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2. Artificial Intelligence for Climate Smart Agriculture

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Abstract:

Climate-Smart Agriculture is an approach that aims to address the challenges posed by climate change in agriculture while promoting sustainable and resilient farming practices. Artificial intelligence has numerous applications in agriculture and animal farming, ranging from precision management practices to improved monitoring and decision-making. A sustainable development of agriculture has great potential to alleviate various global challenges, including biodiversity loss, food and water security, as well as climate change. We believe that data science can facilitate this process. The working group is committed to developing and applying cutting-edge data-driven techniques such as interpretable machine learning and deep learning for a broad range of agriculture-related problems. We are interested in exploring the potential of artificial intelligence for improving agricultural management, testing novel hypotheses that cannot be tested with conventional statistical methods, and discovering unexpected patterns from uniquely combined datasets across scales and sectors. Artificial intelligence plays a vital role in precision agriculture, optimizing resource allocation and improving crop yields. Artificial intelligence algorithms analyses data from multiple sources, including sensors, drones, and satellites, to provide insights into soil conditions, weather patterns, and crop growth. This information helps farmers tailor irrigation, fertilization, and pesticide application to specific areas within a field, minimizing input waste and maximizing productivity. This chapter present a connection between artificial intelligence for climate smart agricultural and its usefulness in adaptation efforts in smart agricultural technologies. We also highlight the limitations in the existing literature, and present recommendations to address the open issues.

Keywords:

Agricultural, Artificial intelligence, Climate smart agricultural, Algorithms.

2.1 Introduction:

Agriculture Sector plays important role in economic sector. Due to increasing population day by day and also increasing demand employment and food. For every nation's economic sector, agriculture is essential. The global population is growing, and there is a daily increase in the demand for food. The farmers' conventional methods are at present not capable to match the demand. Several creative ways to automation have been developed in order to meet these objectives and provide many workers in this area with excellent job chances. Artificial intelligence has become one of the most important technological developments across many sectors, including banking, robotics, agriculture, and education. It is revolutionizing the agriculture industry and playing a very important part in the agricultural sector. AI covers the agriculture sector from a variety of difficulties, such as food safety, population growth, climate change, and employment issues. Artificial intelligence has improved crop production, real-time monitoring, harvesting, processing, and marketing. In order to identify numerous crucial criteria, including weed detection, yield detection, crop quality, and many more, various high- tech computer-based systems are created **(Aparna and Sandeep.,2023).**

2.2 Artificial Intelligence:

Artificial Intelligence (AI) is the branch of computer science which deals with intelligence of machines where an intelligent agent is a system that takes actions which maximize its chances of success. The term artificial intelligence describes computer programs that can perform tasks that are typically associated with human intelligence, such as recognition of speech, identifying objects, prediction, and natural language generation. Massive processing of data and pattern- finding are the ways artificial intelligence systems acquire the ability to make decisions by themselves. In many cases, humans will supervise an Artificial intelligence learning process, reinforcing good decisions and discouraging bad ones, but some Artificial intelligence systems are designed to learn without supervision **(Saini., 2023).**

Artificial intelligence systems can execute more and more tasks with increasing skill over time. As a result, they can adapt to new inputs and make decisions without special programming. To automate tasks and solve issues more quickly, artificial intelligence is essentially the study of teaching machines to think and learn like people.

2.2.1 Reason Is Artificial Intelligence Important:

The goal of artificial intelligence is to give machines the same processing and analytical power as humans, enabling them to function as helpful companions to people in daily life. Artificial intelligence may save time and close operational gaps that humans miss by interpreting and sorting large amounts of data, solving complex problems, and automating multiple operations simultaneously. Artificial intelligence is the cornerstone of computer learning and is applied in nearly every sector of the economy, including healthcare, banking, manufacturing, and education. It facilitates data-driven decision-making and the completion of labor-intensive or repetitive tasks.

Artificial intelligence is used in many modern technologies to improve their capabilities. Artificial intelligence assistants on cell phones, recommendation algorithms on e-commerce sites, and self-driving cars are instances of it. Additionally, artificial intelligence contributes to public safety by spearheading healthcare and climate initiative research, testing online fraud detection systems, and developing robots for hazardous tasks. In any nation, agriculture is a vital component of the economy. The need for food is rising daily due to the growing global population. There is currently insufficient supply to meet the need using the farmers' traditional methods.

Therefore, to meet these needs and give many people in this industry fantastic career prospects, several new automation techniques have been implemented. One of the most significant technological advancements in many fields, including banking, robotics, education, agriculture, and others, is artificial intelligence. It is fundamentally changing the agriculture industry and playing a significant role in it. Artificial intelligence protects the agriculture industry from a variety of threats, including population increase, climate change, job shortages in this industry, and food safety. Artificial intelligence has raised the bar for today's agricultural system. Crop productivity has increased along with real-time monitoring, harvesting, processing, and selling thanks to artificial intelligence. Numerous advanced computer-based technologies are intended to identify several crucial criteria, including crop quality, yield detection, weed identification, and many more.

2.3 Artificial Intelligence Application in Agriculture:

There are other difficulties that farmers encounter, much like with conventional agricultural practices. AI is widely being employed in this industry to address these issues. AI has emerged as a game-changing tool for agriculture. Better agricultural yields, pest management, soil monitoring, and several other benefits are just a few of the manners in which it benefits farmers.

Listed below are a few significant uses of AI in the agriculture industry:

A. Weather and Price Forecasting:

As discussed in challenges, climate change makes it harder for farmers to make the best decisions around harvesting, seeding, and sowing. However, farmers can prepare for the type of crop to produce, the seeds to sow, and the crop harvesting process with the use of AI weather forecasting, which provides information on weather analysis. Price forecasting can help farmers maximize their profits by giving them a clearer estimate of the price of crops over the following few weeks.

B. Crop Health Monitoring:

Soil type and nutrition have a significant impact on crop quality. However, the quality of the soil is deteriorating daily due to the increasing pace of deforestation, and this is difficult to measure. Artificial intelligence has developed a new program called Plantix to address this problem. PEAT created it to detect soil inadequacies, such as illnesses and pests that affect plants. Farmers can use this application to gain ideas on how to apply better fertilizer, which will raise the quality of the harvest. Through the use of AI's image recognition technology in this app, farmers may take pictures of their plants and obtain quality information.

C. Agricultural Robotics:

Robots are employed extensively to carry out complicated jobs in a variety of industries, primarily manufacturing. Currently, several AI startups are creating robots for use in the agricultural industry. These AI farm robots are designed to be able to do various duties.

AI robots are also taught to inspect crops for quality, identify and manage weeds, and harvest crops more quickly than a human.

D. Intelligent Spraying:

Artificial intelligence sensors make it simple to identify weeds and identify locations where it has spread. Once these locations have been identified, herbicides can be applied accurately to minimize herbicide consumption while saving time and crop damage. AI companies are developing robots that can precisely spray weeds using AI and computer vision. With the deployment of AI sprayers, farmers can save money and enhance crop quality by using fewer chemicals in their fields.

E. Diagnosis of Disease:

With AI projections, farmers can easily learn about illnesses. With this, they can quickly and accurately detect illnesses using the right approach. It can spare farmers' time and save the lives of plants. First, computer vision technology is used to pre-process plant photos to do this. This guarantees that plant photos are correctly segmented among sections that are unhealthy and sections that are not. The diseased portion is cut after it is discovered and sent to the lab for additional diagnosis. In addition, this method aids in the identification of pests, nutrient deficiencies, and many other issues.

F. Precision Farming:

It is all about "Right place, Right time, and Right products" in precision farming. The labour- intensive portion of farming that involves carrying out repetitive chores can be replaced with a far more precise and regulated method called precision farming. Plant stress level identification is one application of precision farming. High-resolution photos and various plant sensor data can be used to obtain this. The data obtained from sensors is then fed to a machine learning model as input for stress recognition **(Aparna and Sandeep.,2023).**

2.4 AI's Advantages and Difficulties in Agriculture:

2.4.1 AI Makes Decision-Making Easier:

Application of artificial intelligence in climate smart agriculture allow analyzing and processing large amounts of information, combining various information resources on one platform, controlling and reducing production risks, meeting the information needs of a wide range of stakeholders, from the state to the end user, as well as ensuring security in cyberspace. An important role in the climate smart agriculture is played by the resource potential of people employed in smart agriculture. Special attention is paid to the development of research centers, training courses, where an in-depth study of modern high-precision agricultural technologies is conducted **(Gryshova *et al.*,2014).** The agriculture industry is genuinely benefiting from predictive analytics. Finding the best times to plant and harvest crops is one of the main problems it assists farmers with solving. Other obstacles include analyzing market demands and anticipating prices.

Artificial intelligence-driven devices may also assess crop quality, monitor the weather, provide recommendations for fertilizer, and assess the health of the soil and crops. Farmers are able to cultivate more effectively and make better decisions thanks to all these advantages of AI.

2.4.2 Artificial Intelligence Reduces Costs:

Farmers are able to cultivate more crops with fewer money and resources when they use AI- enabled precision farming equipment. Farmers can make informed decisions at every stage of farming with the help of artificial intelligence (AI), which offers real-time insights. This wise choice results in minimal loss of goods and chemicals as well as economical and time-efficient utilization of resources.

Additionally, it enables farmers to pinpoint the precise regions that require pesticide treatment, fertilization, and irrigation, hence reducing the amount of chemicals applied excessively to the crop. When all of these factors are combined, the usage of herbicides is decreased, crop quality is improved, and profits are increased while using less resources.

2.4.3 AI Reduces the Labor Shortage:

Labor shortages in the agriculture sector have long existed. This farming automation problem can be resolved with AI. AI-driven harvesting robots, intelligent spraying, driverless tractors, intelligent fertilization and irrigation systems, vertical farming software, and smart spraying are a few examples of how farmers can efficiently complete tasks without hiring more staff. Artificial intelligence-powered machinery and tools outperform human farmhands in terms of speed and accuracy.

2.5 Adoption Challenges of AI in Agriculture:

Given the benefits of artificial intelligence (AI) for sustainable agriculture, adopting this technology could seem like an intelligent choice for any farmer. Everyone is aware of the following significant obstacles, nonetheless, which still are out there:

- **Lack of Insufficient Knowledge of AI Devices:**

Although there are many advantages to employing AI in agriculture, most people worldwide are not familiar with the use of AI-enabled tools and solutions. Farmers should first receive basic equipment from AI businesses to help them get acquainted with the technology before receiving more sophisticated machinery to address the remaining concerns.

- **Insufficient Familiarity with New Technology:**

It can be difficult for developing nations to adopt AI and other emerging technological advances in agriculture. Such technologies will be very hard to sell in areas where they have not yet been implemented in agriculture. In these places, farmers require assistance to use this technology.

- **Security and Privacy Challenges:**

AI may give rise to several legal concerns because there are currently no defined rules and guidelines for its use. Furthermore, there can be security and privacy problems like cyberattacks and data leaks because of the use of software and the internet. For farmers or farm owners, all of these problems could pose serious challenges.

2.6 Climate Smart Agriculture:

Climate-smart agriculture refers to an approach that sustainably increases productivity, enhances resilience (adaptation), reduces greenhouse gases (GHG) (mitigation) where possible, and enhances achievement of food security and development goals **(FAO., 2013).**

It helps people who manage agricultural systems to respond effectively to Climate change **(Lipper *et al.*, 2014).** The climate-smart agriculture sustainably increases productivity and incomes without degrading forests, adapting to Climate change and reducing greenhouse gases emissions where possible **(Nkumulwa and Pauline., 2021).**

A range of agricultural practices that transform agricultural systems to support food security in the face of climate change has been collectively known by the name climate-smart agriculture (CSA). A climate-smart agriculture approach tries to integrate climate change into planning and implementation of sustainable agricultural practices. It also aims to increase the resilience of agriculture to climate variability through better adaptation to climate change and reduce agricultures contribution to global warming.

2.6.1 Need of Climate Smart Agriculture:

Climate change accelerates degradation processes in already-degraded environments and has negative impact on food production and food system. In India, the countrywide decline in major crop yields due to climate change effects between 2010 and 2039 could be as high as Nine percent.

This has heightened the need to embrace the notion of Climate Smart Agriculture (CSA) in the face of climatic vagaries to reduce the negative impacts of climate change on agricultural systems. A transformation of the agricultural sector, including crop and livestock production, fisheries and forestry, is urgently needed to respond to climate change and sustainably increase agricultural productivity and incomes. Climate-smart agriculture is rooted in sustainable agriculture and rural development objectives which, if reached, would contribute to achieving the Millennium Development Goals (MDGs) of reducing hunger and improved environmental management.

2.6.2 Implementation of Climate-Smart Agriculture:

Climate-smart treatments require a lot of knowledge and are very location-specific. But putting this strategy into practice is difficult, in part because of an absence of resources and expertise.

It is crucial to comprehend these challenges and how they affect the adoption of climate-conscious farming techniques. It will take a lot of work to build the skills and knowledge needed to implement climate-aware agriculture. An identification and critical analysis of the factors that limit adoption of climate smart agriculture practices and a policy framework will enable policy makers to come up with concrete actions to scale up/ out adoption of climate smart agriculture practices in developing countries **(Barnard *et al.*, 2015). (Dobermann and Nelson 2013)** offered possible solution to this by suggesting the implementation of the following processes.

- Diagnosis: this involves knowing the world of agro ecological knowledge and the context in which an endeavor or intervention will be carried out.
- Contextualized principles: by determining the appropriate ecological, social, and economic principles that are pertinent to the requirements of farmers.
- Getting it right locally: by giving local people the tools they need to enhance the farming system's efficiency by agro ecological principles and regional preferences.
- Scaling and support: by expanding the scope of the effort or intervention (in terms of numbers of people involved and the size of the territory) and create the necessary value chains, services, support systems and self-sustained business models.
- Evidence: through monitoring and documenting the performance, and learning to enrich the local and global knowledge base to influence policies that will support further implementation. According to **(Knaepen *et al.*, 2015)** there are also four processes to implement climate smart agriculture in farmer’s level.

a. Knowledge is the foundation for the implementation of climate-wise agriculture, which is essential to sustainable practices. Raising awareness among all stakeholders is essential for both promoting the dissemination of knowledge and scaling up efforts (i.e., their understanding of the climate problem, solutions, and practices available). Furthermore, more research on context-specific climate-smart agriculture techniques based on risk profiling, vulnerability, and readiness assessments is necessary to fill in knowledge gaps. In addition, indigenous knowledge should feed directly into research findings **(FAO, 2013).**
b. A multi-stakeholder strategy involving all relevant parties, including farmers, businesses, and civil society, can provide a practical path in advance for the implementation of climate- smart agriculture. Using coalitions, assemblies, seminars, and associations, these players need to be provided with forums for exchanging strategies and expanding native expertise. To increase local capacity for adaptation, mitigation, and resilience-building, there needs to be better collaboration among stakeholders.
c. By mainstreaming climate change into agricultural strategies, governments have the power to foster a favorable environment. Maps of lessons learned that are to be distributed to other regions or areas of the nation should serve as the foundation for these policies. Programs are subsequently developed, outlining specific implementation recommendations, based on a more unified institutional framework and governance structure.
d. Gaps in climate-smart agricultural implementation can be filled with adequate finance. Using creative funding sources and tying climate and agriculture finance together is the way forward. At the same time, the private sector offers a chance to profit from investments in climate- friendly agriculture.

2.7 Climate Smart Agriculture: Characteristics:

- Contrary to conventional agricultural development, climate smart agriculture systematically integrates climate change into the planning and development of sustainable agricultural systems.
- Climate smart agriculture three primary pillars are interrelated concerns-increased productivity, enhanced resilience and reduced emissions. However, the resultant trade-offs often cannot maximize the pillars simultaneously, only optimize them.
- Climate smart agriculture maintains ecosystem services: Ecosystems provide the agricultural sector with a number of unpaid services –clean natural water, materials, food, sunlight etc. Climate smart agriculture attempts to ensure the sustainability of these services, preventing their degradation.
- Climate smart agriculture is not a rigid set of particular practices, technologies or methodologies- it is only a concept amenable to adaptation. It has multiple entry points, ranging from the development of technologies and practices to the elaboration of climate change models and scenarios, information technology, insurance schemes, value chains and the strengthening of institutional and political enabling environments.

2.8 Strategies for Climate Smart Agriculture:

These strategies are discussed below.

2.8.1 Efficient Resource Management:

Resource management is very significant feature of climate smart agriculture and future climate. Food loses are found through all stages of the food production till food utilization. Almost one third part of food produced is wasted **(Gustavsson *et al.*, 2011).** The energy consumed in annually world food losses are almost 38 % of the final energy utilized by the total food chain. All the food chains, from agricultural, transport, conservation, processing, cooking and consumption are likely areas for improving energy use efficiency **(FAO, 2011).**

2.8.2 Integrated Farming Systems with Renewable Energy Technology:

A smooth transition to energy-smart and efficient food systems requires the implementation of appropriate energy technologies, equipment, and services in agricultural settings. Natural conditions, transportation, and the facilitation of mid-season aeration by temporary drainage will all influence the character of these technologies.

Skills that are available in employment. Energy-smart food systems may benefit greatly from several innovative technologies, such as:

- Wind mills,
- Solar panels,
- Photovoltaic lights,
- Biogas extraction units,
- Power generators,

- Tools for bio-oil mining and purification,
- Fermentation and distillation processes for ethanol extraction,
- Pyrolysis units,
- Hydrothermal conversion tools,
- Solar-wind electricity production or
- Bio-energy-operated water pumps,
- Renewable energy-powered vehicles,
- Monitoring systems,
- Information and communication technologies (ICT),
- Cooking stoves,
- Equipment for water supply, distribution and purification.

The availability of raw materials made manufacturing more valuable due to these recently created technologies. In terms of integrated food energy systems, these technologies can be coupled on a farm.

2.8.3 Availability of Technical Knowledge of Farmers:

To meet the demands of today, this kind of expertise is necessary. Over time, people's conventional understanding of the environment has grown and developed, providing a variety of concepts and workable possibilities for adaptation techniques.

Research has shown that traditional farmers have evolved their understanding of earthquakes, landslides, and droughts and have created more effective strategies to mitigate the effects of climatic and natural changes.

2.8.4 Institutions' Role in Enhancing Climate-Smart Agriculture:

Institutions that produce and distribute useful knowledge, mentor people in the interpretation of emerging technologies, and assist them in working with them are vital. Institutions like farmer field schools help and guide farmers in applying new techniques; farm radio shows share easily available, practical, and weather-related agricultural information to rural communities; agricultural plot exhibitions for the public; and farmer-to-farmer idea sharing.

It typically takes time for the gains from employing land-sustainable management strategies to become apparent. During this time, the farmers have to tolerate the total expenditure that includes expenditure of labor, land and cash **(McCarthy *et al.,* 2011).**

Since poor farmers have no resources to access credit and markets, and they are unable to adapt to these new techniques for the success of CSA the strong institutions have to maintain agricultural markets and financing mechanisms which are very important.

The most efficient technique allows researchers, private sector investors, community members and policy makers to collectively describe troubles that are planned to resolve **(Kristjanson *et al.,* 2009).**

2.8.5 Technologies That Conserve Resources:

The term "resource-conserving technologies" (RCTs) refers to a set of methods that increase the effectiveness of resource management or input application, leading to the utilization of clear, observable, and understandable economic benefits such as decreased production costs, reduced fuel, labor, and water consumption, and better yields from timely crop sowing. Seeds are sown directly onto uncultivated soil in a regenerative crop technology (RCT), also known as zero tillage systems (ZT) or no-tillage. The method of cultivating crops into tiled soil by constructing narrow channels with just the right amount of depth and width to provide appropriate seed coverage is one way to describe it. Remaining soil is left as if no tillage is done with it **(Derpsch *et al*., 2010).**

2.8.6 Crops Genetic Modification:

Environmental stress mostly affects the decay of organic matter in the soil, availability of nutrients and water to the plant and recycling of water and nutrients. Nutrient concentration and period of environmental limits conclude level of effect on crop growth cycle and biomass accumulation **(Cruz *et al*., 2007).** Adjustment techniques can be enhanced by the availability of new crop varieties that are tolerant to heat, drought and salinity and thus reduce the risks of climate situation. Genetic diversity of the seed structure and seed composition has been recognized as a very effective defense against plant disease and pest attack and risks of climate.

2.8.7 Land-Use Management:

Changing land use practices, like the location of crops and livestock production, rotation or shifting production between livestock and crops, shifting production out of marginal areas, changing the intensity of the application of fertilizers and pesticides, capital and labor can help minimize the risks from climate change on production of agriculture. Adjustment of sequence of the crop by altering the time of sowing, spraying, and harvesting the crop, in order to take benefits of the altering length of seasons of growth and levels of changing heat and humidity associated is one more option. Changing the time at which the fields are sown can also help the farmers to regulate the length of the growing season for the better adaptation to the altering environment. Adaptations of farmers can also be involved by changing the timing of irrigation or the use of other elements like fertilizers **(Amin *et al.*, 2015).**

2.8.8 Cropping Season Variation:

Planting dates can be set to reduce the infertility induced by the increased temperature which may save the flowering period to coincide with the hottest period. Mitigation strategies to reduce the negative effects of increased climate variations as normally experienced in semi-arid tropics and arid regions may consist of changing the sowing or planting dates to take benefit of the wet period and to avoid intense weather events in the growing season. Changed cultivation systems include improving the better cultivars and enhancing the intensity of farming various crops. Farmers will have to manage the changes in different hydrological regimes by adopting changed crop rotations **(Pathak *et al.*, 2012).**

2.8.9 Efficient Pest Management:

Variations of temperature and rainfall unpredictably influence pest and disease incidence and extremeness on major crops. It is due to the effect of climate change that will inherently affect the relationship of pest / weed, the host population and pest / weed hosts interactions. Some possible adaptation techniques include:

- Development of cultivars resistant to diseases and pests;
- Integrated pest management (IPM) adoption having more dependence on the biological control and change in cultural practices.
- Adoption of substitute crop production and techniques, as well as places that are resistant to pests and other hazards **(Amin *et al.,* 2015).**

2.8.10 Forecasting:

To reduce the risks of climate loss, early warning systems and weather forecasts will be highly beneficial. Technology for information and communications (ICT) can effectively assist researchers and administrators in creating backup plans. In the field of forecasting a new technique Multi Criteria Analysis (MCA) tool has implemented to evaluate climate change policy alert on mitigation and adaptation options **(de Bruin *et al.,* 2009).** A multi-level MCA is used to identify and locate potential adaption strategies, and it is the most appropriate idea that the decision makers can incorporate into their decision-making process. Expert decision- making serves as the foundation for developing the MCA.

2.8.11 Crop Modelling:

A novel and innovative technique for managing risks in agriculture is crop modelling. Computer-aided simulation models are a valuable tool for approaching crop management response strategies and yield forecasting. The use of simulation models to suggest appropriate crop management practices and improve crop development is highly beneficial. Models can help determine the potential impact of climatic fluctuation on agricultural yields in the future, as well as the creation of climate-smart agriculture and mitigation strategies. Crop simulation models are vital instruments in field trials to develop new crop management approaches, similar to novel management alternatives and suitable genotypes that are crucial aspects for greater yield. In this point of view, two crop management systems are APSIM (Agricultural Production System Simulator) and DSSAT (Decision Support System for Agro Technology Transfer) mostly used in the whole world (Ahmad *et al.*, 2014).

2.8.12 Integration of Modelling and Forecasting:

Although there remain some uncertainties owing to lack of knowledge, crop simulation models can appreciably estimate and quantify the impact of specific water stress conditions (possible due to climate change) on crop productivity if these are well calibrated and validated in field experiments (Clarke *et al*., 2001). The crop models permit variation of environmental factors such as the water regime and temperature and simulate the crop response via many calculated growth parameters like crop yield.

Due to the complexity of the problem, research continues and improvements are constantly being made to models, for example, drought impact assessments.

2.8.13 GIS Mapping

GIS (Geographical Information System) is used in analysis and mapping which helped in the estimation and computation of the storm course and flooding associated with hot cyclones. The study incorporated population allocation, infrastructure and other under threat resources **(Amin *et al.*, 2015).**

2.9 Conclusion:

The future of AI in farming largely depends on the adoption of AI solutions. Although some large-scale researches are in progress and some applications are already in the market, yet industry in agriculture is underserved.

Moreover, creating predictive solutions to solve a real challenge faced by farmers in farming is still in progress at an early stage. By leveraging AI technologies, farmers can optimize resource usage, improve decision-making, and mitigate risks, ultimately contributing to more sustainable and resilient agricultural practices.

Climate- Smart Agriculture aims to create a sustainable and resilient agricultural system that can adapt to and mitigate the impacts of climate change. By embracing the principles and objectives of CSA, farming communities can enhance productivity, build resilience, reduce greenhouse gas emissions, and contribute to sustainable development goals.

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