Review Article

Role of Climate-Smart Agriculture towards Sustainable Food Production

Abstract

Agriculture output is currently under severe threat from global climate change. The two biggest challenges of this century are thought to be reducing greenhouse gas (GHG) emissions and maintaining food security. The idea of Climate-Smart Agriculture (CSA) can address the difficulties facing agricultural development. By improving adaptation, lowering GHG emissions, and assuring domestic food security, it can achieve this in a sustainable manner. There hasn't been any comprehensive research done yet on CSA advancements in developed and developing nations. Reviewing the recent developments, difficulties, and potential future orientations of CSA will be both timely and beneficial. The definition of CSA and its development objectives are discussed in this article. The most recent CSA developments in industrialized and developing nations are then examined. The current issues and difficulties in CSA are examined and identified. Finally, suggestions for the future prospects and directions of CSA are made. The primary directions for CSA's future development include using cutting-edge internet technology to ensure the security of agricultural information, enhancing crop management and planting practices, providing "internet + weather" services to raise the caliber of agricultural services, and offering insurance based on agricultural weather indices. This review article offers fresh concepts and methods for enhancing ecological environmental defense, encouraging environmentally friendly agricultural development, and reducing the impact of climate change.

Keywords: Adaptation, Climate change, Greenhouse gas emissions, Mitigation, Sustainable development goals

1. Introduction

Currently, around 690 million people worldwide face hunger, while there is a growing global demand for action on climate change, particularly from the younger generation. Addressing climate change, reducing greenhouse gas (GHG) emissions, and ensuring food security have become increasingly vital [1]. Climate-smart agriculture (CSA) provides a guiding framework to transform agri-food systems towards environmentally friendly and climate-resilient practices [2]. Aligned with internationally agreed goals like the Sustainable Development Goals (SDGs) and the Paris Agreement, CSA aims to achieve three main objectives: promoting sustainable agricultural productivity and income, building resilience to climate change, and mitigating GHG emissions whenever possible [3]. This approach is in line with the FAO Strategic Framework 2022-2031, which prioritizes the "Four Betters": improved production, enhanced nutrition, a healthier environment, and an improved quality of life for all, with a focus on inclusivity [4].The specific practices of climate-smart agriculture vary based on local socio-economic factors, environmental conditions, and climate change impacts [5,6]. To advance CSA, it is recommended to expand the existing knowledge base, establish supportive policy frameworks, strengthen national and local institutions, secure sufficient funding and financing options, and implement CSA practices at the farm level [7,8]. These five steps, endorsed by the Food and Agriculture Organization (FAO), aim to promote the widespread adoption of climate-smart agriculture [9,10].

Agriculture contributes 4.3% of global GDP but provides employment to 26.4% of the world workforce[11]. With agriculture relying on unpredictable factors like climate, market fluctuations, and topographical conditions, it is considered one of the riskiest industries. Efforts are underway to provide a much-needed boost to this sector and its workforce [12]. The agri-food systems sector is estimated to be responsible for about one-third of global anthropogenic greenhouse gas (GHG) emissions [13,14]. However, it also holds significant potential in advancing global climate goals. Consequently, there is an urgent need to transform agri-food systems, encompassing crops, livestock, fisheries, aquaculture, agroforestry, and forestry [15,16]. This transformation requires integrated and inclusive approaches that consider gender, poverty reduction, and the synergies between climate change adaptation and mitigation [17,18]. Meeting the Sustainable Development Goals necessitates sustainable increases in production within agri-food systems. The Food and Agriculture Organization (FAO) advocates for a climate-smart agriculture (CSA) approach to manage cropland, livestock, forests, and fisheries, addressing the challenges of food security and climate change [19]. Agro meteorology, which involves studying weather patterns and utilizing weather and climate information, can further enhance this approach by facilitating improvements in irrigation technologies, promoting renewable energy use, and more [20].

Climate-smart agriculture (CSA) has gained significant attention in recent years as a strategy to address the challenges of climate change adaptation and mitigation [21,22]. It encompasses three main objectives: enhancing agricultural productivity to improve incomes, food security, and overall development; strengthening adaptive capacity at various levels, from individual farms to national systems; and reducing greenhouse gas emissions while promoting the expansion of carbon sinks [23]. The relative importance of these objectives may vary depending on the location, with smallholder farming systems in least developed countries focusing more on productivity and adaptive capacity [24]. A crucial aspect of CSA is to identify the synergies and trade-offs among these objectives, integrating climate change considerations into sustainable agriculture planning and implementation to inform decision-making processes [25,26].

2. Climate change adaptation

In regions closer to the equator, the impact of climate change on agriculture and economic prospects will be substantial and predominantly adverse. Research suggests that global maize and wheat yields have decreased by 3.8% and 5.5% respectively since 1980 when compared to a hypothetical scenario without changes in temperature and rainfall patterns [31]. By 2050, land areas twice the size of those experiencing reduced water stress are projected to face increased water stress due to climate-related factors [32]. In the coming decades, heightened climatic variability will lead to more frequent and severe floods and droughts, posing greater risks to crop growers and animal keepers and impeding their capacity to adapt [33]. Climate change-induced declines in agricultural revenues, heightened risks, and market disruptions pose challenges to both rural and urban communities in accessing food [34]. Vulnerable groups, including resource-limited producers, landless individuals, and marginalized ethnic communities, are particularly at risk. Adaptation measures can help mitigate the adverse effects of climate change, ranging from simple adjustments in production practices to comprehensive systemic changes in agricultural and food production systems [35].

Developing adaptive capacity is a vital component of climate-smart agriculture (CSA) for farmers, service providers, and key institutions. It enables them to effectively respond to long-term climate change and manage the risks associated with increased climate variability [36]. Enhancing adaptive capacity encompasses diverse actions, with one significant aspect being the development of ecosystem services within agricultural systems to boost resilience [37]. This involves implementing practices such as managing soil, water, and plant nutrients, improving on-farm water storage and irrigation systems, adopting crop varieties that are more tolerant of heat, droughts, floods, and salinity, diversifying farm enterprises through mixed crop and tree systems, and strengthening institutions to facilitate collective action, knowledge sharing, and local adaptation planning [38]. Access to climate information services, including crucial details on planting dates, pest and disease control [39] and water availability [40] is essential. Managing risks may also involve fortifying social safety nets and providing agricultural insurance.

3. Sustainable Solution for Climate Change Mitigation

3.1 Renewable energy and climate change:

The global climate debate has been centered on the goal of limiting global warming to below 2°C for more than a decade [52]. The significant increase in the use of fossil fuels since 1850 has made them the dominant source of energy, leading to a rapid rise in carbon dioxide emissions. By the end of 2010, data confirmed that the consumption of fossil fuels accounted for the majority of global anthropogenic greenhouse gas emissions, with concentrations surpassing 390 ppm (39%) above preindustrial levels [53,54].

Renewable energy sources are considered clean and sustainable alternatives, offering minimal environmental impact, reduced secondary waste, and long-term viability to meet current and future economic and social needs. The adoption of renewable energy technologies presents a significant opportunity to mitigate greenhouse gas emissions and combat global warming by replacing conventional fossil fuel-based energy sources [55].

3.2 Renewable energy sources:

Renewable energy sources derive from natural and continuously replenished energy flows within our immediate environment. They include bioenergy, direct solar energy, geothermal energy, hydropower, wind energy, and ocean energy (tide and wave) [56].

3.3 Renewable energy and sustainable development:

Renewable energy plays a crucial role in sustainable development, influencing human development and economic productivity. It offers various opportunities in terms of energy security, social and economic development, energy access, climate change mitigation, and the reduction of environmental and health impacts [57]. The potential benefits of renewable energy sources in promoting sustainable development are illustrated in Figure 1.

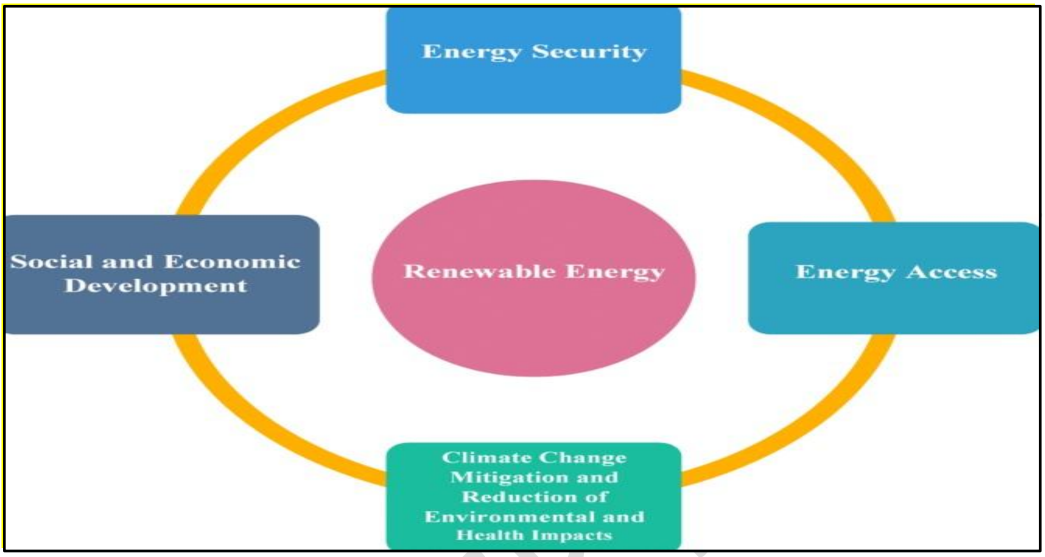

Figure 1. Advantages of renewable energy sources

4. Key points for effective CSA implementation:

CSA interventions have been successfully implemented worldwide, and the Food and Agriculture Organization (FAO) has outlined five key action points for effective CSA implementation:

4.1 Expand the evidence base: This involves assessing the impact of climate change on food production and agri-food systems, identifying vulnerabilities within the agriculture sector that affect food security, addressing institutional and financial barriers, and exploring climate-smart adaptation and mitigation options [27].

4.2 Support enabling policy frameworks: This action point focuses on developing relevant policies, legislation, plans, and investments that create a supportive environment for CSA. It also involves modifying existing policies as necessary and facilitating coordination between institutions responsible for agriculture, climate change, food security, and land use [28].

4.3 Strengthen national and local institutions: This step aims to empower and motivate farmers by supporting institutions. It involves building the capacity of national policymakers to effectively engage in international climate change and agriculture policies and collaborate with local public authorities [29].

4.4 Enhance funding and financing options: This action point emphasizes accessing funding instruments such as the Green Climate Fund (GCF), Global Environment Facility (GEF), official development assistance (ODA), and national sectorial budgets. It also involves establishing innovative links between climate finance and public and private agricultural investments and integrating climate change considerations into agricultural planning and budgeting [30].

4.5 Implement practices at the field level: This step focuses on engaging local farmers to select climate-smart agriculture practices that are suitable for their specific knowledge, requirements, and priorities.

To assess the progress of CSA practices across its three pillars, it is crucial to establish streamlined monitoring and evaluation practices throughout these five action points.

5. The pillars of climate-smart agriculture

Climate-smart agriculture (CSA) encompasses a set of practices and methods aimed at increasing agricultural production, system resilience, and ecological sustainability in the face of climate change. It involves adopting strategies that promote the sustainable management of natural resources, reduce greenhouse gas emissions, and facilitate adaptation to changing climatic conditions [41]. The pillars of climate-smart agriculture, as recognized by the Food and Agriculture Organization (FAO), include various approaches and techniques to address these goals [42].

5.1 Sustainable intensification: This pillar emphasizes boosting agricultural output while reducing harmful environmental effects. It entails implementing new technology to increase yields while consuming fewer resources, such as integrated pest management, efficient irrigation systems, and precision farming methods [43].

5.2 Adaptation: Climate change presents new challenges for agriculture, such as altered rainfall patterns, rising temperatures, and more frequent occurrence of weather extremities [44].Climate adaptive measures involve building resilience to these changes. Examples include using drought-tolerant crop varieties, implementing agro- forestry practices to provide shade and wind protection, and enhancing water management systems.

5.3 Mitigation: Agriculture plays a substantial role in greenhouse gas emissions, primarily due to activities like deforestation, methanogenic emissions from livestock, and the application of synthetic fertilizers.Implementing sustainable land management techniques is the goal of mitigation methods, which seek to lower these emissions [45]. This might involve encouraging organic farming methods, reforestation and afforestation to capture carbon, and better animal management practices to cut down on methane emissions [46,47].

5.4 Conservation and enhancement of natural resources: For agricultural sustainability over the long term, climate-smart agriculture recognizes the significance of protecting and repairing ecosystems. This pillar involves actions like sustainable water management to protect water resources and conservation agriculture, which promotes biodiversity by preserving natural ecosystems and reduces soil disturbance [48,49].

5.5 Knowledge and information management: For farmers to decide on climate-smart practices, access to pertinent information and expertise is essential. Through farmer education, extension services, and the application of digital technologies, this pillar places an emphasis on the distribution of climatic knowledge, technical know-how, and best practices [50].

5.6 Institutional and policy support: In order to be adopted and put into practice, climate-smart agriculture needs enabling policies, institutions, and financial methods. Governments, international organizations, and stakeholders all play a significant part in fostering an enabling environment for climate-smart agriculture by offering incentives, rules, and assistance [51].

The pillars of climate-smart agriculture offer a comprehensive framework to tackle the challenges presented by climate change while promoting the development of sustainable and resilient food production systems.

6. Conclusion

In summary, climate-smart agriculture is an innovative and sustainable approach that addresses climate change while enhancing food security and nutrition. It is vital for achieving the Sustainable Development Goals (SDGs) by promoting sustainable productivity, income growth, and resilience while reducing greenhouse gas emissions. CSA positively impacts various SDGs by emphasizing a comprehensive strategy to integrate practices for better outcomes in sustainable agriculture and food security. Embracing CSA is crucial for resilient and sustainable agricultural systems in a changing climate.

7. References

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