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Impact of crop residue management on crop productivity and soil health: A review

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Abstract
An essential component of sustainable agriculture is the appropriate handling of crop residue. The productivity of the land and the ecosystem may be greatly impacted by how farmers handle the residue. Improved management of crop residues results in higher levels of organic carbon and nitrogen in the soil, changes the pH of the soil by accumulating carbon dioxide and organic acids during their breakdown, helps to manage and reclaim saline and alkaline soil, acts as a reservoir for plant nutrients, increases the porosity of the soil and decreases its bulk density, and supplies energy to microbes for growth and activity. Agricultural productivity may be increased and crops' nutritional requirements can be met through the sustainable and environmentally responsible management of crop residue. Moreover, crop residue on or below the soil surface improves moisture availability and temperature regulation close to the crop's rooting zone, which in turn promotes root and microbial activity as well as nutrient transformation. Enhancing soil health is the outcome of all of these, which contributes to sustained agricultural productivity.

Keywords: Crop residue, management, recycling, soil health, productivity

Introduction

Intensive agriculture diminishes crop production capacity and depletes vital nutrients due to non-scientific land management practices. To get the intended results from grown crops, the soil has to be physically sound enough to sustain optimal crop development and permit maximum utilization of its resources (Meena *et al*., 2018) [28]. With climate change and the world's population continuing to rise, society is calling for a more sustainable management of agro-ecosystems. Agro-ecosystem sustainability and resource usage efficiency may both be enhanced by crop residues since they are a significant source of plant nutrients (Kumar *et al*., 2023) [21]. Concerns about the economy and environment have raised interest in using crop residue as sustainable, renewable sources of bioenergy and bioproducts throughout the past years (Kumar *et al*., 2019) [22]. Crop residue, which is regarded as "the greatest source of soil organic matter" for agricultural soils, is the most readily available and accessible kind of biomass (Turmel *et al*., 2015) [47]. Crop residues are the materials left in the fields after crops are harvested for grain, seed, or fiber, including stems, leaves, chaff, and husks. After harvesting, keeping agricultural remains is thought to be an efficient antierosion strategy and help prevent soil degradation. Crop residues can help fix CO_2 in the soil, decrease evaporation, increase the amount of organic matter in the soil, and enhance soil structure. Agricultural productivity and the environment, however, can be impacted by the breakdown of crop residues in both beneficial and negative ways (Lu *et al*., 2020) [25]. Although crop residues are sometimes referred to as "wastes," they are also regarded as "potential black gold" since they are a valuable and natural resource (Reicosk & Wilts, 2005) [36]. Crop residues, on the other hand, provide a substantial but limited potential mechanism for cycling nutrients and sequestering carbon (Rathod *et al*., 2019) [35].

On agricultural areas, effective residue management techniques have a number of beneficial effects on soil quality. Moreover, agricultural leftovers can be utilized to produce biofuel. Policies for encouraging beneficial management practices are guided by information on residue cover, which also aids in the assessment of soil carbon (Elhaddad, 2020) [13].

Given that crop residues include an incalculable amount of organic matter that may be retained in or removed from the agro-ecosystem, their destiny is one of the crucial management issues that is now being debated. Optimizing soil quality through crop residue management is crucial for sustainable farming practices. Crop residues are incorporated into the soil to aid in the restoration of biological activity and to maintain and enhance the physical properties of the soil over time. Additionally, it promotes the development of soil organic matter (SOM), enhances soil aggregation and stability, bulk density (BD), porosity and pore size, moisture holding capacity, hydraulic characteristics, penetration resistance, and brings about changes to the thermal and moisture regimes of the soil (Zhang *et al*., 2014) [52]. It also contributes to the nutrient pools of the soil. According to Blanco-Canqui and Lal (2009) [5], it also lessens ineffective soil and water losses, extremes in soil temperature, and changes the microbial environment that promotes the growth of soil biota. In order to maintain the productive potential of cropping systems, management practices must focus on enhancing the structural and hydraulic properties of the soil, which in turn help to reduce nutrient losses, create a favorable environment for microbes, and control soil degradation in an efficient and cost-effective manner. Increasing the amount of SOM in the soil by incorporating agricultural residue is one of the more affordable ways to improve the general state of the soil. Crop residue recycling on farms is the best management strategy for replenishing the depleted SOM content, which is the foundation for enhancing the physical, chemical, and biological conditions of the soil and maintaining agricultural output (Salahin *et al*., 2017) [39].

The precise proportions of crop residues required to enhance the qualities of the soil, which are essential for creating economic strategies, are, nonetheless, little understood. Given its wide range of benefits and favorable impact on soil health, crop residue management stands out among the other options. Although crop residue is typically seen negatively, with proper management they may enhance the dynamics of soil organic matter and nutrient cycling, which will help to create an environment that is relatively conducive to plant development and thus improved the productivity. The various facets of crop residue management, including their effects, the use of natural resources, and the strategies that need to be developed for improved residue management in farming systems, have been the main focus of this review. These aspects are closely linked to the current environmental problems.

Crop residues and intensive agriculture: Current situation in India

The extensive use of outside inputs is essential to the present intensive farming system. Modern farmers that engage in such input-intensive farming methods typically rotate their crops intensively, leaving the land fallow for the duration of the cropping year's crop season (Brahmachari *et al*., 2019) [7]. Micronutrient deficits and decreasing soil fertility are frequently caused by the adoption of intensive farming techniques combined with high-yielding cultivars and contemporary irrigation equipment. A systematic transition away from these practices to the application of various organic manures and conventional plant nutrient components has been shown as a possible solution to this issue (Sarkar *et al*., 2018) [41].

Appropriate handling of agricultural residues contributes organic matter to the soil and feeds soil microorganisms (Shan and Yan, 2013) [42]. A good soil that has been supplemented with organic matter increases crop yield. Crop residues are incorporated to increase soil organic matter (Purwanto and Alam, 2020) [32]. After the profitable portions of field crops are harvested, the residues-stem, leaves, husks, etc.-have a significant impact on enhancing soil quality and resolving many environmental problems. Generally speaking, these agricultural leftovers are the main source of elemental carbon in soil (Fang *et al*., 2018) [14]. Crop leftovers are typically regarded as waste materials due to their low economic value. India generates 500 Mt (Million tons) (Table 1) of agricultural wastes annually, according to a Ministry of New and Renewable Energy paper on the subject (NPMCR, 2020) [29]. The highest producing states are Uttar Pradesh (60 Mt), Punjab (51 Mt), and Maharashtra (46 Mt). The highest amount of residues (352 Mt) is produced by cereals, with fibers (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and sugarcane (12 Mt). Uttar Pradesh produces the most grain crop residues (53 Mt), followed by West Bengal (33 Mt) and Punjab (44 Mt). The state of Andhra Pradesh generates the highest fiber crop residues (14 Mt), whereas Maharashtra produces the most pulse residues (3 Mt). Most oilseed crop residues (6 Mt) are produced in Gujarat and Rajasthan. Both home and industrial uses are made of a sizable portion of leftovers. A significant amount is also kept in the field and burnt annually, according to several study publications. It's also noteworthy that the amount of agricultural leftovers jointly generated by other nations in the same region is almost equivalent to the residue percentage burnt in India as waste material.

Table 1: Comparison of India's production of agricultural waste with that of a few other countries

Country	Agricultural Waste Generated (million tons/year)
India	500
Bangladesh	72
Indonesia	55
Myanmar	19

(***Source***: NPMCR, 2020; Jeff *et al*., 2017) [29, 19]

Crop Residue Management Practices

Maintaining highly productive cropping requires the highest rate of plant nutrient recycling feasible in order to prevent the unfavorable environmental effects of high-level fertilizer applications, as well as effective protection of soils against erosion, conservation of relatively high amounts of soil organic matter, and provision of ideal conditions for soil biota (Bahadur *et al*., 2015) [4]. Simultaneously, reducing human influence on troposphere chemistry calls for reduced emissions of greenhouse and other gases, and preventing the major health risks associated with smoke means enforcing rigorous regulations or completely banning the burning of any superfluous biomass. All of these objectives may be met with the assistance of appropriate field management of crop residues.

Table 2: Crop residue management practices/options

Sl. No.	Practices	Management
1.	Residue burning	Traditionally, residues are removed for animal feeding as a low-cost procedure. But in the last several years, when harvesting has been done by machines, which leaves loose straw on the soil's surface, farmers have been burning the crop residue to quickly clear the field in order to prevent any disturbance while planting the next crop. The Indo-Gangetic plains (IGP), especially the states of Punjab and Haryana, are known for this practice. According to Kumar *et al.* 2019 [22], burning crop waste is never good for the land, the environment, or people's health. Burning causes beneficial soil microbes and SOM to be depleted, which is one of the main reasons for the IGP's diminishing productivity.
2.	Surface retention and mulching	A thin layer of crop residue left on the soil's surface might be another management option. This provides a significant benefit in terms of preventing erosion from wind and water on the top layer of soil. Additionally, when the surface waste breaks down, it supplies a substantial amount of organic matter (OM) and other necessary nutrients, along with mild temperature variations (Dutta *et al*., 2022) [12]. According to Bacon (2013) [3], this technique can enhance soil N content by 46% and crop output by 37% over burning of crop residues.
3.	Residue removal	The stability of the aggregate is negatively impacted by residue removal because it uses fewer organic binding agents for aggregate formation and stability. Furthermore, the impact of raindrops closes open-ended bio-channels, influencing the soil's ability to hold and transmit water (Such as infiltration and hydraulic conductivity) and thereby increasing the amount of soil lost to runoff and erosion. According to Bahadur *et al*. (2015) [4], residue removal also causes surface soil moisture to evaporate, increases temperature variations throughout the day, and decreases the amount of organic matter needed to increase soil water retention.
4.	Residue incorporati on	Using the proper tillage techniques to incorporate crop waste into the soil at the correct depth is one of the option for managing crop residue on-field. It is said that this procedure is quite effective in enhancing the general health of the soil. Straw inclusion raises SOM, N, P, and K content in contrast to removal or burning (Zhang *et al*., 2014) [52]. However, the immobilization of residues caused by soil absorption, especially from cereals, causes a temporary N shortage, which reduces crop yields by around 40%. According to study findings, applying 15-20 kg/ha of N as a starting dosage and incorporating crop residue can help overcome the N immobilization issue and result in a greater yield than burning straw (RWC-CIMMYT, 2003) [38].

Crop residue management: Impact on soil health

***Texture*:** Reintroducing residue from crops into the soil can enhance its physical characteristics by raising its moisture content, lowering its bulk density, and raising aggregate stability and total porosity (Brankatschk *et al*., 2015) [8]. Compared to no straw treatment, the soil water content significantly increased by 19% after two years of straw integration in rice-wheat system (Zhao *et al*., 2019) [56]. Changes in soil structure may be indicated by variations in soil bulk density. According to a study adding maize and wheat straw for seven years, the bulk density of the soil in the 0–20 cm layer dropped by 5.7%, furthermore the soil bulk density in both soil layers (0–20 cm and 20–40 cm) was reduced by straw return treatments (Zhao *et al*., 2018) [53]. A reduction in soil bulk density was noted along the soil profile by 9.5% and 8.6%, respectively, at the 0–20 cm and 20–40 cm soil layers due to the impact of straw residue treatments on reducing soil bulk density (Xu *et al*., 2018) [49]. One of the fundamental physical characteristics of soil is its total porosity, which also serves as an indicator of soil productivity and fertility. When deep ploughing is used to combine crushed crop remains with the soil, the permeability of the soil rises. In 2019, the residue of wheat straw substantially enhanced the porosity of the soil in the 0–10 cm, 10–20 cm, and 20–30 cm soil layers by 5.06%, 5.21%, and 2.75%, respectively, in comparison to the no treatment group (Zhao *et al*., 2021) [54].

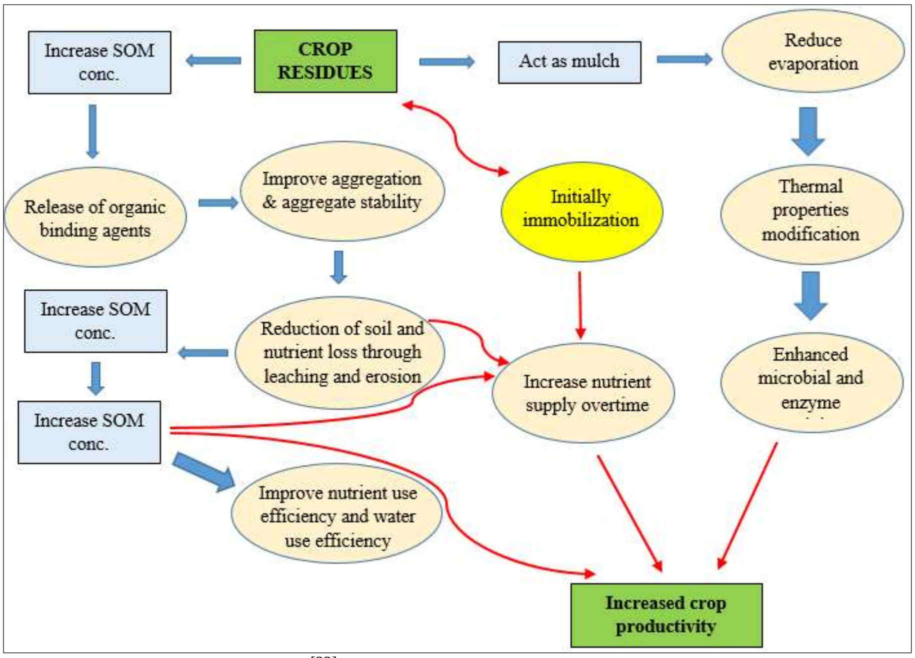
pH and cation exchange capacity: Particularly in soils with limited buffering capacity, crop wastes may have a significant impact on the pH of the soil. In a 30-day incubation experiment, Pan *et al*. investigated the ameliorating effects of four agricultural straw decayed products (SDPs) on an acidic ultisol. The findings revealed a 55%–75% improvement in soil pH (Pan *et al*., 2020) [30]. The management of crop residues has a substantial and positive impact on the soil's cation exchange capacity (CEC). Crop residues containing an accumulation of soil organic matter (SOM) may generate additional negative charges, raising CEC (Rezig *et al*., 2013; Abbasi *et al*., 2009) [37, 1]. In a three-year field experiment with sweet sorghum, Malobane *et al*. discovered that a 30% crop residue retention (Based on total harvested fresh biomass) generated 11.3% and 27.32% greater CEC than that of 15% crop residue retention and crop residue removal, respectively (Malobane *et al*., 2020) [26]. Furthermore, when solitary wheat residues were continuously integrated, the topsoil (0–20 cm) CEC rose considerably by 9.39–21.59% compared with the control in a five-season wheat–guar rotation experiment (Rezig *et al*., 2013) [37].

Organic carbon (OC) and NPK: Crop residue that have decomposed are regarded as fundamental elements in the nutrient cycle. The amount of organic carbon, nitrogen, accessible phosphorus, and potassium in soils may increase when crop residue gets recycled (Ali *et al*., 2020). Moreover, adding agricultural debris to the soil can increase the availability of vital nutrients and stop nutrient loss (Rasool *et al*., 2020) [2]. Crop residue have an approximate 40% organic carbon content, which can control soil characteristics and increase soil stability by forming big aggregates. When 5% (w/w) raw garlic stem was applied in 2016 and 2017, the amount of soil organic carbon rose by 52% and 50%, respectively (Ali *et al*., 2020) [2]. Moreover, crop residue recovery can lessen the loss of organic carbon (Chen *et al*., 2016) [11].

The synthesis of proteins, amino acids, and nucleic acids requires nitrogen. Crop residues include nitrogen that may be converted by nitrification and mineralization into NO_3^- and NH_4^+. At soil thicknesses of 0–20 cm the addition of straw and partial fertilizers considerably enhanced the soil accessible nitrogen by an average of 64% (Zhao *et al*., 2019) [56]. Nonetheless, the C/N ratio of agricultural leftovers is rather large (60–100:1). Thus, more residues being returned might lead to better nitrogen immobilization, which might need applying more nitrogen fertilizer (Fontaine *et al*., 2020).

The element phosphorus is necessary for both cell division and energy processes. Microorganisms may break down crop leftover phosphorus into $H_2PO_4^-$ and HPO_4^{2-}. Crop straw integration during a 30-year period increased the amount of phosphorus accessible in the top 0–20 cm of soil. Phosphorus utilization efficiency improved concurrently with mineral fertilization +3750 kg/ha wheat straw treatment, rising from 43% in 1983 to 72% in 2012 [51]. Crop remnants readily release potassium. Crop leftovers are a contributing factor to the soil's potassium buildup (Guo *et al*., 2018) [17]. Applying raw garlic stem at 1%, 3%, and 5% doses enhanced the amount of accessible potassium by 4.4%, 6.5%, and 3.8%, respectively (Ali *et al*., 2020) [2]. Furthermore, keeping 90% (7.0 t) of soybean residues increased soil potassium by 89.7 kg, while 90% (13.8 t) of wheat residues contributed 232.2 kg of potassium over the course of five years (Yadav *et al*., 2021) [50].

Soil microbial and enzyme activity: Microbial communities in the soil are crucial to the functioning of the soil ecosystem and the biogeochemical cycle of essential elements like carbon and nitrogen. Returned crop residue can boost the amount of organic matter in the soil and create an ideal habitat for microorganism development and proliferation. The variety and quantity of fungi in the 0–10 cm soil layer of the fallow habitat can be increased by retaining sugarcane straw for a period of 14 months (Zhang *et al*., 2021) [51]. In double-season straw return, there was a greater relative abundance of actinomycetes but a lower relative abundance of bacteria and fungi (Su *et al*., 2020) [44]. Zhao *et al*. 2016 [55] in a 30-year study of summer maize-winter wheat cropping system in north-central China, they found that the abundances of fungi and Gram-negative (Gm-) bacteria increased with straw input rates, but the abundances of total bacteria and Gram-positive (Gm+) bacteria remained unchanged across all treatments. The kinds of returning wastes, the rates of return, and the soil conditions all affected the microbiological characteristics of the soil. Indicators of soil quality and potential fertility under various management approaches can be represented by soil enzymes, which are essential indicators of the soil fertility. Enzyme activity in the soil is influenced by various management strategies and corrective actions that modify the features of the biologically most active surface strata in the soil. When rice straw was integrated into the cropping system instead of being removed, the maximum dehydrogenase (DHA) activity was observed (Goyal *et al*., 2009) [16]. Since rice straw provides bacteria with food and energy, (Chandra, 2011) [9] found increased microbial biomass and enzyme activity after inclusion. Kumawat *et al*. (2017) [23] revealed 14.6% increased fluorescein diacetate (FDA) enzyme activity in 0–5 cm soil depth under 75% crop residue retention as compared to without retention in the maize–wheat cropping system. Singh *et al*. (2015) [43] revealed an 18% increase in FDA activity after 9 years of CR and vermicompost inclusion compared to no straw and vermicompost incorporation in the rice, wheat, and mungbean cropping system. crop residue management techniques have an impact on soil labile carbon pools, which are thought of as markers of soil quality (Plaza-Bonilla *et al*., 2014) [31]. According to Li *et al*. (2007) [24] water-soluble carbon (WSC) rose by around 71–109% in treatments that included rice straw compared to treatments that did not. This was seen while working in the rice-wheat cropping system.



Source: (Ramteke *et al*., 2022) [33]

Fig 1: Mechanism on how crop residue enhances soil health and crop production

Crop residue management: Impact on crop productivity

By preserving SOM levels, conservation agriculture's agricultural residue management can raise soil productivity and crop yield. Enhanced nutrient cycling and retention as well as higher organic matter (OM) close to the soil surface are two important benefits of surface-residue management. Green gram seed production was best improved by incorporating residue under conventional tillage; removal of residue under zero tillage had unfavorable effects (Meena *et al*., 2015) [27]. The addition of residues increased the crop's ability produce higher yield and also enhanced the absorption of N; tillage may have contributed to increased N-mineralization from the residues, increasing the amount of N in the grain and stover. Higher N absorption was the outcome of residue additions that also increased the overall N, C, and other nutrient levels in the soil. The grain and straw yields of wheat are higher in the plot where crop residue was included (Ramesh Chandra, 2011) [10]. Sarkar and Kar (2011) [40] noted that the application of rice and wheat straw residue resulted in a higher productivity of the rice-wheat system in Eastern India as compared to its removal. This was primarily ascribed to increased SOC levels, decreased water evaporation loss, and enhanced water infiltration, all of which enhanced the physical properties of the soil and decreased nutrient losses. Kouyaté *et al*. (2000) [20] reports that the addition of crop residues to cereals increased their grain production by 37% as compared to when it wasn't added. Surekha *et al*. (2003) [46] found that residue treatments had no discernible impact on grain yield in the first and second cropping cycles in the sandy clay loam soils of the Philippines. Nevertheless, in the third and fourth cropping cycles, 100% straw treated plots demonstrated significantly higher grain yield in comparison to 50% straw incorporation and control. Such varying reports have also been reported by Borresen, (1999) [6] which said that the various straw management methods had no discernible impact on grain yield during the first year of the trial. Addition of double and regular volumes of straw in the second year resulted in a considerable improvement in grain output. The straw-managed treatments did, however, significantly lower grain output in the fourth year of the trial. When comparing the mean grain yields of the various treatments, the average increase was 0.29 Mg ha^{-1} when normal and double amounts of straw were added.

Crop residue management: Environmental benefits

Crop residue management is an essential component of sustainable agriculture. In addition to enhancing soil health and crop productivity, effective management of agricultural wastes may help farmers and the environment by supplying a renewable energy source. Farmers may help preserve natural resources and advance the economic well-being of their communities by using sustainable agricultural methods. Several off-site effects of using new farming technology and enhancing cultural traditions may be among the social advantages of agricultural residue management. Reduced floods and sedimentation improve the health of streams, rivers, and lakes by reducing runoff and soil erosion from farmland and rangeland. Improved water quality can prolong the usable life of public infrastructure, which is advantageous to society and the environment (Reicosk & Wilts, 2005) [36].

The ability of the agriculture industry to reduce greenhouse gas emissions and remove CO_2 from the environment is substantial. Improved residue management and reduced tillage practices should be encouraged because of their beneficial role in reducing soil degradation and increasing soil productivity. These advantages are facilitated by soil carbon sequestration, which also has the potential to significantly reduce global climate change. Soil C is an essential resource for both food security and environmental enhancement. A large amount of greenhouse gas emissions can potentially be compensated by crops residue management. Farmers may lessen the quantity of carbon dioxide and other gases emitted into the environment by planting agricultural wastes in the soil as opposed to burning them or allowing them to break down naturally. Furthermore, sustainable crop residue management methods can support ecosystem service and economic growth. Using sustainable crop residue management methods can also aid in the fight against climate change and lessen the effects of climate change and their carbon footprint. Sustainable crop residue management methods can also lessen the need of artificial pesticides and fertilizers, which can be harmful to the environment and public health.

Challenges and constrains of Crop residue management

In recent years, there has been a lot of interest in using crop residues as a feedstock for the production of value products and renewable energy. The long-term advantages of preserving and enhancing our soils' production, however, must be weighed against these applications. There are several difficulties with using crop residue in the field. These include challenges with insect infestation and the seeding and application of fertilizer and herbicides. Burning crop residues has an adverse effect on human health and contributes significantly to more severe air quality (Particulates greenhouse gases). Additionally, burning crop residues results in the loss of valuable nutrients, including N and S, as well as organic matter. According to Gupta *et al*. (2004) [18], burning rice straw releases gases that include 70% CO_2, 7% CO, 0.66% CH_4, and 2.09% N_2O. Crop leftovers are essential to the stability of the agricultural environment and a valuable source of nutrients for plants. Long-term soil functions such as detoxification, nitrogen cycling, and microbial activity will all be impacted by the loss of carbon from the soil. Burning crop residues can eradicate pests and illnesses linked to the stubbles and straw of previous harvests, as well as temporarily boost the amount of nutrients available for plant development. However, the majority of mesophilic organisms that actively engage in the transformation of nutrients in the upper layer of soil are killed by the sudden increase in surface soil temperature that occurs soon after burning crop debris. The microbial population may be permanently reduced by frequent burning incidences in the field, even though the effect is only transient since the microorganisms rebuild after a few days. Long-term residue burning reduces the amount of organic carbon in the soil, which is essential for soil life.

Conclusion

For farmers, managing crop residue is a significant challenge. Crop residue burning swiftly prepares the ground for the timely sowing of the next crop. On the other hand, this technique is detrimental to the ecosystem, the soil, and human health. In addition to burning, farmers can manage residue by removing it from the field, mulching it, placing it on the surface, or incorporating it into the soil. By preserving SOM levels, agricultural residue management can raise crop productivity and soil health. Enhanced nutrient cycling and retention as well as higher organic matter (OM) close to the soil surface are two important benefits of crop residue management. Increased microbial activity and biomass close to the soil surface improves structural stability for better infiltration and serves as a storage for nutrients required for crop production. Enhancing crop residue management to improve soil C sequestration is an affordable way to reduce the environmental impact of agriculture. Additionally, yields are seriously threatened in the majority of agricultural systems by the diminishing soil organic carbon. Therefore, adding crop residue to the soil or keeping it on the surface may be a better way to raise the amount of organic carbon in the soil. Crop productivity can be maintained and soil health can be enhanced as long as crop wastes are handled scientifically.

References

1. Abbasi MK, Mushtaq A, Tahir MM, *et al*. Cumulative effects of white clover residues on the changes in soil properties, nutrient uptake, growth and yield of maize crop in the sub-humid hilly region of Azad Jammu and Kashmir, Pakistan. Afr. J Biotechnol. 2009;8(10):2184-2194.
2. Ali A, Ghani MI, Haiyan D, *et al*. Garlic substrate induces cucumber growth development and decreases Fusarium wilt through regulation of soil microbial

community structure and diversity in replanted disturbed soil. Int. J Mol. Sci. 2020;21(17):20.

3. Bacon PE. Effect of nitrogen fertilization and rice stubble management techniques on soil moisture content, soil nitrogen status, and nitrogen uptake by wheat. Field Crop Res. 2013;17:75-90.
4. Bahadur I, Sonkar VK, Sanjay K, Jyoti D, Pratap SA. Crop Residue Management for improving Soil Quality and Crop Productivity in India. Indian Journal of Agriculture and Allied Sciences. 2015;1(1):2395-1109.
5. Blanco-Canqui H, Lal R. Corn stover removal for expanded uses reduces soil fertility and structural stability. Soil Sci. Soc. Am J. 2009;73:418-26.
6. Borresen T. The effect of straw management and reduced tillage on soil properties and crop yields of spring-sown cereals on two loam soils in Norway. Soil Till Res. 1999;51:91-102.
7. Brahmachari K, Sarkar S, Santra DK, Maitra S. Millet for Food and Nutritional Security in Drought Prone and Red Laterite Region of Eastern India. Int. J Plant Soil Sci. 2019;26:1-7.
8. Brankatschk G, Finkbeiner M. Modeling crop rotation in agricultural LCAs - challenges and potential solutions. Agric Syst. 2015;138:66-76.
9. Chandra R. Effect of summer crops and their residue managements on yield of succeeding wheat and soil properties. J Indian Soc. Soil Sci. 2011;59:37-42.
10. Chandra, Ramesh. Effect of Summer Crops and their Residue Management on Yield of Succeeding Wheat and Soil Properties; Journal of the Indian Society of Soil Science. 2011;59(1):37-42.
11. Chen S, Xu CM, Yan JX, *et al*. The influence of the type of crop residue on soil organic carbon fractions: an 11-year field study of rice-based cropping systems in southeast China. Agric, Ecosyst & Environ. 2016;223:261-269.
12. Dutta A, Patra A, Hazra KK, Nath CP, Kumar N, Rakshit A. A state of the art review in crop residue burning in India: Previous knowledge, present circumstances and future strategies. Environmental Challenges. 2022;8:100581. https://doi.org/10.1016/j.envc.2022.100581.
13. Elhaddad A. Remote sensing application in agriculture. In Elsevier eBooks; c2020. p. 871-914. https://doi.org/10.1016/b978-0-12-815826-5.00024-6.
14. Fang Y, Singh BP, Collins D, Li B, Zhu J, Tavakkoli E. Nutrient Supply Enhanced Wheat Residue-Carbon Mineralization, Microbial Growth, and Microbial Carbon-Use Efficiency When Residues Were Supplied at High Rate in Contrasting Soils. Soil Biol. Biochem. 2018;126:168-178.
15. Fontaine D, Eriksen J, Sørensen P, *et al*. Cover crop and cereal straw management influence the residual nitrogen effect. Eur. J Agron. 2020;118:126100.
16. Goyal S, Singh D, Suneja S, Kapoor KK. Effect of rice straw compost on soil microbiological properties and yield of rice. Indian J Agric. Res. 2009;43:263-68.
17. Guo ZB, Liu H, Hua KK, *et al*. Long-term straw incorporation benefits the elevation of soil phosphorus availability and use efficiency in the agroecosystem. Span J Agric. Res. 2018;16(3):12.
18. Gupta PK, Sahai S, Singh N, Dixit CK, Singh DP, Sharma C, *et al*. Residue burning in rice–wheat cropping system: causes and implications. Curr. Sci. 2004;87:1713-1717.
19. Jeff S, Prasad M, Agamuthu P. Asia Waste Management Outlook. UNEP Asian Waste Management Outlook. United Nations Environment Programme; Nairobi, Kenya; c2017.
20. Kouyaté Z, Franzluebbers K, Anthony SR, Lloyd J, Hossner R. Tillage, crop residue, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. Plant Soil. 2000;225:141-51.
21. Kumar N, Chaudhary A, Ahlawat O, Naorem A, Upadhyay G, Chhokar RS, *et al*. Crop residue management challenges, opportunities and way forward for sustainable food-energy security in India: A review. Soil & Tillage Research. 2023;228:105641. https://doi.org/10.1016/j.still.2023.105641.
22. Kumar P, Lai L, Battaglia ML, Kumar S, Owens V, Fike J, *et al*. Impacts of nitrogen fertilization rate and landscape position on select soil properties in switch grass field at four sites in the USA. Catena. 2019;180:183-193.
23. Kumawat C, Sharma VK, Meena MC, Kumar S, Barman M, Chobhe KA, *et al*. Fluorescein diacetate activity as affected by residue retention and P fertilization in maize under maize-wheat cropping system. Int. J Curr. Microbiol. App. Sci. 2017;6:2571-77.
24. Li H, Gao H, Wu H, Li W, Wang X, He J. Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. Aust. J Soil Res. 2007;45:344-50.
25. Lu X. A Meta-Analysis of the Effects of Crop Residue Return on Crop Yields and Water Use Efficiency. PLoS ONE. 2020;15:e0231740.
26. Malobane ME, Nciizah AD, Mudau FN, *et al*. Tillage, crop rotation and crop residue management effects on nutrient availability in a sweet sorghum-based cropping system in marginal soils of South Africa. Agronomy. 2020;10(6):13.
27. Meena JR, Beheraa, Umakant K, Chakraborty, Debasis, Sharma AR. Tillage and residue management effect on soil properties, crop performance and energy relations in greengram under maize-based cropping systems; International Soil and Water Conservation Research. 2015;(3):261-272.
28. Meena RS, Lal R. Legumes for Soil Health and Sustainable Management; Springer: Singapore; c2018.
29. NPMCR (National Policy for Management of Crop Residues). Incorporation in Soil and Mulching Baling/Binder for Domestic/Industrial as Fuel. Government of India Ministry of Agriculture Department of Agriculture & Cooperation. Available online: http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf (accessed on 10 February 2020).
30. Pan XY, Shi RY, Hong ZN, *et al*. Characteristics of crop straw-decayed products and their ameliorating effects on an acidic Ultisol. Arch. Agron. Soil Sci. 2020;1-14. DOI:10.1080/03650340.2020.1805104.
31. Plaza-Bonilla D, Alvaro-Fuentes J, Cantero-Martinez C. Identifying soil organic carbon fractions sensitive to agricultural management practices. Soil Till Res. 2014;139:19-22.
32. Purwanto BH, Alam S. Impact of Intensive Agricultural Management on Carbon and Nitrogen Dynamics in the Humid Tropics. Soil Sci. Plant Nutr. 2020;66:50-59.
33. Ramteke P, Vashisht BB, Ghosh S. Crop residue management: Impacts on soil and crop productivity. In book: Futuristic Trends in Agriculture Engineering &

Food Science. 2022;2:207-222. ISBN: 978-93-95632-76-8, IIP Publisher, Book 10, Part 4, Chapter 1.
34. Rasool G, Guo XP, Wang ZC, *et al*. Coupling fertigation and buried straw layer improves fertilizer use efficiency, fruit yield, and quality of greenhouse tomato. Agric. Water Manage. 2020;239:9.
35. Rathod PH, Bhoyar SM, Katkar RN, Kadu PR, Jadhao SD, Konde NM, *et al*. Recycling and Management of Crop Residues for Sustainable Soil Health in Climate Change Scenario with Farmer's Profit as Frontline Moto. J. Pharmacogn. Phytochem. 2019, 51-55.
36. Reicosky DC, Wilts A. Crop-Residue Management. In Elsevier eBooks; c2005. p. 334-338. https://doi.org/10.1016/b0-12-348530-4/00254-x.
37. Rezig FAM, Mubarak AR, Ehadi EA, *et al*. Impact of organic residues and mineral fertilizer application on soil–crop system: II soil attributes. Arch Agron. Soil Sci. 2013;59(9):1245-1261.
38. RWC-CIMMYT. Addressing Resource Conservation Issues in Rice-Wheat Systems of South Asia: A Resource Book. Rice-Wheat Consortium for the Indo-Gangetic Plains-International Maize and Wheat Improvement Centre, New Delhi, India; c2003.
39. Salahin N, Alam K, Mondol A, Islam MS, Rashid MH, Hoque MA. Effect of tillage and residue retention on soil properties and crop yields in wheat-mungbean1rice crop rotation under Subtropical Humid Climate. Open J Soil Sci. 2017;7(01):1.
40. Sarkar R, Kar S. Temporal changes in fertility and physical properties of soil under contrasting tillage-crop residue management for sustainable rice-wheat system on sandy loam Soil. J Crop. Improv. 2011;25:262-90.
41. Sarkar S, Banerjee H, Ray K, Ghosh D. Boron Fertilization Effects in Processing Grade Potato on an Inceptisol of West Bengal, India. J Plant Nutr. 2018;41:1456-1470.
42. Shan J, Yan X. Effects of Crop Residue Returning on Nitrous Oxide Emissions in Agricultural Soils. Atmos. Environ. 2013;71:170-175.
43. Singh G, Kumar D, Sharma P. Effect of Organics biofertilizers in crop residue application on soil microbial activity in rice-wheat and rice-wheat mungbean cropping system in the Indo-Gangetic plains. Cogent Geosci. 2015;1:1085296.
44. Su Y, Lv JL, Yu M, *et al*. Long-term decomposed straw return positively affects the soil microbial community. J Appl. Microbiol. 2020;128(1):138-150.
45. Su Y, Yu M, Xi H, *et al*. Soil microbial community shifts with long-term of different straw return in wheat-corn rotation system. Sci. Rep. 2020;10(1):6360.
46. Surekha K, Kumari AP, Reddy NM, Satyanarayana K, Cruz PC. Crop residue management to sustain soil fertility and irrigated rice yields. Nutr. Cycl. Agroecosyst. 2003;67:145-54.
47. Turmel M, Speratti AB, Baudron F, Verhulst N, Govaerts B. Crop residue management and soil health: A systems analysis. Agricultural Systems. 2015;134:6-16. https://doi.org/10.1016/j.agsy.2014.05.009.
48. Kumar V, Gathala MK, Saharawat YS, Parihar CM, Kumar R, Kumar R, *et al*. Impact of tillage and crop establishment methods on crop yields, profitability and soil physical properties in rice–wheat system of Indo-Gangetic Plains of India. Soil Use Manage. 2019;35:303-313. 10.1111/sum.12473.
49. Xu X, Pang DW, Chen J, *et al*. Straw return accompany with low nitrogen moderately promoted deep root. Field Crops Res. 2018;221:71-80.
50. Yadav D, Vishwakarma AK, Sharma NK, *et al*. Sustaining the properties of black soil in Central India through crop residue management in a conservation-agriculture-based soybean–wheat system. Land Degrad & Dev; c2021. p. 16.
51. Zhang CF, Lin ZL, Que YX, *et al*. Straw retention efficiently improves fungal communities and functions in the fallow ecosystem. BMC Microbiol. 2021;21(1):13.
52. Zhang P, Wei T, Jia Z, Han Q, Ren X. Effects of straw incorporation on soil organic matter and soil water-stable aggregates content in semiarid regions of Northwest China. PLOS ONE. 2014;9:928-39.
53. Zhao HL, Shar AG, Li S, *et al*. Effect of straw return mode on soil aggregation and aggregate carbon content in an annual maize-wheat double cropping system. Soil Tillage Res. 2018;175:178-186.
54. Zhao J, Liu Z, Gao F, *et al*. A 2-year study on the effects of tillage and straw management on the soil quality and peanut yield in a wheat–peanut rotation system. J Soils Sediments. 2021;21(4):1698-1712.
55. Zhao SC, Li KJ, Zhou W, *et al*. Changes in soil microbial community, enzyme activities and organic matter fractions under long-term straw return in north-central China. Agri & Ecosyst Environ. 2016;216:82-88.
56. Zhao XL, Yuan GY, Wang HY, *et al*. Effects of full straw incorporation on soil fertility and crop yield in rice-wheat rotation for silty clay loamy cropland. Agronomy. 2019;9(3):12.