BioThink E – Magazine, Vol. -2, Issue -4, October 2025
ISSN No. – 3048- 7943
www.biothink.in

Agri-Waste to Wealth: The Future of Crop Residue Utilization in India

Aditi Agarwal ✉

College of Agribusiness Management, GBPUAT Pantnagar, Uttarakhand

✉ aditiagarwala416@gmail.com DOI : 10.5281/zenodo.17331997

India stands at crossroads where an environmental crisis overlaps with a massive economic opportunity. Each winter, the northern plains and the capital city -Delhi, Delhi NCR are blanketed with smog, a large part of which is caused by the burning of crop residue in Punjab and Haryana. Yet hidden within this problem is one of the country's most undervalued resources—the 500 to 550 million tonnes of agricultural residue generated every year. The real debate is not whether this residue can be converted into wealth, since the technology, policy frameworks, and pilot projects already exist. The actual challenge is whether India possesses the political will and institutional capacity to execute such an effort at the required scale and urgency.

The sheer magnitude of agricultural waste makes it a difficult issue to solve. India is the world's second-largest generator of crop residue. Official figures from the Ministry of Power's SAMARTH report suggest that around 230 million tonnes of surplus agro-residue is produced annually, while other studies place the number closer to 500 million tonnes when agro-industrial waste is included. This enormous quantity of biomass represents both a severe environmental threat and a vast economic opportunity.

The environmental repercussions of burning crop residue are disastrous. Worldwide, burning of stubble is among the biggest air-polluting sources. Over 90 percent of Punjab and Haryana farmers burn their fields to easily clear them between harvests. This burning emits harmful pollutants like PM2.5 particles, carbon monoxide, methane, and volatile organic compounds. These emissions exacerbate the toxic winter smog of northern India, which has been identified with a public health crisis. Apart from damaging the air, stubble burning drains soil organic carbon and kills microorganisms essential for soil fertility, resulting in decreased agricultural yield in the long run.

Even though these are remarkable environmental expenses, the economic potential of agricultural residue is equally impressive. The Ministry of New and Renewable Energy estimated that agricultural waste can produce over 18,000 MW of electricity annually. Studies by NTPC further suggest that surplus biomass could support thousands of

megawatts of renewable power generation. Projections indicate that if 1,500 bio-CNG plants were established, each processing around 50 tonnes daily, India could produce 3,000 tonnes of gas per day while also reducing about 44 million tonnes of carbon dioxide emissions annually.

Recognizing this dual challenge, the Indian government has launched several ambitious schemes. The 2018 Crop Residue Management (CRM) Scheme allocated more than ₹4,300 crore and supplied over 319,000 on-farm machines to farmers and cooperatives in high-burning states. Around 41,000 custom hiring centres were set up, and over 27,000 drone-based demonstrations were carried out to showcase residue management techniques. The impact has been visible to some extent. During the 2024 season, incidents of paddy stubble burning in Punjab, Haryana, and Uttar Pradesh dropped by 57 percent compared to the previous year. Subsidies of up to 80 percent on tractors for high-powered seeders also reflected a more holistic approach to mechanization.

Yet, the gap between policy ambition and field-level results remains wide. Reports suggest that nearly one-third of the subsidized machines in Punjab are non-functional. Problems such as poor maintenance, lack of farmer training, and limited technical support have prevented many initiatives from achieving their full potential. In addition, the lack of suitable tractors and supporting infrastructure often means that even well-designed subsidies fail to deliver their intended outcomes.

Technology, however, continues to open up new possibilities for utilizing agricultural waste. Bioenergy options are among the most established. The government is now promoting initiatives and establishing biomass-based power plants, bio-CNG units, and second-generation ethanol production. Some famous initiatives of the Indian government are the GOBAR-dhan scheme and the SATAT program. The biochar (black carbon produced from biomass sources) received by the process of pyrolysis (thermochemical decomposition of complex organic material at a very high temperature, 400°C to 700°C) increases soil fertility and helps in increasing nutrient and water holding capacity of soil. Waste from agriculture, after proper treatment, can also be used as fodder.

Developments in the field of Materials Science have given us hope of utilising the agricultural waste. Researchers at IIT Madras have developed packaging materials made from crop residue combined with mycelium, offering biodegradable and compostable alternatives to harmful plastics. Similarly, scientists at IIT Guwahati are experimenting with bioplastics derived from agricultural waste, providing solutions to both the waste problem and plastic pollution. These innovations illustrate the biorefinery model, in which different components of biomass are broken down and processed into multiple high-value products.

The central challenge in this transition lies in how agricultural residue is valued in the marketplace. Current economic mechanisms do not account for the social and environmental costs of burning or the benefits of sustainable use. Farmers often burn residue not because they are careless about the environment but because it makes immediate

economic sense. The costs of collecting, baling, and transporting crop residue frequently exceed the uncertain income they could earn from selling it.

This is particularly evident in the case of second-generation ethanol. Despite the government sanctioning nearly ₹200 crore to support twelve demonstration plants in 2019, only one plant was operational by 2025. The higher costs of processing farm waste compared to conventional feedstocks make such ethanol uncompetitive without guaranteed pricing and sustained policy backing. Farmers and processors alike face risks due to the absence of stable supply chains and reliable pricing mechanisms.

Creating a functioning market for crop residue requires new systems of price discovery and risk-sharing. Farmers require guarantees of equitable prices, whereas processors seek stable and low-cost feedstock supplies. Aggregation models like farmer-producer organizations (FPOs) and cooperatives can act as a crucial component by aggregating resources, concentrating biomass, and reducing infrastructure costs.

We can not ignore the fact that the majority of the Indian farmers have small and marginal land holdings, which can create a challenge in the proper collection and processing of such a huge amount of agricultural waste. Additionally, shortage of labour, lack of financial resources, and pressure to sow next crop are some practical challenges. Coordinating action between institutions also makes the picture more complicated. Proper management of residue involves coordinating central and state policies, district-level implementation, and village-level adoption. Experiences with rural development schemes in the past indicate that it is difficult to coordinate in practice.

We have to realize that to get sustainable growth, a solution for agricultural waste is very crucial. All the stakeholders, the government and its institutions, farmers, and environmental activists must come forward to find a long-term solution to these issues. The government has to understand that providing subsidies will not be enough to address the problem, but to form a streamlined value chain. Fixing prices, establishing quality standards for products based on these wastes, and establishing and promoting more research in this field could be our first steps.

To encounter the issue of marginal land holding, the government may decentralise the system and give power to local authorities rather than governing the issue from one body. It will further reduce the transportation costs of carrying out waste, and will give economic benefits. The government can further adopt the PPP model, i.e., the Public Private Partnership model, utilizing the capacity of public players. This will not only reduce the financial burden on the government but will also lead to a sustainable waste management system.

The management of agricultural waste is not a simple task. A lot of work will have to be performed to get a strong and stable solution for this issue. The Government alone is also not capable of fighting this problem. We all have to do our part in the work towards a healthy and greener environment.