AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 05 (May, 2026)
Available online at http://www.agrimagazine.in

From Waste to Wealth: How Crop Residue Management Can Rebuild Farm Fertility

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Crop residue management (CRM) plays an important role in improving soil quality and sustainable farming. This research reviews CRM in India, especially in rice–wheat systems, which burns residues leading to nutrient loss and environmental degradation. It explores in-situ and ex-situ methods to transform residues into resources, enhancing soil fertility, carbon storage and crop yields. CRM can mitigate environmental hazards, save input costs and facilitates climate smart agriculture.

Introduction

- Today's agriculture is faced with soil degradation, high cost of fertilizers and environment issues; intensive crops region like Punjab. Crop residues (cereal, pulse and oilseed crop residues) contain valuable nutrients, like for 1 ton of rice straw and wheat stubble, 24 - 36Kg nitrogen, 8-13 Kg phosphorus, 70Kg-80 kg potassium and sulphur450-550g. CRM is different from burning which is greenhouse gases emitter and causes soil degradation, this recycles the biomass to build long term fertility.
- Straw burning is not economical as farmer has to purchase nutrients again and this is environment friendly as it is part of our 2018 Crop Residue Management Scheme.

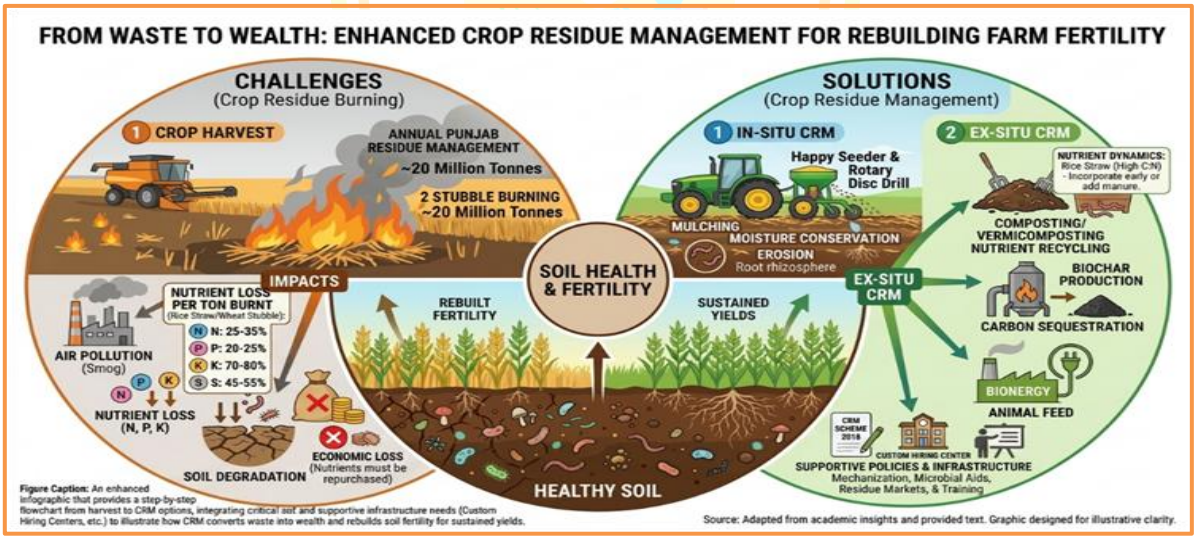

Figure Caption: An enhanced infographic that provides a step-by-step flowchart from harvest to CRM options, integrating critical soil and supportive infrastructure needs (Custom Hiring Centers, etc.) to illustrate how CRM converts waste into wealth and rebuilds soil fertility for sustained yields.

- This flow chart of CRM from crop to either mulch in-situ or valorise ex-situ (compost and biochar) thereby improving soil fertility, this type of division is shown here.

Agronomic Role and Processes

- CRM enhances fertility of the farm physically, chemical and biologically. Mulching on the soil surface prevents soil erosion, improves water retention and over time improves

soil structure. Residues recycles nutrients, elevates cation exchange capacity, increases soil organic carbon (SOC) and increases water and fertilizer use efficiency.

- Biologically, residues provide microbial, earthworm and enzyme activity, and form a robust rhizosphere. Adoption in Punjab's rice-wheat farms over time increases SOC and yields, and reduces costs.

In-Situ Management

- Don't remove residues, practice zero tillage or direct sowing (e.g. Happy seeded or Rotary Disc Drill). These can be used to sow quickly without burning, and are suitable for shorter crop cycles in Punjab.

Ex-Situ Management

- Take excess to be composted, made into vermicompost, mushroom substrate, briquettes or biochar. This provides revenue and solves biomass problems if site is small.
- Nutrient management: Residues with a high C:N ratio (such as rice straw) can immobilise N: incorporate 30-45 days before sowing or apply manure.

Challenges and Evidence

- Barriers include availability of machinery and labour, and planting timelines in Punjab, which generates 20 million tonnes of paddy stubble annually. Research indicates CRM enhances seedling emergence, reduces cost and increases yield; a Bareilly intervention led to higher adoption and income.
- It helps the environment by reducing pollution and lowers costs by reducing fertiliser use

Parameter	Conventional Practice (Residue Burning)	CRM Practices (In-Situ and Ex-Situ)	Impact in Punjab
Paddy residue generation	Approx. 20 million ton annually, largely burned	Residues will be retained, incorporated, or processed.	Efficient utilization of biomass resources
Soil organic carbon (SOC)	Continuous decline of SOC	Gradual increase with repeated CRM adaptation	It improved soil structure and long-term fertility
Nitrogen availability	Significant loss due to volatilization process	Nutrient started recycling through residue incorporation	It reduced dependency on synthetic fertilizers too
Wheat yield	Baseline productivity	Increase of Approx. 5–10% (reported trends)	It improved crop establishment and stability of the yield
Cost of cultivation	Higher due to residue removal and fertilizer inputs	Reduced input costs (fertilizer and land preparation)	It enhanced profitability of the farm
Air pollution	High emissions of these gases (PM2.5, CO_2, CH_4)	Substantial reduction in emissions of polluted air	It improved environmental and public health of the world
Water use efficiency	Became lower due to exposed soil	It improved through mulching and residue cover	Became better moisture conservation
Mechanization	Limited use of residue management machinery	Increased use of Happy Seeder, RDD, SMS	Facilitates timely sowing and better field operations
Farmer adoption	Initially low	Increasing due to subsidies and awareness programs	Positive trend toward sustainable practices

Source: Adapted from Sidhu et al. (2021), Singh et al. (2021), Sisodiya et al. (2023), ICAR (2023), CEEW (2025), and Kumar et al. (2024).

Conclusion

- Crop residue management is an environmentally sustainable way to turn waste into a resource for improving soil fertility and productivity. Through lower burning, it reduces pollution, greenhouse gas emissions, and enhances soil fertility, via higher soil carbon and nutrient cycling. In-situ and ex-situ CRM practices, coupled with suitable machinery, policies and education can improve climate resilience. Scaling-up CRM is crucial for sustainable, profitable and environment-friendly farming systems in India.
- The potential of CRM is mechanization, microbial inoculum, markets and policies (such as custom hiring centres). It promotes climate-smart agriculture and Punjab's "zero-burn" pledge through diversification and capacity building.

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