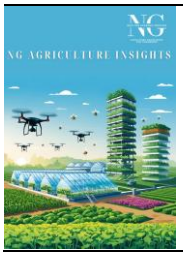

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Stubble Burning: Environmental Impact and Sustainable Management

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A B S T R A C T

Although combustion is a necessary human activity, the poisons produced by the incomplete process and its consequences have caused social turmoil. The consequences of declining health are unknown to the general public: environmental damage, biodiversity loss, and deterioration of product quality. Despite the authorities' sideways application of strategic planning to mitigate the consequences on the population and industrial infrastructure, the local populace still doesn't fully understand. Despite the importance of this subject, not much research has been done on it thus far. The current review aimed to find the underlying causes, environmental effects, and management techniques of stubble burning, particularly in India. Among the sustainable ways to handle vestiges are in-situ residue management, the manufacture of animal and mushroom feed, composting, biochar manufacture, bio-thermal power plants, and the paper sector. Happy Seeder has emerged as a mechanical and successful in-situ management technique. Farmers can use any of the techniques mentioned earlier to manage their trash in an environmentally friendly way by overcoming the obstacles and lessening the environmental impact, no matter how much land they own.

Keywords: Biodiversity, Consequences, Environment, Stubble Burning

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1. INTRODUCTION

India's economy depends upon agriculture because this sector feeds many people across the nation while generating food security. Farmer practice of stubble burning persists as a widespread method for post-harvest field clearing which currently serves as a major environmental and public health issue. Many farmers carry out agricultural waste burning by setting fire to residual rice straws which remain in their harvested fields. The fast and easy procedure of field preparation that stubble burning provides yields major negative effects for both environmental conservation and health safety. The practice of stubble burning allows pollution to reach dangerous levels in the air thereby leading to respiratory illnesses and both air pollution and climate change effects. Soil nutritional content together with organic material both suffer depletion from stubble burning which results in enduring soil deterioration conditions. The widespread practice continues because economic constraints related to time shortfalls between harvest seasons and a lack of practical sustainable farming knowledge in addition to high staffing costs prevent alternatives from taking effect (Prusty et al., 2021).

This article studies the complete picture of stubble burning root causes in India together with their environmental effects and showcases techniques for sustainable resource management. A thorough examination of foundational reasons along with feasible solutions enables us to develop sustainable

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agricultural methods which properly match farmer necessities with environmental priorities and community needs.

2. ROOT CAUSE OF STUBBLE BURNING

Due to the difficulty of managing a significant amount of stubble, farmers resort to burning (Sain, 2020). The following are the most probable reasons for stubble burning in India:

2.1. Lack of time period between two successive crops

The most crucial agronomical technique in agriculture is "time/date of sowing." It is advised that paddy be sown in the second two weeks of May, then moved in the second two weeks of June, until July 5th, to allow the crop to develop in November. Ironically, because the next wheat crop is sown in the first two weeks of November, farmers in a rice-wheat cropping sequence are unable to manage rice straw effectively. Conversely, late-planted varieties have emerged that can be planted as late as the first week of December for a maximum of 20 days between consecutive crops (Ravindra et al., 2019).

2.2. Lack of knowledge in stubble management

The Indian government is trying to educate farmers about residue management, despite their lack of knowledge about it and their conviction that burning is the simplest way to get rid of agricultural waste (Lehmann & Joseph, 2015).

2.3. Mechanical harvesters

Since rice is the most important cereal crop and is grown in vast quantities, harvesting it requires an exorbitant amount of labour. As a result, mechanical harvesters were developed, with combine harvesters being one of the most common. Because it is not intended to cut the plant to the surface and absorb it into the soil, a considerable amount of straw is left in the field itself (Mittal et al., 2009).

2.4. Lack of responsibility

Few people carelessly burn stubble in the field while being aware of residue management and its effects on the environment; as a result, lawmakers have passed new legislation to curb these careless actions by a small number of farmers (Gottipati et al., 2021)

2.5. Unlikely for cattle

For use as cow feed, dairy products are made from the majority of the leftover material from cereal and forage crops. There is no way to get rice straw to the dairy, despite the fact that it is not recommended for use as cow feed in the northern regions because of its high silica and lignocellulose content and low protein content (2–7%). However, due to its remarkable palatability, cattle seem to favor feed made from basmati rice (Na et al., 2014)

2.6. Scarcity and cost of labour

The expansion in intensive agriculture, which has resulted in a gradual decrease in the utilization of human labor and an increase in mechanical power, has caused the contribution of Punjab's agricultural workers and all workers to drop from 62.67% to 35.96% between 1970–71 and 2012–13. Labor earnings have increased dramatically in recent years. To reduce these costs, farmers simply burn their leftovers, which is free of charge (Saha et al., 2025).

3. MANAGEMENT OF CROP RESIDUE

Crop residue can be used in a variety of ways, all of which call for some fundamental understanding and awareness.

3.1. Crop residue as bedding material for cattle

Throughout the southern Indian states, paddy straw is frequently utilized as bedding in cattle shelters. But these days, on government advice, this is also done in northern regions, primarily during the winter months. The study's findings at the College of Agriculture, PAU, demonstrated that the comfort, leg, and udder health that crop residue bedding offers throughout the winter months significantly improves both the quality and quantity of milk output. During the winter, bedding keeps animals warm and controls heat loss. Lameness and injury are also less likely since it produces a dry, grippy, safe, clean, and secure environment. Healthy legs and hooves help cows produce more milk and have better reproductive capabilities (Singla et al., 2012). Biogas plants have the potential to repurpose this leftover paddy straw.

3.2. Crop residue in Mushroom Production

Rice, wheat, and sugarcane bagasse residues make great substrate for growing mushrooms. Paddy straw, which has a high lignocellulosic content and is relatively less expensive, is ideal for growing mushrooms. In order to counteract the growing expense of mushroom production, it can therefore be used profitably. The oyster mushroom (*Pleurotus ostreatus*) is the most widely accessible edible species in India among a variety of other mushroom species, including *Agaricus bisporus* (button mushroom),

Calocybe indica (milky mushroom), and *Volvariella* spp. (paddy straw mushroom). The kind of compost that is used to nourish these mushrooms has a significant impact on how well they thrive. But how well the mushroom spawn utilizes different compost components depends on the bagged substrate, which in turn depends on a number of physicochemical parameters that affect both the composting process and the mushroom growth. In India, just 0.03% of field agricultural leftovers are employed in mushroom production, despite the enormous potential for using them (Gupta et al., 2016).

3.3. Crop residue in the paper industry

The 40:60 ratio of paddy straw to wheat straw is utilized in the production of paper. Biogasification could be utilized to generate energy from the leftover sludge from the production of paper. Currently, some paper mills are using this technology to supply about 60% of their energy needs. Additionally, paper and pulpboard are frequently made using paddy straw as a raw material (Sain, 2020). An alternative to deforestation could be this management technique (Prusty et al., 2021).

3.4. Stubble mulching

Stubble/straw mulching is the practice of equally distributing wastes throughout the land surface to reduce weed development, preserve soil moisture, and stop soil erosion from wind and water. Few studies have demonstrated that mulch conserves soil moisture in the deeper layers, which explains why root length is roughly 40% longer when compared to no mulch treatments (Singh et al., 2008). Compared to a crop that is not mulched, the use of rice straw as mulch has improved water use efficiency by 25%, raised wheat production, and reduced crop water demand by 3–11%.

3.5. Happy seeder

This mechanical tool, which is placed on a zero-till tractor, cuts the existing rice straw on the ground, plants wheat seeds, and turns the leftover material into mulch. This mulch inhibits weed development, stops soil erosion, and preserves soil moisture. Additionally, using the happy seeder can cut labor costs for collecting and planting residue by 80%, pesticide use by 50%, and irrigation requirements by 20% to 25%. Happy Seeder, also known as the "Super straw management system," functions effectively when combined with the fundamental straw spreading mechanism. The super straw management technique enhances work quality and production stability by connecting this to a combine harvester so that residue is evenly distributed throughout the harvest width (Lohan et al., 2018). CSIRO, Griffith, and Punjab Agricultural University (PAU) engineers and researchers initially created the Happy Seeder in July 2001. In northern India, there are currently roughly 11,000 happy seeders in use, with about 80% of them operating a machine in the state of Punjab can be utilized again in biogas plants in the future. Crop waste in biogas facilities: Biogas, which is made from agricultural waste, can be used as an alternative to fossil fuels. One of the main sources of lignocellulose, which is needed to produce biogas, is agricultural crop leftovers, especially rice straw. The agricultural wastes can also be used to make biogas and biochar. When producing biogas, stubble is chopped into small pieces using grinders before being added to digesters along with other materials. This entirely anaerobic method yields solid and liquid organic fertilizers as byproducts in addition to biogas (Ravindra et al., 2019).

4. CONCLUSIONS

Stubble burning is a serious problem that has an adverse effect on soil, human health, and the environment. It causes respiratory disorders, air pollution, and the depletion of soil microbes. When there is not enough time between harvesting rice and growing wheat, farmers frequently turn to burning. To lessen this issue, experts advise planting rice ten days sooner. Straw is used for cattle feed, mushrooms, bio-thermal energy, paper industries, bio-char production, mulching, and soil incorporation, among other alternatives to stubble burning. The Happy Seeder is a creative way to properly manage crop waste. In order to safeguard the health of the environment, efforts are still being made to enforce laws and promote sustainable practices.

Conflicts of Interest: The authors declare no conflicts of interest.

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