

Review Article

A REVIEW INSUSTAINABLE AND CLIMATE SMART AGRICULTURE

ABSTRACT

This review provides an in-depth examination of the principles, practices, and challenges associated with sustainable and climate-smart agriculture. Sustainable agriculture, with its focus on soil health, biodiversity, water management, and reduced chemical inputs, is crucial for meeting current food production needs while preserving resources for future generations. Climate-smart agriculture builds upon sustainability by emphasizing climate adaptation and mitigation strategies, including climate-resilient crop selection, greenhouse gas reduction, and technology integration.

However, several challenges hinder the widespread adoption of these practices. Farmers often lack knowledge and resources, while financial constraints and policy barriers pose significant hurdles. Additionally, climate variability and market access issues further complicate the transition to sustainable and climate-smart agriculture.

Efforts to address these challenges require comprehensive education and training programs, supportive policies, financial incentives, and increased collaboration among governments, NGOs, and the private sector. Achieving sustainable and climate-smart agriculture is crucial for ensuring food security and resilience in the face of climate change

Keywords: Sustainable agriculture, climate change, climate-smart agriculture, food security, soil health, biodiversity, policy barriers

Introduction:

Sustainable and climate-smart agriculture has increased significant attention in recent years due to the pressing need to address climate change and ensure food security. This review aims to provide an overview of key concepts, practices, and challenges associated with sustainable and climate-smart agriculture. Due to its crucial role in these countries economic progress,

Comment [AS1]: Principles or keyconcepts ?

Comment [AS2]: Climate-smart Agriculture or Climate Smart Agriculture ?

Comment [AS3]: All farmers in the world or in specific region (Indian Farmers)?

Comment [AS4]: Look at the previous comments

Comment [AS5]: Look at the previous comments

Comment [AS6]: Key concepts or principles? It's better to be consistent

agriculture is accorded sovereign or priority status in the majority of developing countries. In addition to enabling the sustainable and inexpensive distribution of food and maintaining the people's livelihoods, it provides a solid support system for guaranteeing economic stability in times of crisis. However, due to the difficulties posed by climate change and the consequent fragility of farming systems, there are significant risks and uncertainties that must be dealt with by identifying context-specific barriers and effective adaptation methods. Therefore, it is important to address the predicted changes in farming practices that will increase agriculture's resistance and resiliency to the negative effects of climate change. Additionally, agriculture is one of the industries most impacted by climate change (Challinor et al., 2014). Examples of potentially yield-damaging changes that are already being felt in some regions of the world include increased frequency of extreme weather, heat, and variability in pests and diseases—especially in some of the world's most vulnerable regions (Ross and Agostini, 2016). Families use 53% of all agricultural land for food production. (Graeub et al., 2016) Farmers, According to the FAO (2016), measures that have a significant impact on food security and adaptation are frequently but not always also associated with decreased greenhouse gas emissions or enhanced carbon sequestration.

Climate change impacts on agriculture :

"Climate" is the term used to describe general weather patterns that occur over a wide area. Both weather and climate consider variables such as temperature, precipitation, and humidity. According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change is defined as a change in the climate that can be directly or indirectly connected to human activities and that exceeds the natural climate variability that has been observed across similar time periods. Although the weather has always been erratic, the current rapid climate change makes agriculture substantially more vulnerable. The updated climatic estimates should be taken into account when planning for adaptation to climate change in the future. In the general circulation of the atmosphere, the Indian monsoon is one of the most significant climate systems. A period of around four months (June to September) is devoted to the southwest monsoon season, during which the country receives more than 80% of its annual rainfall. The seasonal start, end, total amount of rainfall, and distribution all have a substantial impact on the agricultural industry each year. Over the past century, the surface of

Comment [AS7]: Is this author's name already on the reference list?

Comment [AS8]: Look at the previous comments

the Earth has warmed, and there is now unquestionable evidence that human activity is mostly to blame for this warming. It has also been highlighted that various precipitation-related variables, such as snow cover, sea ice, extreme weather events, etc., have changed. However, these adjustments exposed significant regional inequalities. Every plant type has a certain temperature range that is appropriate for vegetative growth, with growth slowing as temperatures increase or decrease. One of the regional repercussions of global warming may be the monsoon in India in the summer. Similar to animals, plants cannot reproduce at a variety of temperatures.

Table 1. Impact of Climate change in Indian Agriculture

Parameters	Impacts	References
Production and Quality	Agricultural yields decreased as a result of rising temperatures and CO2 concentrations. Grain density falls when the C/N ratio rises.	Damatta et al., 2010 ; Nardone et al., 2010 ; Bisbis et al., 2018
Soil	Climate change causes the soil to become drier by reducing productivity, increasing soil erosion, and releasing more carbon from the soil.	Porcal et al., 2009 ; Jones et al., 2009
Irrigation	Water resources are becoming scarce due to rising water demand and falling water supply.	Seckler, 1996 ; Doll, 2002 ; Zhou et al., 2010
Pest	Unfavorable weather conditions caused by climate change are causing pests and illnesses to expand their ranges and populations.	Das et al., 2011 ; Skendžić, et al., 2021 ; Rosenzweig et al., 2001 ; Pareek et al., 2017
Livestock	Abiotic stressors such as heat stress caused by climate change are contributing to an increase in diseases like foot and mouth disease among cattle.	Baumgard et al., 2012 ; Kaffenberger et al., 2017 ;
Fishery	Climate change has a negative impact on fish populations and their ability to reproduce.	Graham & Harrod, 2009 ; Munday et al., 2008 ; Moyle et al., 2013 ; Stenevik&Sundby, 2007
Economic Impact	Increased pest and disease outbreaks due to climate change are leading to reduced agricultural output. Climate change has a negative impact on fish populations and their ability to reproduce.	Ju et al., 2013 ; Aydinalp&Cresser, 2008 ; Mahato, 2014 .

Comment [AS9]: Have all these references been written in the bibliography (List of References)?

Climate smart Agriculture:

The concept of climate-smart agriculture (CSA) is relevant in this context. Climate-smart agriculture refers to agricultural practices that increase agricultural production and system resilience while reducing greenhouse gas emissions (Venkatramanan& Shah, 2019). The FAO (2014) advocates for the necessity of strengthening rural communities' adaptive capacity to cope with climate change, increasing climatic variability, and building the ability to adapt to climatic shocks. FAO (2014) recognizes that climate change is a universal and critical challenge for global food security and that there is a need to improve the current way of managing agricultural systems and natural resources to effectively achieve food security. The FAO adopted the exact definition of CSA, which outlines three objectives in the context of landscapes and food systems: (1) sustainably increasing agricultural productivity to support growth in farm incomes, food security, and development; (2) developing resilience to climate change at various scales (from farm to national); and (3) reducing or eliminating greenhouse gas emissions from agricultural operations, which affect the environment, animals, and people. Various configurations of these objectives that are relevant to the local situation are the focus of a strategy known as CSA. It incorporates a variety of policies, institutions, investments, behaviors, technologies, and practices. (Makate, 2019). Minimum tillage, different methods of crop planting, irrigation and nutrient management, and crop residue incorporation, according to Branca, McCarthy, Lipper, and Jolejole (2011), Jat, Sapkota, Singh, Jat, Kumar, and Gupta (2014), and Sapkota, Jat, Aryal, Jat, and Khatri-Chhetri (2015), can improve crop yields, water and nutrient use efficiency, and reduce GHG emissions from agricultural activities. According to Altieri and Nicholls (2013) and Mittal (2012), using enhanced seeds, ICT-based agro-advisories, crop and livestock insurances, and rainwater harvesting can all help farmers lessen the negative effects of climate change and variability on their agricultural operations. As a result, CSA combines regionally relevant conventional and cutting-edge technology, practices, and services to help agriculture adjust to climatic variability and change (International Center for Tropical Agriculture [CIAT], 2014).

Comment [AS10]: If Climate Smart Agriculture has been abbreviated to CSA then in subsequent writing it will simply be written as CSA.

Comment [AS11]: Look at the previous comments.

Comment [AS12]: "Farm" or regional/local/village ?

Comment [AS13]: If there are more than two authors, simply write the first name followed by et al.

Comment [AS14]: Look at the previous comments.

Comment [AS15]: What does ICT stand for?

Comment [AS16]: Look at the previous comments.

Why Climate Smart Agriculture:

"Climate-smart agriculture contributes to the resolution of several pressing environmental and food security issues."

1. CSA deals with malnutrition, inequality, and food security

Despite the recent emphasis on agricultural development and food security, there are still over 800 million people globally suffering from undernourishment, with an additional billion facing malnutrition. Concurrently, one-third of all food produced is wasted, and more than 1.4 billion individuals are overweight. It is estimated that by 2050, the world's population will reach 9.7 billion (United Nations, 2015). Global dietary preferences are also undergoing significant changes, with increased income driving a desire for meat-rich diets. If current consumption patterns and food waste habits persist, it is projected that we will require a 60% increase in agricultural output by 2050. Community-supported agriculture (CSA) plays a crucial role in reducing global food waste while enhancing food security for underprivileged and marginalized communities."

This revised statement provides a more polished and coherent presentation of the information and emphasizes the significance of community-supported agriculture (CSA) in addressing these challenges.

Comment [AS17]: The punctuation mark (".....") means that is a quotation from someone's statement?

Comment [AS18]: Look at the previous comments.

Comment [AS19]: How do you differentiate between the abbreviation CSA as Climate Smart Agriculture and Community Supported Agriculture?

Comment [AS20]: If community-supported agriculture is indeed an important discussion, why not add it as a separate sub-discussion. How does it differ from a climate smart village?

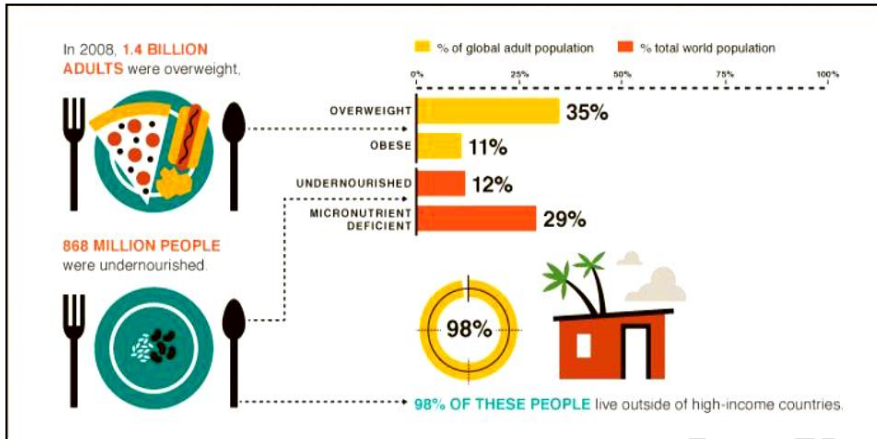


Figure1. Food security, inequity and malnutrition

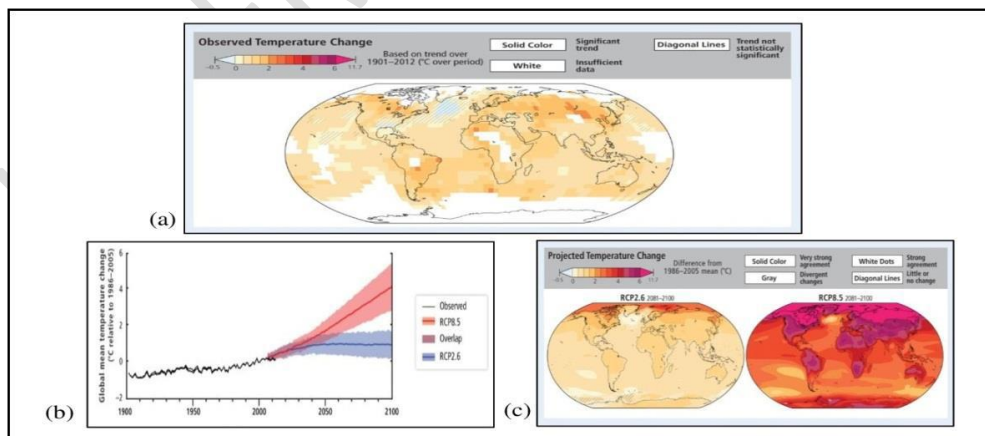
Comment [AS21]: Source ??

2. Climate smart agriculture addresses the relationship between agriculture and poverty

Agriculture is the main source of nutrition, employment, and income for many people in developing nations. According to (Lipper et al., 2014), about 75% of the world's poor live in rural areas and depend heavily on agriculture for their livelihoods. Hence, agriculture plays a crucial role in alleviating poverty. Notably, agricultural growth is often the most effective and fair way to reduce poverty and improve food security.

Comment [AS22]: Pay attention to how the citation/references is written.

Figure2. Observed and projected changes in annual average surface temperature



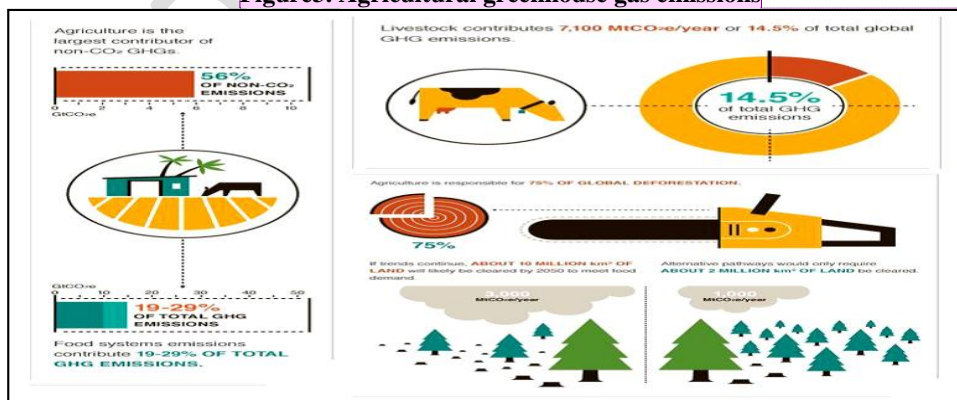
Comment [AS23]: Image captions should be placed at the bottom and state the source.

3. Climate smart agriculture addresses the relationship climate change and agriculture

The impact of climate change is already being felt through increased global temperatures. In the future, temperatures are expected to become more volatile, leading to changes in rainfall patterns and more extreme weather events such as hurricanes, floods, heat waves, snowstorms and droughts. These events can cause rising sea levels, salinization, soil erosion, reduced soil infiltration, and disruption of entire ecosystems. All of these changes will have far-reaching effects on agriculture, forestry, and fishing. Moreover, plant pests and diseases are anticipated to escalate in frequency and extend to new areas, presenting additional challenges to agricultural productivity (Mishra et al., 2022) The agricultural sector is profoundly influenced by climate change, establishing a reciprocal relationship between the two. Between 19% and 29% of global greenhouse gas emissions are attributed to forestry, land use change, and agriculture. Notably, this percentage surges to 74% when focusing on the least developed countries, as highlighted by (Vermeulen et al., 2012.)

It is crucial to note that 70% of all greenhouse gas emissions, assuming temperature increases are constrained within 2°C, will emanate from agriculture (see fig. 3). Assessing the affordability of mitigation options developed in the forestry, transportation, and energy sectors becomes imperative in addressing these challenges.

Figure3. Agricultural greenhouse gas emissions



Comment [AS24]: Look at the previous comments.

Climate smart villages:

Some areas have not adopted **Climate smart village** practices, like as water management or mitigation alternatives. Because development professionals lack concrete examples of how innovations can be successfully incorporated into agricultural systems, there is a poor acceptance of new technologies. They need to understand how farmers can apply various treatments on actual farms while maximizing synergies and minimizing trade-offs. This is complicated by climate change since different places will be affected differently. Because of this, successful implementation an integrated strategy that considers how science, technology, and decision-making relate to regional socioeconomic factors and cultural norms. "In climate-smart villages, farmers not only adopt advanced farming practices but also explore new services. These services include customized weather forecasts for precise planning of planting, harvesting, and other on-farm activities. Farmers receive advisories and weather forecasts through mobile phones, which are also used to facilitate the purchase of index-based insurance. This insurance provides them with a degree of protection in case of extreme weather events."

Comment [AS25]: The punctuation mark (".....") means that is a quotation from someone's statement?

This revised version maintains the original meaning while enhancing the grammar and overall readability of the statement. <https://www.cgiar.org/innovations/climate-smart-villages-and-valleys/>

Indian Agriculture Challenges

"Indian agriculture faces several challenges. One of the main issues is the need for enhanced productivity. Farmers encounter obstacles in adopting modern techniques and technologies that can significantly boost yields. Additionally, inadequate infrastructure, such as irrigation facilities and storage capacity, poses a considerable hurdle. Moreover, fluctuating climatic conditions, including unpredictable rainfall and extreme weather events, further complicate the agricultural landscape. This, coupled with the vulnerability of small-scale farmers to market fluctuations, creates a precarious situation. To address these challenges, there is a pressing need for comprehensive policy reforms. Government initiatives should focus on providing farmers with access to advanced farming practices, improving infrastructure, and implementing effective risk mitigation strategies. Strengthening research and development in agriculture can also play a

Comment [AS26]: Look at the previous comments.

pivotal role in overcoming obstacles and ensuring sustainable growth in the sector."The green revolution has led to socio-economic disparities among the Indian farming community. While it has favored large landholding farmers and agro-based industries, it has negatively impacted small and marginal farming communities, as well as water resources, environment and soil fertility ([Kumari et al., 2019](#))

Therefore, in the post-green revolution era, Indian agriculture is facing the following major challenges:

- 1. Food Security**
- 2. Depletion of water supplies**
- 3. Degradation of the quality of soil**
- 4. Availability of nutrients**
- 5. Differences in socioeconomic status among farmers**

1. Food Security

Food security can be defined as reliable access to a sufficient quantity of nutritious food. However, despite the significant increase in food production following the Green Revolution, which led to a decline in the undernourished population from 18.6% in 1990-92 to as low as 10.9% in 2014-16, many people across the country still face food and nutritional insecurity. Achieving sustainable food security remains a major economic, political, sociological, and scientific challenge in the 21st century.

2. Depletion of water supplies

Indian agriculture is predominantly dependent on the monsoon, leading to uncertainty in water availability for agricultural production. Canal and well irrigation systems have played a crucial role in addressing this challenge within the Indian context. Over the last 50 years, advancements in canal and well irrigation systems have contributed to a twofold increase in the irrigated cropped area.

3. Degradation of the quality of soil

Therefore, resource-intensive agriculture has impeded the continuous availability of freshwater in the present changing climate scenario. Water scarcity significantly influences crop yields compared to other challenges, and the continuous exploitation of water resources is likely to result in rising food prices, food shortages, and increased food imports by third-world countries ([Arulbalachandran et al., 2017](#)). The injudicious use of water resources has also led to increased water logging and intensified soil salinization. Consequently, policymakers should pay proper attention to proper irrigation water management and the judicious use of water resources.

4. Availability of nutrients

According to ([Sathya et al. in 2016](#)), crop plants require 17 different nutrient elements for proper growth and development. These nutrient elements are categorized as either macro or micronutrients depending on the needs of the crop plant. The macro-nutrients are divided into primary and secondary nutrients, with primary nutrients being quickly consumed by plants compared to the secondary nutrients. As a result, primary nutrients are supplied by straight fertilizers, while other nutrients are obtained through organic manures, biological nitrogen fixation, and plant residues, as highlighted by ([Sankar Ganesh et al., in 2017](#)) study. ([Shukla et al., 2015](#)) have emphasized that the mobility of micronutrients is influenced by several factors such as organic matter, pH, the chemical makeup of these micronutrients, their concentration, and their interaction with soil, plants and microbes. As a result, achieving sustainable crop production requires a judicious and integrated approach that involves using synthetic fertilizers and manure, adopting efficient crop varieties, implementing improved agronomic management practices, and fostering proper soil-plant-microbes interaction.

Comment [AS27]: Pay attention to how the citation/references is written.

5. Differences in socioeconomic status among farmers

According to [Nath et al. \(2018\)](#), small and marginal farmers dominate Indian agriculture, accounting for 88% of the total farming community in India. This category is mostly made up of Schedule tribe and Schedule caste categories. In addition, small and marginal landholders cultivate 72Mha of land and contribute approximately 56-60% of India's total food requirements. However, their land holdings are among the most climatically and

ecologically vulnerable lands. As highlighted by [Srivastava et al. in 2016](#), the current climate scenario necessitates the development of ecologically sound technologies that require low external inputs and incorporate traditional knowledge. Such technologies are urgently needed to address climate change and its impacts.

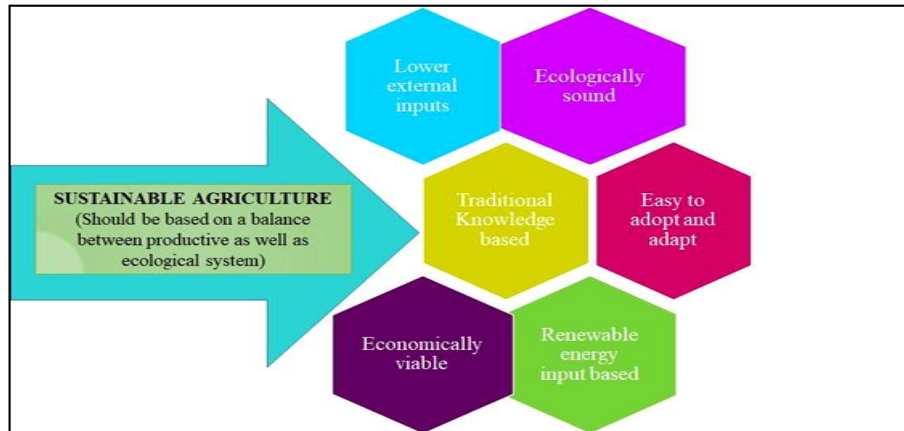
Comment [AS28]: Srivastava et al (2016)

Sustainable Agriculture

Research studies conducted across different regions of India and the world have demonstrated the adverse effects of the green revolution on soil microbial biodiversity. Additionally, stagnation in crop yields has been observed in the Indo-Gangatic plains, where the green revolution technology was adopted. The excessive and indiscriminate use of agrochemicals has resulted in the emission of greenhouse gases from the agricultural sector, contributing to global warming and climate change. As a result, agriculture research has shifted its focus towards holistic natural resource management to achieve long-term crop productivity and ensure food security, as emphasized by [\(Sathya et al. in 2016\)](#). According to [\(Corwin et al., 1999\)](#), sustainable agriculture is characterized by a delicate balance of maximum crop productivity and economic stability while minimizing the utilization of finite natural resources and detrimental environmental impacts. [\(Tilman et al., 2002\)](#) define sustainable agriculture as practices that meet current and future societal needs for food and fiber, ecosystem services, and healthy lives by maximizing the net benefit to society when all costs and benefits of the practices are considered. The need and basis of sustainable agriculture can be better understood through the figure.

Comment [AS29]: Pay attention to how the citation/references is written

Fig 4. Need and basis of the sustainable agriculture (Source: Singh et al., 2019)



Comment [AS30]: Look at the previous comments.

Sustainable agriculture encompasses a comprehensive range of soil, pest, and nutrient management technologies, including the use of crop residues, dung, biological nitrogen fixation, crop rotations, mixed cropping, and others (Mtengeti et al., 2015). These measures not only promote biological diversity but also enhance soil quality, nutrient pools, and ecosystem restoration. Additionally, they contribute to increased climate resilience by reducing soil degradation, all while improving the socio-economic status of farmers.

However, the subsidized rate of synthetic fertilizers and the limited availability of organic nutrient sources present significant obstacles to the transition towards a sustainable agroecosystem.

Conclusion

While the Green Revolution has significantly contributed to fulfilling the role of providing food to a large population, the excessive reliance on external inputs such as synthetic fertilizers and agrochemicals has resulted in the degradation of natural resources and the environment. The Indian government has formulated numerous plans and strategies to address the issue of climate

Comment [AS31]: Have you summarized the key concepts/principles, practices, and challenges that are the aim of conducting a journal review as stated in the introduction?

change. However, the effective implementation of these plans remains a challenge. It is crucial to create and diligently execute appropriate strategies and regulations for climate change in the long run, given its significant impact on agricultural production. Therefore, there is an urgent need to prioritize and implement sustainable practices for the benefit of farmers, the environment, and food security."In the current changing climate scenario, sustainable agriculture has emerged as a viable alternative. Its significance is evident not only in maintaining long-term crop productivity and soil health but also in contributing to the reduction of greenhouse gas emissions from the agriculture and allied sectors. Sustainable agriculture operates in a manner that aims to meet both current and future societal needs for food and fiber, as well as for ecosystem services and healthy lives. This is achieved by maximizing the net benefit to society.

References

Verma, B., Porwal, M., Agrawal, K. K., Behera, K., Vyshnavi, R. G., & Nagar, A. K. (2023). Addressing Challenges of Indian Agriculture with Climate Smart Agriculture Practices, *Emrg. Trnd.Clim. Chng.* 2(1), 11-26. doi: <http://dx.doi.org/10.18782/2583-4770.121>

Arulbalachandran D, Mullainathan L, Latha S (2017) Food Security and sustainable agriculture. Sustainable agriculture towards food security. Springer, Singapore, pp 3–13

Barea JM (2015) Future challenges and perspectives for applying microbial biotechnology in sustainable agriculture based on a better understanding of plant-microbiome interactions. *J Soil Sci Plant Nutr* 15:261–282.

Corwin DL, Loague K, Ellsworth TR (1999) Assessing non-point source pollution in the vadose zone with advanced information technologies. In: Corwin DL, Loague K, Ellsworth TR (eds) Assessment of non-point source pollution in the vadose zone. Geophysical Monogr 108: AGU, Washington, DC, USA, pp 1–20.

Directorate of Economics & Statistics (2019) Agricultural statistics at a glance. <http://eands.dacnet.nic.in/>. Accessed 21 Aug 2019.

Ehrlich PR, Harte J (2015) Food security requires a new revolution. *Int J Environ Stud* 72:908–920. <https://doi.org/10.1080/00207233.2015.1067468>

Kumari T, Singh R, Verma P (2019) Agriculture, forests and environmental management trinity: towards environmental sustainability and climate change mitigation. *Trop Ecol.* <https://doi.org/10.1007/s42965-019-00025-0>

Comment [AS32]: All reference sources in the manuscript must be included in this list.

Comment [AS33]: On the other hand, if it is not in the manuscript, there is no need to write it in the references.

Please pay attention to other reference sources.

Mtengeti EJ, Brenttrup F, Mtengeti E, Eik LO, Chambuya R (2015) Sustainable intensification of Maize and Rice in smallholder farming systems under climate change in Tanzania. In: Lal R et al (eds) Sustainable intensification to advance food security and enhance climate resilience in Africa. Springer, Switserland, pp 441–465.
<https://www.cgiar.org/innovations/climate-smart-villages-and-valleys/>

Srivastava P, Singh R, Tripathi S, Raghubanshi AS (2016) An urgent need of sustainable thinking in agriculture—an Indianscenario. *Ecol Indian* 67:611–622.
<https://www.cgiar.org/innovations/climate-smart-villages-and-valleys/>

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S (2002) Agricultural sustainability and intensive production practices. *Nature* 418:671–677.
<https://doi.org/10.1038/nature01014>.

INECC (2010) The semi-arid region (2010). <http://www.ced.org.in/docs/inecc.pdf>. Accessed 20 Apr 2014 International Fund for Agricultural Development (IFAD) (2012) Sustainable smallholder agriculture: feeding the world, protecting the planet. *International Fund for Agricultural Development, Rome, p 12*.

Mahato, A. (2014). Climate change and its impact on agriculture. *International Journal of Scientific and Research Publications*, 4(4), 1-6.