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Review paper on the effects of conservation agriculture and its components on soil chemical property, biological properties and crop yield in Ethiopia

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Abstract
Conservation agriculture is one of agricultural system that has been promoted as capable of achieving the sustainable intensification required to meet world food demand. It is an alternative agricultural production system that minimizes the soil disturbances and conserves the composition and natural biodiversity. The CA consists of three core principles which are maintenance of permanent or semi-permanent soil cover; minimum soil disturbance through tillage; and regular crop rotations). The Objectives of this paper is to review Conservation agriculture and its components on soil chemical property, biological properties and crop yield. Surface mulch helps reduce water losses from the soil by evaporation and also helps moderate soil temperature. This promotes biological activity and enhances nitrogen mineralization, especially in the surface layers. Where CA leads to greater SOC, this will often have a positive impact on soil chemical properties that can affect crop production a cover crop and the resulting mulch or previous crop residue help reduce weed infestation through competition and not allowing weed seeds the light often needed for germination. There is also evidence of allelopathic properties of cereal residues in respect to inhibiting surface weed seed germination Conservation tillage (zero tillage and reduced tillage) practices simultaneously conserve soil and water resources, reduce farm energy usage and increase or sustain crop production.

Keywords: Conservation agriculture, minimum tillage, crop rotation, mulching

1. Introduction
1.1 Background of the study
Conservation agriculture is one of agricultural system that has been promoted as capable of achieving the sustainable intensification required to meet world food demand. CA involves changing many conventional farming practices as well as the mindset of farmers to overcome the conventional use of tillage operations. Although adoption of CA is increasing globally.

Conservation agriculture (CA), according to the Food and Agriculture Organization of the United Nations (FAO) (2008) [7], is a farming system with three principles, i.e., minimum mechanical soil disturbance (reduced, minimum or no tillage), permanent organic soil cover (with crop residues or cover crops) and diversification of crop species grown in sequence (rotation) and/or association (mixed farming or intercropping). The FAO has recommended CA as a soil and water conservation technique as well as a practice for improving crop yield and reducing labor requirements. However, it has been rarely adopted by local farmers (Friedrich *et al*. 2012) [9].

CA has been reported to improving crop input-output relationship, conserving natural resources through lowering soil erosion, arresting water losses through reducing soil evaporation, sequestering atmospheric carbon in soil and reducing energy needs of agricultural sector. In a crop rotation, different crop species are planted in a particular order over sequential growing seasons; in contrast, a continuous monoculture consists of the same crop species being grown repeatedly over many years (Bullock, 1992) [4].

A recent global meta-analysis of the effect of CA practices on yield concluded that CA (NT + residue retention + crop diversification) on average worldwide leads to yield reductions of 2.5%. In conservation agriculture, successive addition of crop residues over the years increases soil organic matter.

In the beginning, the increase in organic matter is confined to the upper soil layer, but over time, it extends to deeper soil layers also. It plays an important role in improving various soil-water characteristics, and stabilizing the soil temperature.

1.2 Objectives of the review
1.2.1 General objective
- To review Conservation agriculture and its components on soil chemical property, biological properties and crop yield.

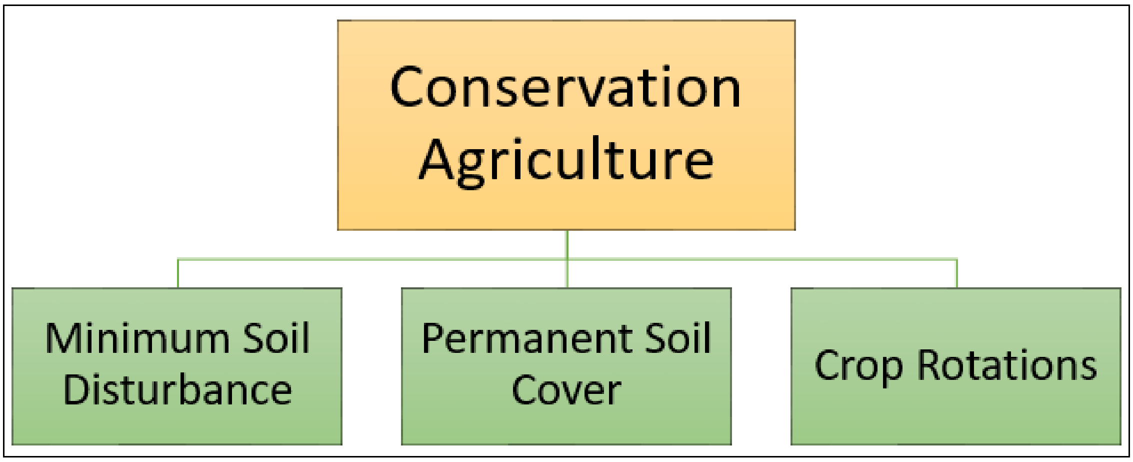
1.2.2 Specific objectives
- To understand the effects of conservation agriculture on soil chemical properties.
- To review the effects of conservation agriculture on soil biological properties.
- To understand the response of crop yield under conservation agriculture component.

2. Literature Review
2.1 Concept of Conservation Agriculture
According to Lal, 2015a). Conservation agriculture aims to sustainably intensify smallholder farming systems and have a positive effect on the environment using natural processes. It helps farmers to adapt and increase profits in spite of climate risks.

Conservation agriculture and its components have been associated with many benefits including greater soil water storage, improved soil quality, decreased erosion and in some instances, greater yield and net farm income. These benefits have led to the identification of CA as an important tool to help ensure future food production and help buffer agricultural productivity against extreme climate events, such as drought and heat waves, which are likely to increase in frequency under climate change.

CA may also have detrimental impacts on crop yield by altering soil physiochemical and biological conditions, such as decreasing soil temperatures in areas of high latitude and seasons with low temperature and aggravating weed and disease incidence. The realistic effects of CA on crop yield may depend largely on specific CA practices, regional climate characteristics and cropping systems.

2.2 Conservation agriculture components
FAO4 of the United Nations defines CA as a 'concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment'. Conservation agriculture (CA) is one such approach that aims to sustainably improve farm productivity, profits and food security by combining three principles. These three principles are: minimum mechanical soil disturbance, permanent soil cover, and crop rotation. When these three principles are adhered to, CA is reported to improve soil quality, optimize crop yields and reduce input costs.



2.2.1 Minimum or zero Tillage
From the farmers' perspective, the main objective of tillage operation is to create a desirable soil surface condition for seedbed preparation and make it suitable for sowing, planting, inter-culture operation, irrigation, drainage, weed control, harvesting operations, etc.

It has been well-established that tilling the soil leads to losses of SOC as cultivation breaks up the soil and exposes organic matter previously protected within soil macro-aggregates to microbial decay (Beare *et al*., 1994) [3]. Cultivation also incorporates and fragments plant material, increasing its vulnerability to microbial attack. Decreasing the amount of tillage or introducing no-till (NT) thus has the potential to decrease the amount of SOC lost from the profile by decreasing the turnover rate of macroaggregates, increasing the physical protection of particulate organic material and reducing soil to residue contact. For example, in a Brazilian Acrisol under cereal cropping, turnover times of 17 vs. 36 years were observed in conventional and CA, respectively, due to the reduced disturbance in the NT CA system (Bayer *et al*., 2006a) [2].

2.2.2 Mulching
Mulching may be defined as the process of covering the soil surface around the plants to create congenial conditions for the crop growth. This may include moisture and soil conservation, temperature moderation, salinity and weed control etc. It exerts a decisive effect on earliness, yield and quality of the crop. Mulch is any layer of material applied to the surface of soil to protect the soil from the erosion and evaporative effects of wind and sun. Mulch can be organic, inorganic or plastic: Mulch can be plant material, like straw and wood chips or it can be gravel or non-living material like recycled glass, cinders, decorative rock, and recycled rubber. In addition to erosion reduction, mulch increases water holding capacity of soil by reducing compaction. It increases infiltration by slowing runoff and giving it more time to soak into the soil by reducing erosion from bare soil and supply nutrients and organic matter to the soils. Mulching helps in controlling moisture content of the soil and temperature fluctuations, improves soil properties such as the addition of the soil nutrients which result in an increase of the crop yield. Mulching increases the crop yield by 50-60 per cent under rain

fed situations and it is a best way of achieving food security sustainably.

Surface mulch helps reduce water losses from the soil by evaporation and also helps moderate soil temperature. This promotes biological activity and enhances nitrogen mineralization, especially in the surface layers (Hatfield & Pruegar 1996) [10]. This is a very important factor in tropical and sub-tropical environments but has been shown to be a hindrance in temperate climates due to delays in soil warming in the spring and delayed germination (Schneider & Gupta 1985) [19].

Retention of crop residue on the soil surface as mulch is an essential component of CA intended to increase carbon inputs and enhance ecosystems benefits such as soil fertility, improved soil water relations and biological properties.

Fig 1: Mulching

2.2.2.1 Crop Residue cover

Crop residues can be defined as biomass remaining on the soil's surface after harvest. In some systems, linear increases in SOC stocks can be observed with increasing rates of residue addition (Duiker and Lal, 2002) [6]. Thus, in CA systems, which emphasize the retention of residues on the soil surface, greater residue input can potentially lead to greater SOC storage. However, where residue production is low e.g., due to low soil fertility or the presence of soil constraints, there can be insufficient residue retention under CA to positively impact SOC stores. In areas with low fertility, integrated nutrient management is essential to ensure a buildup of SOC and the success of CA systems. Low fertility results in low crop yields, which leads to reduced organic matter input and hence, lower SOC (Lal, 2015b) [14]. This cycle can only be broken by the addition of nutrients to the soil system via external fertilizer input (organic or inorganic) and/or the incorporation of legumes into cropping rotations.

Fig 2: Crop residue cover

2.2.3. Crop Rotation

Different crops may have different effects on the quantity, quality and periodicity of C inputs and can modify the soil in different ways (e.g., rates of water extraction, nutrient use), which can influence mineralization rates and the growth of subsequent crops. Thus, differences in crop rotation between CA and conventional agricultural systems also have the potential to impact SOC values. The elimination of monocultures and incorporation of plant species into rotations that return greater amounts of residue to the soil are often associated with greater SOC stock in CA systems. In some systems, root input, in particular, has been found to be important. For example, in one study conducted on a Brazillian Ferrosol of the long-term (17 years) contribution of cover crop or forage based NT rotations to SOC stocks, SOC stocks showed a close relationship with the root additions of different plant species. Where legumes are included, these can also add additional N to the system, which can enhance soil fertility and subsequent crop biomass production. The maintenance of residue cover can also decrease processes that can limit the growth and biomass production of the main crop, such as erosion, nutrient leaching, and weeds, pests and diseases (Tittonell *et al*., 2012) [20]. According to FAO4, any crop rotation should involve at least three different crops alternatively, having shallow and deep rooted systems.

2.3 Effects of CA components interaction

Karlen *et al*. (1994) [12] showed that normal rates of residue combined with zero-tillage resulted in better soil surface aggregation and that this could be increased by adding more residues. Recent papers confirm this observation; Madari *et al*. (2005) [16] showed that NT with residue cover had higher aggregate stability, higher aggregate size values and total organic carbon in soil aggregates than TT in Brazil; showed that after 5 years of NT maize in Mexico, soil wet aggregate stability had increased over conventional tillage (TT) as had soil enzymes, soil organic carban (SOC) and microbial biomass (MBM). They conclude that NT is a sustainable technology.

A cover crop and the resulting mulch or previous crop residue help reduce weed infestation through competition and not allowing weed seeds the light often needed for germination. There is also evidence of allelopathic properties of cereal residues in respect to inhibiting surface weed seed germination.

2.4 Effect of CA on SOC

Soil organic carbon from soil organic matter is a key indicator of the soil productivity. Soil organic matter benefits soil by lowering bulk density, increasing nutrient availability, increasing cation exchange capacity and improving water holding capacity; in addition, soil organic matter increases soil aggregates' stability making soils less susceptible to erosion. A key influence on the soil organic matter content of a soil is the quantity, quality and decomposition of the crop residues returned to the soil (Amézketa, 1999) [1]

The amount of organic matter present in a soil is the net difference between organic matter inputs (biomass) and losses (erosion, decomposition, leaching). The extent and direction that CA affects SOM (typically measured via SOC) is thus a function of how it impacts these inputs and losses. In comparison to conventional agricultural systems, CA makes modifications to tillage practices, residue management and crop/nutrient management. Each of these modifications can influence SOC.

The exact magnitude of the difference in SOC between CA and conventional agricultural systems varies greatly and is influenced by many factors, including climate, soil type, baseline SOC, crop management, time since management change, and sampling depth and methodology. This means that estimates of the magnitude of the change following conversion to CA vary widely. For example, estimates ranging from -0.15 Mg/ha/year in areas such as the Midwestern USA to +0.93 Mg/ha/years in tropical Brazil have been recorded. However, it is clear that in regions where soil and climatic conditions are favorable for biomass production and where negative yield impacts are not observed, then CA systems will often have higher amounts of SOC relative to conventionally managed systems, particularly in the surface of the soil profile. Although, the large range in the sequestration rates observed indicates that the magnitude of change is likely to be highly site specific. It should also be noted that most of the literature regarding the effect of CA on soil properties has focused on NT and residue retention *v* conventional tillage and residue removal. Fewer studies have also considered the impact of species diversification and the inclusion of practices such as cover crops and intercropping on SOC change. Where these are carried out they are often found to lead to greater increases in SOC than NT and stubble retention alone, and the effect of management changes on soil properties would thus often be greater when all elements of the CA system, which may have interactive and synergic effects, are incorporated together.

2.4.1 Impacts of CA on soil chemical properties

Where CA leads to greater SOC, this will often have a positive impact on soil chemical properties that can affect crop production.

2.4.1.1 Soil pH

The larger SOC at the surface of the profile in CA systems, is commonly associated with greater acidity relative to conventionally tilled systems. This is typically associated with the accumulation of plant residues and organic acids at the soil surface (Heenan and Taylor, 1995) [21] and greater rates of nitrogen mineralization combined with the leaching of nitrate-nitrogen (Heenan and Taylor, 1995) [21]. Greater rates of root exudation due to the accumulation of roots in the surface of the soil profile can also contribute to greater rates of acidification (Limousin and Tessier, 2007) [22].

The magnitude of any change in pH will depend on the buffering capacity of the soil, the magnitude of the change in SOM concentrations, climate, and nitrogen management. For example, in semi-arid environments in the absence of fertilizer and lime application, changes can be relatively small, and range from 0 to ~0.1-0.3 pH units following ~10+ years of CA management. However, in legume-based systems and systems with mineral N fertilizer addition, declines in pH can be much higher. For example, in a CA system from southern Brazil, changes in pH were found to range from 0.4 to 1.5 units, with greater decreases observed in treatments with legume-based crop rotations and mineral N fertilization (Vieira *et al.*, 2009) [23].

2.4.1.2. Cation Exchange Capacity

Soil cation exchange capacity (CEC) impacts soil fertility, soil structural stability, and soil pH buffer capacity (McBride, 1994) [24]. While CEC is largely an inherent soil characteristic dependent on mineralogy and clay content, it can also be influenced by changes to SOM and pH (McBride, 1994) [24]. As such, there is potential for the CA to influence CEC. The magnitude and direction of the changes are variable, with increases, decreases, and no change observed. Where CEC is greater, it is generally associated with a higher organic matter content, which increases the amount of negative charge. Lower CEC may be observed in soils where a decrease in pH has occurred and resulted in a decrease in pH-dependent cation exchange sites (Limousin and Tessier, 2007) [22].

2.4.1.3 Plant Nutrients

Where improvements in SOC are observed in CA systems, this can have a significant effect on plant nutrient availability due to both changes to the quantity of nutrients available, and their distribution in the soil profile. In situations where CA successfully leads to greater residue addition and thus input of nutrient containing organic material into the soil, this can lead to higher plant nutrient stores, with greater nitrogen (N), phosphorus, calcium, magnesium, potassium, manganese and zinc concentrations all observed CA systems in response to increases in organic matter.

However, while in many instances increases in the amount of nutrients stored in the soil will lead to greater plant nutrient availability, this may not always be the case. In the case of N, for example, while total stores of N may be higher under CA, the amount of plant available N can decrease, particularly soon after CA is implemented and applications of N fertilizer may be required to maintain yield. This can occur due to slower rates of N mineralization due to reduced soil-stubble mixing, and/or greater rates of immobilization due to the presence of crop residues with high C:N ratios. Where immobilization is responsible for decreases in N availability, a gradual improvement in N supply may be observed over time as a new steady state between C and N supply is attained.

The absence of soil mixing in CA systems, especially those using complete NT, can also lead to the stratification of immobile nutrients at the surface of the soil profile (Mrabet *et al.*, 2012) [25]. This can be a problem in more arid regions, where drying at the surface may prevent plant roots from accessing nutrients from surface layers (Mrabet *et al.,* 2012) [25]. Where CA systems lead to higher soil bulk density and lower air-filled porosity under wet conditions, losses of N due to greater denitrification can also be observed. Similarly, greater water infiltration can be accompanied by increased leaching and the movement of soluble nutrients below plant rooting zones.

2.4.2 Impact of CA on biological properties of soil

2.4.2.1 Soil Microbiology

Where additional SOC is present in CA systems, this can provide an energy source for soil microorganisms and lead to a greater microbial biomass relative to conventional agricultural systems (Dou *et al*., 2008) [5]. Where increases in SOC and residue retention create a more favorable environment for the microbial populations due to improvements in soil aggregation, soil moisture and/or more favorable soil temperature, this can also improve microbial abundance (Kladivko, 2001) [13]. Conservation agriculture can also be associated with an improvement in the diversity of both fungal and bacterial populations, especially in the presence of more diversified crop rotations (Lupwayi *et al*., 2001) [15]. Fungal populations, in particular, are often observed in greater abundance in CA systems incorporating NT due to the absence of tillage, particularly at the surface of the profile (Kladivko, 2001) [13]. A greater abundance and diversity of microbes can have many important implications for crop production as a more microbially diverse soil is more likely to contain organisms that promote plant growth and suppress disease. For example, increases in the populations of arbuscular mycorrhizal fungi have been observed under NT corn grown on sandy loam soils in

Canada and cotton fields on silt loam soils in the US (Mbuthia *et al*., 2015) [26], which may improve P nutrition. The US study also found key enzymes associated with N and P cycling to be greater under CA, corresponding to greater nutrient availability (Mbuthia *et al*., 2015) [26].

2.4.2.2 Macro-fauna
Soil macro-fauna can be significantly influenced by CA systems. Macro-fauna, such as earthworms, termites and beetles, that burrow through the soil and/or break up plant residues are important for the creation of soil macroporosity (and thus water infiltration and hydraulic conductivity) and for helping mix organic material into the soil to aid nutrient cycling and aggregate formation (Kladivko, 2001) [13]. The tillage operations in conventional agricultural systems can affect macrofauna by directly killing or injuring them, by bringing them closer to the soil surface and exposing them to adverse environmental conditions and predators and by destroying their food sources, burrows and tunnels (Kladivko, 2001) [13]. The population of macro-fauna are thus commonly greater, both in terms of abundance and biomass, under CA systems and this increase in abundance becomes larger with the longer duration of the CA system (Kladivko, 2001) [13].

2.4.2.3 Diseases
While much of the soil's microbiology has positive implications for plant growth, numerous diseases also exist and disease prevalence can both increase and decrease under CA systems. For example, greater disease prevalence can occur due to the retention of residues, which provide some pathogens with a refuge to survive the period between harvest and planting when host plants are absent. Reduced soil disturbance, greater soil moisture and lower soil temperatures can also create an environment more favorable for many plant pathogens. Pathogens commonly observed to increase in the absence of tillage and/or residue removal include *Gaeumannomyces graminis* var *tritici* (take all) (Pankhurst *et al*., 1995a) [17], *Fusarium pseudograminearum* (head blight, scab or crown rot), *Pyrenophora tritici-repentis* (tan or yellow spot), *Pythium* spp. (Pythium seed and root rot), *Rhizoctonia solani* (Rhizoctonia root rot, bare patch, purple patch), and *Pratylenchus* spp. (root lesion nematode) (Pankhurst *et al*., 1995b) [17].
However, when reduced tillage and residue retention are incorporated effectively within a CA system that also includes diversification of cropping rotations, increases in disease prevalence are much less. Indeed, the general improvements in biological diversity under CA can increase the abundance of micro-organisms that suppress disease. For example, the prevalence of take-all can decrease due to increases in the prevalence of antagonistic *Pseudomonas* spp. The greater soil moisture often observed under CA may also lead to decreased plant moisture stress and reduced disease severity, even in instances where disease abundance is greater.

2.5 Effects of conservation agriculture on crop yield
Generally yield is a function of many parameters including climate, soil productivity and management. The yield gains frequently observed in dry climates are commonly attributed to the improvements in soil water storage under CA.
Conventional tillage gave comparatively more grain yield than minimum and zero tillage. Similar were the findings by Patil (2013) [27], according to him the grain yield of sorghum was lowest in first year of experiment where minimum tillage operation was carried out as against the conventional tillage. In contradictory to this recorded higher sorghum yields in zero tillage against the conventional tillage. Similarly, also advocated the yield advantage of zero tillage against the conventional tillage. On the other hand, results depicted that mulch had affected the grain yield significantly are in line with.
Use of excessive and unnecessary tillage operations is harmful to soil and add a lot to cost of production. Intensive conventional tillage is known to degrade soil structure. There is need to shift from conventional tillage to minimum and zero tillage for the purpose of protecting soil degradation, increasing water use efficiency, reducing the cost of production of summer crops and improving crop productivity. Conservation tillage (zero tillage and reduced tillage) practices simultaneously conserve soil and water resources, reduce farm energy usage and increase or sustain crop production.

3. Future needs of conservation agriculture, agronomic challenges and opportunity
3.1 Future needs of conservation agriculture
The system of CA agriculture can have clear advantages over conventional agricultural systems of management. In particular, its ability to help reduce input costs, improve soil physical, chemical and biological properties and increase yields is highly valued and has the potential to allow sustainable intensification in many instances (Lyon *et al*., 2004 [28]; Triplett and Dick, 2008 [29]; Verhulst *et al*., 2010 [30]). However, a number of aspects of the CA system mean that its implementation is not without significant challenges and a number of approaches are required to increase worldwide adoption. In particular, this will require that CA systems are well-adapted to individual regions and environments, taking into account the specific agronomic, social and economic challenges present. Where the system is not suitable for a region (e.g., cool, moist environments with high clay content soils), or in situations where the inputs required to ensure the success of CA systems (e.g., fertilizer, seeding equipment) are unavailable, CA may not be a successful system of management. Farmers require access to a range of tools and resources to allow them to identify if the principles of CA are likely to be appropriate for their operation and successfully overcome some of the challenges that can be associated with its use.

3.2 Agronomic challenges
The successful control of weeds, pests and diseases in the absence of tillage, the stratification of immobile nutrients at the surface of the profile, poor plant establishment due to inadequate seeding equipment, decreased N availability, and the development of soil structural issues, such as surface crust and compaction, can all be significant constraints to crop production in CA systems (Dang *et al*., 2015) [31]. In addition, in areas where low yields are the norm, it can be difficult to build up SOC and residue cover to improve soil fertility, prevent erosion and suppress weeds. In many instances these agronomic challenges can be overcome through better adaptation of the principles of CA to local conditions. For example:
The development of locally appropriate seeding equipment and the identification of locally adapted crop rotations/cover crops can help deal with the problems of plant establishment and weed, pest and disease pressures in the absence of tillage.
Appropriate application of fertilizers and/or better incorporation of legumes into cropping systems can help deal with problems of N availability and allow greater plant biomass production to increase residue cover and improve soil fertility. The incorporation of cover crops can maintain soil cover during

periods when the main crop is not growing and add additional organic material to the soil where crop residue production is low.

The use of strategic tillage, which is the practice of occasionally cultivating NT soils, can help with weed, pest and disease management, nutrient stratification and compaction in continuous long-term NT systems. However, in order to successfully identify practices appropriate for different geographical regions and cropping systems, adequate research is required to develop effective and locally adapted approaches.

3.3 Opportunity of conservation agriculture

- Conservation agriculture enhances water intake that allows for more stable yields in the midst of weather extremes exacerbated by climate change.
- Conservation agriculture provides many benefits for farmers and the environment, farmers can face constraints to adopt these practices.

3.4 Recommendation

I recommended that using conservation Agriculture components have very high benefits for Ethiopian farmers because it improves the input-output relationship specially for Benshangul gumz region it is highly recommended due to having enough mulching material such as granular grass and also there is water stressed areas such as Kuremuic woreda these needs conservation agriculture practices.

4. Conclusion

It is clear that when CA systems are well-designed and adapted to local conditions, they can improve the SOC content of many soils compared to conventional agricultural systems and that this can lead to significant improvements in soil chemical properties and productive capacity. However, to increase the adoption of CA worldwide, it is critical that the system be adapted to specific climates, soil types and communities, particularly considering the farmer's investment capacity, and the availability of resources. This may require some flexibility in approach to adapt agronomic management practices to local circumstances. In many soils across the world which are low in crop productivity, maintaining permanent soil cover through crop residues and cover crops can help in restoration soil organic matter and consequently improving in soil chemical and iologica properties. Suitable crop rotation is an important feature of conservation agriculture, which also helps in improving many soils chemical properties and reducing soil erosion. The major harmful impact of excessive long-term tillage is loss of soil structure, possibly due to reduction in soil organic matter and humus content. Therefore, excessive tillage is one of the major factors responsible for decline of soil organic matter.

5. Reference

1. Amézketa E. Soil aggregate stability: A review. J Sustain. Agric. 1999;14:83-151.
2. Bayer C, Lovato T, Dieckow J, Zanatta JA, Mielniczuk J. A method for estimating coefficients of soil organic matter dynamics based on long-term experiments. Soil Tillage Res. 2006a;91:217-226. DOI: 10.1016/j.still.2005.12.006
3. Beare MH, Hendrix PF, Cabrera ML, Coleman DC. Aggregate-protected and unprotected organic matter pools in conventional-and no-tillage soils. Soil Sci. Soc. Am J. 1994;58:787-795.
4. Bullock DG. Crop rotation. Crit. Rev. Plant Sci. 1992;11:309-326.
5. Dou F, Wright AL, Hons FM. Sensitivity of labile soil organic carbon to tillage in wheat-based cropping systems. Soil Sci. Soc. Am. J. 2008;72:1445-1453. DOI: 10.2136/sssaj2007.0230
6. Duiker SW, Lal R. Mulch rate and tillage effects on carbon sequestration and CO_2 flux in an Alfisol in central Ohio, in Agricultural Practices and Policies for Carbon Sequestration in Soil, Eds. Kimble JM, Lal R and Follet RF. (Boca Raton, FL: Lewis Publishers); c2002. p. 53-61. Doi: 10.1201/9781420032291.pt2
7. FAO: Investing in sustainable agricultural intensification, The Role of Conservation Agriculture-A Framework for Action. FAO, Rome; c2008.
8. FAO: Conservation agriculture; c2017 Aug. http://www.fao.org/ag/ca/index.html.
9. Friedrich T, Derpsch R, Kassam A. Overview of the Global Spread of Conservation Agriculture. Field Actions Science Reports [Online] Special; c2012. p. 6. http://factsreports.revues.org/1941. (Accessed on 15 September 2019)
10. Hatfield KL, Pruegar JH. Microclimate effects of crop residues on biological processes. Theor. Appl. Climatol. 1996;54:47-59. DOI: 10.1007/BF00863558.
11. Huggins DR, Reganold JP. No-till: The quiet revolution. Sci. Am. 2008;299:70-77.
12. Karlen DL, Wollenhaupt NC, Erbach DC, Berry EC, Swan JB, Eash NS, *et al*. Crop residue effects on soil quality following 10-years of no-till corn. Soil Tillage Res. 1994;31:149-167. DOI: 10.1016/0167-1987(94)90077-9.
13. Kladivko EJ. Tillage systems and soil ecology. Soil Tillage Res. 2001;61:61-76. DOI: 10.1016/S0167-1987(01)00179-9.
14. Lal R. A system approach to conservation agriculture. JSWC. 2015b;70:82A. DOI: 10.2489/jswc.70.4.82A
15. Lupwayi NZ, Arshad MA, Rice WA, Clayton GW. Bacterial diversity in water-stable aggregates of soils under conventional and zero tillage management. Appl. Soil Ecol. 2001;16:251-261. DOI: 10.1016/S0929-1393(00)00123-2
16. Madari B, Machado PLOA, Torres E, De Andrade AG, Valencia LIO. No tillage and crop rotation effects on soil aggregation and organic carbon in a Rhodic Ferralsol from southern Brazil. Soil Tillage Res. 2005;5(80):185-200. DOI: 10.1016/j.still.2004.03.006.
17. Pankhurst CE, Hawke BG, McDonald HJ, Kirby CA, Buckerfield JC, Michelsen P, *et al*. Root-lesion nematode (*Pratylenchus thornei*) limits response of wheat but not barley to stored soil moisture in the Hermitage long-term tillage experiment. Aust. J Exp. Agric. 1995b;35:1049-1055. DOI: 10.1071/EA9951049
18. Mathew EY, Dodo JD, Maton SM, Dalen MB. Assessment of persistent organic pollutants in soil and water of Kara Bisichi, Barkin Ladi Lga of Plateau state, Nigeria. Int. J Adv. Chem. Res. 2021;3(2):04-11. DOI: 10.33545/26646781.2021.v3.i2a.35
19. Schneider EC, Gupta SC. Corn emergence as influenced by soil temperature, matric potential and aggregate size distribution. Soil Sci. Soc. Am. J. 1985;49:415-422.
20. Tittonell P, Scopel E, Andrieu N, Posthumus H, Mapfumo P, Corbeels M. Agro ecology-based aggradation-conservation agriculture (ABACO): Targeting; c2012.
21. Heenan DP, Taylor AC. Soil pH decline in relation to rotation, tillage, stubble retention and nitrogen fertilizer in SE Australia. Soil Use and Management. 1995 Mar;11(1):4-9.

22. Limousin G, Tessier D. Effects of no-tillage on chemical gradients and topsoil acidification. Soil and Tillage Research. 2007 Jan 1;92(1-2):167-74.
23. Vieira FG, Borges GD, Copetti C, Amboni RD, Denardi F, Fett R. Physico-chemical and antioxidant properties of six apple cultivars (Malus domestica Borkh) grown in southern Brazil. Scientia Horticulturae. 2009 Oct 1;122(3):421-5.
24. McBride JR, Hass KC, Poindexter BD, Weber WH. Raman and x-ray studies of Ce1− x RE x O2− y, where RE= La, Pr, Nd, Eu, Gd, and Tb. Journal of Applied Physics. 1994 Aug 15;76(4):2435-41.
25. Kassam A, Friedrich T, Derpsch R, Lahmar R, Mrabet R, Basch G, *et al.* Conservation agriculture in the dry Mediterranean climate. Field Crops Research. 2012 Jun 14;132:7-17.
26. Mbuthia LW, Acosta-Martínez V, DeBruyn J, Schaeffer S, Tyler D, Odoi E, *et al.* Long term tillage, cover crop, and fertilization effects on microbial community structure, activity: Implications for soil quality. Soil Biology and Biochemistry. 2015 Oct 1;89:24-34.
27. Shulaker MM, Hills G, Patil N, Wei H, Chen HY, Wong HS, *et al.* Carbon nanotube computer. Nature. 2013 Sep;501(7468):526-30.
28. Sayes CM, Fortner JD, Guo W, Lyon D, Boyd AM, Ausman KD, *et al.*. The differential cytotoxicity of water-soluble fullerenes. Nano letters. 2004 Oct 13;4(10):1881-7.
29. Triplett Jr GB, Dick WA. No-tillage crop production: A revolution in agriculture!. Agronomy journal. 2008 May;100:S-153.
30. Verhulst N, Govaerts B, Verachtert E, Castellanos-Navarrete A, Mezzalama M, Wall P, *et al.* Conservation agriculture, improving soil quality for sustainable production systems. Advances in soil science: Food security and soil quality. CRC Press, Boca Raton, FL, USA. 2010 Jun 23:137-208.
31. Horvat TZ, Adel NG, Dang TO, Momtaz P, Postow MA, Callahan MK, *et al.* Immune-related adverse events, need for systemic immunosuppression, and effects on survival and time to treatment failure in patients with melanoma treated with ipilimumab at Memorial Sloan Kettering Cancer Center. Journal of Clinical Oncology. 2015 Oct 10;33(28):3193.
32. Plante AF, McGill WB. Soil aggregated dynamics and retention of organic matter in laboratory-incubated soil with differing simulated tillage frequencies. Soil Till. Res. 2002;66:79-92.