

Conservation agriculture and sustainable development goals

Muhammad Farooq

Department of Plant Sciences, College of Agricultural and Marine Sciences, Sultan Qaboos University, Al-Khoud, Oman

*Corresponding author's e-mail: farooqcp@squ.edu.om

Conservation agriculture (CA) aims to achieve productive and sustainable farming while preserving the natural resource base and environment. This article explores how CA aligns with Sustainable Development Goals (SDGs) of the United Nations and contributes to their achievement, particularly SDG 2: Zero Hunger, SDG 6: Clean Water and Sanitation, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action, and SDG 15: Life on Land. CA has gained significant attention as a sustainable farming system on over 200 million hectares of global cropland, with an annual increase of 10 million hectares since 2008. The principles of minimum soil disturbance, diverse crop rotations and permanent soil cover help improve soil health, nutrients and water management, and contribute to biodiversity preservation. By encouraging sustainable agriculture and enhancing nutrition, SDG 2 seeks to end hunger. CA practices enhance soil health and nutrient availability, increasing crop productivity and reducing reliance on synthetic inputs like pesticides and fertilizers. The resilience of CA to climate change challenges further supports food production. For SDG 6, minimum tillage and soil cover components of CA help reduce soil erosion, resulting in cleaner water by preventing sedimentation in water bodies. Improved water management and conservation contribute to sustainable water use and sanitation. SDG 12 seeks responsible consumption and production patterns. CA promotes efficient resource use, reduces waste, and minimizes the negative environmental impact of agricultural inputs, leading to sustainable production systems with less reliance on external inputs. Regarding SDG 13, CA practices improve soil and water management, increase soil carbon absorption, and lower greenhouse gas emissions, all of which help agricultural systems become more resilient to climate change. Lastly, SDG 15 focuses on life on land preservation. CA's promotion of biodiversity through cover cropping and decreased chemical use provides habitats for organisms, supporting ecosystem services and sustainable land use. In conclusion, CA plays a significant role in achieving multiple SDGs by promoting sustainable agriculture, conserving resources, mitigating climate change, and preserving biodiversity. The adoption and expansion of CA practices are essential for a sustainable and resilient future.

Keywords: Biodiversity, climate change, food security hunger, United Nations.

INTRODUCTION

Conservation agriculture (CA), a suite of technologies encompassing minimum tillage, soil cover, and diversified crop rotations, strives to establish productive and sustainable farming systems while simultaneously safeguarding and enhancing the natural resource base and environment. CA contributes to effective management of nutrients and water, and biodiversity preservation (Landers *et al.*, 2021). This is a sustainable farming system developed and implemented in response to intensive agriculture, climate-induced adversities and environmental degradation.

The contribution of agriculture to Sustainable Development Goals (SDGs) demands climate-smart innovations and sustainable farm approaches (Jat *et al.*, 2020). In the recent

decade, great focus has been given to CA. This system is being practiced on more than 200 million hectares (12.5% of global cropland), with an annual increase in area at 10 million hectares since 2008 (Kassam *et al.*, 2022). The sustainability of crop production systems and food security are heavily dependent on the soil health natural resource base. Consequently, the presence of productive and fertile lands plays a significant role in achieving higher yields, meeting human livelihood needs, and serving as a fundamental basis for attaining the SDGs (Pereira, 2019).

CA aims to enhance crop productivity with environmental sustainability which is central to the issues of poverty, hunger, health, education and sanitation- the core priorities in identified SDGs (Fig. 1). CA approach can help mitigate the



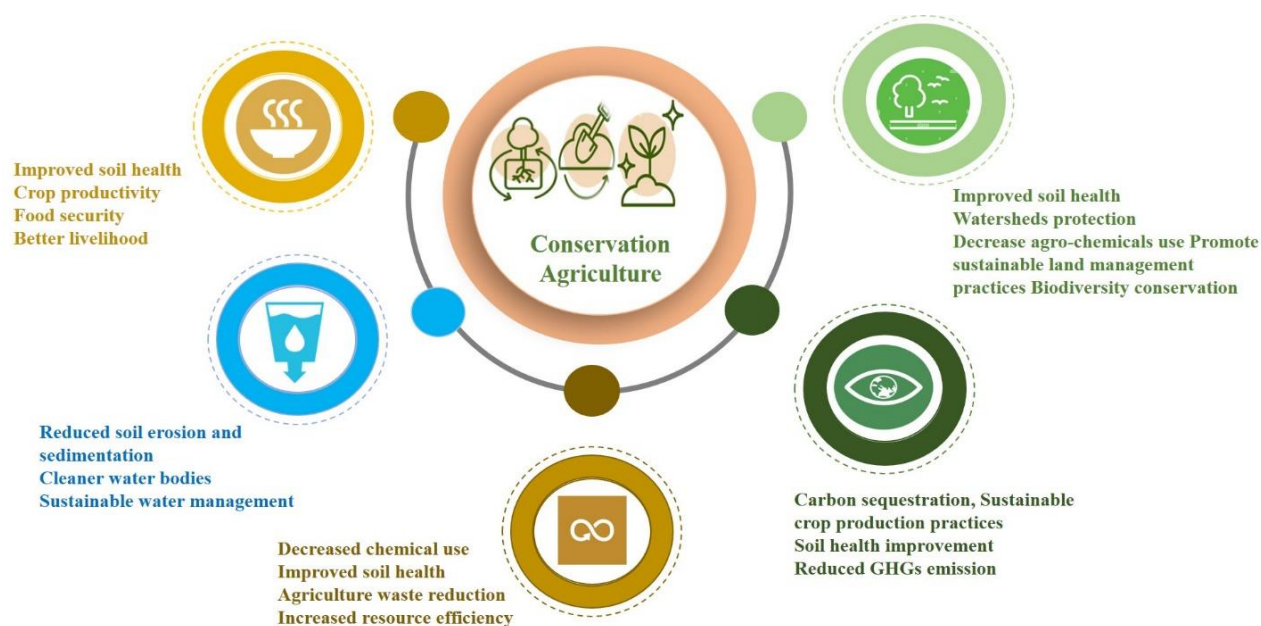


Figure 1. Conservation of agriculture's alignment with sustainable development goals.

negative climate change impacts- a great future concern. CA also contributes to decrease the pollution to a reasonable extent which is beneficial from a health and environmental point of view (Chaudhari *et al.*, 2021), and is a viable option for meeting the SDGs (Chaudhari *et al.*, 2021). In CA, cultivating multiple crops significantly benefits society by improving soil health, conserving biodiversity, and reducing pest pressure, but it also helps farmers with high-income generations (FAO, 2018).

Figure 1 illustrates how Conservation Agriculture (CA) practices align with and contribute to achieving multiple Sustainable Development Goals (SDGs), including Zero Hunger, Clean Water and Sanitation, Responsible Consumption and Production, Climate Action, and Life on Land. CA improves soil health, water management, and biodiversity conservation, making it a vital approach for promoting sustainable farming systems and supporting the broader SDGs.

At the heart of CA's novelty lies its integrated approach toward achieving productivity and sustainability in agriculture. CA has demonstrated potential to contribute to the Sustainable Development Goals, addressing poverty and hunger and mitigating climate change impacts, significantly advancing sustainable farming practices. This study delves into CA's specific impacts and outcomes on small landholder farms, examining its potential to enhance sustainability, promote equitable resource distribution, and achieve the broader SDGs. By understanding the multifaceted benefits and challenges of CA, we hope to contribute to the growing body of knowledge surrounding sustainable agricultural

practices and inform policymakers, farmers, and stakeholders about the potential of CA in shaping a more sustainable and resilient future.

SUSTAINABLE DEVELOPMENT GOALS (SDGs)

In 2015, the 17 SDGs were formed as a worldwide commitment by all 193 UN Member States under the 2030 Agenda for Sustainable Development. These objectives represent a global rallying cry to end poverty, safeguard the environment, and promote prosperity for all people. They encourage long-term progress in economics, society, and the environment by tackling some of the world's most pressing problems. Below is a list of all 17 goals:

1. **No poverty:** The objective is to eradicate poverty in all its manifestations and on a global scale.
2. **Zero Hunger:** The objective aims to address the issue of hunger by increasing production of nutritious food in a sustainable fashion.
3. **Promoting Good Health and Well-being:** Ensuring the attainment of healthy lives and the promotion of well-being across all age groups.
4. **Quality Education:** To guarantee comprehensive and fair access to quality education and foster lifelong learning opportunities for all individuals.
5. **Gender Equality:** The pursuit of gender equality and the empowerment of women and girls,
6. **Clean Water and Sanitation:** To guarantee the accessibility and enduring management of water and sanitation for all individuals.

7. **Accessible and Sustainable Energy:** Ensuring universal access to affordable, reliable, sustainable, and contemporary energy sources for all individuals.
8. **Decent Work and Economic Growth:** The objective is to foster a climate of sustained, inclusive, and sustainable economic growth, while also promoting full and productive employment opportunities and ensuring decent work conditions for all individuals.
9. **Industry, Innovation, and Infrastructure:** The objective is to develop robust infrastructure, encourage inclusive and sustainable industrialization, and foster innovation.
10. **Promoting Equity:** Fostering a more equitable distribution of resources and opportunities both within nations and across borders.
11. **Sustainable Cities and Communities:** The objective is to promote inclusivity, safety, resilience, and sustainability in cities and human settlements, thereby fostering sustainable cities and communities.
12. **Responsible Consumption and Production:** This objective aims at promoting sustainable consumption and production patterns.
13. **Climate Action:** Implementing immediate measures to address the challenges posed by climate change and its associated consequences.
14. **Life Below Water:** Preservation and responsible utilization of marine ecosystems and resources for the purpose of achieving sustainable development.
15. **Conservation and Sustainable Management of Terrestrial Ecosystems:** This objective aims to safeguard, rehabilitate, and advance the responsible utilization of land-based ecosystems, while effectively addressing challenges such as forest management, desertification, land degradation, and the preservation of biodiversity.
16. **Peace, Justice, and Strong Institutions:** This objective is aimed at promoting the establishment of peaceful and inclusive societies for contributing to sustainable development. It emphasizes the importance of ensuring access to justice for all individuals and the creation of effective, accountable, and inclusive institutions at various levels.
17. **Partnerships for the Goals:** Enhancing the mechanisms of implementation and reinvigorating the global partnership for sustainable development.

CONSERVATION AGRICULTURE AND SDGs

These goals provide a comprehensive blueprint for all countries and stakeholders to work together toward a more sustainable and equitable future for people and the planet. The SDGs will be achieved by 2030, and progress is continually monitored and reviewed to ensure that global efforts remain on track. Out of these SDGs, CA aligns with several goals established by the United Nations; a) SDG 2: Zero Hunger; b)

SDG 6: Clean Water and Sanitation; SDG 12: Responsible Consumption and Production; d) SDG 13: Climate Action; e) SDG 15: Life on Land. A detail description of how CA aligns with SDGs is given below.

SDG 2-Zero Hunger: CA can be important in achieving SDG-2 (Zero Hunger). SDG-2 aims to end hunger by promoting sustainable agriculture and improving nutrition, thus achieving food security (Banik 2019). The CA practices such as minimum disturbance of soil, permanent soil cover, and crop diversification improve the availability of soil nutrients and enhances water retention, which are indicators of good soil health, thus improving the productivity of crops and enabling the farming community to grow more crops and get more food from same or even small landholdings (Cárceles Rodríguez *et al.*, 2020). Crop production in the coming years will have to produce more food from less land by efficiently using natural resources with minimal environmental impact. This approach will help in maintaining a balance between demand and food production by conserving soil health for future generations. This approach will help balance demand and food production by conserving soil health for future generations. This can be achieved by adopting sustainable crop and soil management practices (i.e., CA) that help improve soil health parameters and reduce costs at the other end (Hobbs *et al.*, 2008). Conservation practices focus on utilizing varieties and livestock breeds that have high productivity and minimize the use of inputs with negative environmental impacts.

By promoting sustainable farming systems, CA decreases the reliance on synthetic inputs, e.g., pesticides and fertilizers, thus decreasing their negative impacts on human health, the environment and the ecosystem and increasing the viability of food production systems on a long-term basis. It is also well documented that CA helps farmers adapt to climate change challenges (e.g., extreme weather events and erratic rainfall spells) (Choudhary *et al.*, 2016). On the other hand, CA improves soil structure and enhances soil health, thus decreasing soil erosion, increasing water infiltration and increasing the crop's ability to withstand floods and drought. The concept of CA is becoming a viable alternative to maintain soil health and agricultural sustainability, leading to an increase in long-term productivity. Soil conservation services under the CA increase soil capacity to retain water and nutrients, thus playing a pivotal role in preventing land degradation that eventually promotes land productivity and contributes to implementing SDG2 (Zero Hunger) (FAO and ITPS, 2015). Researchers agreed that various CA practices had significant benefits for agricultural, economic and environmental performance indicators; for instance, less soil tillage along with crop residue cover increases yield (6%) and provides additional income (25%) (Jat *et al.*, 2020).

This resilience is crucial for maintaining food production on the eve of climate change. CA also enhances farmers' income and food security by decreasing the cost of production and enhancing productivity (Anghinoni *et al.*, 2021). It also enhances sustainable agricultural practices, which have long-lasting beneficial impacts on the livelihood of farmers. CA can also enhance food access and nutrition by improving production and agricultural efficiency (Amgain *et al.*, 2022). CA, when combined with value-chain interventions and post-harvest management, can ensure the availability of nutritious food to the most vulnerable populations, thus decreasing malnutrition and improving human health. Diversifying production helps stabilize household income, build system resilience to climate change, reduce community vulnerability to shocks like price hikes in food commodities, and improve security (FAO, 2018).

In conclusion, CA ensures the sustainability of food production systems with enhanced productivity and improved livelihood, which are key to achieving SDG-2 (Zero Hunger). By adopting the CA practices, we can maintain a lifestyle where everyone can access sufficient, safe and nutritious food.

SDG 6. Clean Water and Sanitation: CA is also closely associated with SDG 6 (Clean Water and Sanitation). SDG 6 aims to ensure water availability and sustainable management and sanitation. The practices of CA, e.g., permanent soil cover and minimal soil disturbance, reduce soil erosion, thus decreasing water bodies sedimentation and thus maintaining water quality and cleaner water for all (Palm *et al.*, 2014; Mugandani *et al.*, 2021). CA also improves the soil's structure and enhances the water infiltration and soil water retention capacity (Cárceles Rodríguez *et al.*, 2022), which aids in groundwater recharge while maintaining water availability in the rootzone with a simultaneous decrease in runoff. Thus, CA contributes to sustainable water use and conservation by promoting better water management (Mugandani *et al.*, 2021).

The CA promotes the judicious use of agricultural inputs such as pesticides and fertilizers and encourages the integrated use of nutrients and integrated pest management approaches while decreasing the risk of runoff of hazardous agrochemicals into water bodies, thus protecting the aquatic ecosystem and maintaining the water quality. CA practices help minimize the overland flow and prevent the transportation of sediments and pollutants in water bodies and thus improve the water quality and ecosystem health (Mekonnen *et al.*, 2015). Soil functions as the most important water filter and storage system – therefore, soil conservation practices prevent nutrients loss, retain sediments and reduce water contamination and its detrimental effect on aquatic biodiversity (Amundson *et al.*, 2015).

CA also encourages holistic watershed management (Mello *et al.*, 2021). For example, CA improves watersheds' overall health and sustainability by decreasing soil erosion, increasing water infiltration and conserving water. This ensures clean water availability for multiple purposes. Greater infiltration into the soil under well-managed CA positively contributes to the recharge of aquifers and regulates the flow of good-quality water (Mello *et al.*, 2021). CA practices also include wetlands preservation and restoration within the agricultural ecosystem. Indeed, the wetlands play a decisive role in water purification- by acting as natural filters to remove pollutants from water with an increase in water quality. In conclusion, CA decreases agrochemical runoff and soil erosion, thus protecting the water quality and promoting sustainable water management. These are important components of SDG-6 (Clean water and Sanitation). Thus, CA ensures the availability of clean water resources for ecosystems, communities and agriculture, supporting the overall goal of SDG-6.

SDG 12: Responsible Consumption and Production: CA is linked to SDG 12 (Responsible Consumption and Production). SDG 12 goal is to ensure sustainable production and consumption patterns. Indeed, CA encourages the efficient use of energy, nutrients and water (Meena *et al.*, 2016). Likewise, by improving the soil structure and health, the CA increases nutrient retention and decreases the need for synthetic fertilizer. Moreover, better water management in CA through reduced runoff and increased infiltration decreases water wastage. In this way, CA supports sustainable production practices by maximizing resource use efficiency. CA also promotes the wise and judicious use of fertilizers and pesticides and promotes integrated pest management approaches and biological control of insect pests, thus reducing chemical inputs and the environmental impacts associated with chemical use (e.g., ecosystem disruption and water pollution). The CA practices, such as permanent soil cover and minimal soil disturbance, improve soil fertility and overall soil health (Mugandani *et al.*, 2021). The soil with better soil health requires fewer synthetic inputs and has a greater ability to sustain the production of crops on a long-term basis with less reliance on external inputs. CA also emphasizes a decrease in waste in the agricultural production systems. Practices of CA, such as cover cropping, crop diversification and improved post-harvest management, reduce crop losses and waste (Farooq and Siddique, 2015). Thus, by reducing waste and optimizing production, CA supports responsible production and consumption patterns. CA also promotes sustainable farming practices adoption, which have a less environmental footprint (Monjardino *et al.*, 2021). Practices of CA, such as integrated nutrient management, agro-forestry and crop rotations, encourage environmentally friendly and resilient production systems. These practices decrease soil degradation and promote

biodiversity, thus contributing to sustainable production and consumption.

In conclusion, CA contributes to SDG-12 by promoting responsible production and consumption patterns by focusing on decreased chemical use, improved soil health, agriculture waste reduction, increased resource efficiency and sustainable production practices. These efforts contribute to the transition towards more sustainable and environmentally conscious agricultural systems, aligning with the objectives of SDG 12.

SDG 13. Climate Action: CA is linked closely with SDG 13 (Climate Action). SDG 13 targets to combat climate change and its impacts (Fig. 2). Minimum soil disturbance and permanent soil cover- two key components of CA, help to decrease the emission of greenhouse (GHG) from the agriculture sector (Corsi *et al.*, 2012).

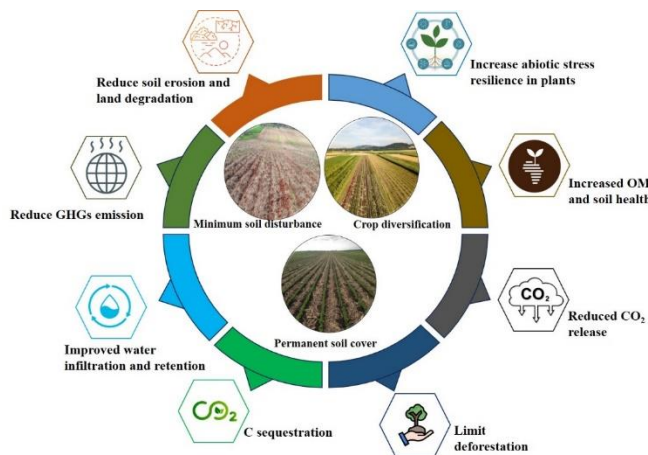


Figure 2. Conservation agriculture's contribution to climate action (SDG 13).

Figure 2 illustrates how conservation agriculture (CA) plays a pivotal role in achieving SDG 13 (Climate Action). CA practices reduce greenhouse gas emissions, enhance soil health, and improve climate resilience in agricultural systems by promoting CA. Adopting and expanding CA practices are essential steps toward mitigating climate change impacts and fostering sustainable farming for a resilient future.

No-tillage management in a sustainable manner and the practice of permanent soil cover lessen GHG emissions and increase carbon sequestration on agricultural soils (Jat *et al.*, 2020; Reicks *et al.*, 2021). In South Asia, the adoption of CA practices helps reduce the soil erosion and GHG emission by 12 – 33%, particularly on loamy soils (Jat *et al.*, 2020). CA contribute to SDG (Climate Action) by capturing organic carbon (OC) and alleviating climatic variability; for instance, soil conservation improves soil function that stores 1500 Gt

OC exceeding the combined C of the atmosphere (about 750Gt) and vegetation (about 560 Gt; Amundson *et al.*, 2015; Growther *et al.*, 2019).

By lowering soil disturbance, the carbon deposits within the soil are less disturbed, thus decreasing the carbon dioxide released into the atmosphere. Moreover, using crop residues and cover crops, as in CA, enhances carbon sequestration within the soil, thus mitigating the climate change impacts through offset of GHG. Likewise, as documented earlier, CA increased the soil's organic matter contents, thus improving soil health (Cárceles Rodríguez *et al.*, 2022). Soils with good soil health have a higher capacity to store carbon, thus acting as a sink. CA helps improve water infiltration and water retention, thus mitigating climate change impacts on water quality and availability (Jayaraman *et al.*, 2021). By decreasing runoff and soil erosion, CA helps conserve water resources, thus ensuring sustainable water management in climate change scenarios. CA also contributes to increase the agricultural system's resilience to climate change's impacts (Choudhary *et al.*, 2016). For example, farming practices such as crop diversification and improved soil management help crop plants withstand extreme weather events, floods and droughts. CA supports climate adaptation strategies by promoting resilient crop production systems. CA also ensures sustainable agriculture intensification- produces more food on existing land (decreasing the need for land expansion) while decreasing the negative impacts of the environment (e.g., deforestation, etc.) contributing to climate change. Therefore, working closely with the farming community to identify suitable conservation tools and adaptation of region-specific CA adaptation strategies will help minimize the climate change-associated risk and uncertainties. In conclusion, with its concrete focus on carbon sequestration, sustainable crop production practices and soil health improvement, CA aligns very closely with SDG-13 (Climate Action). By adopting the approaches of CA, we can contribute to promoting sustainable crop production systems, building climate resilience and mitigating the climate.

SDG 15: Life on Land: CA is also strongly aligned with SDG 15 (Life on Land). SDG 15 mainly focuses on protecting, restoring and promoting sustainable use of terrestrial ecosystems. In agriculture, the CA helps conserve biodiversity by providing habitats to organisms and promoting their biodiversity (Palm *et al.*, 2014; Henneron *et al.*, 2015). The use of crop rotations, cover crops, and decreased use of chemicals in CA support the population of beneficial soil organisms, birds, pollinators and insects, thus promoting biodiversity and enhancing the ecosystem services. CA practices such as permanent soil cover and less soil disturbance improve soil structure and health (Cárceles Rodríguez *et al.*, 2022). Healthy soil is home to many beneficial soil organisms, such as fungi, microbes and earthworms which play a key role in the cycling of nutrients,

soil fertility and overall ecosystem functioning. Conservation agricultural practices such as minimal soil tillage, cover cropping, and crop diversification are suggested to enhance soil organic carbon (SOC), nutrient cycling, and soil aggregation, eventually enhancing soil resilience and recovery potential (Lal, 1997). Maintaining semi-permanent or permanent soil cover of either dead or live crop residues protects the soil from external damage and enhances biological activities, resulting in better soil structure and health and improving the soil's ability to support crop cultivation and ecosystem services (Joshi *et al.*, 2020).

The terrestrial system vitality is also enhanced due to the promotion of soil health in CA agriculture systems. Moreover, the CA promotes the judicious use of agricultural inputs such as pesticides and fertilizers and encourages the integrated use of nutrients and integrated pest management approaches, thus decreasing the negative impacts of these agrochemicals on ecosystem health, wildlife and soil organisms (Paudel *et al.*, 2020; Mugandani *et al.*, 2021). This encourages a more sustainable and balanced approach to agriculture. CA help to reduce soil erosion, thus improving water management in agricultural landscapes by decreasing the water bodies' sedimentation (Mugandani *et al.*, 2021). It also preserves the biodiversity in aquatic life by maintaining water quality through a decrease in agro-chemical runoff towards rivers and streams. CA also CA boosts the integration of shrubs and trees within the agricultural landscape, thus improving biodiversity, contributing to soil conservation and providing habitat for wildlife. In this way, CA supports a variety of animal and plant species and enhances the resilience of the ecosystem by diversifying the agricultural landscapes.

In conclusion, CA improves soil health, protects the watershed, decreases the use of agrochemicals, promotes sustainable land management practices and biodiversity conservation, and all of these are integral components of SDG-15. Indeed, CA creates a balance between terrestrial ecosystem preservation and agricultural production, thus supporting the earth's biodiversity on a long-term sustainable basis.

FUTURE STRATEGIES AND RECOMMENDATIONS

Promote Awareness and Education: To ensure the widespread adoption of CA, there is a need to raise awareness among farmers, policymakers, and other stakeholders about the benefits of CA practices. Educational programs and workshops can be organized to disseminate knowledge about CA principles, implementation techniques, and success stories from farmers who have already adopted CA.

Policy Support and Incentives: Governments and policymakers should play a proactive role in supporting CA adoption by offering farmers financial incentives, subsidies, and technical assistance. Implementing policies encouraging

sustainable farming practices and rewarding farmers for adopting CA can accelerate its uptake.

Research and Innovation: Continued research and innovation in CA practices are essential for improving its effectiveness and scalability. Investment in research to develop region-specific CA practices, climate-resilient crop varieties, and sustainable pest management techniques can enhance the overall impact of CA on sustainable agriculture.

Farmer-to-Farmer Knowledge Exchange: Encouraging farmer-to-farmer knowledge exchange networks can facilitate the adoption of CA. Farmers who have successfully implemented CA practices can act as mentors to others, sharing their experiences, best practices, and lessons learned.

Integrated Farming Systems: Promoting integrated farming systems that incorporate CA principles can enhance the overall sustainability of agriculture. Integrating crop production with livestock, agroforestry, and aquaculture can improve resource use efficiency and diversify income sources for farmers.

Public-Private Partnerships: Collaboration between governments, private sector entities, NGOs, and research institutions can create effective public-private partnerships to promote CA adoption. Joint initiatives can pool resources and expertise to scale up CA practices rapidly.

Capacity Building and Training: Training programs for extension workers and agricultural advisors can equip them with the necessary knowledge and skills to support farmers adopting CA. Building the capacity of these stakeholders will ensure that CA information reaches the grassroots level.

Monitoring and Evaluation: Implementing robust monitoring and evaluation systems to assess the impact of CA practices on sustainable development goals is crucial. Regular assessment of CA's outcomes can help identify areas of improvement and inform evidence-based policy decisions.

Financial Support for Smallholders: Many smallholder farmers need help adopting new agricultural practices. Microfinance and credit facilities tailored for CA adoption can make it more accessible to smallholders.

Climate-Smart Agriculture: Integrating CA with climate-smart agricultural practices can further enhance the resilience of farming systems to climate change. This can include water-efficient irrigation techniques, weather forecasting services, and climate-resilient crop varieties.

In conclusion, CA has the potential to contribute significantly to achieving the United Nations' Sustainable Development Goals. By implementing future strategies and recommendations focused on awareness, policy support, research, farmer engagement, and sustainable practices, we can promote the widespread adoption of CA and move

towards a more sustainable and resilient future in agriculture and food systems.

Conclusion: CA is a sustainable farming approach that aligns with multiple SDGs, including Zero Hunger, Clean Water and Sanitation, Responsible Consumption and Production, Climate Action, and Life on Land. CA plays a crucial role in achieving these SDGs by enhancing soil health, promoting efficient resource use, conserving water, mitigating climate change, and preserving biodiversity. As we strive for a more sustainable and resilient future, adopting and promoting CA practices can significantly contribute to realizing these global goals.

Conflicts of Interest: Author declares no conflict of interest.

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