Hindawi
International Journal of Agronomy
Volume 2023, Article ID 1939379, 6 pages
https://doi.org/10.1155/2023/1939379

Review Article

Challenges, Developments, and Perspectives of Conservation Agriculture (CA) in Modern Agricultural System

Prodipto Bishnu Angon, Shaharia Akter Suchi, and Arpita Rani Roy

Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Correspondence should be addressed to Prodipto Bishnu Angon; angonbishnubau@gmail.com

Received 6 May 2023; Revised 31 October 2023; Accepted 13 November 2023; Published 22 November 2023

Academic Editor: Vera Popovic

One of the long-term solutions for agriculture's depletion of natural resources and degradation of the environment has been identified as conservation agriculture systems with proper crop and soil management. With the progress of the era, great changes have taken place in the field of agriculture. At present, it is possible to produce sufficient crops through conservation agriculture, along with economic, agronomic, and environmental benefits. Conservation techniques greatly lower the danger to food safety on a farm. CA is a farming method used to boost crop yield and sustainability that depends on three principles: minimal soil disturbance, crop rotation, and surface crop residue retention. This paper summarizes the importance, benefits, and challenges of conservation agriculture in a precise manner. In this study, we also discuss the way to increase the practice of conservation agricultureas well as the present research scenario of Bangladesh. At last, some research gaps are highlighted. Through this review, students and researchers will know the current development status of CA clearly and briefly.

1. Introduction

The overexpansion of the human population and modernization of life have been changing the consumption rate. Agriculture is subsistence-oriented in many countries, so traditional management practices are still widespread[1]. Farmers use excessive quantities of agrochemicals without comprehending the harmful effects in order to meet the rising population's demands for food and nutrition. An excessive amount of soil organic matter application worsens deficiencies in macro- and micronutrients, worsens water logging and/or poor drainage, and worsens soil salinity and acidity. The production of rice resulted in 192 megatons of greenhouse gas emissions worldwide in 2014 [2]. Rice fields with irrigation produced 30% of the methane that contributed to global warming [3]. The most significant obstacle to global rice production is the predicted 34% rise in the global population by 2050 [2]. Many management techniques have recently been used, which has improved the country's food and nutrition security and reduced rural poverty. Conservation agriculture (CA) is one of the best practices in modern agriculture. The effective application of cover crops and minimum tillage techniques may be essential to minimizing weed infestation and sustaining productivity [4] and has been found to produce significant fuel and labor savings when compared to traditional tillage. Studies have specifically demonstrated that minimum tillage strategies can reduce labor requirements by 70–74% and fuel requirements by 60–66% [5]. Farmers, politicians, and consumers are major stakeholders in sustainable and value-conservation agriculture. It also helps to minimize the consequences of climate change by sequestering carbon in the soil and lowering greenhouse gas emissions. Through the encouragement of more environmentally friendly farming methods, it can also aid in rural development. By preserving soil health and minimizing the use of toxic pesticides and fertilizers, CA may provide customers with access to wholesome and safe food.

As CA is essential for maintaining soil quality, it also plays an important role in low-cost crop production. We have briefly discussed each feature of CA in this review. This review will give readers a quick overview of all the

advantages and drawbacks of CA. Different policies have been also discussed through which it can be increased. The main purpose of this review is to increase conservation agriculture in farmland throughout the world.

2. About Conservation Agriculture

CA is a farming method that encourages the preservation of a permanent soil cover, fosters the diversity of plant species, and disturbs the soil as little as possible [6]. It enhances biodiversity and natural biological systems at the soil level, which helps increase the effectiveness with which water and nutrients are utilized and supports the maintained and improved production of crops. It has a greater role in modern agriculture than in traditional agriculture (Table 1). It modifies the processes and qualities of the soil more than traditional agriculture [7]. The provision of ecosystem services, such as regulating the climate through carbon sequestration and greenhouse gas emissions and supplying water with the help of the biological, chemical, and physical characteristics of the soil, can be impacted by these changes. Lower emissions of greenhouse gases (nitrous oxide and methane) have been observed in some situations when conservation agriculture is compared with conventional farming [8]. CA can increase soil moisture retention, leading to higher and more consistent yields during dry seasons; however, it is unknown how much residue and how much soil organic matter are needed to achieve increased soil moisture content. CA was initially developed to control water and wind erosion [9], but it is now recognized for providing various ecosystem services. Agricultural revenues, the availability of food, and the ability of the poor to avoid hunger are all directly impacted by climate change [10]. Indirectly, it affects factor pricing ratios, which affect whole food systems and the development of technological advancement [11, 12]. CA is making an important contribution to keeping crop production intact from the effects of climate change. CA practice is increasing day by day for its usefulness in modern agriculture (Table 2).

3. Principles of Conservation Agriculture

There are three main principles of CA. First, soil disturbance rate is minimum: Minimal soil disturbance is the first key idea in conservation agriculture [13]. This is important for preserving soil minerals, reducing erosive forces, and preventing water loss. Soil tillage has historically been considered an important step in the introduction of new crops to a particular region in agriculture. Tilling the soil would promote mineralization, increasing its fertility. A loss in soil fertility can arise from tilling the soil, which can also cause substantial erosion and crusting. With little soil disturbance, it is also possible to reduce the loss of habitats for soil micro- and macro-organisms by the CA method [14]. Porosity is needed for water transport. Minimum soil disturbance and moderate organic matter oxidation, release, and retention are necessary to retain an adequate amount of respiration gasses in the root area [15].

Second, keeping the soil's top covered in a permanent mulch layer: The idea of managing topsoil to create a long-lasting organic soil layer can promote the growth of organisms inside the soil structure [16, 17]. This growth will decompose any mulch that was left on the soil's surface. This mulch will break down into a sizable amount of organic matter, which will act as a surface-level fertilizer for the soil. Additionally, mulching slows down runoff and the impact of raindrops, reducing soil erosion and runoff. Improvements are made in carbon sequestration, biological activity, soil aggregation, and biodiversity.

The third premise is the application of diverse crop rotations [18]. This strategy makes it impossible to rotate pests like weeds and insects with a specific crop. Rotational crops will act as a natural pesticide against particular pests. The construction of soil infrastructure can also benefit from crop rotation. Crops planted in rotation allow the growth of many roots, which enhances water penetration. Legumes, which include rotations that can disrupt pest life cycles, lower off-site pollution, boost biological nitrogen fixation, and increase biodiversity. This helps to minimize the risk of pest populations [19].

Numerous purposes are supported by the three CA principles: Preventing erosion and soil deterioration, weed, disease, and insect control; preserving soil moisture, generating a lot of above- and below-ground biomass to safeguard the soil, maintaining soil nutrients, maintaining the biological infrastructure of the soil; and keeping the C/N ratio in balance while rotating crops [20].

4. Benefits and Challenges of Conservation Agriculture

Due to its many potential advantages, conservation tillage has attracted a lot of attention from the academic, financial, and industrial worlds. Now, it is popular among farmers. By using residue cover during zero-tillage farming, irrigation water is conserved, soil organic matter progressively rises, weeds are controlled, and the expense of equipment, fuel, and labor involved with tilling is decreased. Soil infiltration is increased, soil moisture is retained, and topsoil erosion is reduced when the soil is not disturbed [21]. In spite of harsh weather made worse by climate change, conservation agriculture's increased water intake provides more consistent harvests. CA encourages the possibility of intensification and diversification. It also increases incomes in rural areas, preventing rural-urban migration.

Conservation agriculture is biologically and ecologically sustainable, the varied plant root systems improve the soil systems [22], and biological makeup and functioning of the soil are improved, improving ecological and environmental processes while benefiting farmers and society as a whole [23]; CA has the ability to renew and restore damaged agricultural lands, enhances robustness and efficiency. CA has significant impact on the ecosystem (Figure 1).

Despite the fact that CA provides many benefits for both farmers and the environment, producers may face challenges while attempting to apply it. If there are any marshes or poorly draining soils, adoption can be challenging. There

Table 1: Advantages of conservation agriculture compared to traditional agriculture.

Main concern	Conservation agriculture	Traditional agriculture
Erosion soil	Minimum	Soil and wind erosion
Soil health	Good	Poor
Soil temperature	Moderated	More variable
Soil moisture	Best	Lowest when soil pores become blocked
Soil organic matter	Organic accumulation in the top layers	Oxidizes SOM
Weeds	After 2-3 years, progressively reduce	Increases the germination of weed seeds
Cultivation costs	Low	High
Yield	Higher	Lower

might not be enough crop leftovers to cover the ground since farmers frequently use crop residues for feed first when they are in short supply. Since CA involves a lot of information, not all farmers may have access to the education and training required to apply it. Starting CA requires the use of appropriate seeders, but not all farmers may have access to or be able to buy these. Some other challenges are scientists and extension personnel with rigid attitudes, who make it hard to know how the system works; technical difficulties; lack of long-term research outlook; and inadequate government policies for managing residues. Increased yields may not be immediately felt by farmers, but conservation agriculture steadily increases production.

Other challenges are improper crop harvesting and management practices, leaving leftovers on the soil's surface, lack of suitable farm implements, and farmers' mindsets [8].

5. CA Research Scenario in Bangladesh Context

Zero tillage is the most practiced conservation technique in Bangladesh. In the Bangladesh scenario, it is observed that the level of education, extension media contact, and organizational participation of the farmers have a great relationship with conservation agriculture practice. We selected some studies that indicate the research scenario in Bangladesh on CA.

In a study, 240 farmers were selected at random from Durgapur upazila in Rajshahi district and Baliakandi upazila in Rajbari district in order to ascertain the proportion of Bangladeshi farmers who practice conservation agriculture. According to the survey results, 47.50% of farmers use conservation agricultural technology at a medium level, while 36.67% use it at a high level [24]. The agricultural yield of various types of farmers rose by approximately 0.9–1.3% when conservation agriculture techniques were used, according to a study of 450 farmers from five districts in Bangladesh [25]. Another study discovered that, under conventional tillage maize and rice maize system yields ranged between 7.8 ton/ha and 12.5 ton/ha respectively. But in conservation practice, it was 9.0 tons/ha and 13.8 tons/ha on permanent beds. So, the yields were increased by 9.1% and 6.1%, respectively [26].

An investigation was carried out to determine the percentage of farmers who knew about conservation agriculture, with 300 farmers chosen from five districts (Mymensingh, Bogra, Tangail, Sherpur, and Jamalpur). According to the study, 26.0%, 25.0%, and 18.6% of farmers who were focused, proximal, and control, respectively, had a basic understanding of conservation agriculture practices. According to this study, such practices were received by 28.0%, 19.0%, and 15.3% of farmers, respectively [27].

On a study, 300 farmers were selected from five districts to know the percentage increase of crop productivity under conservation agriculture. The study's findings showed that focal, proximal, and control farmers' BCRs (benefit cost ratios) were 2.58, 2.24, and 2.18, respectively. There was an improvement in crop productivity: 5%, 1.1%, and 1.4%, respectively, for the region's focus, proximal, and control farmers [28].

In Bangladesh, farmers accept raised bed planting and minimum tillage technology in their fields. There are about 425 numbers of raised bed planters and 865 minimum tillage seed drills. 5,764 ha and 21,850 ha areas are covered under bed planting and minimum tillage system, respectively. There are 20,125 farmers involved in raised bed farming for various crop production methods [29].

The government and different governmental organizations and nongovernmental organizations should organize more training and demonstration activities on conservation agriculture involving all levels of farmers and extension workers to popularize the conservation agricultural practices throughout the country.

6. Policies for Conservation Agriculture

The required assistance must also be provided by the government and institutions. They need to be flexible, adaptable to the many shifting needs of farmers, and capable of minimizing risk during the transition phase. Policies should prioritize the following:

(1) Fostering participation from stakeholders through regional and national venues [30].

(2) Assisting in the implementation of national development plans for conservation agriculture's scaling up and adaptation to farmer needs [31].

(3) Using credit lines to simplify purchasing.

(4) Government field personnel, suppliers, and buyers should collaborate as a team to meet the needs and demands of farmers.

Table 2: The distribution of CA agricultural land (in 000 ha) globally and the related % change [6].

Region	CA cropland area (2015-16)	CA cropland area (2018-19)	Conservation agriculture area change in % (2015-16)	Conservation agriculture area change in % (2018-19)
Asia	13,930.20	17,529.02	25.8	3.6
Europe	3558.20	5601.53	57.4	5.2
Russia and Ukraine	5700.00	6900.00	21.1	4.5
New Zealand and Australia	22,665.00	23,293.00	2.8	74
S and C America	69,895.00	82,996.18	18.7	68.7
North America	63,181.00	65,937.22	4.4	33.6
Africa	1509.24	3143.09	108.3	1.1
Total	180,438.64	205,400.04	13.8	14.7

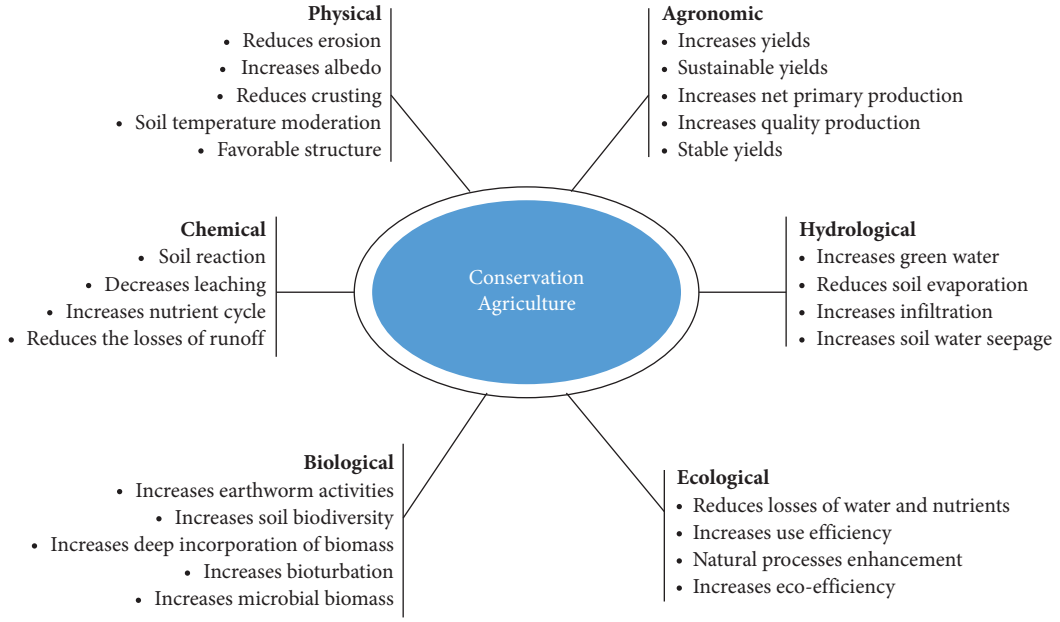

Figure 1: Ecological services provided by conservation agriculture.

(5) Utilizing technical extension initiatives to advance technology and capacity growth [32].

7. Conclusion and Future Work

At present, CA practices are leading to great improvement in agriculture and it represents a fresh paradigm in modern agriculture. It alters the way agricultural land has been managed and the production system. Initially, serious issues encountered by farmers, particularly wind and water erosion, served as the primary impetus for the introduction of CA. CA must be viewed as a key component of sustainable food systems and environmentally sound management. Based on existing works of literature, additional research should seek to understand (1) how conservation agriculture is impacted by climate change and how it affects the climate, (2) the interaction between microclimate and CA, (3) the relationship and interaction between soil management and CA, and (4) the easiest way to make available modern ideas understandable about CA to all-level farmers. So that, they can easily use it on their land. The CA worldwide community must keep working to enhance the effectiveness and quality of CA systems while simultaneously doing strategic research that would enable CA systems to function biologically or organically with little to no input from synthetic agrochemicals. Supporting smallholder farmers as they switch from traditional tillage systems to CA systems with greater returns and incentive environmental benefits is equally crucial. Smallholder farmers already practice CA at a higher rate than large-scale producers. However, it is now more important than ever to pay close attention to the requirements of smallholder farmers. Government should be made aware to support CA systems, which will bring numerous long-term and short-term benefits.

Data Availability

No numerical data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

P.B.A. conceptualized and designed the structure. P.B.A., S.A.S., and A.R.R. curated data, wrote the manuscript, and prepared the final version of the manuscript. P.B.A. visualized and revised the manuscript. All authors have read and agreed to the published version of the manuscript.

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