Chapter 16

Climate-smart Agriculture Solutions

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Abstract

The 2030 UN agenda includes a strong emphasis on addressing climate change, with particular attention to resilience, adaptability, and policy breakthroughs. Climate influence is given first priority in climate-smart agriculture practices (CSAP), which emphasize on carbon emission reduction through adaptation, resilience, and mitigation. With an emphasis on education and operational preparation for sustainable management, this study offers farmers a framework to anticipate important events, evaluate livelihood resources, establish mitigation strategies, analyze outcomes, and adapt to climate-related circumstances. In order to obtain sustainable and consistent profits, this systematic analysis examines climate-smart agricultural (CSA) practices on small-scale farms. It focuses on the adoption, prevalent practices, and factors that support or impede CSA adoption. This study examines the application of CSA in both developed and developing nations, points out challenges, and makes recommendations for the future. Using internet technology for information security, optimizing cropping patterns, integrating weather and internet services, and examining weather index-based insurance are important topics to focus on. The objectives of CSA are to reduce greenhouse gas emissions, increase production, and promote climate change resistance. Establishing a scientific start enhancing institutions, policies, and funding sources, and putting it into practice on the ground are its five main action items. CSA tackles issues in a variety of agricultural subsectors, such as food supply chains, fisheries, aquaculture, forestry, land and water resource management, and crop and livestock production. The research suggests a CSA framework for enhancing integrated agricultural systems, including Mixed Farming Systems, by employing Internet of Things (IoT), cloud computing, bigdata, smart sensors, automated monitoring systems, and sophisticated data collection to encourage sustainability and resistance to climate impacts.

Keywords

Climate change, Climate-smart agriculture (CSA), Resilience, Adaptation, Mitigation, Sustainable management, Internet of Things (IoT), Greenhouse gas emissions, Mixed Farming Systems, Big data

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1. Introduction

The objective of climate-smart agriculture (CSA) is to strengthen rural livelihoods, promote food security, and minimize ecological impacts. However, CSA frequently ignores the requirements of small-scale farmers, which makes it difficult for them to adopt innovative methods and technological advances [1]. To ensure food security and minimize greenhouse gas emissions, CSA, is a prudent approach. On its development in advanced as well as emerging nations, however, there is an absence of systematic research. Something like an in-depth evaluation would be valuable [2]. Since full-time farming significantly promotes CSA adoption, small-scale farmers must consider the payback period, economic advantages, labor efficiency, access to financial resources, inputs, knowledge, education, and land tenure security when implementing CSA practices [3]. Challenges in CSA influence the agricultural sectors, which include forestry, fisheries, aquaculture, crop and livestock production. Developing efficient strategies and production systems, encouraging resilient livelihoods, and ending hunger all depend on a consciousness of these interdependent factors [4]. CSA techniques are necessary since climate change has been reducing efficiency and triggering variability. The objective of CSA is to integrate renewable energy sources and adaptability with mitigating approaches. The literature, however, has not adequately addressed these targets, with affluent countries emphasizing mitigation and impoverished countries prioritizing adaptation [5]. Climate change necessitates advanced farming practices that optimize nutrient cycling and reduce reliance on external nutrients. With a world population that is expanding, CSA is a realistic answer for resource sustainability [6]. The requirement for CSA has increased as a result of fluctuating climatic trends and escalating food production expenditures. While traditional approaches are complicated and out of date, CSA has potential given contemporary technological breakthroughs [7]. Climate change and digital interconnection necessitate innovative approaches, particularly in the agricultural sector, to address urgent problems and provide technical interventions that are essential for growing populations and efficiency [8]. With an ontology for CSA, it will be easier to exchange and obtain information across disciplines, addressing issues and solutions in different fields. By establishing connections among the communities of climate, crop, and economic modeling through information technology, this ontology promotes stakeholders' comprehension and implementation of CSA approaches [9]. Utilizing data on soil, fertilizer, and climate, CSA farming forecasts agricultural yields and optimizes production and food security. In order to minimize their influence on the environment and save operating expenses, farmers utilize this data for predicting planting schedules, choose seed varieties, and choose the best planting regions [10]. CSA technology framework is shown in figure 1.

2. Internet of Things powered Climate-smart Agriculture Solutions

For the purpose of ensuring global food security, the agricultural industry requires to adapt and grow more resilient and efficient. Farmers are confronted with challenges as a result of larger farms, sophisticated technology, commercial dynamics, and government regulations [11]. Utilizing sophisticated monitoring and automated control of production and food supply networks, Internet of Things (IoT) has transformed controlled environment agriculture, a crucial industry for globally growth that is sustainable [12]. Agricultural advancements leverage smart sensor technology to minimize expenses, enhance workflows, and identify illnesses. Planning for smarter villages may take advantage of these teachings [13]. In encouraging climate-smart and sustainable agriculture approaches, the research highlights the real-world implications of emerging technologies including blockchain, artificial intelligence (AI), and IoT [14]. By minimizing manual human intervention and promoting proactive decision-making, smart

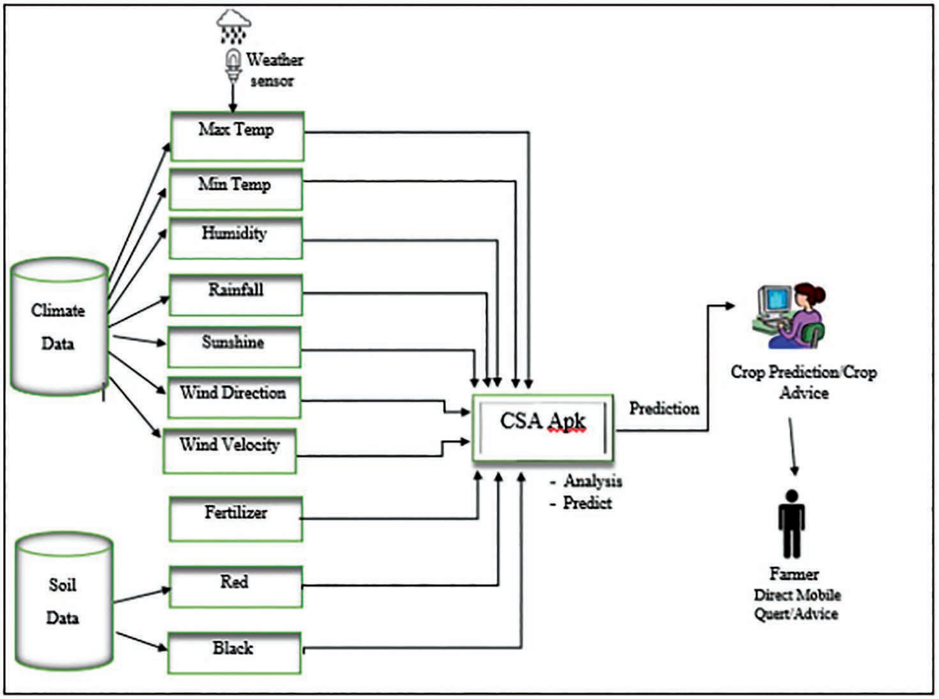

Figure 1. CSA framework

agriculture increases production and efficiency by incorporating technologies such as sensors, blockchain, robotics, AI, and the IoT into the agricultural sector [15]. By optimizing utilization of resources and minimizing human interference, AI and IoT will effectively combat climate change. They may track soil characteristics and improve agricultural productivity while raising farmers' incomes by integrating sensors [16]. CSA deploys real-time monitoring technology to help farmers effectively adapt to climate change. Scientists, farmers, and managers can access data in real time owing to these IoT-integrated devices. By broadening monitoring scales and encouraging citizen participation in big data collecting, this strategy improves knowledge of agricultural processes and dangers [17]. IoT, cloud computing, robotics, artificial intelligence, and various other technologies are being employed in smart farming to transform machinery, equipment, and monitoring cycles. This offers both new and conventional challenges to farming [18]. Resilience, mitigation, and adaptation to climate change are the cornerstones of CSA. Climate-resilient agricultural techniques are implemented employing Industry 4.0 technologies, such as blockchain, AI, and IoT, which encourage sustainable development [19]. Contemporary innovations such as genetic modification, AI, and nanotechnology offer fresh prospects in agriculture, addressing challenges like limited profit margins and land abandonment, thus improving the industry's productivity [20]. Blockchain technology may minimize transaction costs in agricultural production operations, improve food safety, and securely store data. Additionally, it has the potential to strengthen farmers' market access and establish new revenue streams including index-based insurance and smart agriculture [21]. CSA innovations in the agricultural sector, involving data analytics, digital platforms, sustainable

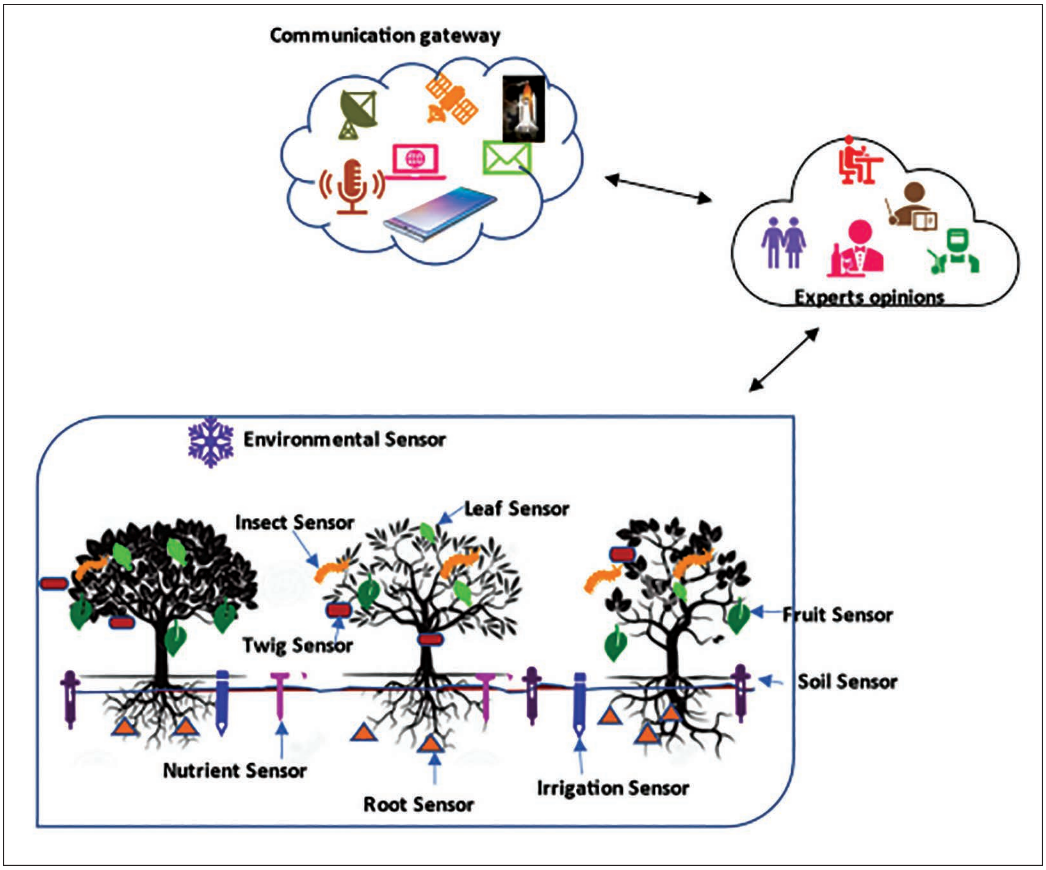

Figure 2. IoT based intelligent farming.

farming, and precision farming. It draws attention to challenges like technological and financial limitations while offering recommendations for future developments in fields like technological advances and 3D printing [22]. Enhancing services in rural regions and enabling automation and digital management of the entire food supply chain are only a handful of the benefits that CSA could provide via the integration of cloud computing and IoT technology in agriculture [23]. CSA approaches in developing countries have been classified and prioritized according to a hierarchical technique. Based on the Analytical Hierarchical Process and Fuzzy AHP, the model emphasizes the significance of knowledge-based smart practices and serves as a roadmap for the adoption of CSA [24]. Agriculture is dependent substantially on IoT for weather prediction, but due to a lack of knowledge about how climate change impacts productivity, its adoption in developing nations, especially in rural regions, is languishing [25]. High installation costs, a lack of specialization, infrastructure access, and misconceptions are some of the challenges impeding digitalization in the CSA. For smallholder farmers, governments should provide subsidies, training, and incentives [26]. Figure 2 shows how IoT based intelligent farming.

3. Recommendations

Thorough review of literature available on the past and current CSA technologies employed, we propose following recommendations.

- Enhancing digital abilities, putting regulations in place, and proving farmers the advantages of digital technologies are all necessary to overcome the barriers in the direction of digital agriculture's adoption and accessibility. Digital agriculture promotes food system sustainability.
- Cutting edge technology combine to solve problems and promote sustainable agri-food systems. However, their full potential necessitates interdisciplinary collaboration, regulatory vision, and ethical innovation.
- Administrative complexity, interoperability issues, and adverse ecological impacts make it challenging to integrate sustainable digital and circular technology into agriculture. Comprehensive training is necessary to overcome these hurdles and guarantee optimal deployment.
- It is anticipated that agricultural technology, organizational procedures, and farm equipment would all be integrated with artificial intelligence and big data services in the future to promote sustainable agriculture.
- The objectives of CSA are to strengthen cropping patterns, promote the security of agricultural information, establish the internet weather services, elevate the standard of services, and implement weather index-based protection.
- By providing incentives like rebates on taxes, governments should promote the growth of digital skills among farmers. Food security, income, and livelihood can all be strengthened through digitalization, which can additionally reinforce market links, streamline input, and maximize production.
- Stabilizing agricultural productivity, guaranteeing food security, and accomplishing CSA priorities will require more research on agricultural weather index-based insurance as well as disaster triggers and techniques.

Conclusion

The review highlights the necessity of employing smart agriculture technologies to efficiently solve current and potential agricultural concerns. It draws attention to ways that technology can be utilized for resource efficiency, sustainability, reducing the effects of climate change, and comprehending the socio-economic effects on rural citizens. By mitigating climate change-related risks, CSA aims to adapt agricultural systems to meet the difficulties posed by the phenomenon. It does this by employing Big Data Analytics to increase productivity and minimize costs, especially for the most impoverished populations. Through cost-cutting strategies and enhanced product quality, technologies that strengthen CSA practices enable smallholder farmers access to high-quality inputs while boosting their standard of living. For them to be ultimate positive aspects, stakeholders must work together. In order to increase efficiency, this study explores the significance that IoT technologies participate in ensuring food security in sustainable agriculture. It offers direction to researchers and engineers by highlighting industrial challenges as well as opportunities. In the agri-food industry, climate-smart innovations can increase profits while promoting sustainable solutions. Blockchain, robotics, 3D printing, digital transformation, and virtual reality are some of the future prospects. But issues like affordability, functionality, and resistance need to be addressed.

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