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**Mini Review**

# Agronomic and Environmental Aspects of Conservation Agriculture on Wheat Crop Production

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## Abstract

Tillage-based soil management for intensive crop production generally leads to soil degradation and eventual loss of crop productivity. Moreover, farmers have been facing high costs for fuel, labor, agro-chemicals, and other production inputs required by intensive cropping. Intensive tillage causes a more significant loss of soil carbon and increases greenhouse gas emission, mainly carbon dioxide, which has a significant role in global warming. Recently, studies on conservation agriculture (CA) reported that it is a sustainable way to intensify crop production and sustain rural livelihoods in several countries including Nepal. This paper reviews the practice of CA as a viable system for sustainable wheat crop production and soil quality improvement. As compared to tillage-based agriculture, CA improved wheat yield, soil structure and stability, increased drainage and water-holding capacity, reduced risk of rainfall runoff and pollution of surface waters with pesticides and lower energy consumption and lower $CO_2$ emissions. Moreover, crop residues are more naturally left on the surface to protect the soil and to drive the carbon cycle towards the conversion of plant biomass carbon to soil organic matter and humus. There is no routine use of herbicides, pesticides and chemical fertilizers in the production of crops and animals in CA. There is always increase in species richness in conservation agriculture than in tillage-based systems. The practice of conservation agriculture requires long-term assessment of yield and soil quality, focus on other crops such as oilseed and legumes, crop diversity and CA, and the effect of climatic parameters on CA.

**Keywords:** Conservation agriculture; No-tillage; Soil erosion; Soil organic matter; wheat yield; mulching

## Introduction

Conservation Agriculture (CA) is recommended to manage farmland for sustainable crop production that simultaneously preserves soil and water resources (Zheng *et al.*, 2014). Conservation Agriculture as a system which is based on minimal soil disturbance (no-till, minimum tillage) and permanent soil cover (mulch, crop residue) combined with diversified rotations with legumes (FAO; CA website, 2004). Conservation agriculture involves durable soil cover through crop residues or cover crops, and crop rotations for achieving higher productivity. Moreover, CA is considered as a resource-saving agricultural production system that aims to make production intensification and high yields. Besides, it also enhances the natural resources (Bhan and Behera, 2014). With the increase in environmental hazard, CA practice has been

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applied worldwide due to its positive effects on soil and water conservation, environmental health, and economic viability (Gupta and Sayre, 2007). It depends on three major principles i.e. maintenance of a permanent vegetative cover or mulch on the soil surface, direct planting to minimize soil disturbance, diversified crop rotation and direct seeding to reach the objective of economically, ecologically and socially sustainable agricultural production (Zheng *et al.*, 2014).

Varied crop rotation is also necessary to avoid disease and pest problems (Gustafson & Friedrich 2006). Conservation Agriculture also prevents the need for tillage when zero till agriculture is practiced over more extended periods. It has been proven that Conservation Agriculture maintains a permanent or semi-permanent organic soil cover. The organic soil cover might be a growing crop or dead mulch. The organic soil cover protects the soil physically from sun, rain, and wind and to feed soil biota. The soil micro-organisms and soil fauna play role in the tillage function and soil nutrient balancing. Mechanical tillage disturbs this process. Varied crop rotation is also necessary to avoid disease and pest problems (FAO, 2006). The benefits of tillage in agriculture are explored before introducing CA has been practiced in its many local adaptations for more than three decades and has spread widely (Hobbs *et al.*, 2007). The practice of CA requires is unrecognizable, so it requires a deeper knowledge of its ecological underpinnings to manage its various components for sustainable intensification, where the aim is to optimize resource use and protect or enhance ecosystem processes in space and time over the long term.

Conservation tillage is a tillage system which increases plant residues on the soil surface which increases water infiltration and reduces erosion. It is a practice used in conventional agriculture to minimize the negative effects of tillage. However, it still depends on tillage as the structure forming element in the soil. Nevertheless, conservation tillage practices such as zero tillage practices can be transition steps towards Conservation Agriculture. According to Bhusari *et al.*, (2015), conservation tillage as the method of seedbed preparation that includes the presence of residue mulch and an increase in surface roughness as the key criteria with potentiality to cultivate compact land with minimum soil disturbance which directs to a better soil environment and crop yield with environment friendly practices.Specifically at least 30% of the crop residue must remain in the soil surface after planting in CA in order to minimize soil erosion by water(Dickey *et al.*, 1985).Conservation tillage is an ecological approach to soil surface management and seedbed preparation. Conservation Agriculture has many advantages it improves soil structure, increases soil organic carbon, minimizes soil erosion risks, conserves soil water, decreases fluctuations in soil temperature and enhances soil quality and its environmental regulatory capacity. Crop residue is an essential and renewable resource.

Conservation Agriculture has both agricultural and environmental benefits. It promotes soil health, productive capacity, and ecosystem services. CA is resource conserving technologies save water and nutrients, increase yields, increase crop diversification, improve efficient use of resources and ultimately reduces the cost of production.CA promotes soils bioactivity and biodiversity. It also improves soil structure and cohesion. Conservation Agriculture has a role in the reduction of soil erosion, soil agronomic inputs transport slightly reduced, while pesticide bio-degradation is enhanced. It protects surface and groundwater resources from pollution and mitigates adverse climate effects. Hence, CA provides excellent soil fertility and saves money, time and fossil-fuel. Mehan (2015) reported that mulching minimizes soil degradation by controlling runoff and soil loss, reducing the weed invasion and stops the progressive water evaporation. Also, it facilitates for more retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil, as it adds nutrients to the soil and ultimately enhances the growth and yield of crops. Further, Devendra and Sevilla (2002) reported that mulching boosts the yield by 50-60 percent over no mulching under rain-fed sustainability of intensive production systems both under irrigated and rainfed conditions. Zero tillage prevents the disruption of soil structure. Mulching by weeds to crops improves soil structure owing to a five-fold higher mean population of earthworms underneath the mulch.

Zero tillage is another emerging practice of CA as a way of transition to Conservation agriculture. However, CA is still facing constraints on its promotion such as lack of appropriate seeders especially for small and medium scale farmers, competition of crop residues between CA use and livestock feeding, burning of crop residues, availability of skilled and scientific manpower and overcoming the bias or mindset of traditional agriculture (Derpsch *et al.*,2011). Further, it also presents the actual gaps or uncertainties concerning the scientists’ positions on these environmental aspects. Researchers have purposed different practices of CA for wheat crop production. However, adoption of this technology is still in the infant phase. To provide the latest updates of CA on wheat production and soil quality enhancement, we carried out this review. The search result of online database google scholar using keywords, ‘Conservation Agriculture,' ‘benefits of CA on wheat crop yield,’ and ‘role of CA on soil quality improvement’ was included. The first section of the paper will discuss the benefits of CA on wheat productivity. The second section of the paper will highlight the advantages of CA on soil quality improvement. Finally, a discussion will be made in the last section of the paper, which will provide some critical research questions and therefore be helpful to researchers.

***Conservation Agriculture and Wheat Yield***

Conservation Agriculture has significant impacts on wheat crop production. Khorami *et al.* (2018) reported that conservation agriculture including tillage reductions, better agronomy, and improved varieties, showed encouraging results with an increase in wheat yield and maize biomass (Govaerts, 2009). However, Acharya *et al.,* (1998) reported that Mulches resulted in 0.06–0.10 $m^3$ higher moisture in the seed-zone when wheat was sown compared with the conventional farmer practice of soil tillage after maize harvest. Mulch-conservation tillage treatments favorably moderated the hydro-thermal regime for growing a wheat crop. The mean root mass density under these treatments at wheat flowering is higher by 1.27–1.40 times over the conventional farmer practice during the 3-year study. Aggarwal (2006) reported that sowing of wheat on beds reduced mechanical impedance and increased root growth in the upper 30 cm of soil, which ultimately resulted in higher crop yield. Thierfelder (2009) reported that CA has the potential to increase the productivity of crops by reducing the moisture stress due to drought and therefore reduce the risk of crop failure. Interestingly, manual weeding for weed control found more effective in bed planting treatment than in conventional, as evident from the significantly lower weed population/m² in the former. A study reported that total water use by the crop is reduced nearly by 5 cm, whereas yield and water-use efficiency increased by 0.22 tonne/ha and 0.03 tonne/ha, respectively, under conservation agriculture. Higher yield and biomass of wheat and maize (*Zea mays* L.) was reported by Afzalinia*et al.,* (2012) because of Conservation Agriculture. A recent meta-analysis by Zheng *et al.,* (2014) on CA practice, reported the 2.9% increase in wheat yield with the No-tillage with straw retention as compared to Conventional Tillage; however, there were no significant effects of No-tillage only practices on the wheat crop yield.

***Conservation Agriculture and Soil Properties***

Conservation Agriculture has positive impacts on soil quality and structure. Thierfelder (2009) reported that one of the immediate benefits of CA in dryland agriculture is improved rainfall-use efficiency through increased water infiltration and decreased evaporation from the soil surface. Also, CA decreases soil runoff and erosion. Acharya *et al.* (1998) reported that CA recycles available organic materials and enrich the soil environment in the long-term. Arshad *et al.* (1999) reported the greater soil water under No-Tillage (NT) over Conventional Tillage without dramatically altering bulk density due to redistribution of pore size classes into more small pores and less large pores. Khorami *et al.* (2018) study on Conservation Agriculture showed that No-Tillage had higher soil bulk density at surface soil, thereby lower cumulative water infiltration. Moreover, the lowest soil organic carbon and total nitrogen were obtained under Conventional Tillage (CT) that led to the highest C: N ratio. Application of maximum irrigation water under CT has negative impacts on water productivity. Afzalinia *et al.* (2012) on Conservation Agriculture showed that it significantly increased the soil moisture retention and slightly increased the soil bulk density compared to the Conventional Tillage method. Conservation Tillage also reduced the soil surface temperature and wheat and corn yield comparing to the Conventional Tillage method. Water-stable aggregation improved under NT compared with CT, perhaps because more soil organic C was sequestered within macro aggregates under NT compared with CT that helped to stabilize these aggregates. Steady-state water infiltration is greater under NT than under CT because of soil structural improvements associated with surface residue accumulation and lack of soil disturbance.

Soil organic carbon (SOC) is greater under NT than under CT nearest the soil surface. Kern and Johnson (1993) reported an increase of 21 to 36 Tg of soil organic carbon in CA over conventional farming. However, minimum tillage conserved current levels of SOC but did not consistently increase SOC above levels of conventional tillage. A study on CA showed that significantly higher water infiltration was on CA fields compared to conventionally plowed maize and wheat fields (De Vita *et al.,* 2007).

Islam *et al.,* (2000) reported that conservation management most consistently and markedly influenced soil quality indicator properties by increasing total and active microbial biomass carbon, increasing the ratio of active microbial biomass carbon to total organic carbon, increasing aggregation and decreasing the rate of basal respiration per unit of microbial biomass carbon. More stable aggregates in the upper surface of soil have been associated with no-till soils than tilled soils, and this correspondingly results in high total porosity under NT plots. Jacobs *et al.* (2009) found that minimum tillage (MT), compared with CT, did not only improve aggregate stability but also increased the concentrations of Soil organic carbon and Nitrogen within the aggregates in the upper 5–8 cm soil depth after 37–40 years of tillage treatments. Generally, straw retention improves aggregate stability, reduces soil erosion, and increases the infiltration and conservation of soil water, thus enhancing soil productivity. Additionally, straw retention directly increases the input of organic matter and nutrients into the soil, in turn improving soil nutrient availability for crop growth.

***Future Directions in Conservation Agriculture***

Most of the research has focused on CA to increase crop yield, soil fertility, and soil quality. However, the contribution of CA to the economy of the farmer is not clear. There is still a contradiction about the CA that whether the weed population crop field is more due to lack of use of herbicides or less due to suppression of growth by mulches.

There is no research at developing countries where conservation agriculture is practiced by a small group of farmers at the subsistence level. Therefore, a study on the economics of CA and pesticides use might be the future area of study. No significant effect of NT on crop yield was found in China. Rusinamhodzi *et al.* (2011) found that NT had no significant effect on maize yield under rainfed conditions. According to Jacob *et al.* (2009), density fractionation of the surface soils revealed that tillage system affected neither the yields of free particulate organic matter (POM) nor occluded POM nor their organic carbon and N concentrations. The effect of CA on carbon and Nitrogen storage after long term practice of CA is further the area of study. Zheng *et al.,* (2014) study reported the introduction of NT in Europe may indeed have exerted adverse effects and had reduced crop yield by an average of 8.5%. Moreover, Continuous NT decreased crop yield in North China, probably owing to the high precipitation (Zheng *et al.,* 2014). The increased crop yield and soil properties because of conservation agriculture in the present studies are based on short-term results, but it is vital to evaluate medium and long-term effects on soil properties, crop yields and water use in future.

Studies reported several benefits of conservation tillage over conventional tillage (CT) concerning soil health, plant growth, and the environment. There are no clear and consistent points on the effect of CA on different agro-ecological zones. Research on Conservation agriculture mainly focused on some combination of reduced tillage, increased crop residue return, improved soil fertility and/or increased application of organic amendments but not on increased crop diversity. Also, there is no plenty of quantitative data on the effect of CA. Thus, a study on the impact of CA on crop diversity might be the area of research for agronomist.

The yield, compatibility, and profitability of wheat with the leguminous crop is calculated meanwhile pulses crops are the core of agricultural sustainability, enhancing both soil health and consuming low nutrient, but there are not enough studies on CA practices and its impacts on pulses and oilseed crop yield. Thus, future research should emphasize the effects of CA on pulses and oilseed crop yield and productivity. The potentiality of CA as a source to conserve biological diversity and preserve ecosystem services cannot be denied, but there are very few researches on a specific climatic parameter that plays a crucial role in reducing wheat yield and then CA practices helpful to a farming system to alleviate and acclimatize those climatic parameters. Thus, future studies should direct the effect of climatic parameters on CA and wheat yield too.

In our study, we reported the positive effects of CA on wheat yield. However, recent studies showed that impacts CA could have both positive and negative effects on crop yield. For example, the positive effects of CA on crop yield were observed in the U.S., Australia, India, and Canada. However, adverse effects were observed in Europe (Zheng *et al.,*2014). Among the CA methods applied in China, straw retention showed a significant positive impact on crop yield. But there was no significant effect for reduced tillage without straw retention (Zheng *et al.,* 2014). Also, there was a positive impact of CA on rice and maize whereas negative impacts of CA practices on wheat yield. The result also found that CA increased crop yield by 6.4% and 5.5% compared to CT in Northwest and South China, respectively, whereas no significant effects were observed in the North China and Northeast China regions, so the impact of CA on various climatic region, crop types and CA practices is further matter of research. Farooq *et al.,* (2011) also reported that there were significant variations in CA effects on crop yield between cropping regions in the U.S. and Canada. To avoid negative impacts of CA on crop productivity, specific CA practices should be used in the specific areas and crops.

De Vita *et al.,* (2007), who reported significantly higher wheat yield under straw retention than under CT only in dry years. Besides, straw retention may depress crop growth by nutrient immobilization in soil microbes and increases in residue-borne diseases. Thus, future studies should be more focused on CA practices such as straw retention about wheat yield. Rusinamhodzi (2011) found that 92% of the data show that mulch cover in high rainfall areas leads to lower yields due to waterlogging, 73% of the data show that conservation agriculture practices require high inputs especially N for improved yield, 56% of the data show that reduced tillage with no mulch cover leads to lower yields in semi-arid areas. There is both positive and negative effect of CA practices. To recommend specific CA practices on that particular biophysical condition, CA practices is further a matter of research on the target area.

## Conclusion

Conservation Agriculture (CA) is a resource-conserving environment-friendly practice for sustainable crop production. Conservation Agriculture has positive impacts on wheat crop production and soil productivity. However, future research should direction the contribution of CA to the economic portion of the farmer by analysing the cost benefits of CA. CA showed a significant positive effect on crop yield on a short-term basis, but research should focus on the economics of smallholder farmers practicing CA in the long run.

Mulching is one of the CA technologies that results in 0.06–0.10 $m^3$ higher moisture in the seed-zone when wheat was sown compared with the conventional farmer practice of soil tillage after maize harvest (Acharya *et al.,*1998). Research has emphasized the effects of CA mostly on wheat and maize, but it should focus on pulses and oilseed crop yield and productivity too. Mostly the details of climatic parameters on effects of wheat yield are given on a qualitative basis. To understand a clear view on the impact of CA on wheat yield, research should focus on providing climatic parameters data on a quantitative basis.

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## References

Acharya CL, Kapur OC, and Dixit SP (1998) Moisture conservation for rainfed wheat production with alternative mulches and conservation tillage in the hills of north-west India. *Soil and Tillage Research* **46**: 153-163. DOI: 10.1016/S0167-1987(98)00030-0

Afzalinia S, Karami A, and Alavimanesh SM (2012) Comparing conservation and conventional tillage methods in the corn-wheat rotation. In *Power and Machinery. International Conference of Agricultural Engineering-CIGR-AgEng 2012: agriculture and engineering for a healthier life, Valencia, Spain, 8-12 July 2012*. CIGR-EurAgEng

Aggarwa lP and Goswami B (2003) Bed planting system for increasing water-use efficiency of wheat (Triticum aestivum) grown on inceptisol (Typic Ustochrept). *Indian Journal of Agricultural Sciences* **73***:* 422-425.

Aggarwal P, Choudhary KK, Singh AK, and Chakraborty D (2006) Variation in soil strength and rooting characteristics of wheat in relation to soil management. *Geoderma*, ***136:*** 353-363.DOI: 10.1016/j.geoderma.2006.04.004

ArshadMA, Franzluebbers AJ, and AzoozRH (1999) Components of surface soil structure under conventional and no-tillage in northwestern Canada. *Soil and Tillage Research*, ***53***: 41-47.DOI: 10.1016/S0167-1987(99)00075-6

Bhan S, and Behera UK (2014) Conservation agriculture in India–Problems, prospects and policy issues. *International Soil and Water Conservation Research*, ***2***: 1-12.DOI: 10.1016/S2095-6339(15)30053-8

Busari MA, Kukal SS, Kaur A, Bhatt R, and Dulazi AA (2015) Conservation tillage impacts on soil, crop and the environment. *International Soil and Water Conservation Research* **3**:119-129. DOI: 10.1016/j.iswcr.2015.05.002

De Vita P, Di Paolo E, Fecondo G, Di Fonzo N, and Pisante M (2007) No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. *Soil and Tillage Research* **92**: 69-78. DOI: 10.1016/j.still.2006.01.012

Devendra C, and Sevilla CC (2002) Availability and use of feed resources in crop–animal systems in Asia. *Agricultural systems*, **71**: 59-73. DOI: 10.1016/S0308-521X(01)00036-1

Dickey EC, Shelton DP, Jasa PJ, and Peterson TR (1985) Soil erosion from tillage systems used in soybean and corn residues. *Transactions of the ASAE*, **28**: 1124-1130. Retrieved from http://www.jstor.org.ezproxy.library.wur.nl/stable/44503097

FAO conservation agriculture website. 2006. Retrieved from http://www.fao.org/waicent/faoinfo/agricult/ags/AGSE/agsee/general/OBJE

Farooq M, Flower KC, Jabran K, Wahid A, and Siddique KH (2011) Crop yield and weed management in rainfed conservation agriculture. *Soil and tillage research*, *117*:172-183.

GillerKE, WitterE, CorbeelsM, and Tittonell P(2009)Conservation agriculture and smallholder farming in Africa: the heretics' view. *Field crops research* **114**: 23-34. DOI: 10.1016/j.still.2011.10.001

Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre KD, Dixon J, and Dendooven L (2009) Conservation agriculture and soil carbon sequestration: between myth and farmer reality. Retrieved from https://repository.cimmyt.org/xmlui/bitstream/handle/10883/1362/97650.pdf

Gupta R. and Sayre KD (2007) Conservation agriculture in South Asia. *Journal of Agricultural Science Cambridge*, 145: 207-214.DOI: 10.1017/S0021859607006910

Hobbs PR (2007) Conservation agriculture: what is it and why is it important for future sustainable food production? J*ournal of Agricultural Science-Cambridge*- **145**: 127. DOI: 10.1017/S0021859607006892

Hobbs PR, Sayre K, and Gupta R (2007) The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **363***:* 543-555.DOI: 10.1098/rstb.2007.2169

Islam K and Weil RR (2000) Soil quality indicator properties in mid-Atlantic soils as influenced by conservation management. *Journal of soil and water conservation*, **55**: 69-78. DOI: 10.2489/jswc.69.6.532

Jacobs A, Rauber R and Ludwi B (2009) Impact of reduced tillage on carbon and nitrogen storage of two Haplic Luvisols after 40 years. *Soil and Tillage Research*, **102**: 158-164. DOI: 10.1016/j.still.2008.08.012

Kassam A, Friedrich T, Shaxson F, and Pretty J (2009) The spread of conservation agriculture: justification, sustainability and uptake. *International journal of agricultural sustainability* **7:** 292-320. DOI: 10.3763/ijas.2009.0477

KhoramiS, Kazemeini S, Afzalinia S, and Gathala M (2018) Changes in Soil Properties and Productivity under Different Tillage Practices and Wheat Genotypes: A Short-Term Study in Iran. *Sustainability*, **10:** 3273. DOI: 10.3390/su10093273

Mehan S and Singh KG (2015) Use of mulches in soil moisture conservation: A review. *Best Manag. Pract. Drip Irrigated Crops*, **2**: 283.

Ortiz R, Sayre KD, Govaerts B, Gupta R, Subbarao GV, Ban T ... and Reynolds M (2008) Climate change: can wheat beat the heat? *Agriculture, Ecosystems & Environment* **126**(1-2): 46-58. DOI: 10.1016/j.agee.2008.01.019

Paudel B, Radovich TJ, Chan-Halbrendt C, Crow S, Tamang BB, Halbrendt J and Thapa K (2014) Effect of conservation agriculture on maize-based farming system in the mid-hills of Nepal. *Procedia Engineering* **78:** 327-336. DOI: 10.1016/j.proeng.2014.07.074

Pittelkow CM, Liang X, Linquist BA, Van Groenigen KJ, Lee J, Lundy ME, ... and Van Kessel C (2015) Productivity limits and potentials of the principles of conservation reality. *Critical Reviews in Plant Science* **28***:* 97-122. DOI: 10.1038/nature13809

RusinamhodziL, Corbeels M, Van Wijk MT, Rufino MC, Nyamangara J, and Giller KE (2011) A meta-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. *Agronomy for sustainable development*, **31**: 657.DOI 10.1007/s13593-011-0040-2

SapkotaTB, Majumdar K, JatML, Kumar A, Bishnoi DK, McDonald AJ and Pampolino M (2014) Precision nutrient management in conservation agriculture-based wheat production of Northwest India: Profitability, nutrient use efficiency and environmental footprint. *Field Crops Research* **155**: 233-244. DOI: 10.1016/j.fcr.2013.09.001

Thierfelder C and Wall PC (2009) Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil and tillage research*, **105***:* 217-227. DOI: 10.1016/j.still.2009.07.007

Van den Putte A, Govers G, Diels J, Gillijns K, and Demuzere M. (2010). Assessing the effect of soil tillage on crop growth: a meta-regression analysis on European crop yields under conservation agriculture. *European journal of agronomy* **33**: 231-241. DOI: 10.1016/j.eja.2010.05.008

Zheng C, Jiang Y, Chen C, Sun Y, Feng J, Deng A....and Zhang W (2014) The impacts of conservation agriculture on crop yield in China depend on specific practices, crops and cropping regions. *The Crop Journal* **2***:* 289-296. DOI: 10.1016/j.cj.2014.06.006