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Effects of Conservation Agriculture on Soil C and N dynamics under Climate Change

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INTRODUCTION

The rate of growth in the atmospheric concentration of anthropogenic CO_2 increased from 1.7 µmol mol^{-1} year^{-1} (2009) to 2.2 µ mol mol^{-1} year^{-1} (2013) at an alarming rate. During, 2015 there was a sharp increase in CO_2 concentration *i.e.*, 3.03 µmol mol^{-1}. At this rate, its level in the atmosphere will increase from its present concentration of 400 mol L^{-1} to close to 650 mol L^{-1} by the turn of the century, causing global warming and associated climate change. Thus, discovering techniques to slow down or reverse this tendency is of utmost scientific interest. A recognised technique for mitigation is to use suitable agricultural methods, including conservation agriculture (CA), to transfer CO_2 from the atmosphere into the soil as soil organic carbon (SOC). The agricultural approaches that have been extensively proved as being particularly beneficial in this regard are conservation tillage practises, which include reduced tillage (RT) and no-tillage (NT). The other key elements of CA that considerably aid in preserving more carbon in soil in organic combination as SOC in the root zone include crop residue management, crop intensification, and diversified cropping. Thus, the future increase in atmospheric CO2 concentration might be partially countered by storing or sequestering carbon in natural and agricultural ecosystems. The annual mitigation potential of CA management options ranges from 0.17 to 0.86 Mg CO_2 equivalent ha^{-1} year^{-1} in a temperate dry climate and from 0.53 to 1.12 Mg CO_2 equivalent ha^{-1} year^{-1} in a temperate wet climate. By influencing soil immobilisation and stabilisation processes, crop residue management and wise tillage techniques can also significantly aid in the efficient utilisation of N from fertiliser, crop residue, and soil organic matter (SOM), thereby preventing its potential leakage to the environment.

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Importance of CA under Climate change scenario

There is ample evidence that more atmospheric CO_2 promotes plant growth because the photosynthesis process is more effective. However, an increase in atmospheric temperature and a change in the pattern of rainfall coincide with an increase in CO_2 concentration. Over the course of the next century, forecast a warming trend of 1.5–2.0°C and a modest increase in total precipitation. Temperature and soil moisture content both influence soil CO_2 fluxes and SOC build-up and are favourable for SOM mineralization. In contrast, there was virtually any correlation between soil CO_2 fluxes and SOC. When future irregular rainfall patterns lead to an increase in the frequency of high-intensity rainfall events, runoff, and floods, the practise of CA may become more pertinent under the upcoming conditions of climate change. There is a significant risk that climate change will cause an increase in global soil erosion rates unless compensating conservation measures are implemented. This risk is based on the type of changes that have occurred over the past century and expectations regarding changes over the next century. In many parts of the world, an increase in the frequency and intensity of intense rainfall has already been noticed. The soil's failure to keep infiltration rates high enough to withstand heavy rainfall events is a matter for concern. As a result of the increased water runoff, this may cause significant soil erosion and nutrient losses. Future efforts to manage this issue will depend more on CA's ability to regulate runoff, reduce soil erosion, increase water infiltration rates, and maintain greater soil profile water content. Short-term mid-season droughts can be avoided with the use of increased water storage and ongoing CA. Therefore, the ability of agricultural crops to adapt to future climate changes will only depend on judicious management techniques. Frequent soil disturbance from conventional tillage (CT) practises can quickly deplete SOC through the process of oxidation. As a result, the health of soil declines and the amount of greenhouse gases (GHG) released into the atmosphere increases. SOC and TN have drastically decreased over the course of 50–100 years of agriculture in semiarid areas of the Great Plains, with losses of 30%–50% of the initial SOC estimated. The rate of SOM decomposition, soil water evaporation, and crop transpiration will all rise significantly even with the small 0.8°C expected temperature increase over the next 50 years. Further global warming may result if anthropogenic warming encourages the loss of soil carbon to the atmosphere. In the future, this might cause a rise in SOM and water deficits. Thus, the availability of water will play a bigger role in agricultural productivity in the future. Unless mitigating strategies such CA practises of agricultural residue retention and minimum/NT are adopted, this might negatively affect crop production. To better adapt agricultural systems to climate change, it is necessary to understand how water interacts with CO_2 and temperature. A crop's life cycle will be shortened by a shorter reproductive phase duration and a lower yield if the temperature rises when the crop is at grain filling stage.

Effect of No Tillage on N_2O Emissions

Agriculturally based N_2O gas emissions have a far bigger influence on climate change and global warming than CO_2 does. N_2O has a far lower atmospheric concentration than CO_2, but it has a much higher global warming potential, *i.e.*, 300 times higher than CO_2. As a result, even minor changes in soil N_2O emissions can have a big effect on agriculture' GHG balance. Roughly 58% of all anthropogenic N_2O emissions come from agriculture, with emissions from soils alone accounting for about 38% of all N_2O emissions related to agricultural operations. N_2O emission rates from NT management in generally warm and moist periods or locations may be similar to or slightly lower than those from chisel plough and mouldboard plough. On contrary of increasing SOC decomposition under improved aeration in chisel plough and mouldboard plough would encourage N_2O emissions, though N_2O formation require anaerobic soil conditions when there is a lack of free air or oxygen in the moist soil. Under arable soil conditions, one cannot anticipate poor aeration while using chisel or mouldboard plough techniques. Although surface soil in NT systems is often rich in SOC, inadequate aeration prevents the nitrification process from occurring, and the mineralization process of SOM stops at NH_4^+ and does not continue to formation of NO_3. Since N_2O can only be produced through the denitrification reaction, there are almost no prospects for its creation in the NT system without NO3. It was found that switching from mouldboard ploughs (5.61 kg N ha^{-1}) and chisel ploughs (7.25 kg N ha^{-1}) to NT (3.37 kg N ha^{-1}) resulted in a considerable decrease in seasonal N_2O emissions over an average of three years. High N_2O emission events were accompanied by increases in NO_3, whereas low N_2O emission events were accompanied by the lowest NO_3 concentrations. The predominant source of N_2O in the fine-textured clayey/clay soils was nitrification. The average emission of NO_2 over three years in the light-textured loam soils were comparably low and similar in the NT and MP plots (Fig. 1). the impact of ploughing in MP on N_2O flux in heavy clay soil is likely the result of enhanced soil porosity, which kept soil aeration and water content at levels limiting denitrification and N_2O generation in the top 0.2 m. Average emissions over the course of three years in the loam soil were comparable in the NT and MP plots. The results of this study suggest that the potential of NT for lowering net GHG emissions may be restricted in fine-textured soils rich in OM that are prone to high water content and decreased aeration. After several years of NT techniques, denitrification possibilities are often raised in SOC-rich heavy and generally moist soils. The favourable benefit of stocking C in soil may be more than countered by increasing rates of N_2O emissions in NT soils as a consequence. The use of NT can result in a variety of N_2O emission effects depending on the soil's texture, OM concentration, and sensitivity to extreme moisture.

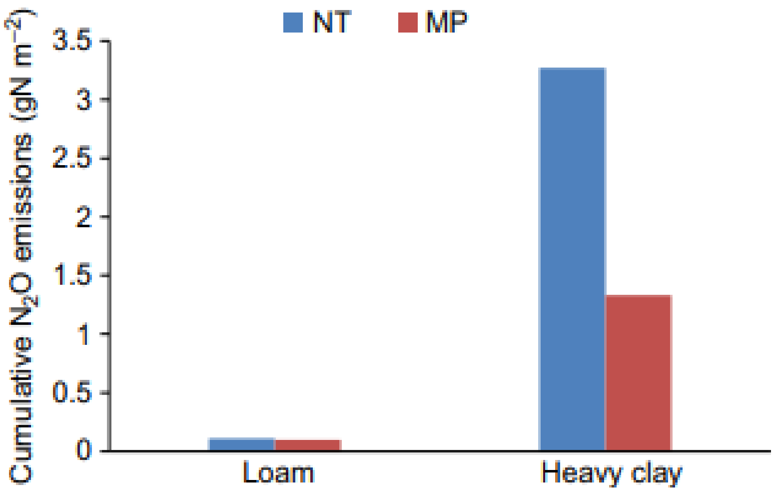

Fig. 1. Cumulative N2O emission from heavy clay and loam soils under no-till (NT) and mould board plough (MP) (mean season values for 2001, 2002, and 2003). (Data for the season in the figure represent pooled data collected before ploughing

Effect of runoff and soil erosion on SOC and N losses

The best management strategies for controlling runoff and preventing soil losses due to erosion are RT or NT with crop residues or surface cover crops. Comparing soil erosion under native cover to soil erosion from agricultural fields, CT causes soil erosion to be one to two times larger. Under these circumstances, long-term erosion may exceed the rate of replenishment brought about by the processes of soil formation. With the aid of radioactive 137Cs, it has been calculated that there was an 87% decrease in soil erosion compared to CT with conversion to NT and residue retention. NT is quite good for reducing soil erosion, even on gently sloped terrain. Under NT cropping systems, leaving a significant amount of cover crop or harvest residues on the soil surface significantly lowers soil erosion and minimises losses of organic C and nutrients Worldwide, no-till crop production methods are gaining popularity in both large- and small-scale agriculture. In order to protect the organic, C- and N-rich surface soil from erosion and to aid in boosting or maintaining SOC stocks, crop production techniques known as minimum tillage (MT) or no-till (NT) systems are widely accepted as reliable agricultural practises. In the NT, residual crop residues on the soil surface minimise soil surface sealing, splash erosion, improve soil porosity through increased biological activity and variety, and reduce runoff by raising soil infiltration.

CONCLUSION

It has been widely documented that using conservation agriculture techniques like RT/NT and crop residue management can reduce the impact of GHG on global warming by increasing soil carbon storage. Other advantages of this method include less energy input, increased soil water storage, decreased runoff and soil erosion losses, decreased soil surface evaporation losses, regulated soil temperature, and decreased turning point in timely sowing of crops in rotation. No-till management techniques have the potential to successfully conserve enough water in the soil profiles of medium to fine-textured soils in order to facilitate reducing fallow periods and increasing cropping intensity, especially under water-restricted regions of dry land and rain-fed agriculture.

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