Review Article

Prospects and Issues in the Adoption of Conservation Agriculture in India

ABSTRACT

Conservation agriculture involves practices such as crop rotations, minimal soil disturbance, and maintaining permanent soil cover through crop residues or cover crops. Despite various challenges to its widespread adoption, India has made significant progress over the past two decades in developing, refining, and promoting conservation-based agricultural technologies. Notable advancements have been made in the Indo-Gangetic plains, especially in the adoption of no-till wheat within the rice-wheat cropping system. Advocates of conservation agriculture understand the trade-offs but recognize that the benefits outweigh the drawbacks. These methods offer potential advantages including reduced production costs, improved water and nutrient conservation, increased crop diversity and yields, and more efficient resource utilization.

Keywords: Conservationagriculture,traditionalagriculture,zero-tillage,resourceuseefficiency

1. INTRODUCTION

The Food and Agriculture Organization (FAO) describes Conservation Agriculture (CA) as a system for managing agro-ecosystems that aims to ensure food security, enhance profitability and protect environmental resources. According to the United Nations' Committee on World Food Security, food security means that everyone, at all times has physical, social and economic access to sufficient, safe and nutritious food that fulfills their dietary preferences and needs for an active and healthy life. Currently, nearly 800 million people lack adequate food, over 2 billion suffer from deficiencies in essential micronutrients and about 60% of individuals in developing countries face food insecurity (1). Additionally, anticipated population growth, climate change and environmental impacts are likely to worsen these issues in the coming decades. Given the scale of the challenge, food security is interconnected with all the Sustainable Development Goals (SDGs) established by the United Nations.

Conservation agriculture is a management approach for agroecosystems that stands out as a key method for achieving agricultural sustainability, aiming to enhance productivity while safeguarding the environment (2). Originating in the 1930s in the USA to address soil degradation caused by water and wind erosion. Conservation Agriculture (CA) is defined by the use of three interconnected principles, which are applied through locally adapted practices and complemented by other agricultural methods (3). These three core principles are:

(1) Continuous minimum mechanical soil disturbance;

(2) Permanent soil organic cover with crop residues and/or cover crops;

(3) Species diversification through varied crop rotations, sequences, and associations.

The main challenges facing the majority of Asian countries are ensuring food security for agro wing population, reducing poverty, and maintaining agricultural systems under recent scenarios of diminishing natural resources, adverse effects of climatic variability, spiraling input costs, and unstable food prices. In addition to these difficulties, soil erosion, a decrease in soil organic matter, andsalinization are the main signs indicating non-sustainable agricultural practices. These are mostly brought on by (□) reduceds oil organic matter content, rate of water infiltration, wind and water erosion as a result of extensive tillage; (□) the inadequate return of organic material; (□) mono cropping. Consequently, for future productivity and to maintain the sustainability of natural resources, a paradigm change in agricultural techniques is required to remove a few aspects of conventional agriculture such as tillage or ploughing of soil, monoculture, and removing soil organic matter.Concerns about the sustainability of agriculture throughout the world led to the development of theidea of conservation agriculture (CA), which has grown gradually to occupy almost 8 percent of thetotal arable land (124.8 million hectares) in the world (4). Conservation agriculture is a resource-saving system of crop production to achieve high yields and production intensification and enhance the base of natural resources (5). According to Wolff and Stein (1998) (6), traditional agriculture, which relies heavily on mechanization and tillage, has been blamed for issues such as surface and subsur face water contamination, soil erosion, and increased water consumption. Additionally, it is linked with low energy efficiency, the depletion of biodiversity and wildlife, the degradation of land resources and the issues associated with climate change (7). Therefore, conservation agriculture is considered as a method of growing both annual and perennial crops that relies on managing crop waste and cover crops, as well as zero and conservation tillage, which offers an enduring soil cover and aspontaneous rise in the amount of organic materials in surface horizons. The primary environmental effects of this technique have been studied globally to provide the farming and scientific communities with an overview of the research and documentation that are now accessible. In contrast to traditional agriculture, it emphasizes the extremely positive effects of a conservative way of farming on the global environment (biodiversity, air, water, and soil) (8). It additionally reveals the actual gaps or concerns regarding the opinions of the scientists on these environmental issues.

CA promotes reverse degradation processes, improves resource quality, reduces production costs and helps achieve sustained high productivity. Global area under CA was about 180Mha, corresponding to about 12.5% of the total global crop land in 2015/16 (9). CA is considered as a sustainable practice, which increases natural biological process, both below and above the soil. This technology is an eco-friendly, more efficient technology, which restores soil fertility along with increasing crop productivity and improving moisture conservation, which directly acts a source of climate change mitigation and reduces total cost of cultivation and helps in timely operations (10). Conservation agriculture encourages most soils with richer biodiversity and bioactivity, improved soil structure, cohesion and higher levels of natural physical protection from wind, rain, and wet or dry spells. This results in decreased soil erosion and bio degradation of pesticides along withslightly reduced transport of agronomic inputs in soil. Conservation agriculture is a productive substitute for conventional agriculture that minimizes its drawbacks.

2. CONSERVATION AGRICULTURE

According to Hobbs (2001) (11), conservation agriculture can be defined as the widely adapted group of management practices that can guarantee more sustainable agricultural output. Conservation agriculture improves and enhances the efficient utilization of natural resources through the integrated management of easily accessible natural resources such as water, soil, and biological resources alongwith external inputs.It supports socially, environmentally, and economically viable agriculturalproduction in addition to environmental protection (12). According to FAO (2014) (12), it is also known as resource-effective or resource-efficient agriculture. This more environmentally friendly farming method has been referred to as "conservation agriculture" to set it apart from the morerestrictive conservation tillage (13). Conservation agriculture can be defined as a kind offarming that preserves the soil cover by retaining agricultural wastes on the surface and reducing oreliminating tillage. The management of crops, weeds, nutrients soil, water, and farm equipment intraditional agriculture requires a paradigm shift to implement conservation agriculture methods. Conservation tillage techniques like zero tillage are one way toward the transition from traditional tillage to conservation tillage. Here it can be said that conservation agriculture addresses a comprehensive idea of the entire agricultural system.

3. BASIC PRINCIPLES

Many regions of the world employ conservation agricultural techniques, which are based onecological principles and increase the sustainability of land usage (14), (15). Conservation agriculture must be used to increase agricultural yield and resource use efficiency (RUE). Essentially, the three basic principles of conservation agriculture, are interconnected with each other for proper planning, design and implementation procedures. These three principles are:

3.1. Minimal disturbance of soil enabled through reduced tillage or no-till

The soil biological activity creates highly stable soil aggregates and a range of pore diametersthat permit air and water penetration. This method is incompatible with mechanical tillage and isreferred to as "biological tillage." The organic activities that structure the soil will be eliminated bymechanicaldisturbanceofthesoil. According to Kassam and Friedrich (2009) (16), minimum soil disturbance balances the ideal amounts of gases required for root respiration in the rooting zone,moderates the rate of oxidation of soil organic matter, offers porosity for transportation of water,retention,andrelease ofwater,andrestrictsthere-exposure of weed seeds and their germination.

3.2. Maximum residues or permanent cover of soil

A permanent cover in the soil is necessary to protect the soil from the damaging effects ofsunlight and rain, to provide a steady supply of food for the micro and macro organisms living there, and to modify the microclimate in the soil to promote the best possible growth and development of microbes and plant roots. Maximum residue retention in soil enhances soil aggregation, soil biological activity, carbon sequestration and soil biodiversity (17).

3.3. Diversified crop sequences or rotations (temporal or spatial crop sequencing)

Croprotationisessentialforprovidingadiversifieddiettothemicroorganismslivinginsoilaswel l as for exploring various soil levels in search of nutrients that have seeped to deeper layers andmay be recycled by the crops in rotation. Additionally, a diversity of soil fauna and flora are found byrotating a variety of crops. Legume crop rotations and crop sequencing disturb the life cycle of pathogens, biological fixation of nitrogen, increase biodiversity, and reduce off-site pollution (18), (16).

4. CURRENT SCENARIO OF CONSERVATION AGRICULTURE IN INDIA

Around 125 million hectares of land are under conservation agriculture globally. Adoption ofconservation agriculture is still in its initial phases in India. Adoption of conservation agriculture andzero tillage has increased over the last three years, covering over 1.5 million hectares. Conservationagricultural methods have been promoted in India for about a decade, but farmers have just begun toaccept them in the last eight to ten years (19). Some of the State Agricultural Universities, institutes under ICAR, and the Rice-Wheat Consortium for the Indo-Gangetic plains have joined forces to develop and promote conservation agriculture. In the irrigated areas of the Indo-Gangetic plains region, where rice-wheat cropping systems are predominant, the expansion of thesetechnologies can be seen. Other important agro-eco regions such as the rainfed semi-arid tropics and the dry parts of the mountain agro-ecosystems have not yet promoted or tested conservation agriculture techniques.

Developing and marketing zero-till seed-cum fertilizer drills for wheat planting in rice-wheatcropping systems has been the main focus for the development of conservation technology. Raised bed planting, residue management techniques, land leveling assisted by laser technology, and substitutes for the rice-wheat system etc. are important interventions. As per the reports of Sangar *et al.* (2005) (20) the area of wheat, planted with the zero-till drill has been rising quickly. Currently, 25 percent to 30 percent of wheat grown in Indo-Gangatic plains as a part of rice-wheat cropping systemis zero-tilled (19). The farmers in the north-western region of India are also adopting raised-bed planting and laser field leveling at an increasing rate.

5. PROSPECTS

The way India as well as other countries in Asia choose to fulfil the energy and food demandsin the upcoming decades will have a significant influence on energy security, natural resource base, and climate change. These challenges emphasize then ecessity and urgency of finding solutions to address the risks to the agricultural sector caused by the depletion of natural resources, rising production costs, and climate change. A potential approach to address these issues is switching to no-till conservation agriculture. Farmers and researchers will always require assistance in reorienting their agricultural techniques to produce more at a lower cost of production by adopting more secure options and routes. Therefore, it appears that continuing with conventional agriculture would not result in sustainable food grain production. Instead, in the majority of ecological and socio-economic situations of Indian agriculture, conservation agriculture-based crop management practices adapted to meet local needs are likely to be essential. The promotion of conservation agriculture in the Indian environment results in the following prospects:

5.1. Limiting production cost

This is one of the major elements driving the fast adoption of zero-till technologies. Researchconducted by Malik *et al.*, 2005 (21) revealed that the cost of production of wheat might decrease by between ₹ 2,000 and ₹ 3,000 per ha. A decrease in the cost of production contributes reduction in diesel, man power and input expenses especially those of herbicides.

Reduced weed incidence

The majority of research shows that when zero-tillage is used, *Phalaris minor* infestation in wheat fields, tends to decrease, which in turn reduces the need for herbicides.

5.2. Yield increase

Yields were constantly higher in well-managed zero-till planted wheat compared to conventionally prepared fields for similar sowing dates. Due to the effects such as improving soilmoisture regime, improving soil fertility, preventing soil degradation and crop rotational benefits,conservation agriculture has been reported to enhance crop yield levels. In the Indo-Gangetic plains, zero-till wheat has shown better yield improvements of 200–500 kg ha^{-1} as compared to the wheat grown conventionally in a rice-wheat cropping system (22). African Conservation Tillage Network (2011) (23) declares that conservation agriculture leads to greater and more consistent crop yields, while there are also many cases of no yield advantages and even cases of declining yield particularly in the initial years of implementation of conservation agriculture.

5.3. Conserving soil nutrients and moisture

Zero-till planting can result in significant savings in soil nutrients and water (up to 20%–30%),especially for crops that are bed-planted and laser-leveled (19).A lower rate ofevaporation over the preceding period can be indicated by a higher soil moisture content under zero tillage than under traditional tillage (24). Additionally, it was revealed that under zero tillage, the soil moisture content was almost 20 percent higher as compared to traditional tillagethroughout the course ofgrowing seasons.

5.4. Opportunities for crop diversification

Crop diversity may be achieved through the conservation of agriculture. Agroforestry systemsand cropping sequences or rotations, when implemented in suitable temporal and spatial patterns, canaugment ecological processes. Studies suggest that a number of crops, including sugarcane, pigeon pea, mustard, and chickpea, may be well suited to this new system of crop production.

5.5. Environmental benefits

Zero-tillage and crop residue retention on the surface in conservation agriculture present abetter opportunity to prevent crop residue burning, which is a major source of greenhouse gases including CO_2, N_2O, and CH_4. Crop residue burning contributes significantly to nutrient loss, which can be recycled through proper management. Large-scale burning of crop residue poses a serious threat to public health.

5.6. Enhancement of resources uses

In combination with surface crop residue, management, no-tillage initiates the processes leading to a gradual breakdown of surface residues, improving soil structure and increasing recycling and plant nutrient availability. Mulch-like surface residues lower soil temperatures, enhance biological activity and decrease evaporation.

6. ISSUES FACED WHILE ADOPTING CONSERVATION AGRICULTURE IN INDIA

Farmers, extensionists, technicians and researchers must adopt a different perspective to transition from conventional tillage to sustainable no-tillage farming (25). Persuading farmers that tillage is not necessary for successful farming is the largest obstacle (26). Many farmers might not notice additional advantages of conservation agricultures in they are primarily concerned with the financial savings from less tillage. Sustaining conservation agriculture as a pathway to sustainable agriculture will need continuous scientific investigation and advancement. The following are some significant obstacles that prevent conservation agriculture from being widelyadopted:

- Many marginal and small farmers are not well equipped with the necessary seeders. Additional research is required despite considerable attempts to develop and commercial izemachinery for sowing wheat in zero-tillage system. Development, standardization, and promotion of high-quality machinery appropriate for arrange of crops and cropping sequences are necessary for successful adoption. Management of crop residue involves developing permanent bed and furrow planting methods and enhancing harvesting techniques for managing crop residues.
- Farmers frequently use crop residues for fuel and animal feed in rainfed areas. Nevertheless, there aren't enough crop residues to cover all demands due to restricted biomass production. This creates conflict between using residues for cattle feed and for conservation agriculture practices. Hence, promoting conservation agriculture in such regions is significantly hampered.
- In the case of the rice-wheat cropping system of North India, due to a lack of machinery forseedsowingunderconservationagriculture,farmersfrequentlyburncropremnantstofacili tate timely seeding of the next crop. Although this approach helps with timely planting, it causes serious ecological concerns in the region.
- Farmers and extension agents lack awareness of the advantages of conservation agriculture.Consequently, all conservation agricultural practices including sowing, harvesting, nutrientand water management, and disease-pest control are to be developed, evaluated, and adaptedtomeetthe needs ofmoderncropproductionsystems.
- Management of conservation agricultural system needs experts. Scientists must collaborateclosely with farmers and other stakeholders and approach issues from a systems view point. Improved methods for exchanging information and knowledge are also required.
- Over the past few decades, conservation agriculture techniques have been adjusted to various socio-economic, agro-ecological and farming systems. For these techniques to spread and assist more farmers, though, more backing from regional, national and local stake holders including legislators is essential. Even thought here has been a lot of study done on conservation agriculture in India, especially at the Indian Agricultural

Research Institute (IARI), farmers have not yet fully embraced it. The previous perception or mindset of thefarmers towards traditional tillage can be considered as a major cause of the limited adoptionof the conservation agriculture concept (26). Hence, Unfavourable legislative contexts and farmers' customary inclination for tillage are major obstacles. Participatory on-farm research to evaluate and improve CA technology is crucial to over coming these obstacles. Large-scale demonstration scan then aid in the promotion of these techniques. To promote its wider use, India is now starting a network research initiative centre don the on-farm assessment and demonstration of conservation technology.

- Considering that conservation agricultural systems are intricate and hence effective management processes necessitate a thorough comprehension of basic processes and component interactions. Farmer collaborations for system approach are critical since farmers have the most in-depth knowledge of their farming systems. For the development and promotion of new technologies, cooperation between farmers, scientists, extension agents, policymakers and stakeholders in the private sector is essential. The FAO (2005) (27) states that advisors ought to collaborate with farmers to identify and address issues rather than relying solely on farmers to carry out outside initiatives. A participatory system is required in place of a top-down strategy, where farmers are given the tools and instruction to test conservation technology and assess its efficacy while making the required modifications for their land.
- It is essential to offer farmers financial assistance at fair interest rates so they can purchase machinery, inputs, and equipment for the successful implementation of conservation agriculture. Furthermore, these purchases have to be subsidized by the government.
- Adaptation of conservation agriculture concepts in local contexts becomes important for small farmers and resource-poor farmers and requires collaborative adaptive research involving community stake holders. To do this, conservation agricultural methods must suit the specific needs of the area. This includes choosing suitable crop species, managing crops and cover crops effectively, maintaining soil cover, and resolving issues with the cost-effectiveness of key inputs like seeds, machinery, and herbicides. To promote thewidespread implementation of conservation agriculture techniques and improve agricultural sustainability and resilience in local ecosystems, policy frameworks that make these inputs more affordable and available must be advocated.

7. CHALLENGES OF CONSERVATION AGRICULTURE IN INDIA

As an innovative model for crop production, conservation agriculture will need an inventivesystem viewpoint to address the flexible, diverse, and context-specific requirements of technologies along with their management. The effort to conduct research and development in conservation agriculture will thus need to incorporate several novel elements to meet the challenge.

7.1. Better understanding of the system

Conservation agriculture is even more complicated than traditional agriculture. It will be extremely difficult to manage such complex systems effectively without a better understanding of component interactions and the fundamental practices, which may impact system performance as a whole. According to Gupta and Jat (2010)(28) crop residues kept on the soil surface function as mulchingmaterial, preventing soil moisture loss from evaporation and maintaining a moderate range of soil temperature. Crop residues, thus, can act as a readily decomposable source of soil organic matter and at the same time, they may contain undesired pest populations. The zero-tillage system affects the depth of root penetration and their distribution in soil layers, which in turn affects the intake ofwater and nutrients as well as the cycling of minerals. Moreover, no-tillage and maintaining surface crop residues improve resources gradually, with benefits emerging overtime. Often, increases in yield are not seen in the early years of adopting conservation agriculture. It is essential to understand thedynamics and interactions of biological, chemical, and physical processes. Therefore, it is importantto know about conservation agriculture as a system and design strategies for its management, andresearchinconservationagriculturerequiresalong-termperspective.

7.2. Technologicalchallenges

The implementation of conservation agricultural techniques in different farming conditions is a significant barrier. These challenges are related to the development, adoption, and standardization of farm machinery for crops owing to crop harvesting that causes the least amount of soil disturbance.

7.3. Sitespecificity

The primary barrier to the widespread adoption of conservation agriculture is the site-specificinformation (25). Strategies for conservation farming systems will need to be extremely site-specific. Knowledge gained across the sites will help to understand why some technologies or practices work well in a few circumstances but not in others. The entire learning process will boost the establishment of the base of foundational knowledge for sustainable resource management.

8. CONCLUSION

Conservation agriculture emphasizes sustainable crop production, conservation of resources, and soil health, and it is a necessary deviation from traditional agricultural practices. This strategy demands better scientific ability, strong farmer alliances, and efficient knowledge-sharing systems. By integrating such components conservation agriculture, especially in rainfed areas, can reverse environmental degradation, lower the cost of cultivation, and improve agricultural productivity andsustainability. Thus, the primary objective in ensuring long-term agricultural sustainability and production is to embrace and promote conservation agriculture. India can ensure more competitive, sustainable and efficient farming practices that benefit both the present and future generations by prioritizing the concept of conservation agriculture.

References

1. Pérez-Escamilla, R. Food security and the 2015–2030 sustainable development goals: From human to planetary health. Current developments in nutrition. 2017; 1(7): e000513.
2. Shrestha, J. I. B. A. N., Subedi, S. U. B. A. S. H., Timsina, K. P., Chaudhary, A., Kandel, M., Tripathi, S. Conservation agriculture as an approach towards sustainable crop production: A review. Farming and Management. 2020; 5(1): 7-15.
3. FAO. Conservation Agriculture. 2015. Available online:https://www.fao.org/conservation-agriculture/en/ (accessed on 19 October 2021).
4. FAO. Food and Agriculture Organization of the United Nations, 2012. Available online athttp://www.fao.org/ag/ca/6c.html. 2012.
5. Abrol, I. P., Sangar, S. Sustaining Indian agriculture-conservation agriculture is the way forward. Current Science. 2006;91(8):1020-2015.
6. Wolff, P., Stein, T.M. Water efficiency and conservation in agriculture– opportunities and limitations. Agriculture and International Soil and Water Conservation Research. 1998; Vol. 2, No.4,2014, pp. 1-12.
7. Boatman, N., Stoate, C. Gooch, R., Carvalho, C. R., Borralho, R., de, Snoo, G., Eden, P.The environmental impacts ofarable crop production in the European Union: practical optionsforimprovement.Areportpreparedfor Directorate-GeneralXI ofthe European Commission. 1999.
8. Derpsch, R., Friedrich, T., Landers, J. N., Rainbow, R., Reicosky, D. C., Sa´, J. C. M., Sturny, W. G., Wall, P., Ward, R.C., Weiss, K., (2011). About the necessity of adequately defining no-tillage – a discussion paper. In Proc. 5th World Congr. Conserv. Agric 26-29 September 2011, Brisbane, Australia.
9. Kassam A, T Friedrich, R Derpsch. Global spread of Conservation Agriculture, International Journal of Environmental Studies. 2019; 76(1):29-51

10. Bilaiya, S., Khare, N. K., Sahu, A., & Patidar, J. (2022). Conservation Agriculture Technology: Extent of Adoption & Constraints Faced by Farmers of Madhya Pradesh, India. Asian J. Agric. Ext. Econ. Soc, 40(12): 466-474.

11. Hobbs PR, Gupta R, Malik RK, Dhillon SS. Conservation Agriculture for the rice-wheatsystems of the Indo- Gangetic Plains of South Asia: A case study from India1, In: 1st WorldCongressonConservationAgricultureMadrid. 2001; 1-5 October,2001 pp 1-7.

12. FAO(2014)Whatisconservationagriculture?FAO-CA. 2014.

13. Wall, P. C., Thierfelder, C., Ngwira, A., Govaerts, B., Nyagumbo, I., Baudron, F. (2014). Conservation agriculture in Eastern and Southern Africa. In Conservation agriculture: Global prospects and challenges. 2014 pp. 263-292, Wallingford, UK.

14. Wassmann, R., Jagadish, S.V.K., Sumfleth, K., Pathak, H., Howell, G., Ismail, A., Serraj, R., Redona, E., Singh, R.K., Heuer, S. Regional vulnerability of climate change impacts on Asian rice production and scope for adaptation. Advances in Agronomy. 2009;102:91-133.

15 . Lal, R. Climate-resilient agriculture and soil Organic Carbon. Indian Journal of Agronomy. 2013; 58(4):440-450.

16. Kassam, A. H., Friedrich, T. Perspectives on Nutrient Management in ConservationAgriculture.Invitedpaper,IVWorldCongressonConservationAgriculture. 2009; 4-7February2009,New Delhi,India.

17. Ghosh, P.K., Das, A., Saha, R., Kharkrang, E., Tripathy, A.K., Munda, G.C., Ngachan, S.V. Conservation agriculture International Soil and Water Conservation Research. Vol. 2, No. 4,2014, pp. 1-12 11 towards achieving food security in north east India. Current Science. 2010; 99(7): 915-921.

18. Dumanski, J., Peiretti, R., Benetis, J., McGarry, D., Pieri. C. The paradigm of conservation tillage. Proceedings of World Association of Soil and Water Conservation. 2006; P1,58-64.

19. Bhan, S., Behera, U. K. Conservation agriculture in India–Problems, prospects and policy issues. International Soil and Water Conservation Research. 2014; 2(4):1-12.

20. Sangar, S., Abrol, J. P., Gupta, R. K. Conservation Agriculture: Conserving Resources Enhancing Productivity. 2005; 19p. CASA, NASC Complex, NewDelhi.

21. Malik, R.K., Gupta, R.K., Singh, C. M., Yadav, A., Brar, S.S., Thakur, T.C., Singh, S.S., Singh, A.K., Singh, R., Sinha, R. K. Accelerating the Adoption of Resource Conservation

Technologies in Rice Wheat System of the Indo-Gangetic Plains. Proceedings of Project Workshop, Directorate of Extension Education, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU). June 1-2, 2005. Hisar, India: CCSHAU.

22. Hobbs, P. R., Gupta, R. K. Problems and challenges of no-till farming for the rice-wheatsystems of the Indo-Gangetic Plains in South Asia. In R. Lal, P. Hobbs, N. Uphoff, & D.O.Hansen (Eds.), Sustainable Agriculture and the Rice-Wheat System (pp. 101-119). Columbus, Ohio and New York, USA: Ohio State University and Marcel Dekker, Inc. 2004.

23. African Conservation Tillage Network. 2011-11-10. www.act-africa.org. Aina, P. O. (1979).Soil changes resulting from long-term management practices in western Nigeria. Soil Science Society of America Journal. 2011; 43: 173-177.

24. DeVita, P., DiPaolo, E., Fecondo, G., DiFonzo, N., Pisante, M. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in Southern Italy. Soil & Tillage Research. 2007; 92:69-78.

25. Derpsch, R. (2001). Keynote: Frontiers in conservation tillage and advances in conservation practice.In Stott, D. E., Mohtar, R. H., and Steinhart, G. C. (Eds.), Sustaining the global farm. Selected papers from the 10th International Soil Conservation Organisation Meeting held May 24-29, 1999 at Purdue University and the USSA-ARS National Soil Erosion Research Laboratory.

26. Hobbs, P.R., Govaerts, B. How conservation agriculture can contribute to buffering climate change. In M. P. Reynolds (Ed.), Climate Change and Crop Production (pp. 177-199). CAB International 2010.

27. FAO. (2005). Drought-resistant soils: Optimization of soil moisture for sustainable plant production.In Proc Electronic Conference Organized by the FAO Land and Water Development Division.FAOLandandWater BulletinVol.11.Rome: FAO.

28 . Gupta, R. & Jat, M. L. Conservation agriculture: addressing emerging challenges of resource degradation and food security in South Asia. In Behera, U.K., Das, T.K., Sharma, A.R. (Eds.), Conservation Agriculture (pp.1-18).Division of Agronomy, Indian Agricultural Research Institute. 2010; NewDelhi–110012, 216 p.