

Sustainable Crop Production as Influenced by Conservation Agriculture:A Review

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Abstract
The conservation agriculture defined as insignificant soil disturbance (no-till) and Sustainable soil cover combined with rotations by incorporating leguminous crop in the rotation to enrich soil fertility, as a more sustainable cultivation system for the future. Cultivation and tillage play an important role in agriculture. The benefits of tillage in agriculture are explored before introducing conservation tillage (CT), a practice that was borne out of the American dust bowl of the 1930s. The adoption of this modern concept of agriculture varies among the countries. The review concludes that conservation agriculture is a more sustainable and environmentally friendly management system for cultivating crops and agriculture in the next decade. It will have benefits of sustainably produce more food from less land through more efficient use of natural resources and with minimal impact on the environment in order to meet growing population demands. Promoting and adopting conservation agriculture management systems can help meet this goal. This review describes the benefits of conservation agriculture and its influences in sustainable crop production a suggested improvement on conservation tillage, where no-tillage, mulch and rotations significantly improve soil properties and other biotic factors.
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INTRODUCTION

The world population continuous to increase and it is projected to reach 9.1 billion by 2050 (Kumar, 2017). This increase is expected to come mostly from developing countries. It is obvious that those increase population depend on limited amount of land to ensure food supply and food security. In the long run, climate change is predicted to impact negatively with more frequent and prolonged drought and higher temperature (FAO, 2010).The combination of these problems put more pressure on limited arable land available fresh water needed for food production. Today farming especially in Africa continent have a double challenge which are to increase production and preserve natural resources simultaneously (Marthin, 2013). The main causes of these challenges are resulted by deforestation, removal or burning of crop residues, poor rangeland management and inadequate crop rotations that do not maintain vegetative cover or allow appropriate restitution of organic matter and plant nutrients and these practices leave the soil exposed to climatic hazards such as wind and rain.

According to Marthin, (2013), described year-to-year variability of rainfall is a significant constraint to the sustainability of rain-fed farming systems in poorer countries of the tropics in SSA as farming decisions have to be made in spite of production and season quality uncertainty. To meet the demand of food for increasing world population from limited land and water resources, a key issue in modern agriculture, could be achieved through practices of CA. Conservation Agriculture is gaining acceptance in many parts of the world as an alternative to both conventional agriculture and to organic agriculture. Although the practice of conservation agriculture on a large scale emerged out of Brazil and Argentina, similar developments were occurring in many other areas of the world, notably North America in zero tillage, and Africa and Asia with technologies such as agroforestry.

Conservation agriculture has the ability to achieve expected yield in the long run with the help of modification/restored of physical, chemical, and biological properties of soil. The crops are grown in the soil, and soil properties directly or indirectly affect the availability of water and nutrients to crops. Zero tillage is now applied on more than 95 million ha worldwide, primarily in North and South America (Derpsch, 2005). Approximately 47% of the zero tillage technology is practiced in South America, 39% is practiced in the United States and Canada, 9% in Australia and about 3.9% in the rest of the world, including Europe, Africa and Asia. Conservation agriculture is particularly relevant to the areas which have high level of soil degradation, water scarcity and low soil fertility status. This review of literature provides an overview of the role of conservation agriculture on sustainable crop production.

Agricultural environmental management

According to Marthin, (2013), explanation, conservation agriculture way of farming that conserves, improves and makes more efficient use of natural resources through integrated management of available resources combined with external inputs. Conservation agriculture has the ability to achieve expected yield in the long run with the help of modification/restored of physical, chemical, and biological properties of soil (Kumar, 2017). Food and Agricultural Organization (FAO,2010), defined conservation agriculture in another way as minimum soil disturbance no-till(NT) and permanent soil cover (mulch) combined with rotations is a recent agricultural management system that is gaining popularity in the many parts of the world.

Principles of Conservation Agriculture
Conservation agriculture consists of three principles, minimum soil disturbance, legume-based cropping and application of organic soil surface mulch (Baudeon *et al*., 2007). This improves infiltration, reduces evaporation and soil erosion, and ultimately builds up soil organic matter.

Tillage Practice
The idea is to disturb the soils as little as possible and achieved by preparation of permanent planting basins of 15cm long 15 cm wide and 15cm deep at 90* 60cm spacing or rips lines at 90*30cm spacing and 15cm depth. This ensures minimum destruction of the soil structure, no soil exposure or loosening, slower mineralization of organic matter. In other word, tillage is the act of disturbing the soil through use of an implement powered manually or by animals or tractors. Other name for tillage includes plowing, cultivation, and digging. According to Hobbs, (2008), tillage stated as the following benefits: it is used to incorporate the previous crop residues, weeds, or amendments added to the soil, such as inorganic or organic fertilizers. Also it is the first step in the preparation of a seedbed, essentially the name for soil that is prepared to receive the seed of the planted crop. It helps aerate the soil organic matter, which in turn helps release and make available to plants nutrients tied up in this important soil component. It is a recommended practice for controlling several soil and residue borne diseases and pests, since residue burial and soil disturbance have been shown to help alleviate this problem. It provides compaction relief, may be only temporarily, a physical property of soil that restricts root and water penetration and reduces production. Lastly, tillage is aesthetically pleasing in terms of look and smell.

Tillage also has detrimental effects on both the environment and farmers: Tillage costs money in the form of fuel for tractors, wear and tear on equipment, and the cost of the operator. If animals are used as the power source, the costs of feeding and caring for the animals over a full year are also high. Greenhouse gas emissions from the burning of the diesel fuel add to global warming. Soil organic matter is oxidized when it is exposed to the air by tillage with resulting declines, unless organic matter is returned to the soil as residues, compost, or other means. Tillage disrupts the pores left by roots and microbial activity. The bare surface exposed after tillage is prone to breakdown of soil aggregates as the energy from raindrops is dissipated. This results in clogging of soil pores, reduced infiltration of water and runoff, which leads to soil erosion. When the surface dries, it crusts and forms a barrier to plant emergence. The bare surface after tillage is prone to wind erosion.

Table 1.The extent of no tillage adoption worldwide.

Country	**Area under no-tillage (m ha)**
USA	25.30
Brazil	23.60
Argentina	18.27
Canada	12.52
Australia	9.00
Paraguay	1.70
Indo-Gangetic-Plains	1.90
Bolivia	0.55
South Africa	0.30
Spain	0.30
Venezuela	0.30
Uruguay	0.26
France	0.15

Permanent Soil Cover
According to Diekow *et al*., (2005), reported that cover crops contribute to the accumulation of organic matter in the surface soil horizon. Mulch helps recycling of nutrients, especially when legume cover crops are used through the association with below ground biological agents and by providing food for microbial populations. A cover crop, mulch and previous crop residue help to reduce weed infestation through competition and not allowing weed seeds the light often needed for germination. According to Jungi, (2004), examined that cereal residues have allopathic properties which inhibit weed seed germination. Ground cover promotes an increase in biological diversity below ground and above ground and also increase numbers of beneficial insects (Jaipal,

2002). Soil cover helps in reduction of direct rain drop impact thus reducing soil erosion, reduction in evaporation, suppression of weed growth and provides a buffering effect by protecting against extreme temperature. It is also an effective way of organic matter and nutrient replenishment. The high moisture retention by residues provides a favorable environment for development of micro fauna and flora communities.

Crop rotation

According to Miller, (2007), have found that annual legumes such as pea can reduce reliance on fertilizer nitrogen and can be managed to conserve water for subsequent crops. According to Leake, (2003), reported that rotations increase microbial diversity, risk of pests and diseases out breaks. Rotation of different crops with different rooting patterns combined with minimal soil disturbance promotes extensive root channels and macrospores in the soil. Instead of planting a single crop, farmers should plant several crops in rotation or as intercrops by including a rotation with legumes. Rotation with legumes is essential in maintaining and improving soil fertility and exploration of different soil layers by different crop species helps prevent formation of a hard pan. Nutrient losses are minimized by the use of deep rooting cover crops that recycle nutrients leached from the topsoil. There is optimum plant nutrient use by synergy between different crop types and by alternating shallow-rooting crops with deep rooting ones.

Challenges of Conservation Agriculture

Weed Pressure

There are numerous reports that weed pressure can increase significantly during the initial years of conservation agriculture which increase labor demand for weeding, especially where no herbicides are used (Umar *et al*., 2010). According to Mashingaidze *et al*., (2012), find that, in a study of conservation agriculture in Zimbabwe, the minimum tillage system showed a higher early weed growth than the conventional tillage system, even after four years.

However weed management is an important aspect of conservation agriculture because Weeds compete with the crop for nutrients, water light and space which result in yield reduction. According to Marthin,, (2013), reported that challenges of weed in conservation agriculture can managed by using agronomic practices like cover crops, mulch, crop rotation ,intercropping and hand weeding. Some experiments have shown that planting cover crops (e.g. cowpea) within ten days of the main crop result in weed suppression and high yields in both the main and cover crop (Umar *et al*., 2010).

Land preparation

Land preparation viewed as a difficult exercise as farmers are expected to dog basins in the dry season. This is more so in areas with heavy soils. Related to land preparation, the soil type has effects on some conservation agriculture components like light soils tillage- digging of basins and water harvesting are not effective because of the poor water holding capacities of such soils (Marthin, 2013). In Zambia and Malawi adoption of conservation agriculture become stagnant because of digging basin need more labor (Andersson, 2014). Labor constraints and limited potential to grow cover crops during dry season are the major challenges of adoption of conservation agriculture in Zambia (Umar *et al.,* 2010).

Lack of Mulch

Crop residues for cover crops have many places been found to be conflicting with other purposes (i.e. high opportunity costs) such as livestock feed, fuel and building materials (Arslan *et al*., 2014). According to Baudron *et al*., (2015), reported that competition between soil mulching and livestock feeding is extremely challenging in the mixed crop-livestock farming systems that dominates most of Eastern and Southern Africa. Less than 5 % of farmers that have practiced conservation agriculture in southern Africa have retained crop residues in their conservation agriculture plots. The reasons being: Stover has multiple uses which include feeding animals, making compost and thatching for some types like pearl millet. In the semi- arid areas there is low biomass production and thus the stover may not be enough to for conservation agriculture and other uses Most of the farmers, especially the vulnerable have unprotected fields and thus animal graze all the stover in the dry season. These challenges can be solved by using right cover crop like edible, use for fodder, for fencing, weed suppression and cover crops which have medicinal value (Marthin, 2013).

Factors Affecting Sustainable Crop Production

Climate change

Crop productions are highly influenced by climate change. Climate change affect sustainable crop production by resulting scarcity of water by 2025, population in water-scarce countries could rise to 2.8 billion, representing roughly 30 per cent of the projected global population and next two decades the world will need 17% for agriculture. Changes in temperature, CO2, and precipitation under the scenarios of climate change for the next

30 years present a challenge to crop production (Hamdy, 2014). A positive impact from elevated CO_2 and the resultant effect on stomatal conductance was to reduce the impacts from increasing O3 (Heagle, 2001).

According to Roberts, (2009), explain that slowest warming scenarios crop yields would decline 30 to 46% by the end of the century and under the rapid warming scenario, yields would decline 63 to 82%. According to Kucharic and Serbin, (2008), conducted their analysis for Wisconsin data from 1976 to 2008 and reported for each degree of warming in the future corn yields could decrease by 13% and soybean by 16% without a change in precipitation. According to Prasad *et al*., (2006), reported that grain yield, HI, pollen viability, and percent seed-set of sorghum were highest at 32/22ºC and progressively reduced as temperature increased, falling to zero at 40/30ºC. Boll harvest index was highest at 28ºC with further declines with increasing temperatures until zero boll harvest index occurs at 33 to 34ºC (Reddy *et al.*, 2005). According to Mills *et al*., (2000), yield or dry matter accumulation of crops are decreasing linearly with O_3 concentration. Increases in heavy rainfall due to more intense storms and associated turbulence and wind gusts, increase the potential for lodging of crops.

Land degradation

Land degradation defined as a change in one or more of lands properties that result in a decline in land quality which directly affect agricultural productivity. Land and soil degradation includes loss of soil cover, soil erosion, salinification, acidification and compaction. According to FAO, (2015), definiton, soil degradation "as a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. Recent estimates suggest that 5 – 6 million hectares of arable land worldwide are irreversibly lost each year as a result of soil erosion, salinization and other degradation processes (Hamdy, 2014). Salt-affected soils occupy an estimated 950 million ha of land in arid and semi-arid regions, i.e., nearly 33% of the potentially arable land area of the world. Soil acidity and the resultant toxicity caused by high concentrations of aluminium and manganese in the root zone are serious problems in sub-humid and humid regions (Gomeiero, 2016), According to Lal, (2005), reports that soil compaction is a worldwide problem and can reduce crop yield by 20%–55%. Agricultural mismanagement, deforestation, excessive use of fertilizers, pesticides and other chemical are major causes of chemical soil degradation. Biological soil degradation is associated with lowering or depletion of soil organic matter, continuing negative soil nutrient balance, imbalance in fertilizer application.

Soil degradation became one of the major environmental constraints affecting agricultural Production as the world especially in developing countries. Today the major constraints of sustainable crop production are soil degradation. Soil degraded physically (soil erosion, compaction), biologically (loss of OM) and chemical (fertility depletion, soil salinity and soil acidity) (Hillel, 2012). Worldwide 20 % of cultivated areas, 30% of forests and 10% of grasslands of forests and 10% of grasslands undergoing degradation (Bai *et al*., 2008). Immediate causes of land degradation are inappropriate land use, degradation of soil, water & vegetation cover, Loss of both soil and vegetative biological diversity, loss of ecosystem structure and function loss of ecosystem structure and function (Snel and Bot, 2003).

Role of conservation agriculture in crop sustainability

Conserve and enhance soil fertility

Experiments (up to 4 years) conducted showed that conservation agriculture can reduce soil erosion and runoff soil organic matter and mineral nutrients in Ethiopian dry lands (Temesgen *et al*., 2009). Soil carbon is a major determinant of the soil's ability to hold and release water and other nutrients that are essential for plant growth and rooting systems. Soil carbon also plays an important role in maintaining the biotic habitats that make land management systems sustainable. These soil carbon conserved by conservation agriculture.

According to Marthin, (2013), stated that conservation agriculture prevents soil losses 150/t annually and 40% land degradation due to Conventional methods in developing countries. In Ethiopia soil and water conservation techniques practiced for long years those includes both physical (counter farming, check dams, proper soil management) and biological (soil vegetative cover, crop residue cover, a forestation) methods (Semu, 2018).

By using the plough in conventional systems, air is mixed into the soil leading to quick mineralization or oxidation of the organic matter which result as soils lose their structure and eventually degrade (Lininger *et al*., 2011). In the absence of a plough, mineralization processes are reduced and the integrity of the soil is preserved. This allows time for the buildup of more soil aggregates and solid humus structures. The described interplay of the biochemical and physical processes eventually results in an increased cation exchange capacity – which is an indicator of the soil's "natural" yield potential. A high cation exchange capacity is linked with better nutrient retention and thus a slower release of nutrients to crops.

Table 2. Mean number of various arthropods under tilled (CT) and no-tilled (NT) Plots in Spain.

Family	2000		2001	
	CT	NT	CT	NT
Araneae	18.3a	31.4b	8.4a	14.5b
Formicidae	10.8a	10.2a	32.7a	101.7b
Coleoptera	8.8a	12.4a	19.0a	33.7a
Parasitoids	7.9a	11.4b	4.0a	5.6b
Collembola	4.7a	12.3b	55.2a	56.4a
Diptera	11.1a	9.5a	19.7a	31.9b
Homoptera	11.4a	7.0a	19.6a	16.2a
Acarina	0.2a	3.0b	24.5a	15.0a

Sources (Rodriguez et al., 2006)

Table 3. Earthworm populations under various tillage treatments with and without residue mulch in Australia.

Residue Management	Direct Drilling (NT)	Reduced Tillage (RT)	Conventional Tillage (CT)
Retain Straw residue	17	14	4
Burn Straw residue	18	7	4

Water Conservation

According to MOA, (2015), reported by reducing runoff and inorganic fertilizer input, downstream water quality improves. Conservation agriculture is used to improve rainfall infiltration and soil moisture storage as well as increase in soil and root volume compared with tillage systems. Conservation agriculture is a sustainable land use approach with soil and water conservation (Lal, 2013). Due to higher rainfall infiltration and reduced runoff and soil erosion, conservation agriculture also decreases flood risks, raises water resource quality and quantities, and can reduce infrastructure maintenance costs and water treatment costs (Kassam *et al*., 2009).

Conservation agriculture improves the physical as well as the biochemical properties of agricultural soils and thus improves their capacity to hold and to provide water and nutrients to the crops. Through the specific land preparation techniques, i.e. ripping or planting basins, as well as the vegetative cover, water infiltration rates are increased and thus water run-off and erosion are largely reduced. In addition, water evaporation in minimum tilled soils is much less than in ploughed soils. Thus, the humid period in the soil is prolonged and more water can be used by the present or succeeding crop. These effects not only lead to more water being available for the crop but also to an increased water use efficiency of the entire cropping system.

Increase crop productivity

According to Milkha, (2008), reported by using balanced fertilization through integrated nutrient supply results sustaining crop yield and quality without adversely affecting the environment in south Asian countries. The use of improved technologies such as conservation agriculture may be in place as farmers seek to achieve gains in the face of harsh climatic conditions (Hove, 2006). CA is used to improve crop yield by improving the soil structure, water retention and reducing the need for chemical fertilizers (Hobbs, (2008). According to Govaerts, (2005), described that soil quality of plots after more than 10 years of different tillage and residue management have direct and significant relation between the soil quality status and the crop yield.

According to Kumar, (2017), reported zero-tillage with crop residue retention obtained the highest crop yields as well as the highest soil quality status while uncovered soil under zero-tillage showed the poorest soil quality. More compaction, lack of moisture resulting in the lowest yields of maize when monoculture than when rotate with other crops (Jat *et al*., 2012).Wheat yield was significantly higher under NTF during the 1st year while tillage practices had non-significant effect in the succeeding two years. Thus, conservation agriculture that combines reduced tillage, crop residue retention, and functional crop rotations, together with adequate crop management, permit the adequate productivity, stability and sustainability of agriculture (Kumar, 2017).

Table 4. Comparisons of CA farmers and non-CA farmers in Zambia

Nearest Neighbor		
	Crop Productivity (log)	Income (log)
CA farmers	357	359
Non CA farmers (N)	219	481
ATT	0.062	0.029
Std.Error	0.098	0.097
T	0.358	0.0632
CA farmers	349	349
Non CA farmers	481	481
Total	830	830

Source (Elias, 2017)

The results in the table indicate that conservation agriculture is positively correlated with crop productivity and ATTs in the table indicate that on average CA increases crop productivity by 6.20% and household income by 2.90% (Elias, 2017). According to Awotide *et al*., (2012), equally found a positive impact of adoption of improved technology on sustainable productivity and farmers' welfare in Nigeria.

Table 5. Comparison of different tillage practices with traditional tillage using the maresha plough (TRAD): (+) increase, (–) decrease, and (+/ –) variable response.

Tillage practice	Yield	Soil water	Soil fertility
Minimum tillage	+	+	+
No-tillage	-	-	+
Permanent beds	-	+	+
Tied-ridges	+	+	+
Sub soiling (25-30 cm)	+	+	-

Sources (Temesgen *et al*., 2009)

In zero tillage gradually, organic matter of the surface layers of zero tilled land increases, due to reduced erosion, increased yields resulting in more crop residue added to the soil surface, and differences in the assimilation and decomposition of soil organic matter. 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 fertilizers and rotations with legumes (Burayu *et al*., 2006).

Increase Profitability

The most challenges of small holder farmers is lack of capital so conservation agriculture have advantage because it need minimum land preparation which minimize the cost for labour and animal. Hobbs, (2008), reports that conservation agriculture lowering production costs through reduced inputs of energy, labour, machinery, fertilizers, water and pesticides, thus raising related productivity and efficiency. Conservation agriculture is used to increased factor productivities and yields by Up to 70% decrease in fuel energy or manual labour up to 50% less fertilizer use; 20%, more reduction in pesticide and herbicide use some 30% less water requirement and reduced cost outlay on farm machinery. Conventional tillage systems require high labor which barrier to participation for poor,disabled,elderly farmers and women headed but conservation agriculture overcome these problems because minimum tillage (Temesgen, 2007).

Mitigating and Adapting Climate Change

Conventional agriculture is a source of three primary greenhouse gases. These include carbon dioxide, methane, and nitrous oxide. Sustainable agriculture acts as a sink for carbon dioxide because it sequesters it and uses it as organic matter in soil. It is sustainable agriculture approaches which lead to a decrease in greenhouse gas emissions. Conservation practices that are employed in sustainable system of agriculture decrease soil erosion and enhance carbon methane consumption in soil. Agriculture is rightly recognized as a source of greenhouse gas emissions and carbon footprint. Organic agriculture tends to improve yield of crops due to which low input is provided.

According to the FAO, (2015), "conservation agriculture offers climate change adaptation and mitigation solutions while improving food security through sustainable production intensification and enhanced productivity of resource use". Conservation agriculture enhance climate change adaptability of cropping systems, farms and landscapes because of improved soil-plant moisture relations while at the same time achieving greater carbon sequestration and lower emissions of greenhouse gases particularly CO_2, N_2O and CH_4. Conservation agriculture contributes to environmental conservation as well as to enhanced and sustained agricultural production. Carbon sequestration, the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils, can help reverse soil health degradation and soil fertility loss, and reduce the impact of climate change on agricultural ecosystems (Lal, 2013).

CONCLUSION

Conservation agriculture practices are ecological approach to soil surface management. Proper use of crop residues with zero tillage favored the nutrient buildup, improved the soil environment and resulted in increased crop yield in a wide variety of soil. There is some evidence that the soil physical properties, organic carbon and nutrient availability in the top 5 cm of the profile may be greater under zero tillage when residue is retained. Combinations of tillage, residue management and crop rotation had a significant impact on nutrient distribution and transformation in soils. Zero tillage practices without residues retention also improved the soil organic matter and nutrients but to a lesser extent as compared to zero tillage with residues retention. Zero tillage with residues retention on flat as well as bed planting was the most beneficial in cropping system. Conservation agriculture based crop production system is one of the pathways for improving productivity and food security while sustaining the natural resources in variety of ecological region. Crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources and with minimal impact on the environment. Only by doing this will food production keep pace with demand and the productivity of land are preserved for future generations. This the main work for agricultural scientists, extension personnel and farmers. These can be successfully implemented by using conservation agriculture which used for conserving water and soil. Use of productive but more sustainable management practices can also overcome this problem. Crop and soil management systems that help improve soil health parameters (physical, biological and chemical) and reduce farmer costs are essential. Overcoming traditional mindsets about tillage by promoting farmer experimentation with this technology in a participatory way will help accelerate adoption. Generally crop production can sustain if and only if the natural resources are conserved or conservation agriculture approach is implemented.

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