

Enhancing Sustainability: The Role of Crop Residue in Modern Agriculture

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Abstract

In the quest for sustainable agriculture, effective management of crop residues has emerged as a critical factor in enhancing soil health, improving crop yields, and reducing environmental impact. Crop residue management in modern farming practices can increase organic matter, enhance nutrient availability, and improve soil structure, which collectively contributes to more resilient and productive agricultural systems. Additionally, the article discusses innovative techniques such as resource conservation technology, residue recycling, its utilization and alternative uses like composting, bio fuels, bio gas/energy and mulching. On the other hand, burning of crop residue increases greenhouse gas emissions and environment pollution. By adopting effective crop residue management practices, farmers can significantly achieve sustainability goals, ensuring long-term agricultural viability and environmental stewardship.

Introduction

Agriculture is the mainstay of Indian economy, contributing about 17.4 percent of the country's gross domestic product (GDP) and providing livelihood to about 48.9 percent population. In India, agricultural crops are the backbone of food security of the Nation with the current food grain production of 285.71 mt (Agriculture Statistics at a glance, 2022). These crops produces 686 mt gross crop residue biomass on annual basis, of which 234 mt (34% of gross) are estimated as surplus for bio-energy generation (Hiloidhari *et al.*, 2014). The processing of agricultural produce through milling and packaging also produces residues, which are used for animal feeding, soil mulching, composting, thatching roofs as well as fuel for domestic and industrial purposes. Thus, crop residues are of tremendous value but large portion of it is burnt on-farm primarily to clear the field for sowing of the succeeding crop. In recent years burning of crop residues causes environmental pollution, is hazardous to human health, produces greenhouse gases causing global warming and results in loss of nutrients like N, P, K and S. In an estimation about 93 mt of crop residues are burnt on-farm in the country (Pathak *et al.*, 2010). Therefore, appropriate management of crop residue assumes great importance.



The RCTs with innovations in residue management avoid straw burning, improve soil organic C, enhance input efficiency and have the potential to reduce GHGs emissions (Pathak *et al.*, 2011). Recent research efforts have developed conservation agriculture-based crop management technologies which are more resource-efficient than the conventional practices. The other alternative uses of crop residues are preparation of compost, mulching, bio energy, bio-fuel and bio-gas production.

India has the challenging task of ensuring food security, for ensuring the country's food security both in the short- and long-term perspectives and making agriculture sustainable, the soil resource base must be strong and healthy. Conservation agriculture, with crop residues as an integral component, is an effective solution to the aforesaid challenges and ensures a strong natural resource base. The conservation agriculture sets principles towards sustainable production systems and these principles need to be translated into practices as per site-specific requirements. Crop residues are of great economic values as livestock feed, fuel and industrial raw material, and in conservation agriculture for which it is a pre-requisite. Crop residues, either partly or entirely must be used for conservation agriculture for ensuring the country's food security, making agriculture sustainable and the soil resource base healthy.

Crop residue

Crop residue is defined as the above ground part of the plant remaining after the grain is harvested. It includes both the stubble left after the harvest process and the leaves and stems left over after threshing.

Crop residue management

Crop residue management: Crop residue management refers to the practices used to handle the remains of crops after harvest. It also provides seasonal soil protection from wind and rain erosion, adds organic matter to the soil, conserve soil moisture, improves infiltration, aeration and tilth.

Different methods for crop residue management are incorporation into soil, mulching, burning, composting animal feed, bioenergy production and retaining residues helps to utilized available crop residue generated from various crops. Each method has its own advantages and is chosen based on factors such as crop type, soil conditions, climate, and economic considerations. Combining methods, such as using cover crops and incorporating residues, can often yield the best results for sustainable farming.

Generation and utilization of crop residues in India

Table 1: Generation of crop residues in India

Sr. No.	Crop	Crop residues (mt yr ⁻¹)	Percentage to total (%)
1.	Cereals	367	53
2.	Fibres	80	12
3.	Oilseeds	49	7
4.	Pulses	18	3
5.	Sugarcane	111	16
6.	Horticulture	61	9

Utilization of crop residues in India

According to the energy Report current use of crop residues as Fodder 300.3 mt, Fuel 214 mt and Others 105 mt (TERI, 2015)

Table 2. Utilization of crop residues in India

Sr.No.	Crop Residue	Utilization
1.	Cereal crops	fodder, fuel, roof thatching, packaging and composting.
2.	Rice straw and husk	Fuel in boilers for parboiling rice
3.	Sugarcane	Tops used for feeding animals
		Trash burnt for growing a ratoon crop
		Trash used as mulching
4.	Groundnut	Fuel in brick kilns and lime kilns
5.	Cotton	Fuel for household needs as domestic fuel
6.	Pulses	--
7.	Oilseeds	--

Burning of crop residues in India

The surplus residues i.e., total residues generated minus residues used for various purposes, are typically burnt on farm. Estimated total amount of crop residues surplus in India is 91-141mt.

Adverse effects of on-farm burning of crop residues

1. Burning of crop residues leads to human and animal health problems.
2. It also leads to emission of greenhouse gases (GHGs) causing global warming.
3. Loss of plant nutrients like N, P, K and S.
4. Burning of crop residues increases soil temperature
5. Death of microbial population,
6. Long-term burning reduces total N and C from the upper soil layer.

Emission of greenhouse gases (GHGs)

One ton of crop residues on burning releases CO₂ - 1,515 Kg, CO - 92 Kg, NO₂ - 3.83 Kg, SO₂ - 0.4 Kg, CH₄ - 2.7Kg, VOCs-15.7 Kg (volatile organic compounds), Ash-199 kg and particulate matter - 3 kg. These gases and aerosols lead to adverse impacts on human health in addition to contributing to global climate change.



Reasons behind on-farm burning of crop residues

1. Increased mechanization
2. Declining numbers of livestock
3. Long period required for composting and unavailability of alternative economically viable solutions
4. Labour shortage, high wages during harvesting season

Reasons behind intentional burning of crop residues

1. Clearing of fields to facilitate land preparation for sowing/planting.
2. Soil fertility enhancement.
3. Controlling weeds, pest and diseases.
4. High transportation cost.
5. Availability of nutrients like P and K
6. Reduces soil acidity.

Benefits of crop residues

1. It acts as a reservoir of plant nutrients and also prevents their losses
2. It affects the availability of nutrients by chelation
3. It helps in buffering capacity of soil
4. It helps in maintaining soil structure
5. It helps in transmission of heat
6. It is a source of carbon for heterotrophs
7. It influences the efficiency of chemicals, their degradability and toxicity
8. It helps plant through growth substances
9. It reduces the toxicities of pollutants like heavy metals
10. It conserves the soil and water
11. It is a soil amendment
12. It helps in conservation of energy
13. It helps in minimization of environmental pollution
14. It helps in bridging the fertilizer gap

Crop Residue and Ecosystem Services

1. Crop residues have numerous competing uses, such as removal for biofuel production, animal feed and industrial raw material or returned to soil as an amendment.
2. Soil application of crop residues as amendment is necessary to enhance/maintain soil quality and sustain agronomic productivity.



Conclusion

Agricultural crops are the backbone of food security of the Nation. These crops produce huge amount of crop residue annually. The processing of agricultural produce through milling and packaging also produces residues, which are used for animal feeding, soil mulching, composting, thatching roofs as well as fuel for domestic and industrial purposes. Large portion of it is burnt on-farm primarily to clear the field for sowing of the succeeding crop that leads to environmental pollution. Burning is hazardous to human health, produces green-house gases causing global warming and results in loss of nutrients like N, P, K and S. Therefore, appropriate management of crop residue assumes great importance.

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