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Review Article

Influence of Conservation Agriculture on Certain Soil Qualities Both Physical and Chemical in Relation to Sustainable Agriculture Practices a Review

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Abstract

Conventional tillage raises the possibility of soil erosion and degrades crucial physical characteristics of the soil, such as soil organic carbon (SOC) reduction. Additionally, ineffective management techniques result in a decrease in soil organic matter, a breakdown of the soil's structure, and more erosion. As a result, crop yields have decreased. Conservation agriculture (CA) is being considered as a potential system having the capability of improving soil quality and providing stable yields. This review's primary goal is to demonstrate how conservation agricultural practices affect certain physical and chemical characteristics of soil in order to support sustainable agriculture. So as to produce production system that are sustainable, conservation agriculture refers to cropping system management approaches that support permanent soil cover, low soil disturbance, and appropriate crop rotation. With the use of conservation agriculture techniques, it is possible to enhance the physical and structural health of the soil (by reducing bulk density and improving soil aggregation), in addition to increase soil water infiltration, decrease water runoff and soil loss, decrease evaporation loss, decrease soil organic carbon, and lower greenhouse gas emissions from agriculture. These factors are crucial for maintaining soil health and sustainable crop production. In general, applying the conservation agriculture concepts of limited tillage, soil cover, and legume integration would promote the development of soil microorganisms and organic matter by decreasing erosion. Conservation agriculture is therefore regarded as one of the agricultural systems that have the ability to favorably contribute to soil physical and chemical improvement as well as techniques for mitigating and adapting to climate change.

Keywords

Conservation Agriculture, Soil Physical Properties, Soil Chemical Properties

1. Introduction

Soil is one of the most valuable natural resources on Earth, and a decline in soil health is the main factor limiting subsistence farmers' ability to produce high-quality crops, which in turn leads to a significant increase in food insecurity [33]. Continuous application of inefficient soil management practices, such as burning and clearing agricultural residues, heavy tillage, and mono-cropping farming methods that expose the soil to erosion and leaching, causes a decrease in soil fertility. Tillage techniques are essential parts of soil management systems that have a big influence on plant devel-

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opment and soil properties. Tillage methods alter a variety of soil physical, chemical, and biological characteristics, which have an influence on crop growth. Encouraging conservation agriculture (CA) practices like cover crops, reduced tillage, the use of soil additives (like biochar), and crop rotation is an effective way to improve soil quality, increase crop productivity, and reduce soil erosion losses [23]. Thus, among the different tillage-based agricultural practices, conservation agriculture (CA) has the potential to lower soil loss, enhance soil moisture, improve soil fertility, and boost soil organic matter levels while requiring less or no tillage operations. In addition, it can save expenses [13], these methods are crucial for controlling the stability of organic carbon, nutrient release and loss, and soil formation and erosion. Permanent soil cover with organic materials, crop diversification, and little soil disturbance are the characteristics of conservation agriculture, a type of climate-smart agriculture. Without compromising yields at high production levels, conservation agriculture offers a genuinely sustainable production system that not only preserves but also improves natural resource and expands the diversity of soil biota, fauna and flora (including wild life) in agricultural production system. Because of the presence of a carbon pool and improved soil structure, conservation agriculture (CA) practices improve the properties of soil, such as soil aggregation, reduce bulk density, and increase soil penetration resistance, which can improve aeration and infiltration while lowering erosion and nutrient loss over time [36]. Due to these advantages, conservation agriculture has been (CA) has been recognized as a crucial instrument for securing food supply in the future and protecting agricultural output from extreme weather events like heat waves and droughts, which are projected to occur more frequently due to climate change (FAO, 2019). This paper's primary goal is to provide a narrative summary of the peer-reviewed research on the impact of conservation agriculture (CA) and its constituents on the physical and chemical properties of soil.

2. An Overview of Conservation Agriculture

Conservation agriculture (CA) is a farming system designed to improve the sustainability of agricultural production by conserving and protecting soil, water and biological resources. Through the preservation of natural resource quality and the addition of stable or semi-stable organic cover to the soil, conservation agriculture increases soil microbial life and promotes sustainable farming practices. The functional diversity of soil microorganisms, which is crucial for increased crop productivity, better soil quality, and several ecosystem services, can also be impacted by conservation agriculture [65]. According to FAO (2019) conservation agriculture as an agronomic practice that includes rotating crops with pulses and legumes, maintaining crop residue, planting green manure crops as a cover crop, and reducing, eliminating, or using minimal tillage. Some of the advantages of conservation agriculture include reduced weed germination, decreased irrigation needs, enhanced aeration and infiltration, increased soil organic matter, increased nitrogen in the soil, decreased fuel, time, and labor consumption.

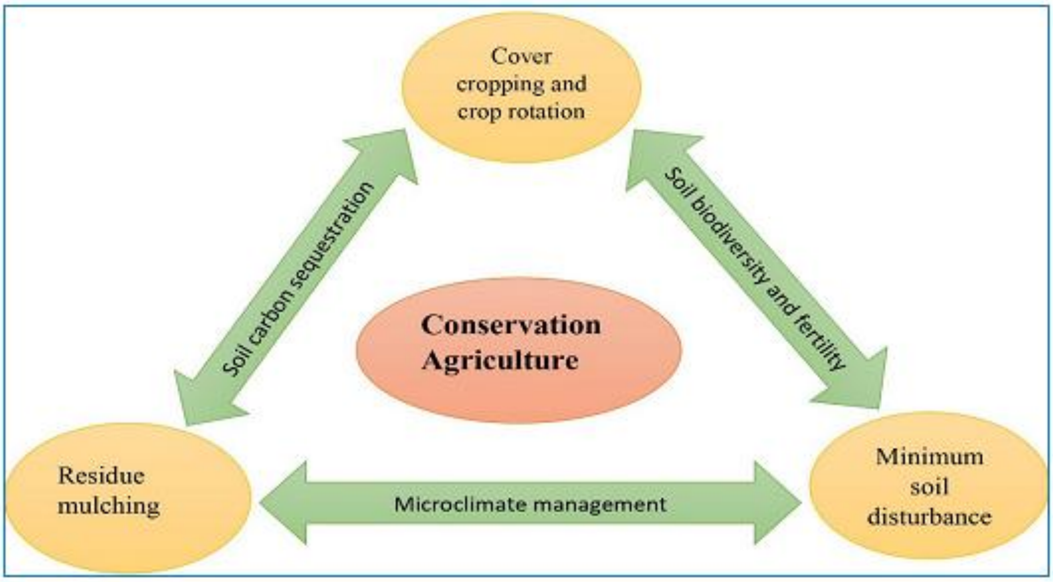

Figure 1. *Components of conservation agriculture and its positive interaction with environment.*

The concepts of conservation agriculture can be applied to a wide range of crop production systems, from rainfed, low yielding environments to irrigated, high yielding ones. However, depending on the biophysical, system management, and farmer circumstances, there will be a wide range of approaches to implementing the principles of conservation agriculture. Additionally, conservation agriculture employs meticulous waste and residue control along with a balanced application of chemical inputs. This reduces the need for long-term chemical inputs, lessens soil erosion and pollution of land and water, slows down the physical, chemical, and biological degradation of soil, enhances water quality and efficiency, and lowers greenhouse gas emissions by using fewer fossil fuels, all of this results in improved environmental management [59]. Furthermore, the practice of conservation agriculture results in an increase in soil organic matter since it slows down the breakdown of plant roots and crop residues and allows fauna and flora to continue building up organic matter in the soil [32]. The qualities of conservation Agricultural practices vary depending on the location and can range from small-scale mechanized systems using hand tools for direct planting to large-scale mechanized systems using tractor-mounted direct seeders. [34].

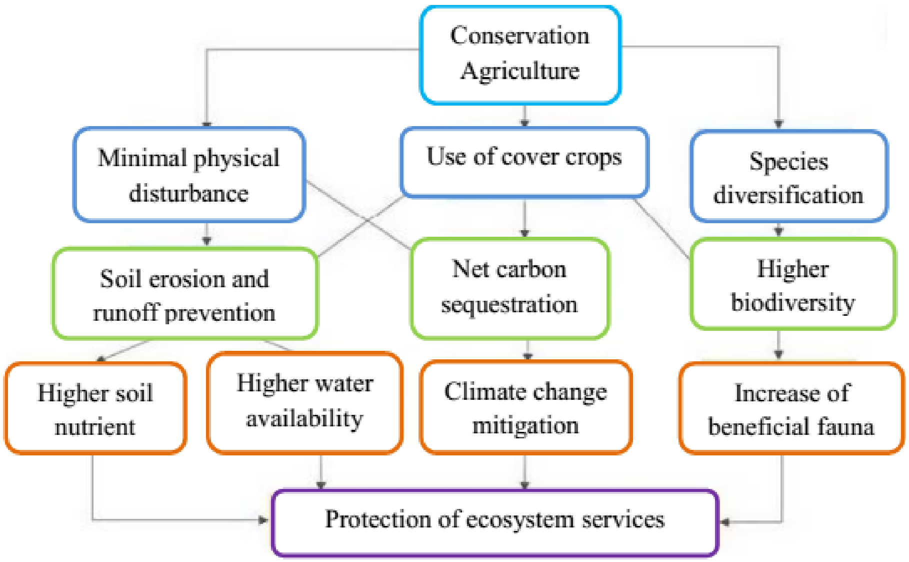

Figure 2. *Influences of conservation agriculture practice on soil and environment.*

3. The Impact of Conservation Agriculture on the Physical Characteristics of Soil

3.1. Soil Structure and Aggregation

An essential component of soil functioning, soil structure plays a significant role in assessing the sustainability of agricultural production system. Soil structure is comprised of various elements such as the capability of the soil to support robust root growth and development, the size, shape, and arrangement of solids and voids, the continuity of pores and voids, and their ability to retain and transport fluids and organic and inorganic substances. Additionally, the stability and structure of the soil are critical to several physical processes, including root formation, moisture retention, erosion reduction, mechanical resistance to penetration, and aeration [49]. Land management has the power to alter soil structure, which in turn affects a variety of soil processes and functions, including root growth, microbial activity, resistance to physical erosion, water and nutrient retention and transport, aeration, and resistance to physical erosion [4]. As a result, when soil structure deteriorates, it also degrades the soil, which lowers agricultural productivity and ecological stability [25].

With a focus on soil carbon sequestration and water quality in particular, soil structure is essential to the health of the soil, its capacity to support plant and animal life, and the moderation of environmental quality. A common way to describe soil structure is as the level of aggregate stability [9]. Secondary particles known as aggregates are created when mineral particles mix with both organic and inorganic materials. By mitigating soil erosion and facilitating air permeability, water infiltration, and nutrient cycling, soil aggregation is a crucial process that enhances soil fertility [67]. Aggregates of soil have a crucial role in retaining soil organic carbon and preventing its decomposition [21]. In order to maintain overall stability and the upkeep of a healthy soil structure, soil organic matter is crucial. Low-organic matter soils have aggregates that are more likely to slake into smaller subunits when wet, which can limit water infiltration and seedling emergence and raise the risk of soil erosion.

According to Barto *et al.*, [5], the use of various tillage systems in soil management has an impact on soil aggregation both directly by physically upsetting macro aggregate and indirectly by changing biological and chemical factors. As a result, the deterioration of these aggregates contributes to the degradation of the soil, which lowers agricultural productivity and ecological stability. Additionally, throughout the entire crop season, intense tillage, residue removal, and burning practices accelerate soil erosion, contamination of the environment, soil deterioration, and have an impact on ecosystem processes. Consequently, using sustainable land management techniques like conservation agriculture is a substitute that enhances agricultural output and soil structure. Because they conserve energy and create more favorable soil conditions for sustainable crop production and soil organic carbon sequestration, from an ecological and financial perspective, conservation tillage techniques with minimal soil disturbance and residue retention are becoming more and more appealing [26]. According to Govaerts *et al.,* [19], the return of crop residue to the soil surface increases aggregate formation and decreases aggregate breakdown by reducing erosion and shielding the aggregates from the impact of raindrops. Zero tillage with residue retention also improves dry aggregate size distribution when compared to conventional tillage. Similarly, Govaerts *et al.* [20] noted that modifications to crop rotation might have an impact on the quantity and quality of organic matter input, which may alter soil organic carbon and subsequently have an indirect impact on soil aggregation. Furthermore, Six *et al.* [55] indicated that because plant roots are significant binding agents at the scale of macro aggregates, crops can influence soil aggregation through their rooting system. According to Lichter *et al.*, [36], soil under a wheat crop had noticeably bigger macro aggregates than soil under a maize crop. Compared to maize, wheat has a more horizontally developing root system and a denser superficial root network due to its higher plant population. This denser root network may have a beneficial effect on stability and aggregate formation [10]. Conservation agriculture (CA) practices promote aggregate stability more in the topsoil layer and decrease with depth. According to Zhang *et al.* [66], treatments with straw return showed a higher increase in soil aggregate stability in the surface layer (0-20 cm) than in the subsurface layer (20-40 cm) when compared to treatments without straw. In a similar manner, Laborde *et al.,* [31] found that the impact of the management system was higher in the 0-5 cm depth than in the 5-10 cm depth. They also found that the mean weight diameter of dry soil aggregates varied between the 0-5 cm layer and the 5-10 cm depth, with conservation agriculture (CA) reporting 3.92 mm and conventional practice (CP) reporting 2.70 mm. This indicates that when comparing conservation agriculture (CA) to conventional practice (CP), the mean weight diameter of dry soil aggregates increased by 45% at the 0 to 5 cm level and 24% at the 0 to 10 cm depth. Additionally, In a study spanning six seasons, Nyambo *et al.,* [48] found that, when it came to aggregate stability, the interaction between crop rotation, tillage and residue management were significant ($P<0.01$) at the 0-5 cm depth but not at the 5-10 cm depth ($P > 0.05$). Thus at the 0-5 cm depth, mean weight diameter (MWD) increased with season under no tillage (NT) and the various crop rotations. The average mean weight diameter across all seasons for no tillage was 0.292 mm, 0.266 mm and 0.271 mm for maize-oat- maize (MOM), maize-fallow- maize (MFM) and maize-vetch-maize (MVM) treatments, respectively. Conversely, in season one, the mean weight diameter values of conventional tillage (CT) plots was higher and varied with the seasons. He was also reported that in all crop rotations and crop residue management treatments, no tillage (NT) had higher mean weight diameter (MWD) compared to the conventional tillage (CT) treatments. Plots with treatments of no tillage (NT), maize-oat-maize (MOM), and crop residual retention (R+) had the highest mean weight diameter (MWD) (0.324 mm), while the conventional tillage (CT) plot with treatments of maize-vetch-maize (MVM) and crop residual removal (R-) had the lowest mean weight diameter (MWD) (0.189 mm). This was due to the continued accumulation of soil organic matter (SOM) on the top soil layer over time may be responsible for the increased mean weight diameter (MWD) under no tillage (NT) throughout crop cycles and residue management plans. One possible explanation for low mean weight diameter (MWD) at the 0-5 soil layer under conventional tillage (CT) treatments is the periodic turning of the soil.

According to Mupangwa *et al.*, [45] soil aggregate development and stabilization depend on soil organic matter (SOM). Frequent soil disturbances from tillage operations break down pre-existing soil aggregates and expose soil organic matter (SOC) to further oxidation, which reduces the soil's carbon concentration [71]. Organic matter in the soil can improve soil macroporosity and boost the soil's resistance to deformation. When aggregates are wetted, a higher organic matter concentration in the topsoil prevents slaking and disintegration [61]. Since the management of past crop residues is essential to the development and stability of the soils structural integrity because organic matter plays a major role in soil aggregation. Crop residue that has been returned to the soil surface not only encourages the formation of aggregates but also prevents them from disintegrating by reducing erosion and protecting the aggregates from the effects of rainfall. These improvements are important because they increase the rates at which water percolates into the soil, strengthen the soil's resilience to erosion from wind and water, improve the organic matter's physical protection, and expand the number of habitats that are favorable to microbial activity. Furthermore, cultivating cover crops has a direct and indirect influence on the physical characteristics of the soil. Studies have shown that cover crops encourage the development of soil pores and aggregates, and they have an indirect impact on how quickly plant waste breaks down [7]. According to Blanco-Canqui *et al.*, [9] a 15-year no-tillage system in a silt loam enhanced wet aggregate stability with cover crops. In addition, no-till reduced near surface soil compaction as compared to tilled and no-cover management. Likewise, According to Villamil *et al.*, [62], winter cover crops increased the wet aggregate stability on a silt loam soil in a five-year no-tillage regime. It is commonly recognized that adding organic matter (OM) significantly enhances soil structure. For instance, the addition of organic matter (OM) supports to bind soil particles into stable aggregates, increasing the pore volume within and between the aggregates and increasing the total porosity of the soil [39].

3.2. Bulk Density and Porosity

Bulk density is one of the most often used physical criteria to assess the effects of tillage and crop residue on agricultural soils because it measures how compacted the soil is and shows how well it can support structures, transmit water and other substances, and aerate the soil. High bulk density cause root impedance and lead to humble crop emergence. Bulk density has an impact on soil aeration, root penetration, soil strength, and porosity all of which are critical for crop growth and development. The types and varieties of crops farmed, the texture, mineralogy, particle size and structure, organic matter, and management practices such as tillage, intercultural activities, and residues all affect bulk density [52].

Conservation agriculture is one type of agricultural management technique that modifies the physical properties of soil both shortly and permanently. As such, they directly affect crop yield and growth as well as the sustainability of agriculture [70]. There is disagreement, nevertheless, regarding the influence of conservation agriculture on soil bulk density. While some studies have reported lower soil bulk density in conservation agriculture when compared to conventional tillage [47], others have not originate any discernible differences between the two practices [53]. These variances in bulk density in the different trials may be due in part to the type of the farm. In order to improve the physical properties of the soil, tillage an important agricultural management technique involves rotating, upending, and disturbing soil particles, plant growth and yield may be impacted by this. According to Shahzad *et al.* [54], the bulk weight and total porosity of soil are significantly impacted by the interaction of various tillage systems and techniques. Al-Wazzan and Muhammad [1] found that no-tillage systems considerably lower soil bulk density while raising soil porosity and organic matter in contrast to conventional tillage systems. Similarly, According to Bai *et al.* [2], for conventional tillage and no tillage treatments, the mean soil bulk density in the experimental site in November 2013 was 1.27 g cm^{-3}, with soil depths ranging from 0 to 30 cm. After a two-year trial with different tillage intensities, there was a little decrease in soil bulk density in the no-till plots with straw cover compared to conventional tillage. In the no-till treatment, the mean bulk density in 20–30 cm soil layers was 5.6%, which was significantly lower than in the regular tillage treatment in 2014. In comparison to typical tillage in 2015, the mean bulk density in the no-tillage treatment was 11.6% lower at the same depths. According to Bitew *et al.* [6], conventional tillage delivered the highest bulk density (1.47 g cm^{-3}), while conservation agriculture gave the lowest bulk density (1.31 g cm^{-3}). The continued addition of adequate crop residues and the lack of soil disturbance, which resulted in a rise in organic matter and an improvement in soil structure, may be the cause of the decrease in bulk density at all conservation agriculture practices, and at conservation agriculture-based maize-legume cropping systems in particular. According to Zhang *et al.* [66], conservation tillage may enhance the topsoil's ventilation and soil structure, albeit this possible benefit may change depending on the tillage system used. The mean bulk density of soil in the 0–60 cm tilth was 1.42 g cm^{-3}, but as the experiment carried on, the bulk densities of the various tillage systems decreased and the differences between them increased. He indicated that after the ten-year experiment, the soil bulk density of no tillage/conventional tillage/ subsoiling (NCS) rotation (1.31 g cm^{-3}) and subsoiling (ST) (1.36 g cm^{-3}) significantly decreased by 7.7 % and 4.2 %, respectively ($P < 0.05$). In contrast, there was no discernible change in the soil bulk densities of no tillage (1.41 g cm^{-3}) and conventional tillage (CT) (1.42 g cm^{-3}) at soil depths of 0-60 cm prior to the 2007 experiment. According to Parihar *et al.* [51], the bulk density under conservation agriculture (CA) methods (zero tillage and permanent raised beds) was lower in soil depths of 0-30 cm compared with conventional tillage (CT) in a long-term study of crop rotations based on maize (Zea mays L.). In deeper soil layers (30-60 cm), differences between management systems were non-significant. Verhulst *et al.* [61] found that the bulk density under the high-mulch treatment was 58% lower and that under the low-mulch treatment was 19% lower at a depth of 0-3 cm when compared to the bulk density under the un-mulched treatment. Similarly, the bulk density under the high-mulch treatment was only 36% lower in the 3-10 cm depth, while the bulk density under the low-mulch treatment was 9% lower than the control. According to Blanco-Canqui *et al.* [8] the bulk density in the 0–5 cm layer dropped from 1.42 Mg m^{-3} (control) to 1.26 and 1.22 Mg m^{-3}, respectively, when maize residue was retained at 5 and 10 Mg ha^{-1} for a year in zero tillage systems in a silt loam. There are spaces and solids in the soil. The spaces, known as pore space or porosity, are necessary for root development, water storage, gas exchange, and water circulation. The amount of organic matter, soil fauna, and soil aggregate stability all have an impact on soil porosity, which is produced by the aggregation of soil particles. According to Zhang *et al.* [68], the mean soil porosity in the 0-60, cm tilth was 46.42% prior to the experiment. Following a 10-year trial, the soil porosity under no-tillage/conventional tillage/ subsoiling (NCS) rotation (50.69 %), no tillage (NT) (46.75 %), subsoiling (ST) (48.68 %) and conventional tillage (CT) (46.35 %) increased by 9.2 %, 1%, 4.9 % and -0.1 %, respectively.

Table 1. Influence of tillage systems on soil porosity and bulk density with soil depths.

Tillage	Soil depth (cm)	Bulk density (gm/cm^3)	Soil porosity (%)
No tillage	0-10	1.32	43.77
	10-20	1.63	30.84
Conservation tillage	0-10	1.51	35.91
	10-20	1.7	27.15

Source: Al-Wazzan and Muhammad [1]

3.3. Hydraulic Conductivity

The characteristics of soil that permit water to pass through them are known as hydraulic conductivity. In contrast, the pace at which water percolates through it is known as the infiltration rate. The rate of infiltration is contingent upon hydraulic conductivity. The rates at which water percolates through soil and evaporates are largely determined by surface conditions. Tillage affects residue cover, surface roughness, and pore space the form, volume, and continuity of pores making it the most effective method of changing the properties of the soil surface. From an agricultural standpoint, soil water movement is essential to plant development. Processes including water and nutrient movement to plant roots, salt leaching from the root zone, and soil surface evaporation are all impacted by hydraulic conductivity. Hydraulic conductivity varies greatly and is influenced by field conditions and management techniques. Soil infiltration is directly related to structural stability, bulk density and pore structure. Long-term conventional tillage and no-tillage systems have the potential to change the soil's bulk density, aggregate stability, total porosity, and organic carbon content. These changes can also affect the soil's structure and the several soil variables that influence the soil's ability to store and transmit water. Tillage operations in a conventional tillage system compact the soil below the tilled zone, disrupt surface-vented pores, increase the breakdown of residues and increase surface sealing. Understanding the factors that influence hydraulic conductivity and infiltration rate in agricultural fields may illustrate a potential to decrease runoff. Negative soil hydraulic behavior has been linked to monoculture agricultural systems, insufficient organic residue return to soil systems, and soil structure deterioration caused by conventional intensive tillage techniques. Miriti *et al.* [42] state that low porosity and high bulk density soils have an adverse effect on saturated hydraulic conductivity (Ks) and infiltration rate. Steward *et al.* [58] reported that the primary mechanism for the higher maize yield of conservation practice compare to conventional practice (CP) under climate stress is thought to be an improvement in soil hydraulic properties, such as increased water infiltration and transmission, soil moisture retention, and plant available water capacity. Conservation tillage is one management practice that can influence the features of the field and increase infiltration of water into the soil. Thierfelder and Wall [59] found that a conservation agriculture system had an 87% higher infiltration rate (and hence a higher saturated hydraulic conductivity) than a conventional system. This led to a higher maize grain yield in Zambia, demonstrating higher rainfall-use efficiency. Reynolds *et al.*, [53] stated that in long-term no-till fields, the saturated hydraulic conductivity rose up to 5-10 times above the optimal (ideal) level. Likewise the ideal saturated hydraulic conductivity (Ksat) for agricultural soils, as suggested by Reynolds *et al.*, [53], is between 5.0 $\times 10^{-3}$ cm s^{-1} and 5.0 $\times 10^{-4}$ cm s^{-1}. This range is perfect for accelerating infiltration, redistributing water available to plants, and lowering surface runoff and soil erosion by promoting comparatively quick drainage of excess soil water in the soil profile. Eze *et al.*, [14] revealed that across the three trial sites, land management had significant effects on hydraulic conductivity (Ksat) transmission pores, fine storage pores and residual pores.

Nebo and colleagues [43] observed that hydraulic conductivity was higher under no-till (NT) (58.4 mm h^{-1}) than under conventional tillage (32.8 mm h^{-1}). He suggested that the reason for the higher average saturated hydraulic conductivity under no-tillage is a well-structured soil, with higher total porosity leading to an increase in soil organic matter (SOM) and the influence of plant roots. However, Six *et al.*, [56] reported that lesser saturated hydraulic conductivity in conventional practice was due to mechanical breakdown of aggregates during tillage, leading to structural degradation in the conservation tillage (CT) plots. Mloza-Banda *et al.*, [43] found that where short term (<5 years) conservation agriculture (CA) practices increased Ksat to a maximum value of 0.04 cm/min in central Malawi.

Kodesova *et al.* [28] found that improved soil structure, elevated total porosity, increased soil organic matter (SOM), and plant root impacts account for the greater average saturated hydraulic conductivity under no tillage (NT). Moreno *et al.*, [44] suggested that the presence of preferential flow paths due to earthworm activities was the reason for higher saturated hydraulic conductivity under no tillage (NT) compared to conventional tillage (CT). The biological actions of earthworms affect soil structure and influence soil properties such as porosity and water content. Zhang *et al.* [64] revealed that after 24 years, there were noticeably more macropores (more than 11%) under no-till with residue retention compared to conventional tillage with burned residue. According to Eze *et al.* [14], in all three of the Malawian sites, the conservation agriculture (CA) plots had significantly higher hydraulic conductivity than the conventional practice plots. Additionally, the results showed that the surface soil layers at all three sites had significantly higher hydraulic conductivity values than the lower soil layers. The establishment of a more stable soil structure with higher pore volume and pore connectivity is more common in conservation agriculture (CA) plots due to significantly lower soil disturbance, compared to conventional practice (CP) plots where plowing methods cause the disruption of pore structure.

3.4. Infiltration Rate

According to Jat *et al.*, [27], agricultural techniques based on conservation agriculture had a substantial impact on the rate and cumulative penetration of infiltration. Therefore, the highest infiltration rate was recorded under conservation agriculture-based maize-wheat-mungbean (0.29 cm h^{-1}) and rice-wheat-mungbean (0.31 cm h^{-1}) systems, whereas the lowest was noted under conventional agriculture (0.09 cm h^{-1}). In addition, it indicated that cumulative infiltration was increased with time interval. Thus conservation agriculture based maize-wheat-mungbean system showed highest cumulative infiltration in all the time intervals than others. Verhulst *et al.*, [61] revealed that higher infiltration in zero tillage with residue retention might result from residue cover's direct and indirect effects on water infiltration [61]. Compared to traditional tillage, zero tillage produces stable aggregates with residue retention, which reduces aggregate disintegration and the likelihood of surface crust formation. In comparison to conventional tillage, McGarry *et al.* [42] showed increased infiltration rates and cumulative infiltration under zero tillage with residue retention. Zero tillage with residue retention may have contributed to the increased infiltration under conservation agriculture-based systems by facilitating the establishment of continuous soil pores from the soil surface to depth [17].

4. Effect of Conservation Agriculture on Soil Chemical Properties

4.1. Soil pH

Ineffective management techniques result in a decrease in soil organic matter, a breakdown of the soil's structure, and more erosion. As a result, crop yields have decreased. It is thought that conservation agriculture (CA) is a viable system with the ability to enhance soil quality and produce consistent harvests. Ligowe *et al.*, [37] reported on his medium term conservation agriculture experiment the lower pH values were observed in 2007 unlike in 2011 with an average of 5.04 and 5.82 respectively. His findings showed that after the fifth year, the soil pH values in the CA treatment plots had increased, while the soil pH values in the control/common practice had fallen. The intercrop plot of maize and velvet beans had the highest pH value (6.14) in the top soil among the CA treatments. Ligowe *et al.*, [37] further suggested that following conservation agriculture interventions, the pH of the soil increased relative to the pH recorded from the control plot. This discovery implies that the annual removal of crop residuals depletes the soil organic matter (SOM), increasing the solubility of sesquioxides in the form of iron (Fe), manganese (Mn), and aluminum (Al) under conventional agricultural practices. Buildup of iron (Fe), manganese (Mn), and aluminum (Al) is toxic and hinders essential plant nutrients like phosphorus from getting to the soil and growing plants. Because of the high concentration of soil organic matter (SOM) in the conservation agriculture (CA) plots, there was an increase in pH due to a nutritional buffer effect. According to Ngwira *et al.*, [46], after four years of conservation agriculture (CA) practice, the pH of the soil was marginally higher under all conservation agriculture treatments than it was under conventional farming. In a comparable manner, Govierts *et al.*, [18] found that the permanent raised beds with full residue retention had topsoil with a pH that was noticeably higher than that of conventional raised beds with residue retention.

4.2. Soil organic Carbon

Soil organic matter is an important soil quality indicator and its increase leads to improved nutrient cycling, cation exchange capacity, buffering capacity and crop yield [35]. Soil organic matter (SOM) enhances soil structure, fertility, productivity, and sustainability, which makes it a major driver of soil quality. The dynamics of soil organic carbon (SOM) are influenced by agricultural management practices such as tillage, mulching, crop residue management, and the use of mineral and organic fertilizers. Tillage is critical to controlling the release and storage of nutrients from soil organic matter (SOM). Similarly, tillage accelerates oxidation of organic matter by soil microorganism through changes in soil water, aeration and temperature regimes, aggregation and nutritional environment.

Soil lost nitrogen (N) and carbon (C) due to the rapid mineralization of soil organic matter (SOM) during conventional tillage. Most studies across different climatic conditions have found that conservation agriculture significantly increased soil organic carbon concentrations compared to plots conventional practices. Additionally, crop monocultures and deep tillage with layer inversion have been used to exploit agricultural soils, which have led to a gradual deterioration of the soil's structure, compaction, and loss of organic matter. These harmful developments have increased soil water and wind erosion, CO_2 emissions, and adverse cascade effects on soil fertility and biota. Kristof, *et al.*, [30] reported that Plowing removes over 60% of organic carbon in temperate regions and 75% in tropical ones; this removal accounts for roughly 23% of greenhouse gas concentrations in the atmosphere. Increasing soil tillage also enhances the soil's CO_2 flow. Frequency and intensity of tillage had significant influence on disintegration and decomposition of organic matter including residues. Enhancing soil organic matter (SOM) is a goal worth pursuing because it is linked to higher crop production, plant nutrition, and soil physical attributes like increased porosity, reduced bulk density, and stronger aggregate stability. Soil organic carbon (SOC) of surface soil is considered as a primary indicator of soil quality because it is vital horizon that received the much of seeds, fertilizers and other chemical applied. It is well known that soils treated with long-term no till or reduced tillage techniques often have greater soil surface concentrations of soil organic carbon (SOC) than soils treated with conventional tillage [60]. A numeral of interacting mechanisms, including less mixing and soil disturbance, enhanced residue return, lowered surface soil temperature, increased moisture content, and a lower risk of erosion, are thought to be responsible for this rise in soil organic carbon (SOC) concentration. Conversion of convention tillage to conservation agriculture increases the accumulation of soil organic carbon (SOC) in the soil surface layer. Conservation agriculture increases soil organic carbon (SOC) stock through the reduction in soil organic carbon (SOC) losses by oxidation and erosion, the increase in organic carbon inputs to the soil (plant residues), or a combination of both factors.

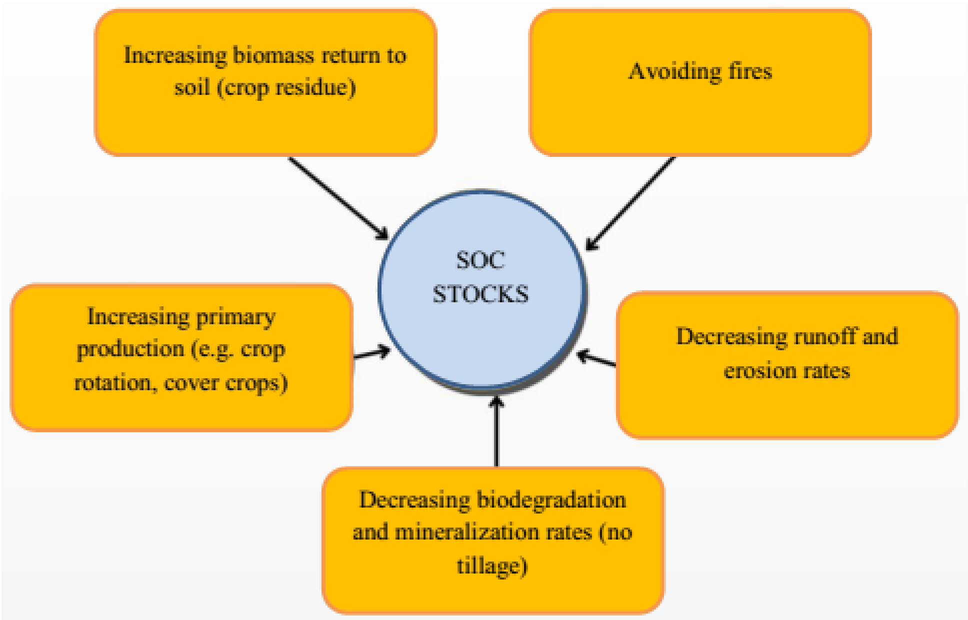

Figure 3. *Conservation agriculture practices that rise soil organic carbon stock.*

By adding more organic matter to soil mixtures with a high C:N ratio, conservation agriculture can change the characteristics of the soil and increase the nutrients available for subsequent crops [24]. Since conservation agriculture increase soil carbon and nitrogen, they contribute to the reduction of the deleterious effects of global warming by increasing sequestration of atmospheric CO_2 and N_2O [15]. Conservation agriculture add to above and belowground biomass in the soil which results in organic carbon increase. Furthermore, conservation agriculture can lessen the loss of soil organic carbon (SOC) by minimizing soil erosion, which could act as a conduit for that loss [7]. According to Mazdarani and Eghbal's [41] reducing tillage slows down the breakdown of organic matter and stabilizes carbon in fine grains, both of which lessen soil erosion. Consequently, ending the destructive effects of conventional tillage leads to an incensement in carbon content. According to Thomas *et al.* [60], no till produced a greater soil organic carbon (SOC) content in the uppermost layers and a dramatic fall in the deeper levels. Conventional tillage with residue inclusion also produced a higher SOC content in the deeper layers. Balota *et al.*, [3] reported that no till had 3.86-31% higher organic matter as compared to conventional. Considerable increase in soil organic matter (SOM) under no-till in the 0-10 cm soil level, but a decrease in the 10-15 cm depth when compared to the conventional method. He *et al.*, [22] reported that in the 0-5 cm soil layer, the average soil organic matter (SOM) for no-till with straw cover was 18.8 g kg^{-1}, much greater than the 14.3 g kg^{-1} observed on the conventional tillage plot. However, these differences decrease in deeper layers. Similarly, Zibilske *et al.* [69] noticed, following nine years of testing, that the top 0-4 and 4-8 cm under no till had significantly greater soil organic carbon (SOC), which was 15.1% and 57.8% higher than under plow till. When compared to conventional practice, the main result of the conservation agriculture-based scenarios was a greater build-up of organic carbon (OC) at the soil surface. The conservation agriculture-based maize, wheat, and mungbean system had the highest organic carbon (OC) (7.7 g kg^{-1}), followed by the conservation agriculture-based rice, wheat, and mungbean system (7.5 g kg^{-1}). At 0-15 cm soil depth, conventional farmers' practices had the lowest organic carbon (4.5 g kg^{-1}). In comparison to other systems, the rice, wheat, and mungbean system based on partial conservation agriculture showed the highest organic carbon (4.9 g kg^{-1}) at 15-30 cm soil depth [27]. According to Ligowe *et al.*, [37], the amount of soil organic matter (SOM) increased steadily and gradually on the top soil of the conservation agriculture (CA) treatments, from a mean value of 34.0 g kg^{-1} in the first year (2007) to 42.0 g kg^{-1} in the fifth year (2011). Among the conservation treatments, the rotation of cowpeas and maize had the highest soil organic matter (SOM) concentration (45.0 g kg^{-1}) in the top layer of the soil (0-10 cm). As a result, over the course of five years, standard procedure decreased the soil organic matter (SOM) content from 35 g kg^{-1} in year 1 to 31 g kg^{-1} by year 5, resulting in a mean decrease of 4 g kg^{-1}. It was seen in both years that as soil depth increased, the amount of soil organic matter (SOM) decreased. Results of soil organic matter (SOM) content also showed non-significant differences between soil depths, along the soil profile of study.

4.3. Total Nitrogen

Nitrogen is an essential component of protein, amino acids, nucleic acids, enzymes, and chlorophyll molecules. It is the most frequently limiting element for crop growth among all the basic nutrients. Nitrogen gives agricultural plants the greatest reaction and promotes the quickest rate of vegetative development. Tillage practices enhance the mineral-nitrogen pools and nitrogen mineralization's, encourage soil aggregate disruption, and expand the amount of soil organic carbon (SOC) available to soil microbes [56]. Numerous studies have shown that nitrogen in soil was increased by retaining plant residues on soil surface [38]. The reason for increasing nitrogen accumulation in soils under conservation tillage system is to retain plant residues in the soil surface, increase granulation and formation of aggregates, increase the amount of carbon in large clods, and increase the activity of microorganisms. Since that soil organic matter (SOM) contains 5% nitrogen, an increase in soil organic matter (SOM) in the soil could likewise have a significant impact on the nitrogen cycle. Spargo [57] calculated that in the no-till system, an increase in soil organic matter (SOM) of 1%, or about 22 mg soil organic matter (SOM), in the top 15 cm of the soil layer might lead to the retention of 1.1 mg of N ha^{-1} in the soil. In contrast, by dissolving soil aggregates and exposing soil organic matter (SOM) shielded by soil aggregates to soil microbial attack, plow tillage systems accelerate the rate of residue decomposition [56]. Thus, the rates of soil organic nitrogen mineralization and soil organic carbon (SOC) breakdown are accelerated [29]. When compared to traditional till, permanent raised beds and no till produced noticeably greater total nitrogen levels [18]. According to [60], there was a 21% increase in total Nitrogen at 10 cm depth under no-till compared to traditional till. Wang, [63] reported that after 15 years of experimentation, total nitrogen (0-30 cm) improved by 21.3% on no-till with straw cover compared to the initial year, while it fell by 11.9% on regular tillage with straw removal. Higher quantity of residue additions (both above as well as below-ground) and their slow decomposition due to less soil disturbance might have caused higher organic carbon (OC) and total nitrogen (N) concentrations in the surface layer under conservation agriculture [12].

4.4. Available Phosphorous

Dhillon *et al.*, [11] estimate that 5.7 billion hectares of agricultural land worldwide lack phosphorous. *In* actuality, plants only absorb a small percentage of the phosphorous fertilizers that are sprayed. Conversely, the bulk is fixed in soil in various forms that are less accessible. Generally, the rate at which phosphorous is immobilized or mineralized in soil is determined by the amount of phosphorous present in the extra residue. conservation agriculture (CA)-based methods have the ability to raise phosphorous availability in the soil by altering the variety of the microbial population and its enzyme activity, which in turn affects the soil's phosphorous availability [27]. Due to less soil disturbance caused by no-till (NT), more nutrients especially those with poor mobility like phosphorous from fertilizer and crop residues are able to accumulate in the upper layer of the soil. Wei *et al.*, [64] reported that retention of organic matter and reduced tillage can improve the structure or aggregation of weathered soils and possibly contribute to better availability of phosphorous. By lowering the overall soil surface area in these soils, improved aggregation can lower the amount of soluble Phosphorous inorganic that is exposed to possible sorption sites.

According to Marahatta *et al.*, [40], during 16 years of testing, the available phosphorous under no-till with straw retention was 97.5% greater than under conventional till with straw removal in the 0-5 cm layer. A higher phosphorous content resulted from enhanced microbial biomass caused by a higher proportion of residues in the surface under the no-till system [16]. Improving phosphorous availability may represent an additional advantage of conservation agriculture (CA) in weathered soils because reduced tillage and residue retention could reduce phosphorous fixation, increase labile phosphorous, and increase phosphorous accumulation and its mineralization by phosphatases. Organic matter (OM) additions under residue retention can reduce phosphorous fixation by increasing organic anion competition for P binding sites [50].

5. Conclusion

Conservation agriculture (CA) combines continuous minimum soil disturbance, maintaining cover and diversified economically viable crop rotations. Conservation tillage systems have an immensely positive effect on physical and chemical soil characteristics, which maintain the sustainable agriculture. The main drive of conservation agriculture(CA) is increasing soil organic matter(SOM) which is improve soil aggregation, reduce bulk density in long run due to the presence of carbon pool and improvement of soil structure. The higher amount of soil organic matter in surface soil layer in conservation agriculture (CA) is due to higher accumulation of crop residue, which also increases the availability of mineral nutrition.

Abbreviations

CA: conservation Agriculture
CP: conventional practice
CT: conservation tillage
MWD: mean weight diameter
NT: no tillage
OM: organic matter
SOC: soil organic carbon
SOM: soil organic matter

Conflicts of Interest

The authors declare no conflicts of interest.

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