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Chapter

Adoption of Conservation Agriculture as a Driver of Sustainable Farming: Opportunities, Constraints, and Policy Issues

Pomi Shahbaz, Shamsheer ul Haq and Ismet Boz

Abstract

Sustainable farming is critical for rural development and global food security, but it is threatened by intensive agriculture and climate change. Conservation agriculture (CA) is a sustainable farming system developed in response to intensive agriculture, environmental degradation, and climate change caused by traditional agriculture systems. This chapter discusses the role of CA in sustainable farming and examines the factors influencing CA adoption globally through a review of previous studies. The review results indicated that CA assists farmers increase farm sustainability by influencing economic, social, and environmental dimensions through minimum mechanical soil disturbance, permanent soil cover, and diversification. CA adoption aims at maintaining soil fertility, improving farm yield, and reducing the use of external inputs necessary for sustainable farming. Therefore, the number of CA-adopting countries has grown significantly over the last decade but its adoption is constrained by a variety of factors such as farmers’ demographic characteristics, farm characteristics, institutional factors, capital ownership, cognitive factors, and farm manager entrepreneurial ability. Moreover, abundance of small-scale farming and a lack of awareness about the role of CA in sustainable farming also pose a challenge to the global adoption of CA. Farmers’ entrepreneurial abilities and awareness of CA benefits should be improved to increase adoption of CA and sustainable farming.

Keywords: conservation agriculture, farm sustainability, sustainable farming, sustainable land management, sustainable agriculture

1. Introduction

Farming systems play a critical role in ensuring food security worldwide, and healthy soils are necessary for sustainable food production. Farming systems are under huge pressure to meet the increasing demands of agricultural commodities due to an increasing global population and climate change. Farming systems try to meet growing demands through intensified agriculture. Intensified agriculture poses a threat to sustainable farming as it affects the quality of natural resources [1]. Monoculture farming, heavy use of off-farm inputs, and machinery have multifaceted negative
impacts on the environment and soil health [2]. The intensive nature of conventional farming raises the risk of soil degradation. Moreover, land and soil degradation have increased dramatically because farming systems have transitioned from high manpower and low input production to low manpower, high use of external inputs, and a highly mechanized system. Machines with more horsepower that move faster than required speed harm the quality and health of the soil. This also increases the loss of soil organic matter, slows water infiltration, and lowers the soil’s ability to hold water, all of which are prerequisite for sustainable production [3]. Thus, degradation of land and ecological system services due to intensified agriculture should be avoided, and previous degradation of land must be remedied for sustainable farming [4].

In addition to intensified agriculture, climate change also poses a serious threat to global farming sustainability. Agriculture accounts for nearly one-fourth of total global greenhouse gas emissions and is also directly affected by the effects of climate change [5]. Thus, agriculture is both a cause and an affectee of climate change [6]. Moreover, extreme climatic events are occurring more frequently and are having a severe impact on agriculture by degrading soil and land health [7].

Climate change and land degradation necessitate a more sound and sustainable farming production paradigm that is both environmentally sustainable and economically profitable without compromising yield and productivity [5]. Furthermore, the production system’s flexibility and strength must be increased in response to shocks and stress caused by climate change. Similarly, increasing biodiversity above and below ground in the crop production system has numerous important benefits that improve soil health and enable farmers to produce in a way that is supported by society [8]. All of these measures result in sustainable farming, which includes increased production (economic sustainability), a healthier environment, and high resilience to climatic shocks and stress (environmental sustainability) [9]. To conserve and enhance the natural habitats and resources of the environment, “sustainable production intensification” is a new production paradigm [10], which acknowledges the prerequisite for productive and remunerative farming [4, 11]. So, all of these goals can be reached with a no-till method, which is also called Conservation Agriculture (CA). Tilage has a significant impact on soil health because it disrupts the soil’s water retention capacity, temperature, and evapotranspiration process [1]. Furthermore, tillage results in a significant loss of soil organic carbon [12].

CA is a sophisticated modern production system that enables farmers to perform sustainable production, which leads to the achievement of sustainable farming goals [13]. Somasundaram et al. [14] define “CA” as “a set of management practices for sustainable agricultural production that avoids excessive soil disturbance in order to protect it from soil degradation processes such as erosion, compaction, structural/aggregate breakdown, loss of soil organic matter, and nutrient leaching. FAO [15] defines CA as a farming system that promotes minimum soil disturbance, the maintenance of a permanent soil cover, and the diversification of plant species. Thus, CA has three principles, which are as follows: 1) low mechanical soil disturbance; 2) permanent soil cover; and 3) diversification (Figure 1).

No-tillage, minimal disturbance, and direct seeding without tilling the soil are all examples of minimal mechanical soil disturbance. It explains how to cause the least amount of soil disturbance through cultural farm practices or mechanical operations. Direct seeding into soil is encouraged for sustainable farming [16]. FAO [15] also suggested that the disturbed area should be 15 cm wide or less than 25% of the total cropped area. Minimal or no-tillage is an effective erosion control measure that increases fertilizer and water use efficiency and crop yield [17].
Permanent organic soil cover refers to the ground surface’s permanent biomass soil mulch cover. It is particularly encouraged when there is a long gap between harvesting and planting the next crop [15]. Crop biomass, cover crops, and rootstocks can all be preserved. Microbes decompose the cover crop naturally in the soil [18]. When the field is empty, it protects the soil and mobilizes and accelerates the nutrient recycling process. Soil cover also preserves the soil structure and reduces hardpans and compacted layers. Moreover, it also reduces weed growth and pest attacks.

Diversification refers to the preservation of soil nutrients through crop rotation, which entails the proper sequence and association of annual and perennial crops, as well as a balanced mix of legume and nonlegume crops [5]. Crop rotation feeds the soil because many nutrients leach down to the deeper layers of soil and are no longer available for better crop growth. These nutrients are naturally recycled through proper and balanced crop rotation [15].

As a result, CA is critical for sustainable farming, and this chapter will discuss CA’s brief history and current global situation. Furthermore, the chapter will discuss the role of CA in sustainable farming and list the CA practices that are being implemented on farms around the world. The chapter also aims to provide information on the challenges that farmers face when implementing different farm practices on their farms and concludes with policy recommendations for improving the CA situation, especially in developing countries.

2. History and global status of CA adoption

2.1 Historical background of CA

Tillage is the use of farm machinery to manipulate soil. Tillage has a long history, dating back a million years, when men transitioned from hunting to sedentary and conventional farming, particularly in the Nile, Euphrates, Tigris,
Indus Valley, and Yangtze valleys [19]. Tillage was traditionally used to soften the soil layers for seedbed preparation, control and manage weeds, and improve the oxidation mineralization process [13]. In the years following the industrial revolution in the 1990s, the invention of the engine made machinery available for performing farm activities, such as plowing, planking, seed drilling, and so on. In the Midwestern United States, dust bowls destroyed large areas, and tillage-based farming was called into question for the first time in history in the 1930s [20]. As a result, for the first time, CA practices such as reducing tillage and covering the soil for soil protection were adopted on farms. The seedling machine was invented in the 1990s, allowing seeds to be planted without disturbing the soil. CA was first theoretically proposed in 1943 by Edward H. Faulkner in the manuscript “Plowman’s Folly” [21]. The CA idea has become more and more popular over time and is used a lot in sustainable farming.

No-tillage was first used in farming in Brazil in the early 1970s, and agriculture has been transformed by incorporating no-tillage practices into the farming system known as CA today. Furthermore, in the 1970s, no-tillage was practiced in West Africa [22, 23]. Before CA reached a significant adoption level in South America and the rest of the world, significant improvements in farm equipment and agronomic practices regarding CA were made and developed to enhance crop growth and machine efficiency. Also, as fuel prices went up in the 1970s, farmers switched to a system that farming resources. Commercial farmers used the CA to avoid soil erosion caused by drought, along with the fuel-saving system [24].

Since the early 1990s, the CA has become well known and has spread rapidly, and agricultural systems in Brazil, Paraguay, and Argentina have been transformed into CA. The development of the CA system drew the attention of the rest of the world, and international organizations such as FAO, CGIAR, IFAD, EU, ACT, CIRAD centers, and many others began to take an interest in the CA system’s promotion. Following that, a study tour to Brazil, research projects, and workshops were organized all over the world to raise awareness and increase CA adoption. After that, CA adaptation has been observed in African countries such as Tanzania, Zambia, and Kenya, as well as in Asia, particularly in China, Pakistan, India, and Kazakhstan. The CA was also significantly adapted in developed countries such as Australia, Spain, Canada, and Finland at the end of the millennium [25]. The CA adaptation is not restricted to specific geographical and ecological environments. Farmers practice it from the Arctic Circle (e.g., Finland) to the tropics (e.g., Uganda, Kenya). CA has also been adopted at 3000 m altitude and under severe environmental conditions with 250 mm of rain a year (e.g., Morocco, Western Australia), as well as in countries such as Brazil and Chile where heavy rainfall occurs during the whole year. No-tillage is also used in sandy and clay soil types. It is used in soils ranging from 90% sand (as in Australia) to 80% clay (as in Brazil’s Oxisols and Alisols). Similarly, the CA system can grow any crop [20, 26].

2.2 Global situation of CA adoption

CA is currently practiced in over 79 countries worldwide [5], and the number of farmers adopting CA practices on farms is increasing in both developed and developing countries due to its beneficial effects on farm resources and crop production. CA is practiced on every continent, but Europe has the most countries that have adopted
CA (Figure 2). CA has also begun to gain traction in Asia and Africa, with the number of countries adopting CA on these two continents increasing significantly over the last decade.

Despite the fact that the number of countries adopting CA has increased significantly, the area under CA remains minimal in comparison to the total world cropped area. In 2015/16, the total area under CA in the world was 180.44 million hectares. Europe has a large majority of CA-adopting countries, but its share of the total global CA area is negligible. Similarly, Asia and Africa contain significant world agricultural land as well as habitats for the world’s large population, which is more vulnerable to climate change and food insecurity, but their share of total CA world area is also minute.

![Figure 2](image_url)

**Figure 2.** Area under CA and number of adopting countries on each continent.

<table>
<thead>
<tr>
<th>Continent/country</th>
<th>CA area share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>America and the Caribbean</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>32.47</td>
</tr>
<tr>
<td>Brazil</td>
<td>24.05</td>
</tr>
<tr>
<td>Australia and Oceania</td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>98.39</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1.61</td>
</tr>
<tr>
<td>Asia</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>64.61</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>17.95</td>
</tr>
<tr>
<td>Europe</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>54.01</td>
</tr>
<tr>
<td>Spain</td>
<td>9.72</td>
</tr>
<tr>
<td>Africa</td>
<td></td>
</tr>
<tr>
<td>South Africa</td>
<td>29.09</td>
</tr>
<tr>
<td>Zambia</td>
<td>20.94</td>
</tr>
</tbody>
</table>

**Table 1.** Countries with the highest share in area under CA in their continents.
The United States and the Caribbean countries that practice CA have the largest share of the total CA area in the world, followed by Australia and Oceania. Table 1 depicts the major CA adopting countries by area on each continent. The United States accounts for nearly one-third, with Brazil accounting for nearly one-fourth of the total area under CA in America and the Caribbean countries. Australia is the largest CA adopter on the Australian continent. CA was widely practiced in Asia, with China accounting for nearly two-thirds of the total area covered, followed by Kazakhstan. Russia and Spain were major contributors to the CA area in Europe. South Africa alone accounts for nearly one-third of the total area under CA on the African continent.

3. Conservation agriculture and sustainable farming

Sustainable development is defined as “the ability of the current generation to meet their needs without jeopardizing future generations’ ability to meet their own needs” [27]. In order to apply the concept of sustainable development to farming, farming must be socially acceptable, economically viable, and environmentally friendly. Farming will therefore be sustainable if it is socially, economically, and environmentally sustainable [28]. Hobbs et al. [13] described CA as a modern way of farming that helps farmers achieve their goals of sustainable development through sustainable farming.

The impact of CA on crop yield can be used to explain CA’s role in achieving economic sustainability [29, 30]. A high crop yield is one of the farmer’s primary goals in order to enjoy a good economic return. Crop yield is affected by numerous management (timely and proper application of off-farm inputs) and ecological factors (uneven rains, harsh weather, water deficiency, etc.). CA is critical in reducing the negative impact of these factors on crop yield. No-tillage, for example, improves soil fertility and structure while also softening the soil, which improves seed germination and crop growth [31]. A well-grown crop with good germination results in a good crop yield, which increases the crop surplus. Farmers make a good profit from the high crop surplus, which lets farmers keep their high standard of living. CA also boosts crop yield and economic returns, which makes farming socially and economically more sustainable. Thus, the CA improves farmers’ long-term welfare by increasing crop yield, high economic returns, and food security [32–35].

Zheng et al. [36] discovered that adoption of CA practices has a positive impact on crop yield in China. The study showed that adoption of CA on farms significantly increases crop yields. However, the impact of CA on crop yields is dependent on geographical location, climatic conditions, and the type of adopted CA practice. The study also found that conventional tillage with straw retention produced better crop yields than no-tillage with straw retention. Moreover, the study also reported that CA practices produce better results in geographical locations with annual precipitation of less than 600 mm and a mean temperature of greater than 5°C. The potential for high crop yields with CA is greater in rain-fed areas than in conventional tillage systems [37]. The CA is more effective in terms of yield and farm productivity effects when all three CA principles are implemented in combination than when they are implemented alone on farms. Even sometimes, CA principles implemented separately can have a negative impact on farm productivity. Pittelkow et al. [29] stated that no-tillage has a negative impact on crop yield, but when combined with the other two principles (cover crops and crop rotation); it generates an equal or greater crop yield than conventional agriculture. Therefore, no-tillage, cover crop, and diversification (crop rotation) produce high crop yields ensuring the CA system’s economic sustainability [38–40].
The widespread adoption of three CA principles around the world has ushered in a new era of environmental control and mitigation for damages associated with conventional agriculture. No-tillage leaves the soil untouched, improving its physical properties, which is a major component of the environment. The organic carbon stock is three times more concentrated in the soil than in the atmosphere [31, 41]. Increased soil carbon level is highly associated with increased soil carbon level through improved mineralization processes, which reduces the negative effects of climate change on crop yield [42, 43]. CA provides climate-smart sustainable farming systems that enable farmers to cope with the adverse impacts of climate change [44]. Similarly, growing cover crops on fallow lands lowers the risk of soil erosion [45]. By covering the field where no primary crop is grown, it can control weed germination and enhance N-input leaching [46]. It also increases the soil’s water-holding capacity, maintains soil structure and porosity, and balances the nutrient cycle [47–50]. Similarly, crop rotation reduces climate vulnerability and improves soil health by reducing herbivores, increasing yields, and generating high economic benefits. It also provides a more stable planting system in extreme weather conditions [51–53]. Likewise, CA improves soil fertility [54], reduces soil erosion [55], improves water filtration and retention, and reduces greenhouse gas emissions [56], all of which contribute to the farming system’s high environmental sustainability. Therefore, the CA is an ideal solution for resolving the environmental problem in agriculture. CAs associated environmental benefit improves agriculture’s environmental sustainability.

Moreover, CA also contributes to social sustainability by increasing gender equality, labor participation, and farmer welfare, and it is expected that promoting the CA farming system will increase the participation of women in farming [57].

**Figure 3.** Conservation Agriculture (CA) and Sustainable Farming (SF).

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DOI: http://dx.doi.org/10.5772/intechopen.106002
For example, women’s participation in Zimbabwe increased grain yield and improved food diversity and security. Furthermore, the use of CA has altered intra-household decision-making between males and females. Women’s participation in decision-making, crop management, and improved agency were observed in Zimbabwe [58, 59]. Furthermore, crop residue retention can be used to describe the labor requirements of CA [60]. Women practicing CA are good time managers because they start clearing land on time to prepare it for early planting [61].

Based on the preceding discussion, it is clear that CA adoption helps farmers cope with climate change while also increasing farm-level sustainability (social, economic, and environmental). Thus, adoption of CA works as a driver of sustainable farming, as depicted in Figure 3. CA principles provide multifaceted benefits that lead to sustainable farming. Improving soil fertility, for example, improves farmers’ economic conditions, which in turn affects farms’ economic and social sustainability. Similarly, reducing the use of machinery for tillage reduces greenhouse gas emissions while also reducing costs, which helps to improve environmental, economic, and social sustainability. As an outcome, CA’s minimal soil mechanical disturbance principle influences all three dimensions of sustainability. Similarly, the other two CA principles help farmers improve their farms’ economic, social, and environmental sustainability. As a result, CA adoption can play a critical role in global farming sustainability.

4. Globally adopted CA practices and constraints

4.1 CA practices and factors influencing CA adoption on farms

CA practices aim to improve farm resource utilization by integrating natural resource management such as soil, water, and biological resources with the fewest external farm inputs [62]. Therefore, CA is being adopted all over the world in response to the growing concerns of national and international institutions related to farm sustainability, and CA is one of the most important and rapidly expanding adoption systems in all regions of the world. Different types of CA practices are preferred on different farms and in different regions depending on the climate, the land type, the farmer’s skills, and the farm’s resources. Moreover, the CA practices adoption on farms is also majorly dependent on the purpose of adoption CA. Moreover, the CA practices adoption on farms is also majorly dependent on the purpose of adoption. As a result, CA practices used in one country or farm may be different from those used in another country due to the difference in intended objectives of CA adoption.

Table 2 shows the CA practices adopted around the world, as well as the factors that influence the adoption of these CA practices on farms. Different types of CA practices are preferred on different farms and in different regions depending on the climate, the land type, the farmer’s skills, and the farm’s resources. According to the literature, farmers in different countries adopted different CA practices on their farms, but zero tillage/no-tillage was one of the most widely adopted CA practices on farms. The minimum or zero-tillage CA practice is widely used around the world, but crop residuals retention in the field is more complicated [74]. Moreover, cover crops and crop rotation are also commonly practiced CA strategies in the world. Crop rotation is underutilized in terms of pest control, disease cycle disruption, income risk reduction, and soil fertility [74].

Farmers’ demographic characteristics, farm characteristics, institutional and social inclusion, capital ownership, and cognitive factors (farmer attitude, CA perception, and farming behavior) were identified as major influencing factors in
<table>
<thead>
<tr>
<th>Country/Region</th>
<th>CA practices</th>
<th>Influencing factors</th>
<th>Objective/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria [63]</td>
<td>Zero tillage, minimum tillage, contour stripping, not burning field, tree planting, cover crops, dead tree trunks, mulching</td>
<td>Age, education, innovativeness, attitude toward conservation, risk bearing, credit, farm income, input-output prices, off-farm occupation</td>
<td>Soil erosion controlling</td>
</tr>
<tr>
<td>Rwanda [64]</td>
<td>Organic inputs</td>
<td>Monetary and physical factors, human capital, investment risk, wealth, and liquidity sources</td>
<td>Land conservation investment and organic inputs use</td>
</tr>
<tr>
<td>United States [65]</td>
<td>Conservation tillage, contour farming, strip-cropping, grass waterways</td>
<td>Farm size, age, college education, program participation, land tenure, annual precipitation.</td>
<td>Adoption of CA practices and land tenure</td>
</tr>
<tr>
<td>Zimbabwe [66]</td>
<td>Zero tillage, crop rotation, contour ridging technologies</td>
<td>Farm and farmer characteristics, institutional factors</td>
<td>Analyzing the adoption of CA by small farmers</td>
</tr>
<tr>
<td>Spain [67]</td>
<td>Not burning olive-de suckering debris, using shredded olive-pruning debris as soil cover, cover crops under mower control</td>
<td>Socio-economic characteristics of a farmer, social capital indicators, farm characteristics, farm management</td>
<td>Assessing the soil conservation practice as CA in olive groves</td>
</tr>
<tr>
<td>Zimbabwe [68]</td>
<td>Winter weeding, digging planting basins, crop residues, manuring, basal fertilizer, topdressing, Timely weeding, crop rotation</td>
<td>Age, Education, own land, drought power, Extension services, labor, conservation agricultural experiences.</td>
<td>Assessing the adoption of CA among different clusters of farmers.</td>
</tr>
<tr>
<td>Australia [69]</td>
<td>No-tillage, crop stubble, legumes rotation, controlled traffic farming.</td>
<td>Various socio-economic factors</td>
<td>Assessing the adoption of CA as climate change mitigation activity</td>
</tr>
<tr>
<td>Bangladesh [70]</td>
<td>Conservation agriculture principles</td>
<td>Farm size, family size, farming experience, age and education of head, extension services, farm and off-farm income</td>
<td>Impact of CA adoption farms' economic viability</td>
</tr>
<tr>
<td>Kenya [71]</td>
<td>Mulching, direct planting, shallow weeding, spraying herbicides</td>
<td>Attitudes, perceived norms and perceived behavioral control, farmer's perception Of the social norms towards CA, farmer's perceived behavioral control</td>
<td>Assessing the farmer's decision of selecting the CA over conventional agriculture.</td>
</tr>
<tr>
<td>South Africa [72]</td>
<td>No-till conservation agriculture</td>
<td>Age, gender, education, experience, training, extension, credit access, land size, income</td>
<td>Assessing the adoption of no-till conservation by small-scale farmers</td>
</tr>
<tr>
<td>Malawi [35]</td>
<td>Zero tillage, mulching of crop residual, and intercropping with legumes</td>
<td>Landholding, education, neighbor's adoption of CA, gender, no. of male and females in family</td>
<td>Decision-making analysis regarding CA adaptation</td>
</tr>
<tr>
<td>United States [73]</td>
<td>Conservation tillage, cover crops, diverse crop rotation</td>
<td>Location and spatial variable, age, college education, area under operation, family network index, organization network index, perception of environmental benefits of the practices.</td>
<td>Assessing the adoption of CA practices</td>
</tr>
</tbody>
</table>

Table 2. CA practices around the world and the factor influencing its adoption.
the adoption of CA practices worldwide. Age, education, farming experience, and family size were among the socio-demographic factors influencing the adoption of CA practices on farms. Farm size, farm income, and land tenure status were the farm characteristics that influenced CA adoption in various countries. Credit utilization and the availability of extension services were institutional determinants of CA adoption. Furthermore, farmers’ attitudes and perceptions were influential factors in the global adoption of CA practices. Giller et al. [75] also stated that socioeconomic factors play an important role in CA practice adaptation.

4.2 Challenges in adoption of CA practices on farms

Although CA is a driving force in achieving sustainable farming, there are numerous challenges and constraints that affect CA adoption on farms around the world, in addition to the factors discussed above. The first and most prominent challenge that limits the adoption of CA cited in previous literature is small-scale farming. Small farmers lack social inclusion, institutional support, capital, and other resources, and they are less likely to implement CA on their farms. Moreover, farmers with owned animal traction are also less likely to adopt CA practices such as minimum tillage/zero tillage on their farms due to readily available tillage sources. Farmers with animal traction typically replace mechanized soil management with animal-driven plowing [76].

Crop residual retention is also used as a CA practice in the fields by the farmers. Crop cultivation and livestock rearing are complementary to each other for farmers, especially small farmers in developing countries, but farmers with crop and livestock interaction tend to have low crop residual retention on their farms. Furthermore, livestock is a more important source of traction and income security in an emergency [76], and crop residuals are a vital source of animal feed [77]. Furthermore, managing crop residuals is more expensive than simply burning crop residuals. The cost of managing crop residuals is more than one-third higher than the cost of burning the residuals [78, 79].

Another major impediment to the adoption of CA practices such as crop rotation is a lack of timely seed availability, as well as dysfunctional markets for final farm outputs [80]. The other challenge faced by farmers in the adoption of CA practices on farms is the unavailability of advanced equipment required for CA adoption. The equipment is either unavailable or its financial costs are high, especially in developing countries. Other than the above challenges, lack of awareness about different CA practices and their associated benefits among farmers in developing countries limits the adoption of CA on farms.

5. Conclusion

Agriculture is one of the largest consumers of natural resources, and adopting sustainable farming systems is necessary not only to preserve natural resources but also to meet the food needs of the world’s ever-increasing population under climatic change scenarios. A sustainable farming system is one that is socially acceptable, economically viable, and environmentally friendly. CA is a sustainable system that helps farmers improve farm sustainability by influencing economic, social, and environmental dimensions through its three basic principles. These three principles of CA are as follows 1) minimal mechanical soil disturbance; 2) permanent soil cover; and 3) diversification. The CA system is intended to improve and maintain soil fertility while
reducing the use of external farm inputs. Thus, the CA system increases crop yields while decreasing input costs, affecting farmers’ economic and social sustainability. Similarly, CA practices aid in mitigating the effects of climate change on farms and also reduce the use of machinery and chemicals in the fields. All of this contributes to the farmers’ environmental sustainability. As a result, implementing CA practices on farms is critical not only for the sustainable management of agricultural land but also for the overall sustainability of the farming system.

The European continent has the most CA-adopting countries, and the United States is the world’s largest CA adopter in terms of area. Despite the fact that CA is being adopted in many countries around the world, the area under CA remains very small in comparison to the world’s total cultivable area. Farmers’ demographics, farm characteristics, institutional and social inclusion, capital ownership, and cognitive factors (farmer attitude, CA perception, and farming behavior) were identified as major influencing factors in the global adoption of CA practices. Furthermore, small-scale farming as well as a lack of awareness about the benefits of CA is regarded as major barriers to CA adoption worldwide.

CA can also play an important role in achieving the Sustainable Development Goals in developing countries, as agriculture is a major driver of their economies. The continuous degradation of natural resources, particularly land, is the primary cause of unsustainable farming systems all over the world. As a result, developing countries should increase the adoption of CA practices in order to transition from unsustainable to sustainable farming systems. The following suggestions are recommended for increasing CA adoption in developing countries:

In order for CA to be adopted in developing countries, farms must be treated as enterprises like any other business. So, farmer entrepreneurship and a culture of entrepreneurship in farming should be encouraged to enhance the adoption of CA and sustainable farming by involving all agricultural socio-economic networks (farmers and their associations, farmer cooperatives, research and advisory organizations, market and chain parties, and government and social agencies).

Increasing farmer awareness about the benefits of the CA farming system is critical to the adoption of CA practices on farms in developing countries. The agricultural extension system remains an important source of information for farmers. As a result, agriculture extension systems can play an important role in the adoption of CA and sustainable farming in developing countries by creating awareness among the farming community. Through their agricultural extension network, policymakers need to develop a comprehensive plan for educating farmers, particularly small-scale farmers, about various CA practices and the benefits associated with them. Before providing information to farmers, the first step should be to train extension workers who are directly involved with farmers to improve their own knowledge of CA. Furthermore, in order to achieve sustainable farming goals, the agricultural extension network must be expanded in terms of capacity and outreach to the larger farming community, particularly small farmers and those living far from city centers. Modern information and communication channels should also be used to raise farmers’ awareness of the benefits of CA practices and sustainable agriculture along with traditional information systems.

Furthermore, small farmers must be provided with CA equipment for the adoption of CA practices such as zero tillage machines, as the majority of farmers in the developing world have subsistence land sizes.

Finally, engaging the younger generation in agriculture is critical to sustainable farming in both the developing and developed worlds, as youth interest in agriculture
as a career has declined dramatically. Therefore, policymakers should look for ways to increase youth participation in agricultural activities in order to ensure sustainable farming.

Conflict of interest

The authors declare no conflict of interest.
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