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Review on Conservation Agriculture in Ethiopia: Status of Application, Opportunities and Challenges

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ABSTRACT

Conservation agriculture has been considered as the potential not only to increase the sustainability of agricultural productivity, but also to help works toward mitigation and adaption of climate change. Farming and soil management practices included in conservation agriculture are based on three core principles, which must be fulfilled concomitantly Minimum soil disturbance, Maintenance of permanent soil covers and Cropping system diversity, crop rotations. The objective of this document is therefore to review the implementation status, opportunities, challenges and limitation of conservation agriculture practices in Ethiopia. Conservation agriculture has economic as well as climatic advantages. The soil conservation practices, including minimum or no tillage have long been practiced by farmers with different approaches or systems in Ethiopia, conservation agriculture and its associated package of best practices were introduced in 1998. Presence of traditional practices contributing for conservation agriculture principle and socioeconomic and extension facilities are some of factors affecting adoption of conservation agriculture in Ethiopia while, Climate change prevention activities and untapped opportunity for the wide-scale promotion are some opportunities for adoption of Conservation Agriculture in Ethiopia. The principal goal of climate smart agriculture is identified as food security and development, while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal. Key challenge with mainstreaming conservation agriculture systems relate to problems with up-scaling which is largely due to the lack of knowledge, expertise, inputs (especially equipment and machinery), adequate financial resources and infrastructure, and poor policy support.

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Introduction

Improving food security in World, in the face of rapidly growing populations and climate change impacts, is a daunting challenge. However, considerable recent success of conservation agriculture programs and agroforestry programs are cause for optimism [1]. Achieving food security and sustainability in the 21st century is expected to become increasingly challenging due to greater soil degradation resulting from climate change, population growth, and depletion of water resources [2].

Agriculture in developing countries must undergo significant transformation if it is to meet the growing and interconnected challenges of food insecurity and climate change [3].Conservation agriculture (CA) that has been considered as the potential not only to increase the sustainability of agricultural productivity, but also to help works toward mitigation and adaption of climate change [4]. The concept of Conservation Agriculture was begun with concept of reduced tillage or no tillage practices in 1970s in USA [5].

Conservation agriculture is the integration of ecological management with modern, scientific, agricultural production. Conservation agriculture employs all modern technologies that enhance the quality and ecological integrity of the soil, but the application of these is tempered with traditional knowledge of soil husbandry gained from generations of successful farmers. Conservation agriculture (CA) is one of the recent sets of farming practices that is being widely advocated and generated widespread policy interest and discussion. In Eastern and Southern Africa, CA has been intensively promoted for more than a decade as a means to increase crop productivity while conserving soil and water.

Agricultural policies input subsidy policies, investments in agricultural extension and access to markets in predicting are challenges for CA adoption. When the extension-personnel-to-farmer-ratios are compared to public expenditures on subsidies, the effect of the subsidy variable appears to have had the stronger effect on CA adoption judging from the simulations involving reductions in subsidy and increasing extension was in most cases the probability of adoption dropped even when extension were increased to mitigate reductions in subsidy [6]. CA adopter farmers have more age, better educational status, less fertile soil, own greater size of land, minimum distance between the residence and plot, cultivated own land instead of sharecropped and rented, participated in kebele or village administration and takes social responsibility and better accessed extension services in the form of field visit, demonstrations, farm training on sustainable land management specifically SWC and CA practices [7]. Development policies and program interventions designed to enhance agricultural productivity through promoting different agricultural technologies in general and conservation tillage technologies in particular [8].

Ethiopia partnered with international institutions to implement innovative food security and participatory watershed development

programs to help smallholder farmers working on marginal land with limited technological resources to break out of a poverty cycle. Climate-smart agriculture entails high knowledge requirements for assessing risks, vulnerabilities, and context specific strategies for increasing agricultural productivity and reducing GHG emissions [9].The three key principles of CA are permanent residue soil cover, minimal soil disturbance and crop rotations. The FAO recently added controlled traffic to this list [10]. The objective of this paper is therefore to review the implementation status, opportunities, challenges and limitation of conservation agriculture practices in Ethiopia.

Review of Literature

Conservation Agriculture

Conservation agriculture (CA) is defined as the simultaneous application of minimal soil disturbance, permanent soil cover through a surface mulch of crop residues or living plants, and crop rotations. It`s a sustainable agriculture production system comprises the farming and soil management practices or techniques which protect the soil from erosion and degradation, improve its quality and biodiversity, and contribute to the preservation of the natural resources, water and air, while optimizing yields [11]. Farming and soil management practices included in CA are based on three core principles, which must be fulfilled concomitantlyMinimum soil disturbance, Maintenance of permanent soil covers and Cropping system diversity, crop rotations [10].

Historically, known are the different modalities or types of agriculture developed in the past few years, to a great extent to attempt to respond to the environmental problems of conventional agriculture. Among others, the integrated agriculture/ integrated production; organic agriculture; extensive agriculture; conservation agriculture are some of them.

It is interesting to analyses which environment problems are really resolved by the above types of agriculture and which are not conservation agriculture (CA) aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations [12]. Conservation agriculture is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment [13].

Although several studies on CA effects in Zambia are positive, more recent work has raised questions about its widespread viability [14]. Thus there is a need for further research to identify in what contexts CF is best promoted.CA, in theory, has the potential to be part of a CSA strategy to agricultural policy making, however, its suitability should be assessed on a case by case basis as local agro-ecological and institutional environment plays a role in determining its adoption and impacts.

Advantage of Conservation Agriculture

In conventional farming, farmers plough and hoe to improve the soil structure and control weeds. But in the long term, they actually destroy the soil structure and contribute to declining soil fertility. Conservation tillage minimizes soil disturbance and increases oxygen levels within the soil, reduces air pollution, limits soil compaction, and helps maintain a habitat for beneficial bugs and nutrients within the soil, improved weed suppression, increased percolation and infiltration, and decreased amount of evaporation of water from the soil surface [15]. Zero or minimum tillage and direct seeding have a positive impact in reduction of wind and water erosion. According to Kidane, the average daily soil moisture content at 30cm soil depth was obtained as 0•334m3m-3 and 0•314 m3m-3 under MT and CT plots respectively in the highland (high rainfall region) of Ethiopia [16]. The results of study showed that, due to the higher infiltration rate at MT, the stored soil water at deeper layers is higher under the MT than that under CT.

Farmers remove or burn the crop residues or mix them into the soil with a plough or hoe. The soil is left bare, so it is easily washed away by rain, or is blown away by the wind. Crop residue management helps reduce soil erosion, captures precipitation (snow and rain), and reduces run off spreading nutrients uniformly and shielding new plants from adverse weather conditions [11]. In the long term, the practice may improve soil physical properties by adding organic matter to the soil and enhancing soil health. In conventional farming, the same crop is sometimes planted each season. That allows certain pests, diseases and weeds to survive and multiply, resulting in lower yields. In conservation agriculture, this is minimized by planting the right mix of crops in the same field, and rotating crops from season to season [10]. Conservation agriculture also helps to maintain soil fertility.

Conservation agriculture produces better farm economy by reducing the overall requirement for farm power and energy for field production by up to 60 % compared to conventional farming [17]. Most of the advantages of CA were summarized by as follows:

- It has flexible technical possibilities for sowing, fertilizer application and weed control (allows for more timely operations)
- It has the nature of increasing and stabilizing yield (as long term effect)
- It protects soil against water and wind erosion
- It promotes greater nutrient-efficiency and
- It has better application of water economy in dry land areas for soil moisture availability

Economic advantages of conservation agriculture

The economic advantages of conservation agriculture for the farmer begin with far fewer inputs being required before planting [18]. Greatly reduced plowing saves farmers energy, labor and time.

CA has mostly been adopted in the world as an energy and labor saving technology. Labor savings mean more time for members of the farm family to pursue other livelihood options, interests and investments such as education, and a smaller portion of farm household income paid out to hired labor [11]. Energy is the product of power by time. A lower energy demand could thus enable the use of smaller and cheaper power sources reduced or no tillage cuts energy requirements by about half compared to moldboard or disc ploughing [19]. Therefore, it appears that CA has mostly been adopted in the world as an energy saving technology, and that adoption has been driven by the need to establish crops with as little energy as possible.

Time savings is yet another immediate benefit of conservation agriculture. Time savings allow farmers to plant earlier, perhaps by weeks. Indeed, some case studies have cited the time savings provided by CA as the primary motivation for the adoption of conservation tillage [20]. Depending on the agricultural environment, this can improve the odds that the crop will mature and be ready to harvest before the onset of late-season drought.CA reduces the time needed for land preparation and seeding, a major benefit in agro ecologies characterized by a short optimum planting

window i.e., where the yield potential declines dramatically with delayed planting [21].

The time of planting was found to be more important than the type of tillage in explaining the performance of different CA systems, with a 5% yield reduction per week planting was delayed [22]. CA adopters in the region tend to plant their crop earlier than farmers using conventional land preparation 12–23 days earlier in Zimbabwe [23].

Improved water use efficiency is yet another immediate benefit of conservation agriculture. CA increases soil water content by increasing infiltration and reducing runoff and evaporation [11]. Increased infiltration improves water use efficiency and buffers crops against drought. In rainfed semi-arid highlands of Mexico, soil water content during dry periods was 10-20 mm higher in maize fields under CA than in those with conventional tillage and residue removal and Infiltration was on average 24-38 mm per ha greater on CA fields in southern Africa as compared to conventionally tilled plots [24].

The benefits of Conservation agriculture are as follows by ICARDA (2012):-

- Consumers by providing affordable food more sustainably than does conventional tillage.
- The rural economy by building agriculture on a firm foundation, creating conditions to allow families who choose to tie their future to continued agricultural development to stay on the land, and creates opportunities for local manufacturers of new seeding machinery.
- The national economy by strengthening food security and contributing to building a more resilient rural economy. And it can be argued that conservation agriculture will benefit the credibility of government officials who are seen to facilitate its adoption.

Environmental advantages of conservation agriculture

While the economic advantages of conservation agriculture are often realized with the first cropping, the environmental advantages emerge more slowly. Conservation agriculture provides direct benefits to environmental issues of global importance [9].

CA have a great benefit to improve soil health because soil is little disturbed, rather than completely turned over several times a year, is able to develop better soil structure. Reducing tillage and maintaining soil cover with crop residues can reduce erosion by up to 80% [24].Crop residues physically protect soil to reduce the wind and water erosion that inevitably diminishes soils left bare by plowing. CA is promoted for the positive benefits of increased organic matter, improved water retention, water infiltration, improved soil fertility, improved soil structure, reduced soil erosion, reduced weed infestation and increased maize yield [25]. Biological activity continues uninterrupted in largely undisturbed soil, and nutrient-rich organic matter is left to accumulate there, rather than become depleted as it is by plowing.

Conservation agriculture sharply reduces greenhouse gas emissions by several avenues. Less plowing requires tractors to burn smaller quantities of fossil fuels, reducing carbon dioxide emissions. Under certain conditions, CA may contribute to climate change mitigation through carbon sequestration and reduced GHG emissions, but climate change adaptation rather than mitigation should be the main policy driver for its promotion [24].

Generally, CA as an alternative paradigm for sustainable agricultural production intensification, offers a number of benefits to the producers, the society and the environment that are not possible to obtain with tillage agriculture [26]. Unless it is too dry to grow crops, CA can be applied in various climatic zones and under different conditions as follows [27].

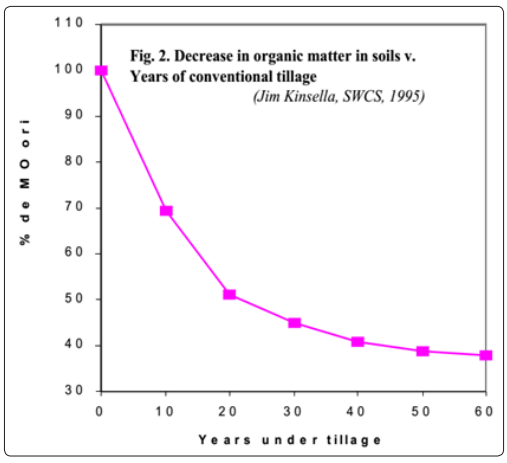
- In semi-arid lands, conservation agriculture retains water in the soil by rainwater harvesting, keeps the soil temperature optimum, and protects the land from erosion during heavy rain.
- In sub-humid and humid areas, weeds and erosion are likely to be more of a problem. Crops are planted at closer spacing, and cover crops help suppress weeds and protect the soil.
- On slopes, conservation agriculture can be used in association with terraces, contour grass strips and other erosion-control methods. Where labor is scarce, perhaps because of different reasons, conservation agriculture enables farmers to produce good yields with less labor.
- In densely populated areas, conservation agriculture increases yields on small plots of land under intensive cultivation.
- On good soils, conservation agriculture keeps the soil healthy and maintains yields. On poor soils, it is a good way to rebuild soil fertility and enhance water-holding capacity, so increasing production.

Potential of Conservation Agriculture

The potential of CA was reported by Corbeels from the findings of Meta data analysis of crop responses to conservation agriculture in sub-Saharan Africa and the key findings were as follows [28].

1. By combining no tillage with mulching, a farmer will yield on average 300 kg/ha in the first three years and even more thereafter, compared to conventional practices. However harvests will be lower in the long run if he practices only no tillage without soil cover and crop rotation.
2. Success for CA by using fertilizer yielded about 400 kg/ha and more if N fertilizer applied is higher than 100kg/ha.
3. Its impact varies depending on seasonal rainfall grater yield if rainfall is more than 1000 mm and low in drier conditions where yield is low to 140kg/ha.

According to Corsi et al, long-term experiments on no till have shown that up to 10 tons of additional carbon could be sequestered in soil than under conventional till [29]. The same author explained that, legume based rotation provided an additional 20 tons of Carbon per hectare after 35 years than conventional.



(Source: Jim kinsella, SWCS, 1995)

Figure 1: Decrease in organic matter in soil with Year of conventional tillage

History of Conservation Agriculture in Ethiopia

Agriculture is the backbone of the Ethiopian economy and therefore this particular sector determines the growth of all the other sectors and, consequently, the whole national economy. On average, crop production makes up 60% of the sector's outputs whereas livestock accounts for 27%and other areas contribute 13% of the total agricultural value added [30]. This agriculture is generally dependent on rain-fed conditions (Table 1) and tillage is done with breaking plough, locally known as 'Maresha', whose shape and structure have remained unchanged for years [31].

Figure 2: Traditional plough

Table1: Biophysical, socio-economic and climate condition of Ethiopian

Biophysical condition		Socioeconomic condition		Climate change
Land coverage	1.1 million sq.km	Population	88 million	GHG emission
Agro-ecology	Highly diverse	GDP	$45billion USD	
Land degradation	>40 million ha	Economy	Dependent on agriculture	
Annual soil loss	1.9billion tones	Average daily income	70% population living on <$2USD/day	Vulnerability to climate change
Productivity of land	80% of cultivated land yields < 1t/ha	Land holding	95% of farmers in the range of 0.5-2ha	

Source: (CSA, 2011) [32].

In recent years, the Ethiopian government has changed its land management policy to a more holistic and land-scape wide approaches that go beyond resource conservation towards improved land husbandry and water management for beneficial conservation [33,34]. With this strategy, different sustainable land management programs have been implemented throughout the country.

While soil conservation practices, including minimum or no tillage have long been practiced by farmers with different approaches or systems in Ethiopia, conservation agriculture and its associated package of best practices were introduced in 1998 by Sasakawa Global 2000 (SG2000) [35]. Although it is limited to Northern and Central Ethiopia where drought and soil degradation are the most important constraints, few studies have reported on the status and effects of conservation agriculture in the country that CA is not widely practiced by farmers. Recently, however Government and Non Government Organizations (NGOs) like SIMLESA in Southern and SG2000 in central parts of the country are widely promoting its use among smallholder farmers throughout the country through demonstrative research and training [36-38,26,39,40].

Adoption Status of Conservation Agriculture in Ethiopia

Agriculture occupies a key position for the Ethiopian economy, which contributes within a single year 85% of employment of the country's population, 95% of land under cultivation and contributes more than 96% total agricultural output [7]. However, the traditional land use system hurts this sector and invites excessive soil erosion by wind and water (runoff) and consequently there is a loss of soil productivity [41].

Substantial farmers through the country face many risks due to soil erosion, water shortage, erratic rainfall, low crop productivity, food insecurity, substantial forest and surrounding environment depletion. The risks come about because of inappropriate farm practices manifested by frequently growing cereal crops without using crop rotation, long-term tillage, and less planting of cover crops [7]. In Ethiopia the average annual rate of soil loss is estimated to be 12 t/ha/year and it can be even higher on highly inclined terrain and on places where the vegetation cover is low [42]. The yield reduction as a result of loss of topsoil each year is increasing to a large extent.

Wondwossen et al., (n.d) conducted survey on SG2000 sites at Bakko and Adaa districts of Central Ethiopia and reported that, more than 57% of farmers adopted CA such as mulching, minimum tillage and use of herbicides [39]. He explained that, farmers who adopted all three components of CA (minimum tillage, soil mulch and mixed cropping) got increased land and labor productivity. This brief analysis suggests that CA has first and foremost been adopted globally under the premises of being energy-saving (time and/or power), erosion-controlling, and water use efficient [13].

According to Haimanot, adoption of conservation agricultural practices in Dangila district, Amhara region, Use of conservation agriculture (CA) could be seen as apotential option for Ethiopia which rely mainly and agriculture seem prime sector that could help in maintaining and improving crop yield, attaining more resilient farming system with reduced risks and hazards, while

protecting and stimulating the biological function of the soil [7].

According to Getahun, Sustainable Intensification of Maize-Legume system for Food Security in Eastern and Southern Ethiopia (SIMLESA) program was launched in Ethiopia in March 2010 with the objective of promoting CA-based cropping system (Minimum soil disturbance, Soil surface cover by retention of crop residues or live mulches, Crop rotation/intercropping involving legume as well as Weed control) and adoption Monitoring survey analysis produced good progress in Ethiopia than other sites with SIMLESA project [43,44]. The author justified that the CA practice is now shifting from on-station to on-farm participatory research.

Potential of conservation agriculture in Ethiopia

In an experiment carried out on vertisols in Ethiopia it was reported that grain and straw yields of plots that were prepared using broad bed maker (BBM) and minimum tillage averaged 1.4t/ha and 3.37t/ha respectively compared with significantly low corresponding yields of 0.91t/ha and 2.36t/ha respectively from conventionally tilled plots [45]. This finding indicates that conservation agriculture can be promoted effectively in vertisol areas of the country where the dominant crops are small cereals like teff, wheat and barley [46].

High population density, low livestock density and better access to markets were taken as the combination of socio-economic factors favoring CA, and vice versa [47]. Finally the author tried to classify cultivation land to CA suitability areas from the combination of both classes.

Table 2: Potential of cultivated areas for conservation agriculture in Ethiopia

	Area (ha)	Proportion within domain area (%)	Proportion from total cultivated area (%)
High potential	10,103,825	56.8	43.3
Moderate potential	5,812,179	32.7	24.9
Marginal potential	1,876,596	10.5	8.0
Total potential area	17,792,600	100.0	76.2
Non-potential area[a]	5,559,662		23.8
Total cultivated area	23,352,262		100.0

RD	Ethiopia	
	Hectare (ha)	%
HBHS	821,006	4.6
HBMS	3,798,715	21.3
HBLS	5,480,280	30.8
MBHS	585,326	3.3
MBMS	2,344,084	13.2
MBLS	2,879,289	16.2
LBHS	165,736	0.9
LBMS	741,940	4.2
LBLS	976,224	5.5
Sum	17,792,600	100.0

NB: Biophysical (left side box) and overall potential considering both variables (right side box)

[a]Non-potential area= cultivated land with slope >50 % and rainfall<400 mm: RD=recommendation domain, H= high; B=biophysical potential; S=socioeconomic potential, M=medium; L=low

The table above indicates generally that, 76.2% of cultivated land has potential for CA and majorly concentrated around central rift ally area and northern parts of the country.

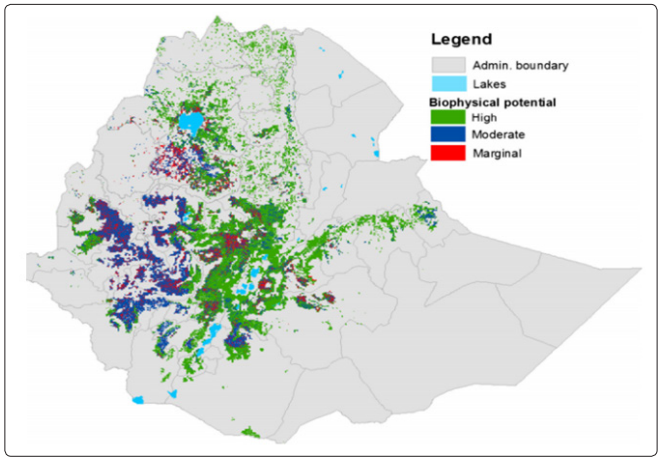


Figure 3: Potential for CA within the cultivated areas of Ethiopia [47].

Factors Affecting Adoption of Conservation Agriculture (CA) in Ethiopia

Adoption of Conservation Agriculture is affected by different factors. There are three primary constraints to adoption of CA among smallholder farmers. These constraints are the use of crop residues for other purposes (such as stock feed), labour constraints and limited potential to grow cover crops during dry season [48]. The regression results revealed that participation of females in decision making, experience with technology, land endowment, and proximity to public extension officers all had positive, significant impacts on adoption. According to same study, the intensity of adoption was positively and significantly influenced by land endowment, experience with technology, proximity of input markets, and access to informal extension support. Ownership of a mould board plough had a significant negative impact on both adoption and intensity

Presence of traditional practices contributing for CA principle

Studies show that over representation of men in programs involving new innovations is linked with strong traditional and cultural practices that distinguish gender roles in agriculture mostly biased towards men [49]. Constraints to adoption of conservation tillage are as follow by ICARDA [18].

- The mistaken perception that soil cultivation (plowing) is essential for high crop production.
- The limited availability of affordable, appropriate seeding machinery that is locally produced and maintained.
- Limited knowledge and experience of how to adopt these practices.
- Perceptions of worsening of weed, pest and disease infestation.
- Unwelcoming policy and extension environments.

Socioeconomic and extension facilities

The findings of the study Stanford et al., suggest the Socioeconomic and extension facilities effect as follow [50].

- Access to wetlands/ stands to increase the probability of a farmer adopting CA. farmers are more likely to take up soil improvement practices because wetlands/dambos will provide alternative land for crop production there by paving way for improving the fertility of the depleted upland soils by means of CA.
- Education status of household head. Advancement in formal education tends to bring about specialization in technical skills that make farming, including CA, less attractive.
- Distance to agro-dealers the longer the distance to agro-dealers the less likely a farmer will adopt CA because of

increased transaction costs and Access to agriculture radio programmes were found to decrease the probability of a farmer adopting CA. Lack of access to media will limit the chances of getting information on soil conservation practices such as CA and hence decreasing the probability of adopting the technology. Limited accesses to relevant agricultural information from the radio broadcasts have probably not had the desired impact of influencing farmers to adopt CA as expected.

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 Yenealem et al., to 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 [51].

Growing concerns in regards to global warming and rising food prices could drive an increasing adoption of CA. According to FAO, Growing concerns in regards to global warming and rising food prices could drive an increasing adoption of CA as follow [27].

- With agriculture consuming 70 percent of the blue water, to meet the MillenniumDevelopment Goals (MDGs), water consumption should increase from 1700 km3 per year to 2200 km3per year. Consequently, reduction on water use is an important challenge for the forthcoming decades; and CA could play a key role by decreasing the level of water consumption and maintaining more moisture in the soils. Conservation Agriculture could help save up to 2500 km3 of water consumption by 2050 [27].
- The simultaneous application of the three CA principles stand to boost yields, which would contribute towards meeting notably, MDG1 of eradicating extreme poverty and hunger, MDG7 of ensuring environmental sustainability and MDG8 of developing global partnership for development.
- In regards to climate change, CA advocates building and storage of soil organic matter, which is important for storage (carbon credit in soils) and/or sequestration of carbon. Carbon is derived from the atmospheric CO2 taken up by the plant and added to the organic matter when the plant dies. In a world concerned with the buildup of atmospheric greenhouse gases, CA presents an opportunity for reversing the green house gas build up [27]. Carbon sequestration is a recognized method in the removal of CO2 from the atmosphere under international treaties, such as the Kyoto Protocol.

Climate Change Prevention Activities

Growing concerns in regards to global warming and rising food prices could drive an increasing adoption of CA and it was justified as follows [27,46].

1. CA could play a key role by decreasing the level of water consumption and maintaining more moisture in the soils to save up to 2500 km3 of water consumption by 2050.
2. In regards to climate change, CA advocates building and storage of soil organic matter, which is important for storage (carbon credit in soils) and/or sequestration of carbon reversing the green house gas build up which the focus of the world currently.
3. Conservation Agriculture is part of Sustainable Land Management (SLM) which promotes agro-forestry or any practice contributing to soil cover and crop rotation is now an emerging top agenda in Ethiopia.

Untapped opportunity for the wide-scale promotion of CA in Ethiopia

Untapped opportunities to support the up scaling of CSA and CA in Ethiopia include the following [46].

1. There is willingness and commitment from the government to reduce poverty and ensure food security while addressing climate change. The government has developed policies and strategies that are pertinent to ensure food security as well as address climate change. The government has moreover ratified international climate change-related conventions.
2. The country has developed a comprehensive green growth strategy that encompasses agriculture in the form of the Climate Resilient Green Economy (CRGE) Strategy. In the MOA, a CRGE coordination unit has been established for piloting climate-smart agriculture as well as mainstreaming the CRGE into agriculture projects and programmes.
3. Regional states have embarked on the promotion of integrated watershed management to improve agricultural productivity, with major emphasis on avoiding open and uncontrolled grazing. This provides a good opportunity for large-scale implementation and promotion of climate-smart practices such as agro-forestry and conservation agriculture.
4. Resources are available in the form of projects and programmes like Agricultural Growth Program (AGP), Sustainable Land Management (SLM) and others. These projects are operating in many parts of the country under various agro-ecological zones and farming systems.

There are private sector organizations and numerous NGOs in the country. At grassroots level there are also adequate numbers of extension and development agents to create climate-related awareness, provide capacity-building training and promote climate-smart agricultural activities.

Conservation Agriculture and Crop Yields in Ethiopia

The result of experiment conducted by Sime et al. in the Central Rift Valley (CRV) area, Ethiopia showed that conventional tillage (CT) had 13–20% higher grain yield than minimum tillage (MT) and 40–55% higher than zero tillage (ZT); and MT had 27–37% higher yields than ZT. Mulching had 23–33% higher grain yield than no mulch [36]. The CT had 28 and 89% higher labor productivity and 6 and 60% higher gross margin than MT and ZT respectively. The MT had 37% higher gross margin than ZT. The highest yield response in CT resulted in its highest gross margin and labor productivity which indicates better agronomic and economic responses over CA.

There is generally little yield benefit from reduced soil disturbance unless the practice is integrated with an adapted soil fertility management including the application of mineral fertilisers and rotations with legumes [52,53]. Integrated soil and water land management program has a significant contribution in increasing crop productivity and hence, increase income to reduce food insecurity of smallholder farmers [51]. In an experiment carried out on vertisols in Ethiopia where the dominant crops like teff, wheat and barley grows, it was reported that grain and straw yields of plots that were prepared using broad bed maker (BBM) and minimum tillage averaged 1.4t/ha and 3.37t/ha respectively compared to conventional of 0.91t/ha and 2.36t/ha respectively [46].

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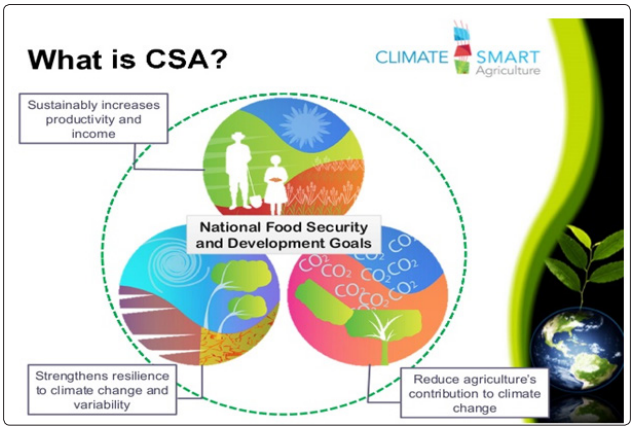
2. Success for CA by using fertilizer yielded about 400 kg/ha and more if N fertilizer applied is higher than 100kg/ha.
3. Its impact varies depending on seasonal rainfall grater yield if rainfall is more than 1000mm and low in drier conditions where yield is low to 140kg/ha.

Climate Smart Agriculture (CSA)

CSA defined 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". Climate-smart agriculture (CSA) is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. The principal goal of CSA is identified as food security and development, while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal [54].



Source: Presentation by Irina Papuso and Jimly Faraby, Seminar on Climate Change and Risk Management, May 6, 2013.

Figure 4: The three interlinked pillars necessary for achieving CSA goal

CSA has received an attention during recent years within the global development and its approach of transforming agricultural systems holds a promise of ensuring food security in face of the dual challenges of climate change and resource scarcity [32]. As a consequence, agriculture and its linkages to climate change and adaptation is now the focus of attention by a wide part of the international community, with actors such as the World Bank and the UN Food and Agriculture Organization (FAO) leading the way. Ethiopia is also one of the countries to actively implementing CSA strategy [46].

Climate-smart agriculture Seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing carbon storage on farmland (AU, n,d). According to the same study, Climate-smart agriculture includes proven practical techniques such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing, and improved water management, but also innovative practices such as better weather forecasting, early warning systems and risk insurance.

Negra et al. stated that, Ethiopia is one of the leading countries to promote the integration of climate-smart agriculture (CSA) into national policies [32]. Accordingly, the country initiated innovative participatory watershed development programs, in partnership with numerous international institutions. Major stakeholders promoting climate-smart agricultural activities in Ethiopia include the Ministry of Agriculture; International organizations (FAO, United Nations World Food Program); the National Agricultural Research System (NARS); Consultative Group for International Agricultural Research (CGIAR) and numerous NGOs [46].

Key Characteristics of Climate Smart Agriculture

1. CSA addresses climate change:Contrary to conventional agricultural development, CSA systematically integrates climate change into the planning and development of sustainable agricultural systems [55].
2. 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.
3. CSA maintains 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 [54,13].
4. 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, and value chain or policy level.
5. 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 take into account 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.
6. 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 [56]. 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.

Challenges of Conservation Agriculture in Ethiopia

According to Karki and Shrestha, the primary challenge of CA adoption is the assumption that soil tillage is essential for agricultural production [57]. Other challenges include those of intellectual, social, technical, environmental and political characteristics. Key challenge with mainstreaming CA systems relate to problems with up-scaling which is largely due to the lack of knowledge, expertise, inputs (especially equipment and machinery), adequate financial resources and infrastructure, and poor policy support [58,59]. Overcoming traditional mindsets about tillage by promoting farmer experimentation with this technology in a participatory way will help accelerate adoption [10].

Wider adoption of CA technologies requires concerted effort of all the stakeholders in the expanded partnership and participatory approaches in which farmers experiment and provides rapid feedback [57]. According to the same author, This would need to be supported by institutional changes that promote knowledge-sharing, flexibility and decentralized decision-making for rapid adoption of technologies to maintain production and productivity, increased food security and livelihood of the farmers.

Key challenges of conservation agriculture in Ethiopia are explained by Negra et al. as follows [32]

1. The way how to improve farmer awareness of CA benefits, and how to efficiently incorporate green manure/cover crops and manage weeds
2. Lack of adequate research findings on CA practices in Ethiopia for the various agro-ecology, soil type, rainfall pattern, farming system, temperature and moisture ranges.
3. Rain is increasingly erratic, with marked seasonal deficits, coupled with more frequent drought and heavy rainfall events.
4. Limited livelihood diversification, coupled with a lack of off-farm income, especially among women and an increasing number of landless youth, poses significant challenges
5. CA is proven successful on-station experiment and research-managed on-farm trials. However, farmers of Ethiopia have not abandoned the age-old traditional systems [44].
6. CA seldom increases yield in the short term and yield increase is rarely a motivation to adopt
7. Its increased dependence on herbicides
8. Use of animal dung and crop residues as energy sources [11].

Major Limitation of Conservation Agriculture

The approach of technology is limited to top-down approach of research, without the participation of the farmers in prioritizing critical problems, defining research importance, and in validating the technology by fine tuning to local conditions. Thierfelder et al. pointed out major limitations of CA as follows [26, 60].

1. Under heavy soil texture minimum tillage may result in water logging effect
2. Institutional factors including the market for selling or buying newly introduced legume covers /intercropping variety is very limited
3. Limited access to necessary inputs such as herbicides and sprayers
4. Increased labor demand for weeding is also a limiting factor for CA adoption
5. CA can cause soil compaction on coarse texture soils in the long-term and may significantly increase runoff as compared to conventional practices
6. CA has no comparative advantage over conventional practices in reducing runoff on relatively fine-textured soils.
7. CA may not suit all soils but better on loamy soils compared to sandy and clay soils

If given the chance, conservation agriculture can sell itself. The task for policy makers and development partners is to give this innovative approach to agriculture a chance with farmers whose practical experience makes them skeptical that crops can grow on land that has not been prepared with heavy plowing. The following can lead to the widespread adoption of conservation tillage ICARDA [18].

Raise awareness

Education is the first need toward achieving understanding and acceptance of conservation agriculture in principle from farmers and the national agricultural research and extension systems upon which they depend. Education consists mainly of presenting to these potential change agents learning from the experience of others. This is how success with conservation tillage In Australia has begun to be transplanted to Iraq and Syria.

Local verification and modification of technology

Participatory research and demonstration needs to leave behind any dogma that may have attached itself to the fine points of conservation tillage. Instead, it needs to take a flexible approach to testing and verifying local modification of the amount and nature of stubble and other residues to be left in the field, the time of sowing, soil fertility management, weed control, and integrated pest management.

Provide appropriate and affordable seeders

As a practical matter, participating farmers must have access to appropriate seeders beginning with participatory research and demonstration. To help overcome their natural skepticism, farmers should enjoy the use of seeders at no cost and bear no liability for seeder breakdown. Once farmers' interest in continuing to use conservation tillage creates local demand for affordable seeders, policymakers and development partners need to help local entrepreneurs acquire the capacity to manufacture new seeders and kits for adopting seeders that are already available locally.

Organize participatory research and demonstrations

Once farmers and extension personnel understand conservation agriculture in principle, they need to see it in practice. This requires participatory research and demonstration enlisting the collaboration of scientists, extension officers, economists, policymakers and farmers. Farmers may require concessions that allow them to participate without taking personal responsibility for crop failure.

Conservation Agriculture Related Policy and Strategies in Ethiopia

The overarching strategic framework guiding Ethiopia's development has been the Agricultural Development Led Industrialization (ADLI) strategy as follow.

Industrial Development Policy (2002)

- ".. Primarily focus on the promotion of agricultural-led industrialization, exportled development, and expansion of labourintensive industries
- ".. The building up of industrialized Ethiopia can be realized

only through the implementation of agricultural and rural centered economic and industrial development

- "If the ADLI strategy can be successfully practiced, it would be gradually transformed into industrial-led development strategy."
- ".. A firm integration between the peasants and the industrialists is another most important element in achieving sustainable industrial development."

Rural Development Policy and Strategies (2003)

- "… one basic objective with regard to economic development: to build a market economy in which (i) a broad spectrum of the Ethiopian people are beneficiaries, (ii) dependence on food aid is eliminated; and, (iii) rapid economic growth is assured."
- "Rural development constitutes the plank that underlies all other efforts towards economic development."
- "This does not in any way imply that development efforts in rural areas will be limited to agricultural development. Indeed …there is a need for rural infrastructure and social development programs… trade and industry ... should emerge"

Climate Resilient Green Economy (2013)

- "…The traditional economic development path could deliver the required growth, but at significant cost of agriculture land expansion (inducing pursuing and accelerating deforestation), soil erosion, and higher emissions as well as at the risk of reaching the limits to further development, e.g., by exceeding the carrying capacity for cattle of Ethiopia."
- "Building a green economy will require an increase the productivity of farmland and livestock rather than increasing the land area cultivated or cattle headcount."
- "..To limit the soil-based emissions from agriculture and limit the pressure on forests…

Summary and Conclusion

Improving food security in World, in the face of rapidly growing populations and climate change impacts, is a daunting challenge. Farming and soil management practices included in CA are based on three core principles, which must be fulfilled concomitantly Minimum soil disturbance, Maintenance of permanent soil covers and Cropping system diversity, crop rotations. The objective of this paper is therefore to review the implementation status, opportunities, challenges and limitation of conservation agriculture practices in Ethiopia.

Conservation agriculture has economic as well as climatic advantages. The economic advantages of conservation agriculture are often realized with the first cropping While; the environmental advantages emerge more slowly. While soil conservation practices, including minimum or no tillage have long been practiced by farmers with different approaches or systems in Ethiopia, conservation agriculture and its associated package of best practices were introduced in 1998.

In Ethiopia more than 57% of farmers adopted CA such as mulching, minimum tillage and use of herbicides. Presence of traditional practices contributing for CA principle and socioeconomic and extension facilities are some of factors affecting adoption of conservation agriculture (CA) in Ethiopia while, Climate change prevention activities and untapped opportunity for the wide-scale promotion are some opportunities for adoption of Conservation Agriculture in Ethiopia.

The principal goal of CSA is identified as food security and development, while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal.CSA addresses climate change, integrates multiple goals and manages trade-offs, maintains ecosystems services, CSA has multiple entry points at different levels, It`s context specific, engages women and marginalized groups. Key challenge with mainstreaming CA systems relate to problems with up-scaling which is largely due to the lack of knowledge, expertise, inputs (especially equipment and machinery), adequate financial resources and infrastructure, and poor policy support. Conservation agriculture of Ethiopia has limitation which should be solved in future [61,62].

Recommendation

The findings of this review have also the following important implications for future studies so as to improve the productivity the country without disturbing the environment.

1. The possibility that the improvement approach involves cost-effective techniques of production and capital formation as it is based upon the use of the relatively abundant resources (e.g., labour for capital formation) and that it could delay the operations of the law of diminishing returns as land is should be saved through labour intensification
2. Soil conservation programmes need special attention as the resource base of the agricultural sector is being depleted at an alarming rate due to the fact that the soil erosion and desertification process continue almost unabated.
3. Linking increased agricultural production to local and international markets including the emerging new market based opportunities such as carbon credits, eco-tourism, organic products among others could be key in the upscaling of CA practices with strong support from policy makers.
4. CSA has to be integrated into tertiary level education including TVET colleges and universities, so as to develop a large number of professionals with an in-depth knowledge of the subject.

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