Sustainable Nutrient Management under Changing Climate

Shagun Jaggi[1]*, Sandeep Manuja[2], G D Sharma[3], B S Mankotia[4] and Pankaj Kumar[5]

[1]*Ph.D. Scholar, Department of Agronomy, CSK HPKV, Palampur, HP, India-176062*
[2]*Principal Scientist, Department of Agronomy, CSK HPKV, Palampur, HP, India-176062*
[3]*Principal Scientist, Department of Agronomy, CSK HPKV, Palampur, HP, India-176062*
[4]*Principal Scientist, Department of Agronomy, Shivalik Agricultural Research and Extension Centre, Kangra, CSK HPKV, HP, India-176001*
[5]*Ph.D. Scholar, Department of Agronomy, CSK HPKV, Palampur, HP, India-176062*

Corresponding Author
Shagun Jaggi
Email: shagunjaggi260299@gmail.com

OPEN ACCESS

Keywords

Sustainability, Climate Change, Management

How to cite this article:

Jaggi, S., Manuja, S., Sharma, G. D., Mankotia, B. S. and Kumar, P. 2025. Sustainable Nutrient Management under Changing Climate. *Vigyan Varta* 6(4): 91-94.

ABSTRACT

Climate change poses significant threats to agriculture, affecting food security and sustainability worldwide. Sustainable nutrient management integrates innovative practices such as precision farming, organic amendments, enhanced efficiency fertilizers, and water-saving technologies to improve soil health and optimize nutrient use. Advanced solutions like biochar, nanofertilizers, and microbial inoculants enhance resilience against climate stress. In India, initiatives like National Mission for Sustainable Agriculture (NMSA), Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and Paramparagat Krishi Vikas Yojana (PKVY) support sustainable nutrient management to mitigate climate impacts. By adopting sustainable nutrient management practices, we can promote sustainable agricultural productivity, reduce environmental degradation, and ensure long-term food security with changing climate.

INTRODUCTION

Climate plays a crucial role in shaping agricultural productivity. Changing climate poses a significant threat to global food and nutritional security, due to increasing temperatures, altered precipitation patterns, and more frequent extreme weather events (Petrovic and Csambalik 2025). The average global temperature is projected to rise by 2°C by 2100, causing substantial economic losses worldwide. The alarming increase in CO_2 concentration, a major greenhouse gas, further exacerbates climate-related challenges (Malhi *et al*. 2021).

Agriculture, being highly sensitive to climatic variations, faces severe economic impacts, especially as the global population is expected to surpass 9 billion by 2050, necessitating a 70% increase in food production (Anonymous 2023). While chemical fertilizers play a crucial role in enhancing agricultural productivity, their excessive use significantly contributes to anthropogenic greenhouse gas emissions. Therefore, adopting sustainable nutrient management practices will not only maintain the crop production but will also reduce the environmental pollution. Sustainable nutrient management approach uses the combination of well tested practices and principles of modern and traditional technologies in an integrated manner aimed at profitable crop production with better crop quality, nutrient use efficiencies and lower environmental pollution using crop management (crop rotation, intercropping), soil management (manures, green manures, organic fertilizers, nanofertilizers and crop residues), site specific nutrient application to fulfil the crop nutrient demand (Rehman *et al*. 2019).

Methods and techniques for nutrient management under changing climate

1. **Precision Agriculture:** Precision Agriculture techniques play a crucial role in efficient nutrient management. Precision agriculture comprises a set of technologies that combines sensors, information systems, enhanced machinery, and informed management to optimize production by accounting for variability and uncertainties within agricultural systems (Gebbers & Adamchuk 2010). Variable rate technology enables precise nutrient application based on real-time crop needs, reducing overuse and minimizing losses. Remote sensing and geographic information systems further enhance decision-making by providing real-time data on soil health and nutrient deficiencies through drone or satellite monitoring.

2. **Integrated Nutrient Management:** It is a practice that aims to maintain soil fertility and plant nutrient levels to sustain crop productivity while also balancing ecological well-being. It involves combining chemical fertilizers, organic manure, biofertilizers, and other natural sources to achieve an optimal nutrient balance. It also seeks to optimize the soil's physical, chemical and biological properties to enhance farm productivity and minimize land degradation.

3. **Conservation Agriculture:** Conservation Agriculture (CA) is a farming system that promotes minimal soil disturbance, maintaining soil cover, and crop diversification (Michler *et al*. 2019). It aims to achieve sustainable and profitable agriculture while protecting and enhancing the environment. Conservation Agriculture is based on three core principles that work synergistically to improve soil health, reduce erosion, and increase water use efficiency.

4. **Enhanced Efficiency Fertilizers:** Synthetic fertilizers contribute to

greenhouse gas emissions, particularly nitrous oxide (N_2O), a potent contributor to climate change. Sustainable practices such as using slow-release fertilizers, nitrification inhibitors, and organic amendments can reduce emissions while maintaining crop productivity. Nanofertilizers provide smart nutrient delivery to the plants and proves their efficacy in terms of crop productivity and environmental sustainability over bulky chemical fertilizers (Babu *et al*. 2022). Encouraging the use of biofertilizers and microbial inoculants enhances nitrogen fixation and nutrient availability, decreasing the dependence on synthetic inputs.

5. **Carbon Sequestration:** Healthy soils play a crucial role in nutrient availability and climate resilience. Practices such as cover cropping, crop rotation, conservation tillage, and agroforestry enhance organic matter content, improve nutrient retention, and reduce soil erosion. Biochar application further improves soil structure, increases nutrient-holding capacity, and aids in carbon sequestration, reducing greenhouse gas emissions. Maintaining soil microbial diversity through organic amendments enhances nutrient cycling and promotes plant resilience against climate-induced stresses.

6. **Water Management:** Climate change affects precipitation patterns, influencing water availability and nutrient transport in soils. Efficient water management techniques such as drip irrigation and fertigation ensure precise nutrient delivery, preventing losses due to excessive runoff or evaporation. Mulching helps retain soil moisture while reducing nutrient leaching. Additionally, adopting rainwater harvesting and moisture conservation techniques ensures sustainable water use in nutrient management.

7. **Use of climate-resilient crop varieties:** The use of climate-resilient crop varieties is a vital strategy for sustaining agricultural productivity amid changing climatic conditions. These crops are specifically bred or genetically modified to withstand environmental stresses such as drought, heat, floods, salinity, and pest infestations. Drought-tolerant varieties, like drought-resistant maize, have deep root systems and improved water-use efficiency, while heat-tolerant crops, such as heat-resistant wheat, possess mechanisms to withstand high temperatures. Additionally, pest and disease-resistant crops, including Bt cotton, help mitigate losses caused by increasing pest populations due to climate change. By adopting these resilient crop varieties, farmers can improve food security, reduce agricultural losses, and adapt to the evolving environmental challenges posed by climate change.

8. **Soil health monitoring and decision support systems:** Artificial intelligence (AI), machine learning, and Internet of Things (IoT) sensors help in real-time soil nutrient monitoring. Decision-support systems (DSS) analyse climate, soil, and crop data to recommend precise nutrient applications.

9. **National programmes for nutrient management under changing climate:** India has key initiatives addressing environmental and agricultural challenges. The National Mission for Sustainable Agriculture (NMSA) promotes sustainable practices, Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) focuses on water management, and Paramparagat Krishi Vikas Yojana (PKVY) promotes organic farming. These efforts support India's sustainability and productivity goals.

CONCLUSION

Sustainable nutrient management under changing climate conditions is crucial to ensure food security, enhance soil health, and reduce environmental impacts. By adopting site-specific nutrient management practices, optimizing fertilizer use through technologies like neem-coated urea and precision tools and incorporating organic and eco-friendly inputs, we can boost crop resilience and productivity. Addressing climate variability through adaptive nutrient strategies not only mitigate nutrient losses but also promotes efficient resource use, contributing to long term agricultural sustainability.

REFERENCES

Anonymous. 2023. Agriculture Census 2015-16. Department of Agriculture, Co-Operation and Farmers Welfare, Government of India. pp 49

Babu S, Singh R, Yadav D, Rathore SS, Raj R, Avasthe R, Yadav SK, Das A, Yadav V, Yadav B and Shekhawat K. 2022. Nanofertilizers for agricultural and environmental sustainability. *Chemosphere* 292:133451

Gebbers R and Adamchuk VI. 2010. Precision agriculture and food security. *Science* 327(5967): 828-31

Malhi GS, Kaur M and Kaushik P. 2021. Impact of climate change on agriculture and its mitigation strategies. *Sustainability* 13(3): 1318

Michler JD, Baylis K, Arends-Kuenning M and Mazvimavi K. 2019. Conservation agriculture and climate resilience. *Journal of Environmental Economics and Management* 93:148-69

Petrovic B and Csambalik L. 2025. Enhancing precision agriculture for climate change mitigation in Visegrad countries: factors shaping adaptation. *Land* 14(2): 399

Rehman A, Ullah A, Nadeem F and Farooq M. 2019. Sustainable nutrient management. *Innovations in Sustainable Agriculture* 167-211.