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Crop Residue Management: An Approach to Soil Health

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Crop residue management refers to the practice of handling crop residues or the materials left in an agricultural field after the crop has been harvested. This includes materials such as stalks, stems, leaves, and seed pods. The manner in which these crop residues are managed can have significant effects on soil health and agricultural sustainability. Crop residue protects the soil from erosion, helps retain soil moisture, improves soil structure and fertility, and contributes organic matter. However, crop residues can also harbor pests, diseases, and weeds if not properly managed. In addition, excess residue can complicate planting operations and interfere with plant emergence. Thus, effective crop residue management requires balancing the benefits of retaining residues with the need to facilitate future planting.
The most common crop residue management practices include leaving residues on the surface, known as conservation tillage, or incorporating residues into the soil through tillage. Conservation tillage involves minimal soil disturbance, which protects the soil structure and leaves a protective layer of residue on the surface. This reduces erosion and water loss while increasing organic matter and biological activity in the soil. However, surface residues can complicate planting if not managed properly. Incorporation of residues through tillage can help break down residues faster while burying weed seeds and pathogens. However, excessive tillage can damage the soil structure and break down organic matter. Most experts recommend a balanced approach using strategic tillage along with crop rotations, cover crops, and other practices to maximize the benefits of crop residues.
Crop residues are parts of the plant's leftover in the field after crops have been harvested and thrashed or left after pasture grazing. These materials are usually considered as waste materials that require disposal, but it has been realized that they are important natural resources, not wastes. Mostly, Indian farmers burned their crop residues. Approximately 730 Mt of biomass is burned annually in Asia, and 18% of that is from India. This creates the major following problems:

- **Loss of nutrients:** It is estimated that crop residues generally 80% nitrogen (N), 25% phosphorus (P), 50% sulfur (S), and 20% potassium (K). It is also estimated that burning of one ton of crop residue accounts for loss of 5.5 kg nitrogen, 2.3 kg phosphorus, 25 kg 1.2 kg sulfur besides complete loss of organic carbon and polluting atmosphere and it also leads to increase in greenhouse gas emission led to climate change. If the crop residues are incorporated or retained in the soil itself, the soil enriched in the abovementioned nutrients, particularly with organic carbon, and also provides food for soil microorganisms and plant nutrients.
- **Impact on soil properties:** Heat from burning residues elevates soil temperature, causing the death of beneficial soil organisms. Burning of the crop residues immediately increases the bicarbonate extractable P content, but there is no build-up of nutrients in the soil profile. Frequent residue burning leads to complete loss of the microbial population,

although the effect is temporary, as the microbes regenerate after a few days. Repeated burning in the field also reduces the level of N and C nutrients and potentially mineralizable N in the upper (0-15 cm) soil layer.

- **Emission of greenhouse gasses (GHG):** Burning of residues emits a significant number of Green House gasses (GHGs). Approximately 70%, 7%, and 0.7% of the C present in rice straw is emitted as carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4), respectively, while 2% of the N in straw is emitted as nitrous oxide (N_2O) upon burning. This leads to an increase in greenhouse gas emissions.

Nutrient content of crop residues

Crop residues are a potential source of plant nutrients, and their beneficial effects on soil fertility and productivity can be harnessed by recycling them into the soil, where on average 30–35% of applied nitrogen and phosphorus and 70– 80% of potassium accumulate in the crop residues of food crops. Approximately 40% of N, 30–35% of P, 80–85% of K, and 40%–50% of the S uptake by rice remains in the vegetative parts at maturity. Similarly, approximately 25%–30% of N and P, 35–40% of S, and 70–75% of K uptake is retained in wheat residue.

Nutrient content of crop residues

Crop Residues	Nutrient content (%)		
	N	P_2O_5	K_2O
Rice	0.61	0.61	1.38
Wheat	0.48	0.48	1.18
Maize	0.52	0.52	1.35
Sugarcane	0.40	0.40	1.28
Pulses	1.60	1.60	1.75

Moreover, crop residues are the primary source of organic matter as carbon (C) constitutes approximately 40% of the total dry biomass, which is indispensable for sustaining agricultural ecosystems. However, they depend upon the soil conditions, crop management, variety, and season to determine the nutrient concentration in crop residues.

Management of crop residues

Balling and removing the straw: Surplus straw from agriculture may be used for many useful purposes, such as livestock feed, fuel, building materials, livestock bedding, and composting for mushroom cultivation.

Soil mulch: Direct drilling in surface mulched residues is a practice that leaves crop residues from a previous crop on the soil surface without any form of incorporation. Surface retention of residues helps protect the fertile soil surface against wind and water erosion. Retention of crop residues on the soil surface increased the soil NO_3^- concentration by 46%, nitrogen uptake by 29%, and yield by 37% compared with burning. It maintains the soil temperature.

Retention, however, provides habitat for both harmful as well as useful organisms and it provides a C substrate for heterotrophic N fixation, increases microbial activity, soil C and N, and reduces fertilizer N requirements for rice. The faster decomposition and release of nitrogen to the soil is possible if the soil is treated with urea and applied during field preparation.

Crop residue incorporation: Crop residues may be incorporated partially or completely into the soil depending on the cultivation method. Straw incorporation can increase crop yield. Ploughing is the most efficient residue incorporation method**.** Incorporation of rice residues before wheat sowing compared with incorporation of wheat straw before rice planting is difficult due to low temperatures and the short-day interval between rice harvest and wheat sowing. Unlike the removal or burning of crop residues, incorporation of residues increases SOM and soil nitrogen, phosphorus and potassium contents.

Conclusion

Crop residue management is a crucial agricultural practice that can significantly impact soil health and the sustainability of food production systems. Thoughtful handling of crop residues left after harvest provides multiple benefits, including erosion control, moisture conservation, enhanced soil biology, and improved soil fertility and structure. However, removing or improperly managing residues can lead to soil degradation, erosion, and reduced agricultural productivity over the long term. Sustainable management strategies involve balancing surface residue retention with judicious tillage incorporation when warranted. Using practices such as conservation tillage, cover cropping, crop rotations, and on-farm nutrient cycling allows farmers to harness the full soil-enhancing potential of residues. With increasing climate stresses and farming demands, appropriately managing crop residues will only grow in importance.