CONSERVATION AGRICULTURE IN INDIA

This summary document provides an overview of the state of conservation agriculture in India. And also covers a literature review of impact studies conducted on conservation agriculture in India. **It is a part of the larger CEEW study,** *Sustainable Agriculture in India 2021: What We Know and How to Scale Up*

Sustainable Agriculture in India 2021: What We Know and How to Scale Up, is a handbook on the prevalence, practices and state of affairs of the 16 most promising sustainable agriculture practices in the country. It presents the economic, social and environmental impacts of these practices with recommendations on their potential to scale-up sustainable agriculture in India.

The study is available at: https://www.ceew.in/publications/sustainable-agriculture-india-2021

Image: CEEW

Conservation agriculture (CA) is defined as an ecosystem approach to agricultural land management based on three interlinked principles.[1,2]

1. Minimum soil disturbance through no-tillage or reduced tillage: though zero-till is ideal, CA can involve controlled tillage where no more than 20-25 per cent of the soil is disturbed.
2. Permanent maintenance of soil mulch by retaining crop residues or cover crops on the field: A minimum of 30 per cent permanent organic soil cover is maintained as per CA definitions.
3. Diversification of cropping systems through proper crop rotation: crop rotation and intercropping using legumes are recommended.

CA is known to enhances biological processes (above and below ground), reduces tillage, and optimises the use of external inputs (agrochemicals) to avoid biological disruption.[3] It involves direct seeding of crops with minimal soil disturbance after the harvest of the previous crop. This requires slashing or rolling the weeds or last crop residues and then directly seeding through the mulch without ploughing. In this way, crop residues are retained, providing soil cover and a source of nutrients for the next crop.[4]

While CA emphasises no-tillage (zero tillage), farmers were apprehensive initially about absolutely no-tillage, so promotion focused on minimum soil disturbance (strip tillage/reduced tillage). It is observed that farmers in the rice-wheat cropping systems of the Indo-Gangetic Plains practise no-tilling in rabi wheat season and tilling before sowing rice. Referred to as 'partial tillage,' this term is gaining popularity for estimating the practice's adoption rates. Even so, zero-tillage (ZT) wheat is used over a significant area in the rice-wheat system of the north-western Indo-Gangetic Plains, as well as raised-bed planting and laser land levelling.[5]

Image: CEEW

Conservation agriculture's linkages to FAO's agroecological elements

In principle, conservation agriculture adheres to and promotes many agroecological elements as defined by the FAO

Elements	Description of agroecological linkages
Diversity	No-tillage and residue retention maintain or increase soil organic matter in the topsoil, providing energy and substrate for soil biotic activities, soil structure, and nutrient cycling. It promotes above and below ground soil biodiversity, while diversified crop rotations also enhance biodiversity.
Co-creation and sharing of knowledge	The principles of CA blend traditional knowledge (maintenance of soil cover and crop diversification) and technical innovations (machinery) developed and refined over the years. Though the practice is known to conserve natural resources, implementing it is knowledge-intensive, and thus farmers need access to training, innovations, and new technologies when adopting CA.
Synergies	CA builds synergies by enhancing key functions of the ecosystem. For example, crop diversification provides plant nutrients and reduces fertiliser use while contributing to soil health and climate change regulation.
Efficiency	CA increases input-use efficiency as it reduces the cost of cultivation through savings in labour, reduces fertiliser use (after a few years), and uses water efficiently. Reduced tilling saves energy and diesel and reduces emissions.
Recycling	When combined with surface management of residues, no-tillage leads to slow decomposition of these residues, increasing the recycling and availability of plant nutrients in the soil.
Resilience	Conservation agriculture enhances crop production systems' resilience and climate resilience by reducing energy use and emissions. It also offers resilience to drought and excessive heat, as increased soil moisture increases transpiration during crop maturity, thereby protecting crops from terminal heat (in wheat). Finally, CA facilitates water percolation in the soil, thus saving upland crops from waterlogging during the rainy season.
Human and social values	CA improves farmers' incomes by using efficient methods in soil, water, and fertiliser use. The practice focuses on resource conservation.
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A brief context in India

Conservation agriculture took off in India in 1994 when the Rice-Wheat Consortium was established in the Indo-Gangetic Plain (IGP) as an ecoregional initiative by the Consultative Group on International Agricultural Research (CGIAR). In the 1990s, scientists proposed practising no-tillage instead of burning wheat stubble, which was a common practice among farmers after harvest. However, the penetration of CA among farmers remained poor initially. Efforts to promote the practice gained momentum with the launch of the Cereal Systems Initiative for South Asia (CSISA) in 2009. CSISA has promoted CA within its project innovation hubs in Punjab, Haryana, Uttar Pradesh, and Bihar.[6]

CA has seen significant research and development in the last two decades as it is a knowledge-intensive approach. The Department of Agriculture, Indian Council of Agricultural Research Institutions, and few others (CIMMYT-International Maize and Wheat Improvement Center, International Rice Research Institute, Rice-Wheat Consortium) made considerable efforts to develop best CA practices through on-station and farmers' participatory research.[7] Under the ICAR, the Consortium Research Platform (CRP) on Conservation Agriculture operates in 11 locations across the country to adapt and mainstream CA practices.[8]

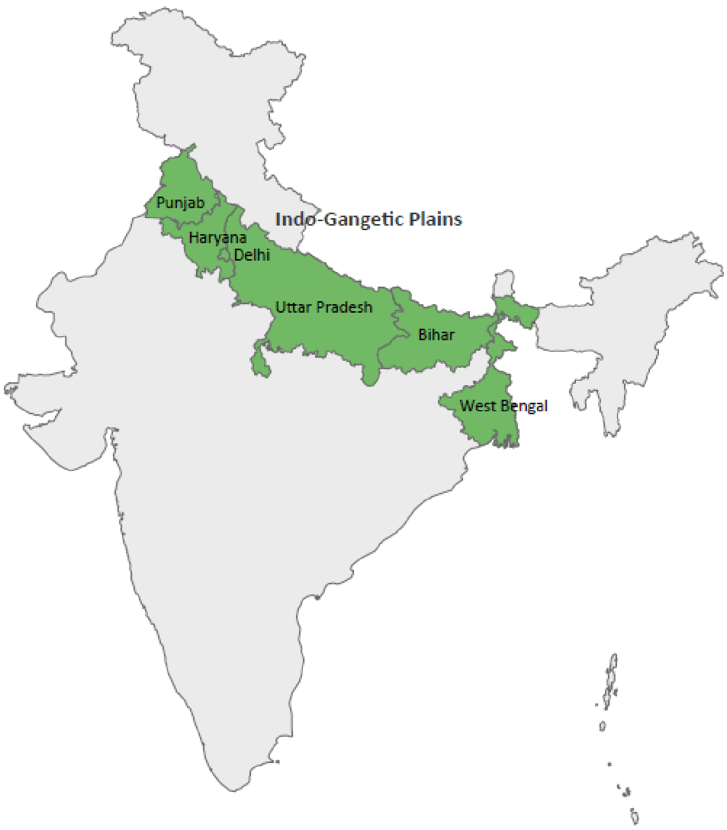
While there is no specific policy intervention for CA, schemes like the *Sub-Mission on Agricultural Mechanization* provide financial assistance for resource conservation techniques (Zero-till Seed Drill, Laser Leveler, Happy Seeder, Rotavator) and residue management, which supports conservation agriculture. The Central sector scheme, *Promotion of Agricultural Mechanization for in-situ Management of Crop Residues (2018-2019),* supports the efforts of states (Punjab, Haryana, Uttar Pradesh, and NCT of Delhi) to subsidise machinery required for in-situ management of crop residue, which is an essential aspect of CA.[9]

Conservation agriculture: acreage, geographies, and cultivation details

How much area in India is under CA? Recent figures estimate around 2.5 million hectares are under the partial CA system in South Asia.[10] The partial CA (where at least one crop has no-till, with or without residue retention) is considered the new methodology for area calculation devised by the CA proponents/experts. Further, stakeholders consulted affirmed that around 80-90 per cent of this area is in India, i.e., approximately 2 million hectares (Tek Sapkota, CIMMYT, personal communications).

At which farm size is CA practised? The practice tends to be adopted more by large-scale than small-scale farmers, as machinery is more suitable for larger plots and is also more accessible to larger farmers. Though the government gives subsidies for CA equipment on a custom-hiring basis, smallholder farmers are not utilising it to its full potential (Tek Sapkota, CIMMYT, personal communications).

Figure 1. The Indo-Gangetic regions where CA is mostly adopted



Source: Author's compilation from literature reviews and stakeholder consultations

How many farmers in India are practising CA? The area under CA-based systems is around 2 million ha, as estimated above, then dividing this by the average landholding size where CA is mostly practised, i.e., Punjab (3.62 hectares) and Haryana (2.20 hectares)[11] can give rough estimates of the farmers practising CA in the country. The area divided by the average landholding size of both these states suggests roughly around 700,000 farmers to practise CA in the country.

Where in India is CA prevalent? CA is clustered in a few parts of the country but is mostly concentrated in the rice-wheat dominant IGP, especially Punjab and Haryana (Figure 1). According to consultations with stakeholders, CA is also practised in rice-wheat cropping systems in the Eastern Gangetic Plains (Bihar, West Bengal, Eastern Uttar Pradesh, Odisha) as well as some parts of Southern India with the insignificant area. The practice has not taken hold in rainfed, semi-arid tropics, arid and mountainous agro-ecosystems.

Which are the major crops cultivated under CA in India? CA is promoted in only a few crops like rice, wheat, sugarcane, and maize-based cropping systems in India. It is also used in cotton, mustard, pea, soybean, pigeon pea, castor, groundnut, pulses, vegetables, cowpea, onion, bean, green gram/black gram, jute, chickpea-sesame, barley, and sorghum.[12]

Impact of conservaton agriculture

This section considers the economic, social, and environmental impacts of conservation agriculture.

ECONOMIC IMPACT

1. Yields

CA is promoted as a resource-conserving practice with the potential to increase yields with a lower intake of inputs; however, reviews of evidence on yield gains from CA systems suggest that the benefits are highly contextual and only occur after several years. The suitability of CA for specific cropping systems depends upon the choice of crops and their combinations, including varieties (short/medium/long duration), sowing time and type, irrigation and nutrient management, weed management, etc., according to stakeholders consulted from the ICAR-National Institute of Abiotic Stress Management.

Stakeholders consulted indicate the early phases (1-2 years) of CA adoption can lead to a loss in yields due to reduced tillage practices resulting in 'nutrient or nitrogen immobility'. A second caveat is that at times, sufficient crop residues or mulch may not be available as farmers may not have a good enough harvest or simply because they would prefer to use them as livestock feed.[13]

What is nutrient or nitrogen immobility?

During the initial years (1-2 years), CA fields may require more nitrogen input as microbes consume some nutrients to decompose crop residues, a condition termed as 'immobilisation.' When reduced tillage and residue retention are followed under CA systems, it leads to a variation in the N dynamics compared to conventional farms. The variation is caused when the crop residues (which have a high carbon-to-nitrogen ratio) decompose because of an increase in biological activity by organisms that lock up the nitrogen (in their bodies), which leads to nitrogen immobilisation.[14]

In India, as CA is promoted in only rice, wheat, sugarcane, and maize-based cropping systems, the literature is focused on crop yields for these crops, especially in the IGP. In the IGP, zero-tillage reportedly gave 10-17 per cent higher yields than conventional tillage in rice and wheat.[15,16] Another study in the IGP compared no-till wheat with conventional wheat in a rice-wheat system. It found yield increases ranging from 200-500 kgs per hectare.[17] Various factors, such as improvements in soil fertility and moisture and rotational crop benefits, are attributed to these higher yields.

In contrast, the few experiments conducted in rainfed regions show that minimum or reduced tillage does not offer much advantage over conventional tillage regarding yield. As observed in semi-arid conditions, pearl millet gave higher yields in conventional tillage than in zero-till conditions. More weeds and less infiltration of water under the zero-till were indicated that led to higher yields.

Yields also vary depending upon the CA approaches and techniques used. For instance, dry direct seeding, which is an alternative method to transplant rice, is reported to give comparable yields as transplanted crops in basmati rice, but direct-sown zero-tilled rice cannot compete with transplanted rice in terms of yield and economics due to heavy weed infestations in the former.[18,19] With a higher rate of experiments conducted in the IGP, more scientific efforts are required to understand crop yield gains and CA's potential in rainfed areas and other agroecological regions to deduce long-term impact.

2. Income

The scientific evidence claims CA as a resource-conserving practice that reduces production costs through the precise and optimal use of inputs – fertilisers, herbicides, energy (fuel), costs of tilling (less labour and use of machinery), labour, water, etc. Residue decomposition, recycling, and plant nutrients, ultimately reduce the need for fertiliser use, implying savings for farmers.

Though its low input and resource conservation tendencies are amplified in the burgeoning literature on CA, similar to yield, it is difficult to have a concise understanding of the CA systems' net returns given that the three principles are rarely followed in combination. Long-term experiments on income are mainly based on the IGP and in zero-till systems, signalling the need for more of these economic analyses to move beyond the IGP.

Experts in the field mostly dwell on the fact that optimised input costs result in cutting costs. For instance, the cost of production is estimated to fall by almost 15-16 per cent through savings to labour, energy, and water, thus enhancing farmers' income.[20] Specifically, systematic studies done in the IGP quantify the average cost reductions to be to the tune of INR 5,760 per hectare (USD 78) (roughly down 5 to 10 per cent); ranging from INR 3,055 to INR 8,500 per hectare (USD 40-115/hectare) in different soils and ecoregions.[21]

A long-term field experiment (10 years) in a rice-maize rotation system showed CA techniques (zero till with residue retention and permanent beds with and without residue retention) incurred lower costs than conventional till due to the avoidance of preparatory tilling.[22] Higher net returns were observed due to yield increases obtained by eliminating tillage methods in rice-wheat in the eastern IGP. In contrast, additional system net returns were observed when both methods (zero-till and permanent beds) were combined with crop residue retention tilling.[23]

To add to the complexity, CA systems' income benefits also tend to vary according to the techniques used. A comparative cost-benefit analysis of a few of the methods found the highest C:B ratio for double zero tillage (1.91), followed by bed planting (1.74), brown manuring (1.66), and direct seeding techniques (1.14). These compared to a C:B ratio on conventional farms of 1.72.[24]

More research beyond the IGP is necessary to establish conclusive findings of CA in diverse regions.

SOCIAL IMPACT

1. Human health

CA contributes to human health by reducing residue burning, which increases GHG emissions and air pollution in nearby cities. This is made possible through machines like the Happy Seeder, which help retain the crop residues as mulch on fields and avoid burning residues. Adopting such no-burn alternatives is known to reduce the associated public health and environmental costs induced by air pollution.[25]

Several papers mention the positive outcomes of CA for human health,[26,27,28] but these studies lack more in-depth investigations or experimental studies to understand these impacts in depth.

2. Gender

Very few papers link the practice with gender-based outcomes. However, the use of zero tillage and paddy transplanters reduced workloads, especially for women farmers, as labour requirements reduced in nursery preparation, tillage, and replanting.[29]

Another study in Kendujhar, Odisha evaluated the impact on women following intercropping in CA systems. This led to an increase in labour hours, particularly for women, who were mainly involved in weeding that required more precision than fields planted with single crops, leaving them less time for non-farm activities.[30]

ENVIRONMENTAL IMPACTS

1. Soil and nutrients

As observed in the literature, soil forms the core of CA as it is widely known to minimise soil disturbance, control soil erosion, enhance soil carbon sequestration and increase infiltration of water and the plant-available soil water.[31] These are mainly attained through its fundamental principles that advocate reducing soil tilling or no-tillage and maintaining a permanent soil cover and soil health through diversification strategies.

Increasing evidence points towards CA as promoting richer soil biodiversity, structural cohesion, and protecting against external weather events due to crop residue cover reducing soil erosion. In fact, in general, CA is known to have the potential to reduce soil erosion by almost 80 per cent.[32]

Minimal disturbance produces stable soil aggregates that allow for air and water to infiltrate well. CA practices like zero or low till avoid soil disturbance, saving nutrients and gradually making them available for plants. However, nitrogen immobilisation in the initial years of conversion to CA can reduce nitrogen levels.[33]Maintaining permanent soil cover using crop residues protects the soil, affects the soil microclimate, improves the physical, chemical, and biological soil properties, reduces evaporative water loss, and increases the soil's water retention capacity. Ultimately, when the crop residue decomposes, it is used as mulch to control weeds and moderate the soil temperature and reduce evaporation.[34] Diversifying crops increases nitrogen-use efficiency and recovers nitrates leached into the soil profile.

A considerable amount of progress is seen in experiments on CA for soil. Still, the research needs to be expanded beyond the IGP regions and its cereal-based cropping system to enable adoption beyond these well-studied regions.

2. Water

Most of the studies on water and CA tend to emphasise water-use efficiency from CA techniques, such as no-till, which enhance the water infiltration and holding capacity of soils, reduce evaporation and run-off, and recharge groundwater. Water infiltration is enhanced due to the permanent soil cover through crop residues that protect the soil from run-off and prevents water from evaporation better than conventional fields with less soil cover.

Overall, CA’s water conservation techniques are known to save water by almost 20-35 per cent.[35] One study in the IGP found that zero-tillage direct-seeded rice with residue retention decreased irrigated water use by 30-50 compared to puddled transplanted rice fields.[36] Laser land levelling, a simple technique for preparing the land before sowing, has particular relevance for water savings. By ensuring an even distribution of water in every part of the field, it minimises any waste from run-off or waterlogging. An evaluation of the impact of the technology in rice-wheat systems of north-western IGP showed its immense potential for lowering the irrigation time for rice compared to traditionally levelled fields.[37]

3. Energy

The literature on energy mostly refers to the potential of minimum tillage and zero tillage systems to reduce the energy requirements through avoided machinery use. Most examples cited are from the IGP and the tropical south.[38] In one study, an improvement in specific energy (81 per cent) and energy use efficiency (13 per cent) was observed in zero-till compared to conventional till, as the former consumed less energy for land preparation and irrigation.[39]

Zero till practices in the rice-wheat systems in the IGP allowed farmers to save around 36 litres of diesel per hectare and approximately 60-90 per cent of the energy.[40] An assessment comparing several CA machines (zero-till drills, strip till drills, roto till drills) with conventional tilling methods found 67 per cent savings in fuel in no-till plots compared to conventional ones, as the fuel consumption was lower in the former (11.30 litre/hectare) than the latter (34.62 litre/hectare) leading to 24 litre/hectare of fuel savings.[41]

4. Emissions

There is compelling evidence for the substantial impact of CA systems on carbon sequestration and emissions, though it mostly comes from the IGP region. The evidence frequently claims that no-till with residue mulching reduces SOC loss and sequesters carbon due to the accumulation of organic matter in the soil from retaining crop residues.[42,43,44] There is also mounting evidence that CA mitigates emissions by reducing fuel consumption, residue burning, and fertiliser use.[45,46]

A meta-analysis of CA practices in the IGP found the annual increases in SOC stock were between 0.16 and 0.49 Mg C ha^{-1} yr^{-1}.[47] A study that measured the SOC concentrations in rice-wheat rotations for about seven years in eastern IGP found zero tillage and partial residue retention boosted SOC benefits.[48] A review study indicates that the carbon sequestration from no-tillage practices ranges between 367–3,667 kgs CO_2/hectare/year.[49] As for emissions, experiments show that farms in the IGP under conventional till emitted 0.6 Mg of CO_2 equivalent per hectare. At the same time, zero-till systems sequestered 0.84 Mg of CO_2 equivalent per hectare, though no difference was observed between the two systems in terms of nitrous oxide emissions. Besides, on average, zero-till is known to save about 60 litres of fuel per hectare, reducing CO_2 emissions by 156 kgs per hectare per year.[50]

In summary, the literature confirms that CA systems show great potential to mitigate emissions in several ways.

5. Biodiversity

Crop rotation and intercropping management practices are done in CA also enhance farm biodiversity.[51] However, the current evidence available and inferences are drawn insignificant; hence, more investigative studies are needed to understand CA systems' genuine impact on biodiversity.

Impact evidence

State of available research discussing the impact of conservation farming on various outcomes.

Evidence Type	Yield	Income	Health	Gender	Soil & nutrients	Water	Energy	GHG emissions	Bio-diversity
Journals	13	4	9	2	49	20	11	12	3
Reports	3	7	1	0	1	0	0	0	0
Articles/case-studies	0	0	0	0	1	0	0	0	0
Others **	0	1	0	0	11	0	0	0	0
Total	**0**	**12**	**10**	**2**	**62**	**20**	**11**	**12**	**3**

*** Thesis, guidelines, conference papers, etc*

Source: Authors' compilation

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and the first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

Stakeholder mapping

The following institutions are involved in the research and promotion of conservation farming; a few were consulted for this research:

Government institutions	Research/implementation institutions	NGOs/Civil society organisations
ICAR - Indian Agricultural Research Institute	International Maize and Wheat Improvement Centre (CIMMYT)	Centre for World Solidarity (CWS)
ICAR-Indian Institute of Rice Research	International Crops Research Institute for the Semi-arid Tropics (ICRISAT)	PRADAN
Directorate of Wheat Research, Karnal, Haryana	International Food Policy Research Institute (IFPRI)	Organic Ubuntu
ICAR-Central Research Institute for Dryland Agriculture	Borlaug Institute for South Asia (BISA)	Centre for People's Forestry
ICAR- Indian Institute of Soil Science	Cereal Systems Initiative for South Asia (CSISA)	Natural Capital

Source: Authors compilation

Note – The stakeholders list is indicative and not exhaustive

Endnotes

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