Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 02 (MAR-APR, 2026)
Available online at http://www.agriarticles.com
©Agri Articles, ISSN: 2582-9882

Agronomic Implications of Crop Residue Retention on Soil Nutrient Stratification and Productivity Sustainability in Intensive Cropping Systems

*Pritesh Mishra and Abhay Kumar Yadav
Research Scholar, Dept. of Agronomy, Shri Durga Ji Post Graduate College, Chandeshwar, Azamgarh (U.P.), India
*Corresponding Author's email: priteshmishra.ace@gmail.com

Crop residue management has become an important component of sustainable agriculture, especially in intensive cereal-based cropping systems such as the rice–wheat system. India produces a very large quantity of crop residues every year; however, a significant portion of these residues is still disposed of through open-field burning. This practice results in serious nutrient losses, decline in soil organic carbon, reduction in biological activity, and deterioration of environmental quality. In contrast, retention of crop residues in the field improves soil structure, enhances microbial activity, conserves soil moisture, and contributes to better nutrient recycling within the soil profile. Residue retention also plays an important role in maintaining soil nutrient stratification and sustaining crop productivity under intensive cropping systems. Therefore, adoption of appropriate residue management strategies is essential for improving soil health and ensuring long-term agricultural sustainability.

Keywords: Crop residue management, nutrient stratification, conservation agriculture, soil organic carbon, rice–wheat system, productivity sustainability, residue burning, soil fertility management

Introduction

Crop residue management has emerged as a major concern in intensive cereal-based production systems, particularly in the Indo-Gangetic Plains of India. The country produces approximately 500–686 million tonnes of crop residues annually, of which nearly 70% originates from cereal crops (ICAR, 2022; Ministry of Agriculture & Farmers Welfare, 2021). Among these, rice and wheat alone contribute nearly 154 million tonnes and 131 million tonnes of residues per year, respectively (Pathak et al., 2011; Singh & Sidhu, 2014). Despite their high nutrient recycling potential, nearly 92 million tonnes of crop residues are burned annually, especially in northwestern India, due to the short interval between rice harvesting and wheat sowing (Jain *et al.*, 2014). Combine harvesting operations leave approximately 12–13 t ha^{-1} residue in paddy fields, which creates operational challenges for subsequent crop establishment and encourages residue burning (Sidhu et al., 2015). Burning of crop residues results in substantial nutrient losses. It has been reported that burning one tonne of crop residue causes loss of approximately 5.5 kg nitrogen, 2.3 kg phosphorus, 25 kg potassium and 1.2 kg sulphur (Gupta *et al.*, 2004; ICAR-IARI, 2012).

Table 1: Nutrient losses due to burning of crop residues

Nutrient	Loss (kg per tonne residue burned)
Nitrogen	5.5
Phosphorus	2.3
Potassium	25
Sulphur	1.2

Residue burning also releases major atmospheric pollutants such as **CO_2, CO, SO_2 and NOx**, contributing significantly to regional air pollution and greenhouse gas emissions (Pathak et al., 2011; Jain *et al.*, 2014). Repeated burning further reduces soil biological activity by destroying beneficial microorganisms and lowering soil organic carbon content (Singh & Sidhu, 2014). Therefore, crop residue retention has become an essential agronomic strategy for improving soil nutrient stratification and ensuring long-term productivity sustainability under intensive cropping systems.

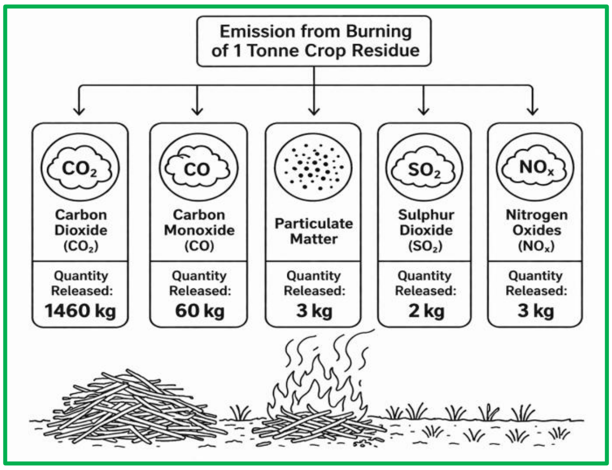


Fig 1: Air pollutant emission from residue burning

Environmental and Agronomic Impacts of Crop Residue Burning

Residue burning negatively affects soil fertility, biological activity, and environmental quality.

Impact on Soil Nutrient Status

Burning causes substantial nutrient volatilization losses, resulting in long-term nutrient mining and increased dependence on chemical fertilizers.

Impact on Soil Biological Properties

High temperatures (400–500°C) during burning destroy beneficial soil microorganisms such as:

- nitrogen fixing bacteria
- phosphate solubilizing bacteria
- beneficial fungi

This significantly reduces biological nutrient cycling capacity of soils (Singh & Sidhu, 2014).

Impact on Soil Physical Properties

Residue burning leads to deterioration of soil physical structure:

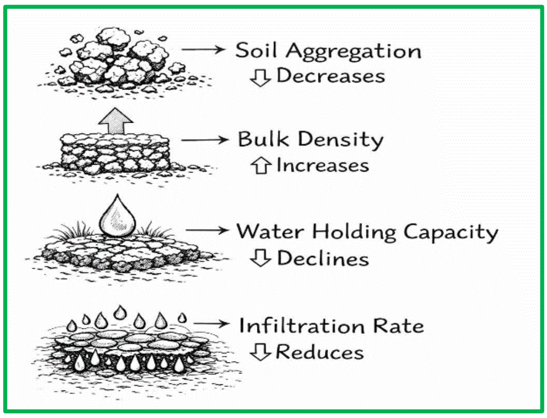


Table 2: Effect on soil physical properties

Soil property	Effect
Soil aggregation	Decreases
Bulk density	Increases
Water holding capacity	Declines
Infiltration rate	Reduces

Impact on Climate and Air Quality

Residue burning contributes significantly to greenhouse gas emissions. It releases large quantities of:

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)

These gases accelerate climate change and influence productivity stability in intensive cropping regions (Pathak *et al.*, 2011).

Crop Residue Retention and Soil Nutrient Stratification

Crop residue retention plays an important role in improving nutrient distribution within the soil profile. Residues left on the soil surface undergo gradual decomposition and release nutrients slowly, improving nutrient availability in upper soil layers.

Residue retention enhances

- soil organic carbon accumulation
- nitrogen mineralization
- phosphorus availability
- potassium recycling efficiency

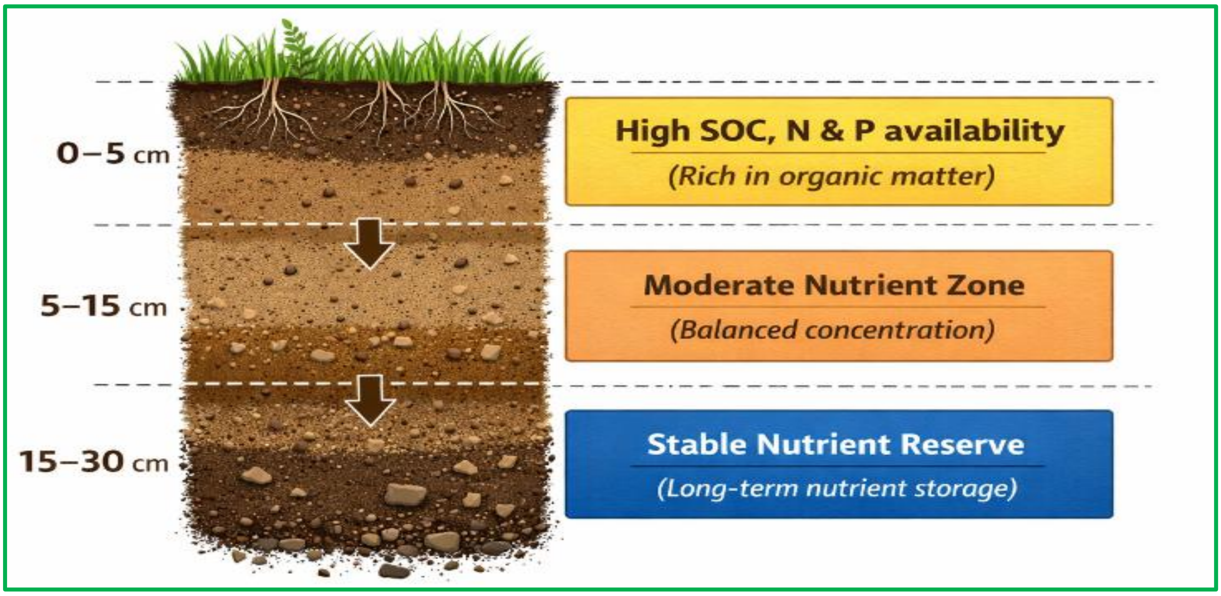


Fig 2: Nutrient stratification pattern under residue retention

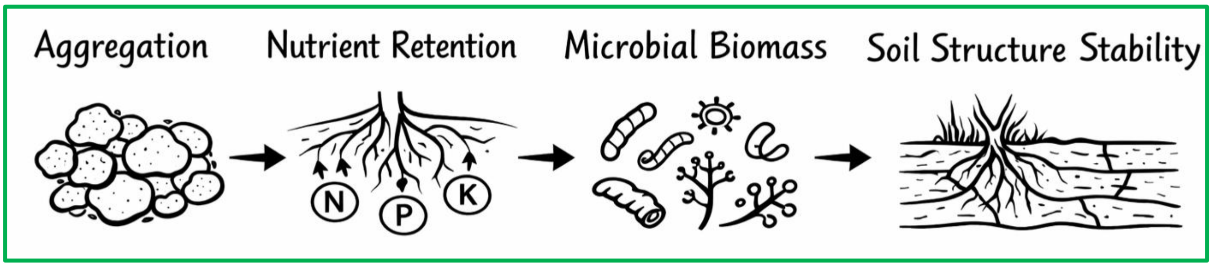
Improved nutrient stratification enhances root growth and nutrient uptake efficiency under conservation agriculture systems.

Role of Crop Residue Retention in Productivity Sustainability

Residue retention improves productivity sustainability through several mechanisms.

Improvement in Soil Organic Carbon

Retention of residues increases soil organic carbon, which improves:



This is particularly important in cereal-based intensive cropping systems (Lohan *et al*., 2018).

Improvement in Soil Moisture Conservation

Residue mulch reduces evaporation losses and improves infiltration rate, thereby improving soil hydrothermal regime under field conditions.

Residue retention may increase soil moisture availability by **5–10%** during crop growth stages (Lohan *et al*., 2018).

Crop Residue Management Strategies in Intensive Cropping Systems

Adoption of appropriate residue management practices is essential for sustaining soil fertility and productivity.

Surface Residue Retention (Mulching)

Surface retention improves:

- soil moisture conservation
- temperature moderation
- weed suppression

Residue Incorporation

Residue incorporation enhances microbial decomposition and increases soil organic matter content.

Conservation Agriculture Approach

Conservation agriculture integrates:

- zero tillage
- residue retention
- crop diversification

These practices improve resource-use efficiency and stabilize crop yields (Gupta & Seth, 2007).

Government Initiatives Supporting Crop Residue Management in India

Recognizing the importance of residue management, the Government of India has implemented several initiatives.

Crop Residue Management Scheme (CRM)

The Crop Residue Management (CRM) Scheme is a Central Sector Scheme launched by the Government of India (2018) to address the major issue of stubble burning (parali burning), especially in northern states like:

- Punjab
- Haryana
- Uttar Pradesh
- Delhi (NCR region)

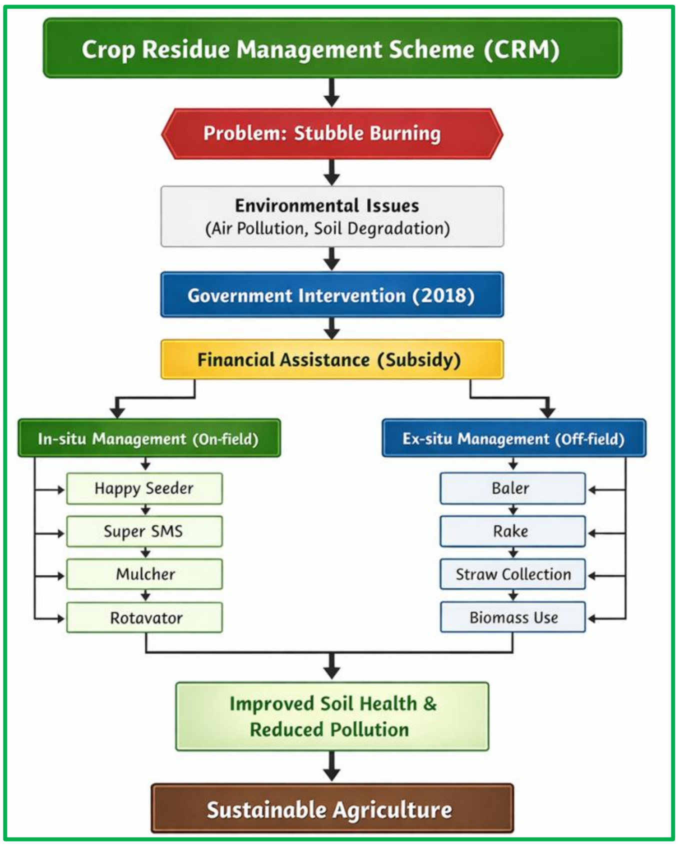


Fig 4: Flowchart of Crop Residue Management Scheme (CRM)

The Crop Residue Management Scheme (CRM) can be easily understood through the flowchart given below, which illustrates its key components, processes, and outcomes.

Sub-Mission on Agricultural Mechanization (SMAM)

The Sub-Mission on Agricultural Mechanization (SMAM), implemented by the Ministry of Agriculture & Farmers Welfare since 2014–15, aims to enhance farm mechanization and improve access to modern agricultural equipment, especially for small and marginal farmers.

- The scheme provides **40–80% financial assistance (subsidy)** for purchasing agricultural machinery.
- It promotes the establishment of **Custom Hiring Centres (CHCs)** to make machinery accessible on a rental basis.

As per recent government-related data:

- **₹6,748+ crore funds** have been released to states.
- **15.7 lakh+ agricultural machines** have been distributed.
- Around **23,000+ Custom Hiring Centres (CHCs)** have been established across India.

National Mission on Sustainable Agriculture (NMSA)

The National Mission on Sustainable Agriculture (NMSA) is a key initiative under the National Action Plan on Climate Change (NAPCC), focusing on climate-resilient and sustainable farming practices.

- It promotes **conservation agriculture**, including residue retention, soil health improvement, and efficient water management.
- A major component is **Soil Health Management (SHM)**, which encourages balanced nutrient use through organic and inorganic sources.

Constraints in Adoption of Residue Retention

Despite several advantages, adoption remains limited due to:

- limited machinery availability
- short turnaround period between crops
- lack of awareness among farmers
- higher initial operational cost

Strengthening extension services and mechanization access can significantly improve adoption rates.

Conclusion

Crop residue retention is an essential agronomic intervention for improving soil nutrient stratification and sustaining productivity in intensive cropping systems. It enhances soil organic carbon status, improves nutrient recycling efficiency and supports soil biological activity. In contrast, residue burning leads to nutrient losses, soil degradation and environmental pollution. Adoption of conservation agriculture practices supported by government initiatives can significantly improve soil health and ensure long-term sustainability of cereal-based cropping systems in India. Therefore, promotion of residue retention technologies should be prioritized for achieving sustainable agricultural intensification.

References

1. Gupta, R. K., & Seth, A. (2007). A review of resource conserving technologies for sustainable management of the rice–wheat cropping systems of the Indo-Gangetic Plains. *Crop Protection*, 26(3), 436–447.
2. Gupta, P. K., Sahai, S., Singh, N., Dixit, C. K., Singh, D. P., Sharma, C., Tiwari, M. K., Gupta, R. K., & Garg, S. C. (2004). Residue burning in rice–wheat cropping system: Causes and implications. *Current Science*, 87(12), 1713–1717.
3. ICAR (2022). *Annual Report 2021–22*. Indian Council of Agricultural Research, New Delhi, India.
4. ICAR–IARI (2012). *Crop Residue Management with Conservation Agriculture: Potential, Constraints and Policy Needs*. Indian Agricultural Research Institute, New Delhi, India.
5. Jain, N., Bhatia, A., & Pathak, H. (2014). Emission of air pollutants from crop residue burning in India. *Aerosol and Air Quality Research*, 14, 422–430.
6. Lohan, S. K., Jat, H. S., Yadav, A. K., Sidhu, H. S., Jat, M. L., Choudhary, M., & Peter, J. K. (2018). Burning issues of paddy residue management in north-west states of India. *Renewable and Sustainable Energy Reviews*, 81, 693–706.
7. Ministry of Agriculture & Farmers Welfare (2021). *Agricultural Statistics at a Glance 2021*. Government of India, New Delhi.
8. Pathak, H., Bhatia, A., Jain, N., & Aggarwal, P. K. (2011). Greenhouse gas emission and mitigation in Indian agriculture. *INCCA Report*, Indian Network for Climate Change Assessment, Government of India.
9. Sidhu, H. S., Singh, M., Blackwell, J., Lohan, S. K., Humphreys, E., Jat, M. L., Singh, Y., & Singh, S. (2015). Development and evaluation of the Happy Seeder for direct drilling of wheat into combine-harvested rice residue. *Field Crops Research*, 184, 201–212.
10. Singh, Y., & Sidhu, H. S. (2014). Management of cereal crop residues for sustainable rice–wheat production system in the Indo-Gangetic Plains of India. *Proceedings of the Indian National Science Academy*, 80(1), 95–114.