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ROLE OF CONSERVATION AGRICULTURE FOR ENHANCING CROP PRODUCTIVITY AND SOIL HEALTH

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Abstract: *During the second half of the 20th century, many energy-consuming agricultural practices were adopted as part of the modern scientific approach to achieve higher yields. Such practices were also encouraged by the large availability of cheap fuel. Heavy tillage, frequent weed control, abundant fertilization and surface water movement across large fields by pumping were keystones of the dominant production paradigm. Plow-based soil cultivation, in particular, has become so common in mainstream modern agriculture that the term "tillage" is widely used as a synonym for "agriculture. Nevertheless, continuous soil disturbance through cultivation and particularly through soil inversion has lead to the degradation of soil structure, soil compaction, and decreased levels of organic matter in soil. This, in turn has caused a wide range of environmental impacts, including soil degradation, water and wind erosion, increased carbon emissions released from the soil due to the use of high energy-consuming machinery, and an overall reduction in beneficial soil organisms and mammals. As soil accumulated over the eons, it provided a medium in which plants could grow. In turn, plants protected the soil from erosion. The agricultural activity of humans has been disrupting this relationship. Climate change has also exacerbated the problems of degradation and variability as rainfall events have become more erratic with a greater frequency of storms (Osborn et al., 2000). A way of minimizing these negative impacts on the agricultural environment is offered by a recently-promoted approach to agricultural production, the "conservation agriculture" (CA) and it is defined by Food and Agriculture Organization (FAO; 2004) as a system based on minimal soil disturbance (no-till, minimum tillage) and permanent soil cover (mulch, crop residue) combined with diversified rotations with legumes. Indeed, CA is the generic title for a set of farming practices designed to enhance the sustainability of food and agriculture production by conserving and protecting the available soil, water, and biological resources such that the need for external inputs can be kept minimal (Garcia-Torres et al., 2003). It is also recognized for its economic benefits which mainly convinced farmers to adopt it: increased yields, reduced production costs, labor reduction, increased farm incomes, better production stability and therefore better food security. Thus, CA could be a way to achieve the UN Millennium Development Goals, of eradicating extreme poverty and hunger while ensuring environmental sustainability.*
Keywords: *Conservation Agriculture, Soil, Productivity, Resources, Erosion, Tillage, Population.*

Introduction: The first key principle in Conservation Agriculture (CA) is practicing minimum mechanical soil disturbance which is essential to maintaining minerals within the soil, stopping erosion, and preventing water loss from occurring within the soil. In the past agriculture has looked at soil tillage as a main process in the introduction of new crops to an area. It was believed that tilling the soil would increase fertility within the soil through mineralization that takes place in the soil. Also tilling of soil can cause severe erosion and crusting which leads to a decrease in soil fertility. Today tillage is seen as destroying organic matter that can be found within the soil cover. No-till farming has caught on as a process that can save soil organic levels for a longer period and still allow the soil to be productive for longer periods [1]. Additionally, the process of tilling can increase time and labor for producing the crops.

When no-till practices are followed, the producer sees a reduction in production cost for a certain crop. Tillage of the ground requires more money in order to fuel tractors or to provide feed for the animals pulling the plough. The producer sees a reduction in labor because he or she does not have to be in the fields as long as a conventional farmer.

The second key principle in CA is much like the first in dealing with protecting the soil. The principle of managing the top soil to create a permanent organic soil cover can allow for growth of organisms within the soil structure. This growth will break down the mulch that is left on the soil surface. The breaking down of this mulch will produce a high organic matter level which will act as a fertilizer for the soil surface. If CA practices were used done for many years and enough organic matter was being built up at the surface, then a layer of mulch would start to form. This layer of mulch that is built up over time will become like a buffer zone between soil and mulch and this will help reduce wind and water erosion. This type of ground cover also helps keep the temperature and moisture levels of the soil at a higher level rather than if it was tilled every year

The third principle is the practice of crop rotation with more than two species. The crop rotation can be used best as a disease control against other preferred crops. In agricultural systems, such type of crop diversification may provide the link between stress and resilience because adiversity of organisms is required for ecosystems to function and provide services [2]. This process will not allow pests such as insects and weeds to be set into a rotation with specific crops. Rotational crops will act as a natural insecticide and herbicide against specific crops. Not allowing insects or weeds to establish a pattern will help to eliminate problems with yield reduction and infestations within fields [1]. Crop rotation can also help build up soil infrastructure. Establishing crops in a rotation allows for an extensive buildup of rooting zones which will allow for better water infiltration.

Effects of Conservation Agriculture

1. On Soil Health: Soil quality has been defined as the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, to maintain environmental quality, to promote plant and animal health and to sustain crop growth and yield. Intensive agricultural activity can reduce soil quality, especially tillage, which gives rise to processes that may damage the natural soil ecosystem [3]. Plow-based tillage determines soil compaction especially when repeated passes of a tractor are made to prepare a seed bed or to maintain a clean fallow [4] and destroys the original soil structure, breaking up the macro aggregates into micro aggregates, thereby altering many physical proprieties. This leads to increased runoff and poor infiltration. Soil structure is important for all crops. It regulates soil aeration and gaseous exchange rates, the movement and storage of water, soil temperature, root penetration and development, nutrient cycling and resistance to structural degradation, and soil erosion [5]. Soils with good structure have a high porosity between and within aggregates but soils with poor structure may not have macropores and coarse micropores within the large clods, restricting their drainage and aeration [6]. As oxygen depletion increases therefore pooraeration reduces the uptake of water by plants and can induce wilting. It can also reduce the uptake of plant nutrients, particularly nitrogen, phosphorus, potassium and sulphur. Poor aeration also retards the breakdown of organic residues, and can cause chemical reactions that are toxic to plant roots [6]. The presence of soil pores also enables the development and proliferation of superficial roots throughout the soil in the rooting zone. Roots are unable to penetrate and grow through firm, tight, compacted soils, severely restricting the ability of the plant to utilize available water and nutrients, and also reducing fertilizer efficiency and increasing the susceptibility of the plant to root diseases. Soils managed according to CA principles show significantly decreased bulk density at the surface this results from the exiting mulch layer on top of non-tilled soils that provides organic matter and food for soil fauna, which loosens surface soil as a result of burrowing activities. Also, below the sub-surface layer, the bulk density of the non-tilled soils usually is lower than in tilled soils. No-tillage also dramatically reduces the number of passes over the land and thus compaction; the FAO now includes “controlling in-field traffic” as a component of CA. This is accomplished by having field traffic follow permanent tracks that can be combined with a permanent bed planting system rather than planting on the flat [7]. In erosion-prone environments, whether in wet or dry warm zones, inversion of soil through tillage promotes unnecessary moisture loss; at the same time, the crop residues that should protect soil from erosion by wind or water and slow soil moisture loss after rain are buried [8]. Soil erosion represents a threat for the sustainability of agriculture worldwide, despite the economic impact on a world scale, the severity of soil erosion is difficult to estimate. The adoption of CA involves minimal soil disturbance (due to the use of no tillage and direct seeding), management of cover crops, crop residues, and crop rotation all of which preserve soil organic matter content [9]. Cover crops may influence soil aggregation and associated Carbon and Nitrogen pools, thereby affecting soil quality and productivity [10,11]. Thus Conservation agriculture practices increase soil organic matter content and organic matter (an important source of C), and a major reservoir for plant nutrients. The presence of surface cover helps to prevent erosion and compaction by minimizing the dispersion of the soil surface by rain or irrigation. It also helps to reduce crusting by intercepting the large rain droplets before they can strike and compact the soil. It further serves to act as a sponge, retaining rain water long enough for it to infiltrate into the soil. Crop residue management improves aggregate and this leads to reduced soil detachment and improved infiltration rates.

2. On Crop productivity and Yield

Improved Cultural Practices: Cultural practices are aimed to ensure better soil and crop management. Successful weed management is not to merely control weeds in a crop field, rather to create a system that reduces weed establishment and minimize weed competition with crops. There are different ways to handle weeds by improved cultural management practices. Effective water management plays a vital role in weed control under the CA System. Soil cover with dead or live mulch and crop cover also one of the pillars of CA. The crop/cover crop residue may also release some toxic substances, which may also suppress weed seed germination process [12]. Crop rotation in CA is a successful approach to reduce the weed pressure. Laser land levelling is an integral part of conservation agriculture as it provides uniform moisture distribution to the entire field and allows uniform crop stand and growth, leading to lesser weed infestation. Reduction in weed population in wheat after 30 days was recorded under precisely levelled fields in comparison to traditional levelled fields [13]. Row crop cultivation is also a good approach to accomplish the management of weeds under reduced tillage. It is very effective to combine the chemical approach and row crop cultivation maintaining high residues in the field. Mulch tillage is specially designed to retain more than 30% crop residues on the surface, suppressing different weeds due to shading or covering effect. Moreover, different types of organic compounds released from mulches through leaching cause inhibition of weed seed emergence.

Nutrient and Water Management: Tillage practices favourably modify the soil physical and biological environment facilitating root proliferation. These actively growing roots can take up nutrients from a greater soil volume and could improve the nutrient use efficiency. Conservation tillage (CT) and deep tillage increased NPK uptake compared to minimum tillage (MT). Tillage practices along with organic matter (OM) further affected the moisture and nutrient availability to crops. The availability of nutrients at different growth stages of Sorghum was increased by deep tillage [14]. The chemical, physical and biological fertility of soil is depending on soil organic carbon [15]. Crop residues enhanced the soil organic matter and total soil N levels in the long term. Found that N yield and fertiliser N utilisation by wheat were increased significantly by crop residues under no tillage compared to the tillage [16]. Higher nutrient use efficiency of applied N under no tillage than in conventional tillage was probably due to better moisture conservation under no tillage which might have facilitated plant nutrient uptake. Formation of a layer of crop residues on the soil surface under no tillage system improved the crop growth rate and nutrient uptake [17]. Conducted on-farm trials in seven districts of Haryana, India, for two consecutive years (2010–2011 and 2011–2012) to evaluate three different approaches to Site Specific Nutrient Management (SSNM) [18] based on recommendations from the Nutrient Expert (NE) decision support system in no tillage and convention tillage based wheat production systems as a result no tillage with site specific approaches for nutrient management can increase yield, nutrient use efficiency and profitability [19]. Nutrient management in CA is a significant concern of agriculture today. Intensive cropping pattern over the years have mined soil nutrients due to improper replenishment. Increasing the awareness and close monitoring of nutrient budgeting will promote the researchers and farmers to compute the soil nutrient input–output balance sheet in rational ways. In the conventional system of crop cultivation, the tillage operation is higher which promote higher level of soil disturbance and affected the nutrient dynamics in soil. The soil surface, covered with crop residue also modified the soil properties in many ways, especially nutrient availability to crops [20]. Nutrient management in CA system mainly follows some basis aspects like:

1. Enhance the soil biological process to protect the soil micro-organism population and diversity, so that the soil organic matter is either build-up or maintained.
2. Maintain the adequate biomass production and biological N fixation in relation to soil biota activities in terms of soil energy and nutrient stocks.
3. Provide adequate access to all plant nutrients by plant root from soil solution, from natural and also from synthetic sources, to fulfil the crop demand.
4. Keep soil pH within the acceptable range.

Therefore in the present context, CA emerged as a new breakthrough system approach for crop production and soil health. It represents biologically and bio-geo-physically integrated system of nutrient management during crop production and maintaining soil health in the long perspective [21]. It could reduce the requirement of external inputs due to generation of high level of internal ecosystem services, which enhanced the crop production factor response in higher magnitude.

The CA practice depends on the climate and resources availability, i.e. in dry tropical and subtropical ecologies with small number of farmers with poor resources, the establishment of CA will take a longer period. The long-term applications of conservation practices improve the soil organic carbon and soil properties, mostly in 10 cm upper soil layer. Increasing levels of C improved the soil aggregates, water holding capacity, microbial growth and plant nutrient transformation and reduced soil erosion. Application of crop residue on the soil surface conserved the soil moisture and mediated the plant nutrient dynamics. Addition of organic residue in CA enhanced the micronutrient concentration, especially cations (Zn, Fe, Cu and Mn), than conventional tillage practices. Hence CA improved the soil properties, i.e. chemical, biological and physical, and plant nutrient concentration influences the soil biological activities and nutrient transforming process. An intensive soil tillage and mismanagement of irrigation water and fertilizers under current agricultural practices have accelerated the pace of degradation of irrigated dry lands in India. Increasing water scarcity and concerns of irrigation water quality have further raised serious doubts about the sustainability of current conventional agricultural systems. Water Use Efficiency (WUE) of crops can be improved by the selection of crops and cropping system based on the availability of irrigation water resources. The latter can be achieved by the selection of irrigation methods, irrigation scheduling, tillage, mulching and fertilization. Incorporation of crop residues on the soil surface minimizes water loss through evaporation which enhances higher growth rate of crop leading to higher water productivity [17]. Reported that CA had significantly higher WUE as compared to conventional tillage [22].

Chemical Weed Management: Herbicides are another weed control option, but greater attention must be given to alternative control methods and to ensuring that chemicals are used properly to reduce health risks and environmental damage. Herbicides are less effective, if improperly applied, for instance, at the incorrect time and dose, or without appropriate adjuvant. Most commonly used burn-down herbicides are glyphosate, paraquat, glufosinate, 2,4-D and dicamba. The rate and time of application is very critical in CA system. Several low-dose, high potency, selective, post-emergence herbicides and mixtures are available for effectively managing weeds in crops like rice and wheat grown in sequence under CA system. However, the recent development of post-emergence broad-spectrum herbicides provides an opportunity to control weeds in CA system. In fact, many farmers in India apply isoproturon, a good broad-spectrum herbicide, by broadcasting it with sand or urea. Improper herbicide use has probably contributed to the herbicide resistance in P. minor in India and A. fatua in Mexico [23]. The use of new herbicides or a mixture of herbicides is another alternative and will remain a part of the weed control strategy. In CA systems the presence of residue on the soil surface may influence soil temperature and moisture regimes that affect weed seed germination and emergence patterns over the growing season. This shows that under CA system, farmers have to change the timing of weed control measures in order to ensure their effectiveness. Soil surface residues can interfere with the application of herbicides, so there is a greater likelihood of weed escape if residue is not managed properly or herbicide application timings or rates are not adjusted. Some herbicides intercepted by crop residues in CA systems are prone to volatilization, photo degradation and other losses. The extent of loss, however, may vary depending upon their chemical properties and formulations. Herbicides with high vapour pressure, e.g. dinitroaniline herbicides are susceptible to volatilization loss from the soil surface.

Integrated Weed Management in CA System: Integrated weed management (IWM) is a holistic approach under CA system. This also includes the biological weed control methods. Biological weed control offers a huge, largely untapped resource for weed control method, it includes a large number of available living entities such as predators, pathogens and other plant competitors of weeds that are exploited to kill or suppress the weeds. Microorganisms that suppress growth of many common agricultural weeds have been identified and commercial development is underway [24]. In short, it is an effective method of weed control in CA systems. IWM is basically a long-term approach which aims to manage weeds rather than controlling weeds. IWM has the potential to restrict weed populations to manageable levels; reduce the economic losses, risk to human health and potential damage to the ecosystem; increase cropping system sustainability; and reduce selection pressure for weed resistance to herbicides. A combination of different weed management strategies such as herbicide rotation, green manures [25], selection of suitable crop cultivars and cropping systems coupled with CA principles may help in weed management [12].

Carbon Sequestration and Green House Gas (GHG) Emission: Increasing the GHG emission in the atmosphere enhanced the atmospheric temperature affected the soil process, crop production and productivity and emergence of new insect pest and caused sudden changes in climatic events. The effects of climate change are assumed to have reached to that level where the irreversible change in the functioning of the earth planet is feared. Today we need to reduce the GHG emission or capture from the atmosphere in a long-lived pool, so that it cannot re-emit to the atmosphere [26]. Among the GHGs, CO_2 plays a crucial role, due to its larger concentration and wide sources of emissions. Intensive tillage practices reduced the soil C emitted into the atmosphere. It reduced the soil fertility and productivity adversely. The CA is one of the options in the agricultural system to reduce the GHG emission and also C sequestration through agricultural crops. The reduced burning of crop residue and incorporation of surface cover enhanced the soil C and reduced the rate of C emission into the atmosphere. Minimum tillage practices also improved the plant nutrient efficiency and cut offthe volatilisation or denitrification losses during the crop production. The CA practice can contribute to making the agricultural system more resilient to climate change. It has a powerful mechanism to adopt climate change by increasing resilience to drought, increasing water use efficiency and thermal stress to agricultural crops and also increasing moisture content in soil. The CA aims to increase the annual C rate into the soil through reducing the C losses through erosion and mineralisation. When the crop residues are retained on the soil surface in combination with no tillage, it improved the soil quality and overall resource enhancement. It leads to sustainable improvement in the nutrient use efficiency, nutrient balance and reduced soil moisture loss, which all enhanced the productivity of system in terms of carbon sequestration. In general the adoption of best management practices in CA sequestered the soil C 1.8 ton CO_2 per hectare per year [27].

Conclusion: Continuous shrinking of natural resources, decline in crop yield, deterioration in soil health and rising costs of agricultural inputs in conventional production system pose a threat to food security and livelihood of farmers. In this situation, CA is an obvious new paradigm in achieving higher productivity, improving environmental quality and preserving natural resources. CA systems involve mainly three principles like providing permanent soil cover, minimum mechanical soil disturbance and diversified crop rotations. Residue retention or inclusion of cover crops (Sesbania, cowpea, mung bean, etc.) on the soil surface is also one of the main CA principles which provide beneficial effects on soil moisture, temperature moderation and weed control. It also minimizes water loss through evaporation which enhances higher growth rate of crop leading to higher water productivity. The combination of tillage and crop residue enhanced the soil organic content in the upper layer of soil. The best crop management practices improved the soil microbial diversity and population, which mediated the nutrient transformation and availability to crop plants. It improved the nutrient use efficiency and reduced the rate of inputs during the crop production and farmer gets higher yield production. The environmental hazards contributed by agriculture can be minimized through the CA. Problematic weed infestations are the major constraints in adoption of CA, however modified tillage practices provided an opportunity for effective weed management in this system. Development of low-dose, high-potency, selective, post-emergence herbicides and herbicide mixtures are necessary for managing weeds in CA system. Herbicide tolerant crops also provide opportunity to managing weeds. Therefore, the paradigm shift from tilled field to CA system requires a thrust on nutrient management to improve soil and crop productivity and environmental quality and spread rapidly across the globe.

References

1. Food and Agriculture Organization (FAO). (2007). Agriculture and Consumer Protection Department. Rome, Italy Available from http://www.fao.org/ag/ca/ (Accessed November 2007).
2. Lakhran, H., Kumar, S. and Bajiya, R. (2017). Crop diversification: An option for climate change resilience. *Trends in Biosciences*, 10(2): 516-518.
3. Pisante, M. (2007). Agricoltura Blu–La via italianadell'agricolturaconservativa – Principi, tecnologie e metodi per unaproduzionesostenibile. Il Sole 24 Ore Edagricole, Bologna, XII+317.
4. Hobbs P.R., Sayre K., Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture, Philos. Trans. R. Soc. Lond. *B Biol. Sci.*, 368 (1491), 543–555.
5. Barth`es, B., Roose, E. (2002). Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels, *CATENA* 47(2), 133–149.
6. Shepherd, T.G., Stagnari, F., Pisante, M., Benites, J. (2008). Visual soil assesment- Field guide for annual crops FAO, Rome, Italy, VIII+26.
7. Sayre, K.D., Hobbs, P.R. (2004). The Raised-Bed System of Cultivation for Irrigated Production Conditions. In: Lal R., Hobbs P., Uphoff N., Hansen D.O. (Eds.). Sustainable agriculture and the rice-wheat system. Ohio State University. Columbus, Ohio, USA. Paper 20, 337–355.
8. Pisante, M. (2002). Tecnicheagronomiche conservativeperlariduzionedeiprocessididegradazione del suolo. Atticonvegnonazionale "Desertificazione: la nuovaemergenzadelbacino del mediterraneo", Catania-Caltagirone-Palermo, 22–25 maggio 2001, 3–9.
9. Wright, A.L., Hons, F.M. (2004). Soil aggregation and carbon and nitrogen storage under soybean cropping sequences, *Soil Sci. Soc. Am. J.* 68, 507–513.
10. Sainju, U.M., Terrill, T.H., Gelaye, S., Singh, B.P. (2003). Soil aggregation and carbon and nitrogen pools under rhizoma peanut and perennial weeds, *Soil Sci. Soc. Am. J.*, 67: 14–155.
11. Holeplass, H., Singh, B.R., Lal, R. (2004). Carbon sequestration in soil aggregates under different crop rotations and nitrogen fertilization in an inceptisol in southeastern Norway, Nutr. *Cycl. Agroecosys.* 70(2): 167-177.
12. Ramesh, K. (2015). Weed problems, ecology, and management options in conservation agriculture: issues and perspectives. *AdvAgron*., 131:251–303.
13. Jat, M.L., Gathala, M.K., Ladha, J.K., Saharawat, Y.S., Jat, A.S., Vipin, K., Sharma, S.K., Kumar, V., Gupta, R. (2009). Evaluation of precision land leveling and double zero-till systems in rice-wheat rotation: water use, productivity, profitability and soil physical properties. *Soil Tillage Res.*, 105:112–121.
14. Patil, S.L., Sheelavantar, M.N. (2006). Soil water conservation and yield of winter sorghum (Sorghum bicolor L. Moench) as influenced by tillage, organic materials and nitrogen fertilizer in semiarid tropical India. *Soil Tillage Res*., 89:246–257.
15. Chan, K.Y., Cowie, A., Kelly, G., Singh, B., Slavich, P. (2008). Scoping paper: soil organic carbon sequestration potential for agriculture in NSW. NSW Department of Primary Industries Science Res Tech paper, pp 1–29.
16. Mohammad, W., Shah, S.M., Shehzadi, S., Shah, S.A. (2012). Effect of tillage, rotation and crop residues on wheat crop productivity, fertilizer nitrogen and water use efficiency and soil organic carbon status in dry area (rainfed) of north-west Pakistan. *J Soil Sci Plant Nutri.*, 12(4):715–727.
17. Sapkota, T.B. (2012). Conservation tillage impact on soil aggregation, organic matter turnover and biodiversity. In: Lichtfouse E (ed) Organic fertilisation, soil quality and human health. Springer, New York, pp 141–160.
18. Sapkota, T.B., Majumdar, K., Jat, M.L., Kumara, A., Bishnoi, D.K., McDonald, A.J., Pampolino, M. (2014). Precision nutrient management in conservation agriculture based wheat production of Northwest India: profitability, nutrient use efficiency and environmental foot print. *Field Crops Res.*, 155:233–244.
19. Kumar, S., Karaliya, S.K. and Chaudhary, S. (2017). Precision farming technologies towards enhancing productivity and sustainability of rice-wheat cropping system. *International Journal of Current Microbiology and Applied Sciences*, 6(3): 142-151.
20. Dotaniya, M.L. (2012). Crop residue management in rice-wheat cropping system. Lap Lambert Academic Publisher, Saarbrücken, p 116. ISBN 978-3–659–29388–7.
21. Friedrich, T., Kassam, A.H. (2009). Adoption of conservation agriculture technologies: constraints and opportunities. Invited paper, IV World

Congress on Conservation Agriculture, 4–7 February 2009, New Delhi, India.

22. Das, T.K., Bandyopadhyay, K.K., Ranjan Bhattacharyyaa, Sudhishri, S., Sharma, A.R., Behera, U.K., Saharawata, Y.S., Sahoo, P.K., Pathak, H., Vyas, A.K., Bhar, L.M., Gupta, H.S., Gupta, R.K., Jat, M.L. (2016). Effects of conservation agriculture on crop productivity and water-use efficiency under an irrigated pigeon pea wheat cropping system in the western Indo-Gangetic Plains. *J Agric Sci.*, doi:http://dx.doi.org/10.1017/S0021859615001264.
23. Malik, R.K., Singh, S. (1995). Little seed canary grass (Phalaris minor) resistance to Isoproturon in India. *Weed Technol.*, 9:419–425.
24. Stubbs, T.L., Kennedy, A.C. (2012). Microbial weed control and microbial herbicides. INTECH Open Access Publisher, Rijeka.
25. Kirkegaard, J.A., Conyers, M.K., Hunt, J.R., Kirkby, C.A., Watt, M., Rebetzke, G.J. (2014). Sense and nonsense in conservation agriculture: principles, pragmatism and productivity in Australian mixed farming systems. *AgricEcosyst Environ.*, 187:133–145.
26. Kundu, S., Dotaniya, M.L., Lenka, S. (2013). Carbon sequestration in Indian agriculture. Climate change and natural resources management. In: Lenka S, Lenka NK, Kundu S, SubbaRao A (eds) New India Publishing Agency. ISBN 978-93-81450-67-3. 269-289. p 363.
27. FAO. (2008). Investing in sustainable agricultural intensification: the role of conservation agriculture a framework for action' FAO Rome, August 2008 (Available atwww.fao.org/ag/ca/).