# THE ROLE AND IMPACT OF CONSERVATION AGRICULTURE FOR SUSTAINABLE AND RESILIENT AGRICULTURE

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**Abstract**

The focal point of the review is on conservation agriculture (CA), which is characterized as revolutions related with insignificant soil aggravation (no-till, NT) and long-lasting soil cover (mulch). Agriculture relies intensely upon development and culturing. The benefits of Prior to introducing conservation culturing (CT), a strategy that rose up out of the American residue bowl of the 1930s, culturing in agriculture is examined. The advantages of CA, a proposed upgrade to CT, are next examined. NT, mulch, and revolutions extensively increment soil qualities and other biotic factors in CA. The article reaches the determination that CA is an all the more naturally dependable and sustainable yield the board method. Case models from the watered maize-wheat frameworks of Northwest Mexico and the rice-wheat districts of the Indo-Hereditary Fields of South Asia are utilized to delineate how CA strategies have been applied in these two environments to increment yield financially and reasonably

**Keywords:** Conservation, Agriculture, Resilient, Sustainable

## 1. INTRODUCTION

Among the challenges facing the world today are ensuring food security for an expanding population, especially in less developed countries, and creating sustainable agricultural production systems.

The biggest problems facing the planet in the twenty-first century. (Allmaras, 1991)In addition to making sure there is enough food for everyone, the difficulty is to fulfil the rapidly expanding middle class population in emerging countries' growing demand for meat, eggs, fruits, and vegetables. Due to impending climate change-related dangers, which have already begun to have negative consequences on many agricultural production systems throughout the world, the difficulties are becoming much more complicated. We must produce more food from less-cultivated land as more and more agricultural land is being converted to industrial and residential purposes across the world. This will put more pressure on the already vulnerable natural resource base, notably the land and water, making it more challenging to supply the world's food needs.


**Figure 1:** Agriculture For Sustainable

Therefore, there is a pressing need to protect or even enhance the natural resources in order to prevent them from being harmed by water and wind erosion, which is greatly accelerated by human activity.

### 1.1 Traditional knowledge and conservation

To maintain food and nutrition security, traditional knowledge is crucial in the context of environmental preservation and sustainability. (Alvarez, 2000) This is of even greater importance now that efforts are being made to document and preserve traditional knowledge, which is seen to hold many beneficial practices related to nutrition in a world where one in nine people, or roughly 800 million people, go to bed hungry (Food and Agricultural Organization 2015). Additionally, it guarantees the preservation of a region's natural resources and biodiversity. Traditional knowledge is important, and the Convention on Biological Diversity (United Nations 1992) at the Rio Earth Summit advocated actions to protect and enhance it. According to Bavikatte et al. (2015), the CBD explicitly links biodiversity, local communities, and indigenous peoples' traditional ways of life.

A region's ecological abundance has also been connected to the cultural variety present there, which takes many different forms and customs. A variety of local cultural forms made various contributions with various goals to create a collection of behaviours, social norms, and group dynamics in addition to a deep knowledge of the surroundings in which and with which they existed. Each of these forms has an association with the ethnic group's natural and cultural history. Their distinctiveness lays in the way that people, their environment, and their traditions were intertwined in a way that promoted greater physical and social well-being. The in-situ maintenance of the local flora and wildlife is closely related to the cultural biodiversity of the area, offering both a context and an unintentional means of preservation.

For a while, research and approaches to resource use from the 20th century held that traditional people were inefficient resource consumers who frequently had outdated beliefs. However, decades of work on indigenous knowledge and people under common property literature has helped dispel this idea that rural communities use resources inefficiently in the latter part of the 20th century (Alvear, 2005 ) This is especially important to keep in mind in instances when so-called contemporary development, such as building, displaces traditional residents, particularly those found in forests. There are risks associated with the indiscriminate harvest and use of natural resources for economic gain in the background of commercial activities. (Ananyeva, 1999 )The symbiotic relationship indigenous populations had with their environment and resources, which protected and nurtured them, is completely absent from this strategy.

## 2. REVIEW OF LITREATURE

Abar (2012) found that traditional practices, technology, and an indigenous agricultural system allowed people to subsist sustainably within an ecosystem and also helped control biodiversity and soil degradation in his research of the Chuktia Bhunjia tribes of Odisha, in the eastern region of India. (Angers, 1993)He adds that while traditional agricultural practices assisted humans in interacting with the ecosystem, they were gradually abandoned, especially after the neo-liberal era, and that these kinds of systems could be adopted to ensure food security, preserve biodiversity, and protect natural resources.

Indigenous knowledge is being explored primarily in the fields of traditional foods and medicinal plants in addition to conventional farming techniques. The corpus of knowledge has been concentrating on all of these areas in an effort to gather and record the data from the circumstances or communities in which they exist. (Angers D. A., 1993)The United Nations' emphasis on "Globally Important Agricultural Heritage Sites" gave traditional agricultural techniques, systems, and knowledge the chance to be recorded for global access and exchange.

It's possible that not everything is done for the benefit of everyone. Additionally, the knowledge could be misused. This point is made by Torri (2013), who takes the rising demand for 16 medicinal plants as an illustration. She points out that over 90% of the medicinal plants used by the pharmaceutical sector are gathered in an unsustainable way. The same might be said about a number of historically well-known nutritious plants and landraces that are currently being sold for commercial purposes. (Angers D. A., 1997) Additionally, as their commercial value has increased, they have dispersed from the population where they were previously consumed to become fashionable and pricey food trends.

One illustration is the rising popularity of quinoa eating. While the UN General Assembly's declaration of a "International Year of Quinoa" contributed to some of the attention, its nutritional benefits were also a factor. However, it started to vanish from the traditional Andean population, where it had previously been preserved, grown, and eaten.

As a result, while some saw the possibility in the growth of local quinoa, others started to see it as a possible export crop (McDonell 2015). According to the author, domestication is the product of a lot of labor over many generations, involving seed selection, adaptation, and, notably in the case of quinoa, a significant amount of intraspecific variability.

Quinoa is in its current condition as a product of generations of selection, cross-pollination, and experimentation by traditional growers. Although studies have shown that the actual benefits these communities received from efforts to globalize quinoa were modest, they are still grateful for its promotion as a "miracle food" (McDonnell 2015).

Additionally, as mentioned by Dalton (2017), the initial demand for ancient grains was primarily local, with some of them being used in worship or rituals. Some have evolved into global commodities over time as whole grains or have been added to processed goods due to rising demand. (Aquino, 1998 )It is crucial to remember that, despite growing interest in indigenous people, their knowledge of plants, and how they use them, indiscriminate and commercial use of this knowledge can have disastrous results by destroying the very ecosystem that these communities had fought to protect.

## 3. CONSERVATION AGRICULTURE ACROSS THE GLOBE

Around 180.4 million ha (or 12.5% of the world's arable land), or the CA, have been consistently growing all through the world (Kassam et al., 2019; Fig. 1). In contrast with Europe and Africa, the level of CA region in South America, North America, Australia and New Zealand, and Asia is 38.7, 35, 12.6 and 7.7%, separately (Fig. 2). 78 countries all through the world have executed the CA (starting around 2015-16). The top countries pushing CA incorporate the USA, Brazil, Argentina, Australia, Canada, and China. Beginning around 2009, the reception of CA has developed by almost 10 million ha every year. Worries about soil disintegration among ranchers, researchers, and the overall population, as well as relentless long haul examination and effort, may have added to the acknowledgment of CA as a sustainable agriculture practice in most of these countries. Around 13.5 million ha of rice and wheat crops are filled in the IGP of South Asia, which incorporates Bangladesh, India, Nepal, and Pakistan (Baker, 2002 )These yields give a great many individuals food security and a method for means.

Zero culturing (ZT) innovation was presented in India and the adjoining nations on account of the ceaseless endeavors of the Rice-Wheat Consortium (RWC) and various organizations of the Public Rural Exploration Framework (NARS), and is currently logically being carried out by the ranchers in IGP (Sharma, 2021). As opposed to India, where CA has generally multiplied in the IGP's watered belts, CA has spread most broadly in rainfed regions across the world. As per Bijarniya et al. (2020), India has a region under CA of around 1.5 million ha, though the region under ZT in the IGP has persistently become around 2.5 million ha. As per research led at the homestead level, 35% of ranchers in the provinces of Punjab and Haryana have embraced wheat with NT as a component of the rice-wheat framework (FAO, 2015). At present, ZT wheat is become on around 25-30% of the IGP's developed land. Furthermore, ranchers are rapidly embracing laser-evened out land and raised-bed establishing frameworks, particularly in IGP.

**Table 1:** Global adoption of Conservation Agriculture

| **Year** | Area (million ha) |
|---|---|

| | |
|---|---|
| **1198** | 25 |
| **1999** | 38 |
| **2000** | 42 |
| **2001** | 49 |
| **2002** | 55 |
| **2003** | 59 |
| **2004** | 65 |
| **2005** | 68 |
| **2006** | 71 |

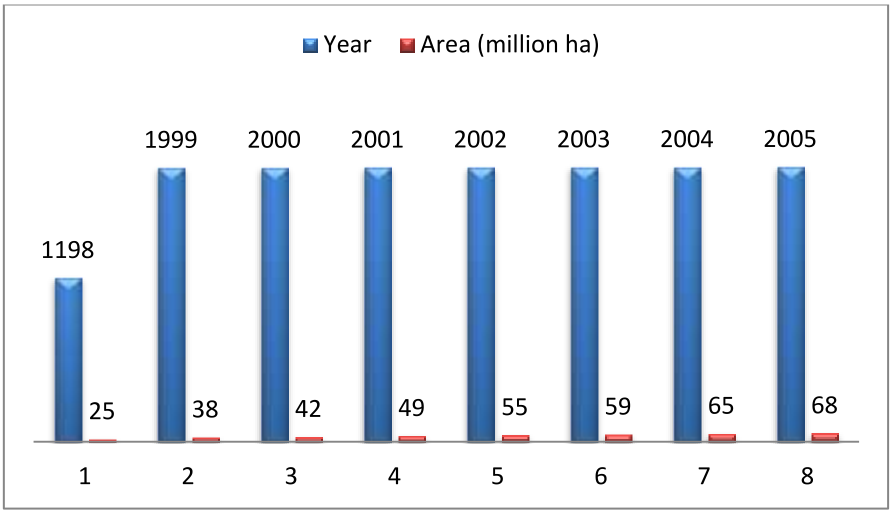


**Figure 2:** Global adoption of Conservation Agriculture

**Table 2:** Continent–wise area under Conservation Agriculture

| Country | Area (Mha) |
|---|---|
| **South America** | 18 |
| **North America** | 22 |
| **Australia** | 29 |
| **Asia** | 35 |
| **Europe** | 44 |
| **Africa** | 52 |

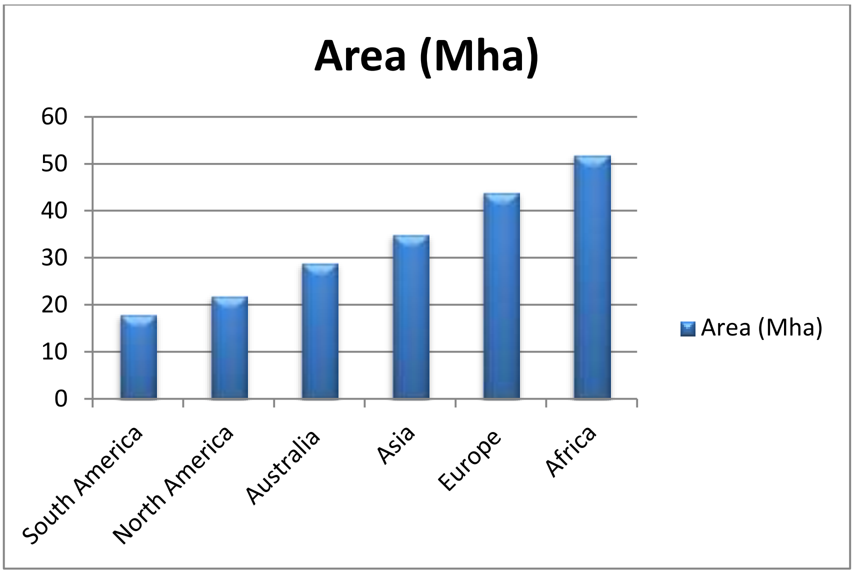


**Figure 3:** Continent–wise area under Conservation Agriculture

## 4. IMPACTS OF CONSERVATION AGRICULTURE ON SOIL HEALTH

### 4.1 Soil physical properties

As per Gathala et al. (2013), serious seedbed planning and repetitive soil aggravation bring about decay of the dirt's actual characteristics and primary respectability, which affect plant root advancement. In the 0-5 cm soil layer, plots under ZT bed planting had a mass thickness (BD) that was around 5% higher than plots under CT bed planting, while plots under wheat buildup recorded a BD that was around 6% lower than plots with no buildup applied. Sepat et al. (2014) found that in a long haul pigeonpea-wheat editing framework, ZT level beds had a BD that was generally 3% higher than CT in the 0-15 cm soil layer, while plots with pigeonpea-wheat buildup had a BD that was 4% lower in the 0-15 cm soil layer than no buildup added (held or covered) plots. (Baker C. J., 2006 )In contrast with PTR-CTW plots, Mishra et al. (2015) tracked down less fortunate soil-entrance opposition under DSR + brown manuring - ZTW and DSR-ZTW.

More significant levels of soil-entrance opposition in the 15-30 cm and 30-45 cm soil layers of PTR-CTW plots were a sign of sub-surface compaction and hard container got on by earlier years' puddling rice and different culturing activities in wheat (Balota, 2004 ). As per a drawn out concentrate by Parihar et al. (2016), at the 0-50 cm root-zone profundity, soil entrance obstruction was 16-27% lower under ZT plots than CT. In the 0-15 and 15-30 cm soil layers, separately, ZT found 23 and 16 more water-stable totals and 47 and 24.5% more mean weight breadth than CT. At 30-45 cm soil profundity, be that as it may, these distinctions were non-huge. As per Bhattacharyya et al. (2013), ZT raised bed plots created a bigger level of huge macro aggregates (2-8 mm) than CT level bed and CT-raised bed plots following 4 years of cotton (Gossypium hirsutum L.)/maize-wheat revolution. ZT energized full scale conglomeration rather than CT, especially in the dirt layer. As indicated by Singh et al. (2016), totals that are 47% more water-stable under ZTDSR than PTR. Furthermore, contrasted with the PTR-CT maize framework, the penetration rate was reliably higher in the ZTDSR-ZT maize treatment.

In contrast with the no-buildup treatment, crop deposits expanded the consistent state penetration rate by 24%. As per Mohammad et al. (2018), a triple ZT framework that included mungbean buildup + ZT DSR-rice buildup + ZT Indian mustard-Indian mustard buildup + ZT summer mungbean framework had complete soil dampness levels (0-30 cm) that were 12.6% more prominent than PTR-CT Indian mustard treatment.

As per Singh et al. (2016), the dirt least temperature was 1.0 to 3.0°C higher and the dirt most extreme temperature was 2.1 to 7.1°C lower in the buildup maintenance plots contrasted with the no buildup plots during the colder cold weather months (December to February).

**4.2 Soil chemical properties and carbon sequestration**

The upgraded gas trade and air circulation achieved by CA further develops soil tilth, construction, and total solidness, which is important for supplement cycling (Das et al., 2013).

Notwithstanding varying feelings, crop buildup the executives and development essentially affect soil pH. As indicated by Choudhary et al. (2018), in a rice-wheat-mungbean framework, soil pH and electrical conductivity (EC) were lower under ZT + buildup than CT. Under ZT, soil response (pH) will in general corrupt over the long haul because of the amassing of supplements and natural matter near the dirt surface. As indicated by Bhattacharya et al. (2018), super durable limited bed with buildup maintenance plots had a 20% more prominent complete soil nitrogen content in the 0-5 cm soil layer than CT plots. As per Sepat et al. (2014), crop buildup improved soil natural C, nitrogen, phosphorus, and potassium by 7.5, 7, 7.5, and 8.0% over no-buildup plots while ZT helped nitrogen and potassium by 9.6 and 5%, separately, over CT plots. (Bautista, . 1996 ) A significant sign of soil quality, soil natural carbon (SOC) is a consequence of good soil the board. With more prominent soil natural matter in the surface layer, zero culturing and crop build-up maintenance can influence the dispersion of SOC in the dirt profile and stop carbon misfortune processes. Culturing skill to expand the openness of harvest deposits to soil microorganisms by blending them into the dirt paces up the oxidation and breakdown of natural matter, which represents the lower centralization of SOC all through the years under CT (Bhattacharyya et al., 2018). Since there is less blending and soil-buildup contact under ZT, soil natural matter from deposits deteriorates all the more leisurely, steadily expanding the dirt natural substance (SOC) (Das et al., 2020). As indicated by Wang et al. (2014), crop buildup maintenance during ZT raised SOC fixation (117.7 Mg C/ha) extensively when contrasted with CT (76.8 Mg C/ha); be that as it may, when buildup was eliminated, there was no distinction. As per the discoveries of different examination, long haul no-till conditions result in expanded SOC gathering/sequestration in the top soil layer (Table 4).

Bhattacharya et al. (2015) found that under the mungbean buildup (MBR) + DSR - rice buildup (RR) + ZTW - ZT mungbean ( MBR + DSR-ZTW + RR-ZTMB) plots, the absolute assessed C info (12.1 Mg C/ha) was 117 and 127% higher than DSR-ZTW and PTR-CTW medicines, separately. Again, the top soil labile C pools in this MBR + DSR - ZTW + RR - ZTMB treatment were around 24% greater than those in PTR - CTW plots. As indicated by Yadav et al. (2021), the strategy of ZT + live-mulch delivered the best degrees of profoundly labile C (2.32 g/kg), while CT created the most elevated levels of labile C (1.72 g/kg). In contrast with different regions, the non-labile C of SOC was likewise more prominent under ZT and ZT+ live mulch at a profundity of 0-10 cm. As per Das et al. (2018), crop buildup maintenance impressively expanded the SOC content in the best 0-5 cm of soil by 4.6%, and long-lasting restricted beds had a carbon sequestration capability of 2.5 Mg/ha while extremely durable wide beds had a sequestration capability of 5.6 Mg/ha. At 0-15 cm of soil profundity, CA rehearses created a 26% higher complete SOC stock than the CT, while at 15-30 cm of soil profundity, there was no distinction among CA and CT. In contrast with the CT framework, Das et al. (2020) observed that the substance of exceptionally labile and labile C was around 50.6 and 47.7% higher under the triple ZT+ buildup framework at 0-5 cm profundity of soil. As indicated by Modak et al. (2019), deposits brought about SOC fixations that were 39-58% higher than those in no-buildup plots and that were by and large 25% higher under ZT than CT in dirt following 9 years of CA.

**4.3 Soil biology and biodiversity**

Dehydrogenase, fluorescein diacetate, beta-glucosidase, antacid phosphatase, as well as higher goal concentrates on like local area profiling by unsaturated fats, DNA fingerprinting, high-throughput sequencing, and so forth, are instances of microbiological exercises that are ordinarily used to assess soil quality (Bayer, 2000 )Microbial catalysts and soil microbial biomass (SMB) are fundamental for safeguarding the biological system and strength of the dirt. Beta-glycosidase is fundamental for C-cycling, while dehydrogenase protein movement (DHA) is believed to be an indication of oxidative action in soil organisms (Jat et al., 2021).

Under long haul CA plots, Badagliacca et al. (2021) revealed an expansion in SOC at a yearly pace of 0.17 g/kg, which animated microbial biomass, particularly Gram-negative microscopic organisms. As indicated by Saurabh et al. (2021), at a dirt profundity of 0 to 10 cm, soil qualities, for example, SOC, MBC, fluorescein-diacetate movement (FDA), and DHA were more noteworthy under ZT DSR - ZTW by 18, 56, 48, and 53%, separately, than PTR - CTW. As opposed to CT, ZT supported MBC and MBN by 29 and 27%, individually, while MBC and MBN for buildup maintenance plots were 56 and 84% higher, separately, than for buildup evacuation, as indicated by Choudhary et al. (2018). Soluble phosphatase action was likewise 5% more noteworthy in ZT than CT and 18% higher in the buildup maintenance treatment than the buildup evacuation treatment.

As per Sepat et al. (2015), the use of blended pigeonpea + wheat buildup expanded the dehydrogenase, beta-glucosidase, and corrosive phosphatase exercises contrasted with the no buildup control bunch. Moreover, contrasted with CT, ZT expanded MBC and MBN by 15.0 and 18.3%, separately. In contrast with CT, CA plots had more prominent soil MBC (45-49%), FDA (37-41%), and soluble phosphatase action (17%), as per Parihar et al. (2016). Like this, Bhattacharya et al. (2018) detailed higher DHA and FDA by 44 and 66%, separately, at 0-5 cm soil under the super durable wide bed with buildup (for example CA) than CT. Since it fills in as the fundamental wellspring of energy for soil fauna and microorganisms, soil natural matter (SOM) is the essential determinant of organic movement. Under CA, a steady soil-microbial local area that contains worthwhile bacterial and parasitic species can develop and control illnesses. Moreover, the establishing of cover crops supports the advancement of organic soil culturing; the surface mulch supplies food, supplements, and energy to underground worms, arthropods, and microorganisms that likewise work soils naturally. Compaction under ZT can be reduced by utilizing natural specialists (such night crawlers) and well established cover crops (Palm et al., 2014). Expanded overflows of macrofauna like bugs and hymenopteran parasitoids as well as mesofauna such soil vermin and arthropods have been seen in ZT conditions (Rodriguez et al., 2006; Palm et al., 2014). As opposed to regions where the buildups were incorporated, buildup mulched fields had more noteworthy groupings of microscopic organisms, actinomycetes, growth, worms, and nematodes (Baghel et al., 2018). Rhizobacteria and underground roots cooperate to work on supplement cycling, nitrogen obsession, biocontrol of plant microorganisms, plant illness opposition, and excitement of plant advancement, all of which affect crop wellbeing, yield, and soil quality.

**Table 3:** Carbon sequestration in conservation agriculture

| Conservation/zero tillage | Crop | Study duration (years) | Depth (cm) | Increase in C sequestration /accumulation over conventional tillage (%) |
|---|---|---|---|---|
| **ZT**<br>**PBB+R** | Rice-wheat<br>Maize-Wheat | 5<br>6 | 1-6<br>1-29 | 12.3<br>20.1 |
| **ZTDSR/ZTM**<br>**ZT+R with subsoiling** | Rice-Maize<br>Maize | 6<br><br>12 | 1-31<br><br>1-9 | 29.2<br><br>41.6 |
| **ZT/PB** | Maize-wheat-Mungeban | 6 | 6-12<br>1-19 | 40-51 |

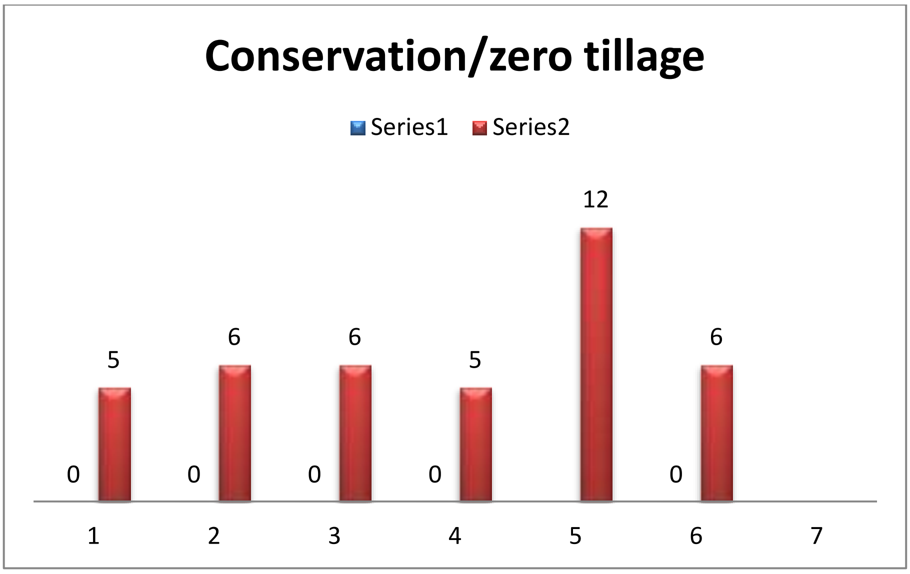


**Figure 4:** Carbon sequestration in conservation agriculture

### 4.4 Carbon sequestration in conservation agriculture

Internationally, $CO_2$ is the vitally human ozone harming substance (GHG), making around 76% of all discharges, while $CH_4$, $N_2O$, and fluorinated gases (F-gases) contribute 16, 6.2, and 2.0% of the complete outflows, individually (IPCC, 2014). Culturing fundamentally influences $CO_2$ outflows, which are connected with the recurrence of farm truck goes through rural fields.

$N_2O$ (from soils, composts, excrement, and the pee of touching creatures) and $CH_4$ (from ruminant creatures, rice development), which both have a more noteworthy GWP than $CO_2$ (Bhatia et al., 2010), are the two essential direct GHG discharges from agriculture. The CA-based works on, including laser land evening out, ZT with buildup maintenance, direct-cultivated rice, brown manuring with Sesbania, unpadded mechanical relocating of rice, raised bed planting, crop expansion, and related part advances like site-explicit supplement the board, present opportunities to diminish input costs, increment asset use effectiveness, and decrease GHG emanations. Since consuming 1 Mg of rice straw radiates 280 kg of $CO_2$, 3 kg of $CH_4$, and 0.07 kg of $N_2$ O-N, with an Earth-wide temperature boost potential (GWP) of 1,118 kg $CO_2$ reciprocals for each hectare (Gupta et al., 2004), buildup maintenance instead of consuming would assist with lessening $CO_2$ and other GHGs. As indicated by Gupta et al. (2015), persistent flooding of relocated puddled rice brought about the most elevated normal $CH_4$ outflow (56.4 kg/ha), which was trailed by irregular wetting and drying of relocated puddle rice (46.8 kg/ha), the arrangement of rice heightening (27.3 kg/ha), and direct-cultivated rice (3.8 kg/ha). DSR (5,065 kg $CO_2$ eq./ha) in Haryana shown a 40% lower GWP than customary CFTPR (8,425 kg $CO_2$ eq./ha). The GWP recorded by ZTW (2,062 kg $CO_2$ eq./ha) was 5% lower than that of CTW (2,180 kg $CO_2$ eq./ha). As indicated by Dendooven et al. (2012), the net GWP under CA was 1,327 kg $CO_2$ for every hectare each year, contrasted with 7,729 kg $CO_2$ for every hectare each year under CT. This distinction was because of soil carbon sequestration, GHG outflows, fuel utilization, compost use, and seed creation. Since the dirts under ZT were commonly moister and SOM was more accumulated at the dirt surface, Bhatia et al. (2010) got higher discharge of $N_2$ O-N in ZT than CT plots, leaning toward more prominent $N_2$ O creation. Just in fine surface soils with unfortunate seepage in muggy environments did $N_2$ O emanations rise, yet not in very much depleted circulated air through soils (Bissett, 1996 )As indicated by Gupta et al. (2016), the Indian-IGP might bring down the GWP of the rice-wheat framework by 44-73% with no apparent decline in framework creation by utilizing DSR, discontinuous dousing and drying, buildup maintenance, and neem oil-covered urea. As indicated by Tellez-Rio et al. (2017), CA techniques (ZT and crop pivot) prompted lower $N_2$ O discharge than CT in a semi-dry low-N input framework, and ZT ought to be proposed to decrease the net GWP of semi-dry agro-environments.

## 5. CONCLUSION

In the approaching decade, crop creation should increment food yield on a more modest measure of land while limiting ecological harm. This is the best way to guarantee that food creation stays aware of interest and that the land's efficiency is kept up with for people in the future. For horticultural researchers, expansion subject matter experts, and ranchers, this will be a difficult errand. Utilization of compelling however more harmless to the ecosystem the board procedures, as examined in this review, can support tackling this issue.

Frameworks for overseeing yields and soil that lower rancher costs while improving soil wellbeing measurements (physical, natural, and synthetic) are significant.

A prerequisite for progress is the production of the fundamental devices to empower ranchers to embrace these frameworks effectively. By 2050, food creation should ascend by one more

1 billion tons to take care of the growing total populace, while additionally recovering assaulted biological systems and soils, bringing down net anthropogenic emanations, and upgrading the climate. It is fundamental to carry out and advance conservation-viable creation methodologies in agriculture since assets are not many. Frameworks in light of conservation agriculture (CA) are fundamental for accomplishing sustainable farming creation. These frameworks give an assortment of environment administrations, including provisioning (food creation, water use effectiveness), directing (soil dampness conservation, soil conglomeration, groundwater guideline, energy use, squander decay and detoxification, soil disintegration counteraction, carbon sequestration, environment guideline), and supporting (supplement gathering and cycling, biodiversity conservation, essential creation) biological system benefits, which are all critical to further developing the utilization proficiency of regular assets.

## 6. FUTURE RESEARCH

1. To scale up CA technology among farmers, a participatory cropping system-based long-term feasibility study of CA under smallholder farms is required.
2. User awareness and an adaptable mindset are crucial for CA adoption. Regular training, counselling, and collaboration may enhance farmers' familiarity with CA equipment/machinery and facilitate CA adoption. Self-help groups and centers for bespoke hiring might be established to speed up the adoption process. Additionally, in order to spread and be adopted, CA might be incorporated into the government's national program for farmers like Mera Gaon Mera Gaurav (MGMG).
3. To have a greater impact under CA, agricultural residues may be quantified and characterized. Any arbitrary residue retention should be avoided since it may affect crop germination, seedling development, allelopathy, and the occurrence of pests, illnesses, and insects. It is necessary to establish the rate constants of mineralization for the immobilized-N under various agricultural residues.
4. There is a need for crop types that are peculiar to California, with early rapid growth, quick canopy-forming abilities, and the most effective root system. For DSR, rice types that can withstand Fe and Zn deficiencies are also required. PTR might be replaced by machine-sown zero till DSR with low seed rate.
5. Developing new selective broad- spectrum wider-window post-emergence herbicides for perennial weeds emerging after pre-emergence herbicide use, as well as rotating herbicide applications with 5-R stewardship and integrated weed management to stop weed resurgence and resistance. For greater efficacy, newer herbicide application methods (artificial intelligence/drones), transgenic or mutation-induced herbicide-tolerant crop varieties, and monitoring herbicide residue (non-selective; selective) in long-term CA studies may be tested in crops across different locations.

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