Chronicle of Bioresource Management 2025, 9(4): 153-157

Chronicle of Bioresource Management
An International E-magazine

December, 2025 Popular Article

Beyond Combustion: Innovative Utilizations of Agricultural Residues

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Citation: Hareesh and Sridhar, 2025. Beyond Combustion: Novel Applications of Agricultural Residues. Chronicle of Bioresource Management 9(4), 153-157.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Keywords:

Biochar, crop residue, soil health, sustainable agriculture, waste management

Article History

Article ID: CBM6514
Received on 08th July 2025
Received in revised form on 25th November 2025
Accepted in final form on 04th December 2025

Abstract

India generates nearly 500 million tonnes of crop residues annually, positioning it among the world's largest producers. Traditionally regarded as waste, residues are increasingly recognized as critical inputs for enhancing soil fertility, nutrient cycling, and sustainable agroecosystem functioning. However, residue burning remains prevalent, resulting in the volatilization of up to 80% nitrogen and 25% phosphorus, elevated particulate emissions, and long-term soil quality deterioration. Crop residue management (CRM) strategies are broadly classified into on-farm and off-farm pathways. On-farm practices, including surface mulching, in-situ incorporation, and microbial consortia-based interventions such as *Pusa Decomposer*, enhance soil organic carbon, microbial activity, and crop productivity. Off-farm utilizations encompass livestock feed, mushroom cultivation, and bedding material. Advanced valorization technologies such as biochar production, composting (e.g., Suchitha method), and biogas recovery promote nutrient recycling and energy generation. Industrial applications in pulp, briquette, bio-brick, and bioelectricity production further integrate CRM within a circular bioeconomy, advancing climate-resilient and sustainable agricultural systems.

1. Introduction

In several agroecological areas of India, this leads to a lot of agricultural residue. The residues were once considered garbage, but with more understanding and research, it is becoming evident that they are not waste but necessary natural gift. Crop residue management entails developing techniques to manage these materials to increase soil health properly, crop yield, reduce environmental impacts, and support sustainable agricultural systems (Kumar et al., 2024). India is far ahead with its neighboring countries in terms of crop leftover generation except China. India generates 500 million tonne per year (mt yr^{-1}) followed by Bangladesh (72 mt yr^{-1}), Indonesia(55 mt yr^{-1}) and Myanmar (19 mt yr^{-1}) based on the reports given by Ministry of New and Renewable Energy (MNRE) (Meena et al., 2022) (Figure 1).

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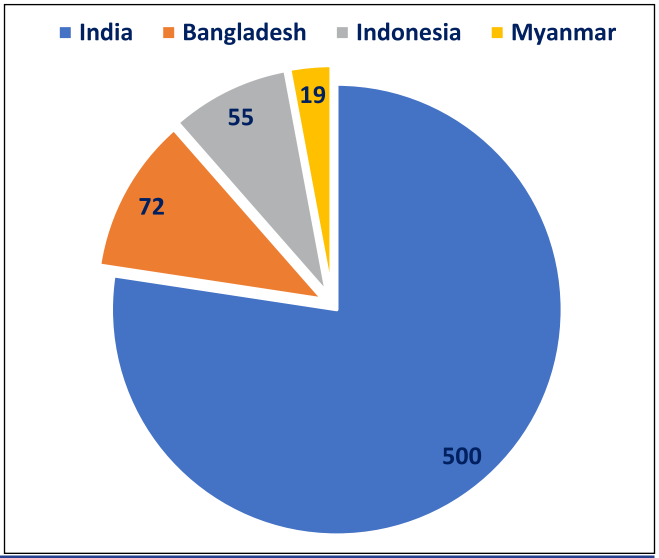
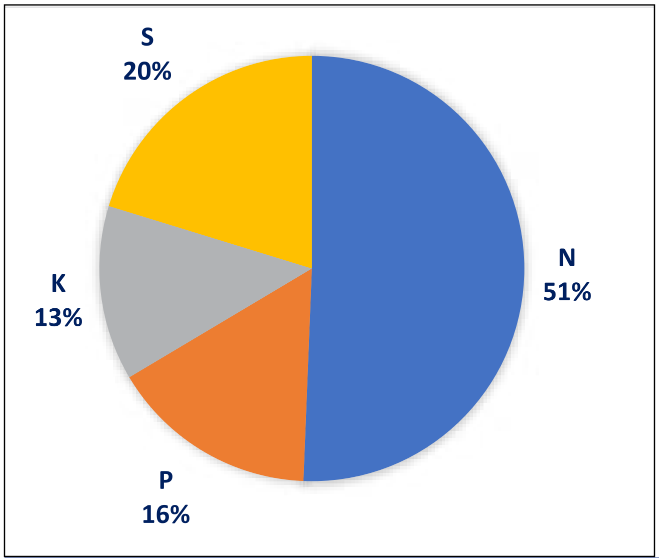


Figure 1: Crop residues (mt yr^{-1})



Figures 2: Combustion of wheat and rice residue

2. Burning Effects Soil Health and Productivity

Burning residues leads to the release of 3.86 million metric tonnes of SOC into the atmosphere, which has a significant and irreversible impact on enhancing soil physico-chemical characteristics. Burning of crop residue primarily create negative effects on the environment, with emissions of GHGs that pay to global warming, raised levels of fine particles i.e., particulate matter (PM) and smog those pose health hazards, a decline in the biodiversity of agricultural lands, and a reduction in fertility of soil (Lohan et al., 2018). The practice of burning residue has detrimental results on both soil fertility and productivity. The combustion of wheat and rice residue is expected to cause the huge loss of 80 % of nitrogen (N), 21 % of potassium (K), 25 % of phosphorus (P), and 4–60 % (on an average of 32%) of sulphur (S) from the soil (Figure 2).

3. Crop Residue Management

Crop waste recycling for plant nutrient supply is now becoming essential not only to counteract the ill effects of residue burning, but also for replenishing plant nutrients thereby maintaining soil health Table 1.

3.1. On-farm management

The crop waste which is generated from the field will be used in the farm itself. All the methods in this management are in-situ residue management tactics which improve the soil structure, reduce the intensity

Table 1: Crop residue management strategies

On-farm management	Off-farm management	Miscellaneous use
Mulching: surface retention	Livestock feed	Banana fiber
Residue incorporation	Bedding material	Areca/jute/glass fiber reinforced hybrid composite plates
Pusa decomposer	Mushroom cultivation	Paper from paddy straw
-	Bio-waste utilization for crop production	Bio brick
-	Suchitha thermochemical organ-ic fertilizer	Briquetting
-	Soil-less planting media	Electricity generation
-	Biochar	

of weeds and improves the productivity than farmers' practices.

Mulching/surface retention: Mulching with organic materials adds to the organic matter to soil and also reduces the nutrient losses observed that it is possible to save nearly 15–20% of fertilizers in the succeeding crop when rice straw is used as mulch (Martin et al., 2024).

Residue incorporation: The above ground portion may be chopped into small sizes and incorporated using machinery. Incorporation of crop residues strengthens the soil, helps in nutrient recycling and also improves the soil health by increasing the soil organic matter (Nawaz et al., 2019).

Pusa decomposer: Pusa Decomposer, developed by ICAR–Indian Agricultural Research Institute (IARI), New Delhi, is a consortium-based bio-decomposition technology designed to manage crop residues sustainably. It is available in capsule form, each containing a mixture of seven lignocellulolytic fungal strains (Trichoderma spp., Aspergillus spp., Paecilomyces spp., etc.) capable of rapid cellulose, lignin, and pectin degradation. For field application, four capsules are dissolved in 25 liters of water along with 150 g jaggery and 50 g chickpea flour, followed by incubation for 3–5 days to enable fungal multiplication. The prepared solution (250 liters) is sufficient to treat one hectare of crop residue. When sprayed uniformly over stubble, the fungi colonize the residues and facilitate decomposition within 25–30 days, compared to 45–60 days under conventional incorporation. The technology is highly cost-effective (₹ 20 per hectare), eco-friendly, and improves soil organic carbon, microbial activity, and nutrient availability, thereby reducing fertilizer demand for succeeding crops. Importantly, no adverse effects on crop performance have been reported, making it a practical alternative to stubble burning for achieving sustainable residue management, improved soil fertility, and reduced environmental pollution.

3.2. Off-farm management

The crop waste which is generated from the field is transported to various locations for different purposes to generate income other than burning it in the field.

Livestock feed: Generally, rice straw is given to cattle as a feed, it is poor in terms of protein but high content of crude fiber. The crude protein and other nutrients are better in legume crops then cereal crops (Win et al., 2021).

Bedding material: Paddy straw can be used as bedding in animal shelters, which after use can be recycled through biogas unit. Using saw dust as bedding is known to improve the quantity and quality of milk production as well as animal health. The advantages of bedding components include:

1. Minimizes heat loss and maintains the animal's warmth during the winter season.

2. Improve the cleanliness, absorb urine and water and provides overall hygiene.

3. Healthy legs and hooves with better reproductive health conditions will ensure higher milk production.

Mushroom cultivation: A total of 39 residues from 26 crops, are used as valuable substrate for mushroom production. The Kerala Agricultural University, Thrissur has released an oyster mushroom mutant (var Ananthan) that can be grown in low-cost substrates such as banana pseudostem, sugarcane bagasse, coir pith, saw dust of various soft and hard wood trees, tea waste, tapioca starch waste and water hyacinth.

Bio-waste utilization for crop production: The Kerala Agricultural University has developed feasible technologies for waste utilization. Two systems are developed to convert bio-waste into bio-manure - 'Suchita' developed at the College of Agriculture, Vellayani and 'Bio-bin' developed at College of Agriculture, Vellanikkara. These technologies are useful in waste management at the source of generation. 'Suchitha', a patented rapid thermochemical biowaste processing technology enables the processing of solid wastes to organic fertilizer in less than a day. Leno et al. (2021) studied the growth and development of vegetables, viz., tomato and okra due to "Suchitha" when combined with different organic and inorganic manures and found that the fortified thermochemical organic fertilizer gave the growth medium a high status of total organic carbon regardless of the organic source of nitrogen utilized. Smart Bio-bin, Gee-bin, Bokashi bucket and Solwearth organic waste converter machines can be successfully used in crop residue management.

Soil-less planting media: Coir pith compost + FYM (2:1) recorded the maximum yield and B:C ratio for bhindi. Similar results were also reported by Soumya and Usha (2015) who observed the effect of different growth media on tomato and found that coir pith compost + FYM (2:1) recorded the maximum fruits per plant (23.41), fruit weight (35.43 g) and yield per plant (883.46 g).

Biochar: Biochar is a carbonaceous material produced from the agricultural wastes contains 1.35–1.62% N, 0.22-0.51% P and 0.89-1.30% K (Pati and Panda 2021). When biochar is applied to the soil as an amendment, it is found to increase soil fertility, soil organic carbon, reduce GHGs and increase fertilizer use efficiency (Nematian et al., 2021).

3.3. Miscellaneous use

Apart from recycling the crop residues back to agriculture, different value-added products can be created from these discarded wastes to generate income, thereby making it a component of integrated farming system. Thus, the agricultural waste problem is managed as well as income can be generated.

Banana fiber: Natural fibers derived from plants, including banana, coir, sisal, jute, kenaf, and many more, have been tested for use in industry. The banana plant comprises numerous components, including the fruit, peel, flower bud, leaves, and pseudostem, all of which can be utilized for diverse industrial applications. The main source of banana waste biomass and a source of high-quality fiber is the pseudo stem. It may find use in manufacturing sanitary napkins, textiles, pulp and paper, food, reinforced composite materials for cars, building materials, aerospace, and other composite materials. Balda et al. (2021) studied the mechanical properties of various natural fibers and have reported that banana pseudo stem fiber had the highest tensile strength, flexural strength and the lowest elongation percentage.

Areca/jute/glass fiber reinforced hybrid composite plates: The use of hard cellulose fibers has been encouraged by the growing interest in introducing cheap, renewable, and environmentally friendly reinforcing materials. The hybrid fibers are a desirable substitute due to their inexpensive price, light weight, and density.

Paper from paddy straw: Kriya labs (a start-up incubated at IIT Delhi) has developed a sustainable technology which is soon to be made available to the public, that can convert agro wastes like paddy straw into pulp. This pulp can then be used to make products like paper, plates and cups that are not only completely biodegradable.

Bio brick**:** Bio-bricks were developed as an alternative and sustainable building material that is made up of agricultural waste. Bio bricks can create a new economic model for farmers and lead to the development of agriculture-based industries. Rautray et al. (2019) has reported bio-bricks as a carbon-negative, sustainable and economically viable material for construction. Decorative wall panels can also be made from banana pseudo stem fibers.

Briquetting**:** The process of briquetting which is compacting the agricultural residue left after harvest allows for substitution of wood as a fuel. Using briquetting technology, agricultural waste may be managed by converting them into densified solid biofuels. It is simpler to transport, store, and use (Setter et al., 2020). Produced briquettes from rice straw using the cold densification method and revealed that the energy consumed for making briquettes accounted for only 5.6–7.5%.

Electricity generation: The increasing demand for energy and gradual depletion of non-renewable energy sources requires a shift to reliable renewable energy resources. Biogas plant has the maximum potential for electricity generation (Jiang et al., 2019). Energy production is 19.34% from wheat straw, 5.32% for barley straw, 40.46% for corn stalk, 25.03% for sunflower stalk, 3.17% for rapeseed straw and 6.67% for soybean straw.

4. Conclusion

Crop residues are typically seen as waste material in terms of economic value, even though they provide elemental carbon to soil and provide several nutrient recycling pathways. Crop residue management improves soil organic carbon, irrigation efficiency, enhances the water holding capacity and reduces the loss of surface soil. It increases the abundance of helpful microbes that assist in transforming nutrients from unavailable forms to forms that plants can uptake. Thus, the awareness to utilize crop residues helps in development of sustainable livelihood of farmers.

5. References

Balda, S., Sharma, A., Capalash, N., Sharma, P., 2021. Banana fibre: a natural and sustainable bioresource for eco-friendly applications. Clean Technologies and Environmental Policy 23(5), 1389–1401.

Jiang, Y., Havrysh, V., Klymchuk, O., Nitsenko, V., Balezentis, T., Streimikiene, D., 2019. Utilization of crop residue for power generation: The case of Ukraine. Sustainability 11(24), 7004.

Kumar, M., Patle, G.T., Lal, M., Kumar, A., Rani, K., Kumar, S., Kumar, S., 2024. An overview of crop residue management challenges, opportunities, and the way forward for sustainable food-energy security in India. Ecology, Environment and Conservation (0971765X), 30.

Lohan, S.K., Jat, H.S., Yadav, A.K., Sidhu, H.S., Jat, M.L., Choudhary, M., Peter, J.K., Sharma, P.C., 2018. Burning issues of paddy residue management in north-west states of India. Renewable and Sustainable Energy Reviews 81, 693–706.

Martin, A.G., Jayapal, A., Vikram, K., Kavya, B., 2024. Crop residue management through utilization: a review. Environment and Ecology 42(2B), 745–753.

Meena, H.N., Singh, S.K., Meena, M.S., Narayan, R., Sen, B., 2022. Crop residue: Waste or wealth? Technical Bulletin 2022. ICAR–Agricultural Technology Application Research Institute, Zone-II, Jodhpur, 1–30.

Nematian, M., Keske, C., Ng'ombe, J.N., 2021. A techno-economic analysis of biochar production and the bioeconomy for orchard biomass. Waste Management 135, 467–477.

Pati, M.M., Panda, N., 2021. Effect of sources of biochar on soil biological properties in an acidic Alfisols. Annals of Plant and Soil Research, 23, 523–525.

Setter, C., Silva, F.T.M., Assis, M.R., Ataíde, C.H., Trugilho, P.F., Oliveira, T.J.P., 2020. Slow pyrolysis of coffee husk briquettes: Characterization of the solid and liquid fractions. Fuel 261, 116420.

Win, K.S., Aung, Y., Kyaw, Z.T., Lay, K.K., Oo, H.L., 2021. Effect of two different types of concentrate on dry matter intake, body weight gain and body growth of Pyar Sein calves fed black gram crop residue. Journal of Livestock Science 12, 65–70.