents of soils of irrigated tomato under grass straw, rice straw, rice husk and sawdust mulches were higher than those in the non-mulching (Nkansah *et al.*, 2003). Liu *et al.* (2010) studied soil water dynamics and water use efficiency in spring maize field under different water management practices on the loess plateau and the result indicates that soil water storage increased in the straw mulch compared to film mulch. Dissimilarly, (Shirgure *et al.*, 2003) study reported that black polyethylene mulching conservation higher soil moisture than soybean straw and grass mulching. Straw mulching increases the soil moisture content of apple orchard (Liu *et al.*, 2013) and maize crop (Tao *et al.*, 2015). Straw mulch conserves soil water by reducing the incoming solar energy, less water was evaporated and mulch reduced the soil moisture depletion in irrigated potato plant (Kar and Kumar, 2007).

In most cases, water stored in the soil increases with increasing mulching rate. Ji and Unger (2001) reported that straw mulching rate increases form 2.0 Mg ha⁻¹ to 4.0 Mg ha⁻¹ soil water storage efficiency increase by 60 to 100%, respectively compared with bare soil. Harmoniously, Ahmed *et al.* (2007) suggested that soil moisture content increase from 2 to 24 % as the mulching rate increase from 1 to 4 tons per hectare. The effectiveness of increasing mulching rate on soil moisture reserve was studied by Uwah and Iwo (2011), the result indicated that soil moisture reserves were highest at mulching rate increases compared with non-mulch.

In Ethiopian case Liben *et al.* (2018) experimental report showed that CA increases by the rate of water infiltration 15%, time-to-pond doubled and soil organic carbon 4 g kg⁻¹ as compared with conventional practice.

5.2. Essential of CA for plant growth and yield

Application of organic mulch more over straw mulching is superior to that of inorganic mulch to provide the highest yield of crops (Ghosh *et al.*, 2006) and facilitate better crop growth and development (Teame *et al.*, 2017). Organic mulching is one of the suitable methods for the production of horticultural and vegetable crops with quality products (Ranjan *et al.*, 2017). Organic mulch increase yield to the extent of more than 50 % if the soil moisture is conserved (Ranjan *et al.*, 2017). Saeed and Ahmad (2009) stated that organic mulches with or without gypsum to the soil being irrigated with saline water increases the yield of tomato by reducing salinity. Seifu *et al.* (2017) suggested that organic mulching has a significant effect on plant height and earliness maturity of garlic crops than bare soil. Identically, Teame *et al.* (2017) reported that straw mulch increases number of seed per capsule, seed weight, and grain yield of sesame. In contrast⁷¹⁴⁸ (Malik *et al.*, 2017) reported that Black Film Mulch significantly increased the yield of sugar beet by 4% over straw mulch.

Ghosh *et al.* (2006) suggested that wheat straw mulch increase yield of ground nut by 30-40% over without mulch and wheat or paddy straw produced 17-24% of higher yield of ground nut over polythene mulch. In contrast Liu *et al.* (2010) , suggested that maize grain yield was increased in film mulch rather than straw mulch. Mukherjee *et al.* (2012) reported that mulching increases tomato yield by 23-57% over non mulching condition. Maize yield was increased by 233.9 kg/ha- 381.8 kg/ha in chopped straw mulching over prostrate whole straw mulching (Tao *et al.*, 2015). In Ethiopia reported by (Liben *et al.*, 2018) studied at Melkassa and Bako agricultural research center who obtained maize grain yield was 10.14 Mg ha⁻¹ for conventional practice compared with 9.01 Mg ha⁻¹ for CA in 2015 at Bako, but maize yields were greater with CA at Melkassa in 2016. Monoculture and intercrop dry bean, respectively, had 40 and 32% more grain yield with CA compared to CP in 2016 at Melkassa. It was concluded that medium-term beneficial effects of CA on soil properties and crop productivity can be expected at Melkassa, but any short-term benefits of CA at Bako were uncertain.

Mubarak and Hamdan (2018) suggested that mulching increase onion bulb yield by 53.4% compared to none mulching. According to Inusah *et al.* (2013) onion bulb yield was improved under straw mulching rather than non-mulching. Onion yield in both grass and rice straw mulches were significantly different from one another; onion yield under grass mulching was increased by 60% than rice straw mulching. Therefore, the sustained yield of onion crop is achieved by mulching.

5.3. Essential of CA on water productivity

A lot of studies argued that conservation agriculture showed CA is one of the water management practice for increasing water productivity as well as increasing irrigable area (Biswas *et al.*, 2017; Assefa, 2018; Belay *et al.*, 2020; Assefa *et al.*, 2021; Yimam *et al.*, 2020). The study of Mukherjee *et al.* (2012), indicated that CA increased water productivity of tomato crop by 54-93%.

According to Igbadun *et al.* (2012) mulching with rice straw and black polyethylene significantly improve

the crop water productivity of onion crop compared with white transparent polyethylene mulch and non-mulch. According to the studies of Rop *et al.* (2016), irrigation water use efficiency values increased with decreasing water application level. The highest 16.2kg/m³ and the lowest 13.1 kg/m³ IWUE of onion crop was observed at 50% DI and full irrigation respectively.

According to Assefa *et al.* (2019) report irrigation water use was substantially lower under CA, 18% to 45.6%, with a substantial increase in crop yields, 9% to about two-fold, when compared with CT practice for two folds vegetables. Recently in Ethiopia according to Assefa *et al.* (2021) CA water productivity of garlic, cabbage, potato, and maize showed increased, by 256%, 43%, 53%, and 9% as compared with CT.

6. Factors Affecting Adoption of Conservation Agriculture (CA) in Ethiopia

In Ethiopia adoption of Conservation Agriculture is affected by different factors. These constraints are competitive use of mulch; the mulch covers used were crop residues, dried grass, and other local organic materials which farmers also use it to feed their livestock (Assefa *et al.*, 2019), limited potential to grow cover crops during dry season (Umar and Nyanga, 2011), some part of the country farmers burned plant residue by fire.

7. Opportunities for Adoption of Conservation Agriculture

In agriculture dependent country like Ethiopia, soil and water conservation is crucial in improving the livelihoods of the rural farm households. This sends an encouraging signal for program designers, implementers, and funding agents. According to (Assefa *et al.*, 2019) CA reducing labour; particularly for tillage, irrigation, and weeding. Increasing water productivity; potential to increase the cycles of vegetable production through increased water productivity. In addition to this CA realize the intended outcomes, future development strategies should consider on how to link such interventions with natural resource management based income generating activities that can provide farmers with short term benefits (Derpsch *et al.*, 2010).

8. Conclusions

I have been organized a lot of experimental studies those literature concluded that conservation agriculture is potentially important to improve sustainable Ethiopian agricultural production and productivity. For dry season vegetable production CA can minimize irrigation water by 18% to 45.6%, and also increase in crop yields by 9% as compared to CT practice for two folds. For rain fed season also similar effects CA improves crop production and productivity. In addition to this CA improves soil quality like increasing soil organic matter and carbon protect soil layer for erosions either wind or runoff, to optimize infiltration rate minimize runoff, to crate the path of soil it contributes micro nutrients move easily to plants. Therefore this agricultural practice (CA) should be able to adopt for irrigated and rain fed farms of Ethiopia.

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