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Turning Ashes to Assets: A Comprehensive Review of Stubble Burning, Its Management and Policies in India

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Abstract: India, the world's second largest agro-based economy with year-round crop production, generates a significant amount of agricultural waste, predominantly crop residue.Periodically, there is an increase in the habit of intentionally lighting the residue left over after harvesting wheat and rice crops. Stubble burning has recently emerged as one of India's most troublesome concerns. This practice is common in major rice-producing areas like as Punjab, Haryana, and Uttar Pradesh, and it has serious implications for air quality, soil health, and public health. This review investigates the complicated issue of stubble burning, focusing on the fundamental factors, such as manpower shortages, increased automation, and the short interval between rice and wheat planting. We assess diverse crop residue management approaches, such as in-situ techniques like stubble inclusion, mulching, and the use of Happy Seeders, as well as off-farm uses like biogas production and composting. The review also discusses government policies and schemes aimed at reducing stubble burning, such as the National Policy for Management of Crop Residue (NPMCR) and various financial incentives.

Keywords: crop residue, happy seeder, rice, stubble burning

1.Introduction:

India, a country with a population of around 1.4 billion and a rich cultural diversity, depends mostly on agriculture, which generates more than 15% of the country's GDP (Singh et al., 2020). Agriculture has historically played a major role in the sustainable growth and development of the Indian economy. High-yielding seeds were introduced during the Green Revolution, greatly increasing land cropping intensity, productivityand per capita income of farmers. However, this resulted in the wheat-rice farming pattern being widely adopted, which in turn led to the inappropriate utilization of natural resources such water, soil and forests (Batra, 2017).India contributes 20% of the world's rice production and is the world's second-largest producer of the grain, after China.

One to 1.5 kg of straw is produced for every kilogram of paddy, with over 80% of this rice straw being burned in fields. According to Gadde et al. (2009), 48% of all open field burning occurs in Punjab and Haryana alone. The short time between rice harvesting and wheat planting is the primary driver of this practice. The term "stubble" is the plant material that is left over after crops are harvested; this includes all plant parts other than those with commercial value (Gottipati et al., 2021).Stubble burning is the practice of setting fire to the stubble from paddy crop harvesting in order to clear the area for wheat sowing. Rice and wheat are the most important cereals in India, accounting for around 30% of the world's food supply and feeding billions of people. Cereal crops produce the largest residues, totaling 352 million tons, with paddy and wheat accounting for 34% and 22% of this production, respectively (Gottipati et al., 2021).

India has a widespread rice-wheat cropping pattern, primarily in the Indo-Gangetic plains which account for the majority of the country's stubble burning (Sain, 2020). The majority of the time, combine harvesters are used to harvest rice, leaving a significant amount of residue. In order to start preparing the ground as soon as possible to sow wheat, farmers who lack the time to gather and utilize the leftover material burn the wastes. Furthermore, because of its high silica content, which renders it unsuitable for feeding, animals tend to avoid rice straw. It is therefore necessary for farmers to burn these residues in the field. This review will look at the challenges, underlying causes, mitigation techniques and government policies surrounding stubble burning, with a focus on India.

2. Stubble burning in India:

India, which accounts for 17% of the world's population and is primarily reliant on agriculture, produces vast quantities of food grains such as rice and wheat for both domestic and worldwide markets.According to the Directorate of Economics and Statistics, the country produced 105 metric tons of rice, 361 tons of sugarcane, and 94 tons of wheat in 2012-2013, with a large amount of the agricultural waste being burned.According to the IARI, approximately 14 million tons of the 22 million tons of rice stubble produced each year is burned. India generates 127 metric tons of crop leftovers annually. Punjab and Haryana, two of India's major rice-producing states, account for approximately half of all stubble burning.According to the National Policy for Crop Residues, Uttar Pradesh generates the most crop residue (60 metric tons), followed by Punjab (51 metric tons) and Maharashtra (46 metric tons). Rice and wheat make up roughly 70% of overall crop wastes. The surplus residue is the remaining waste after it has been used for many different purposes, some of which is burned and the rest is left in the field.

According to Jain et al. (2019) and IPCC, Uttar Pradesh is the leading contributor to residue burning, followed by Punjab and Haryana. According to the IPCC, over

25% of all crop wastes are burned on farms, with rice accounting for the most at 43%, followed by wheat at 21%, sugarcane at 19%, and oilseed crops at around 5% (Sahai et al., 2011).In accordance with Jitendra et al. (2018), 80% of crop waste burning occurs after harvest, between April and May and November and December. This is primarily due to agricultural patterns designed for larger economic returns, resulting in shorter time between succeeding crop cycles. In certain circumstances, farmers choose a three-crop cycle per year, with only a brief period between harvesting and sowing.

3.Primary cause for stubble burning in India:

Crop residue is far from being waste, but various factors contribute to turning this valuable resource into ash. Some of the key reasons are outlined below:

3.1. Labor Shortage:

In today's intensive agricultural systems, keeping up with the speed of farming activities through manual labor has become increasingly difficult. As a result, there has been a considerable change from traditional livestock-driven ways to mechanized farming, such as the implementation of tractors and power tillers in the field (Grover et al., 2017). One advantage of manual harvesting is that it removes the majority of the stubble from the field, which may subsequently be utilized as livestock fodder. Even today, a tiny fraction of basmati rice is hand harvested to avoid grain breakage because this type is prone to lodging, and its straw, which has low amounts of silica, is preferred for fodder (Erenstein, 2011).

However, in Haryana and Punjab, where large-scale cultivation is frequently seen and manpower shortage is common, basmati rice is frequently harvested mechanically with combine harvesters, resulting in residue burning (MoA and FW, 2019). Haryana and Punjab account for around 16.9% and 49.47% of total residue burning, respectively (MoA and FW, 2019). Another factor contributing to labor scarcity is the enactment of employment guarantee schemes such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), which provides stable job opportunities within villages, reducing the incentive for laborers to seek work elsewhere (Bhattacharyya et al., 2021). The National Sample Survey Office has also observed a decline in agricultural labor over recent years (Bhattacharyya et al., 2021).

3.2. Farm mechanization:

Punjab and Haryana have seen a considerable growth in agriculture mechanization during the post-Green Revolution era, which has coincided with a labor shortage. This increase in mechanization is primarily driven by the requirement for timely and cost-effective harvesting of rice. Traditionally, harvesting paddy with conventional methods needs 150-200 man-hours per hectare, which is not economically feasible for most farmers (Lohan et al., 2015, 2018). As a result, combine harvesters have emerged as the most practical choice for farmers. (Bhattacharya et al., 2021). These completely automated devices, which include threshers, are used to harvest standing crops and collect grains efficiently. However, combine harvesters leave a huge amount of residue in the fields, making it difficult for farmers to manage this material (Mittal et al., 2009). As a result, many farmers turn to burning stubble as their only viable option.

3.3. Limited time for wheat seeding:

Farmers have a short window of 7-10 days to sow wheat, and 15-20 days for basmati and conventional high-yielding rice types (Sahai et al., 2011). To guarantee that wheat is planted on time, farmers must remove all rice straw from the field. Due to time constraints, farmers are frequently forced to burn rice straw as the most efficient form of residue management.

3.4. Rejection as fodder:

Paddy straw is rarely utilized as fodder in India due to its substantial silica content (Singh et al., 1996). It has little minerals and proteins, but much of lignocellulose and fiber. Despite being nutritionally equivalent to wheat straw, farmers prefer wheat straw for feed. Additional reasons for rice straw's low acceptance include the risk of 'Degnala' sickness, the difficulty of processing chaff and blending it with green fodder and low palatability due high oxalate content (Migo, 2019).

3.5. Storage problem:

Rice residue is difficult to store because it is fluffy and dense. It takes up a lot of space, which needs to be waterproof and shielded to prevent from blowing away by strong winds (Sidhu et al., 2015). Another issue to consider is rodent infestations. Furthermore, rice straw's hygroscopic nature might result in mold or fungal growth, which is detrimental to cattle, especially during the wetmonsoon season (Goswami et al., 2020).

4. Crop Residue Management:

There are several applications of crop residue, but they all call for a certain level of general awareness and fundamental understanding.

4.1. Ex-setu management:

i) Crop trash as fodder:

Crop debris are the most common source of animal feed in India. Wheat and maize straw are the primary feed sources in Northern India, although rice straw, despite its high silica concentration, is widely used in Southern India, most likely due to a lack of alternative feed options. The demand for crop residues for livestock feed in India is approximately 415.83 million tons, but only 253.26 million tons are available, representing a roughly 40% shortage. Paddy straw is also widely used as bedding in cattle sheds, particularly in Southern India. This practice has recently been extended to Northern India, notably during the cold seasons, in response to government suggestions. A study conducted at the Punjab Agriculture University, found that employing crop residue bedding during the winter considerably boosted the quality and quantity of milk production by providing comfort and health benefits to the cattle's legs. Bedding throughout the winter months keeps cattle warm and regulates body heat loss, resulting in healthier legs and hooves, which contribute to higher milk production and improved reproductive performance in animals (Mandeep et al., 2012).

ii) Crop Residue in Biogas Plants: Agricultural waste, such as rice straw, can provide lignocellulose for biogas generation, a sustainable alternative to fossil fuels. As a byproduct of the anaerobic process, biogas is produced together with liquid and solid organic fertilizers. Furthermore, agricultural leftovers may be utilized to make biochar, which contributes to sustainable energy solutions (Ravindra et al., 2019; Singh et al., 2016).

iii) Crop Residue in Bio-Thermal Plants: Paddy leftovers are crucial for generating power in bio-thermal facilities. Many organizations and power stations are now pushing the use of rice residue to produce energy, giving farmers a more profitable alternative to stubble burning. Farmers may sell agricultural surpluses to power facilities for 350 rupees per tonne (Kumar et al. 2015). Furthermore, the Ministry of New and Renewable Energy, in partnership with the Central Government, has developed about 500 biomass-fueled power plants around the country.

iv) Crop residue in Mushroom Production: Crop leftovers including rice, wheat, and sugarcane are ideal substrates for mushroom production. Paddy straw, in particular, is a low-cost, high-lignocellulose source, making it an ideal alternative for mushroom cultivation. Despite its potential, just 0.03% of field agricultural leftovers in India are now used for mushroom production, indicating a substantial untapped market (Gupta et al., 2016).

v) Crop residue in compost making: Composting involves breaking down organic materials, such as agricultural leftovers, animal manure and vegetable waste, using microorganisms. The technique produces natural organic fertilizer, which improves the soil's physical, chemical and biological qualities. Crop leftovers have enormous potential for conversion into useful organic fertilizer through composting.

vi) Crop Residue in Paper Industries: The straw from paddy is blended with wheat straw in a 40:60 ratio to make paper. It is also a common raw material for the production of paper, providing a substitute to deforestation and a long-term use for crop wastes (Sain 2020).

4.2. In-situ management:

Managing crop residue directly on the farm is an effective and cost-efficient practice for farmers, offering several benefits. The following methods are commonly used for in-situ crop residue management:

i). Stubble incorporation: After harvesting, straw is manually or mechanically incorporated into the soil. Rice straw may be properly handled in the field by leaving 20-25 days between straw integration and wheat sowing. Field trials have demonstrated that adding paddy straw 21 days before seeding wheat considerably boosts wheat yields.

ii). Stubble Mulching: Spreading crop leftovers uniformly across the soil surface prevents erosion, conserves moisture and suppresses weed development. Mulching has been demonstrated to preserve soil moisture in deeper layers, resulting in around 40% longer root development than non-mulched treatments (Sidhu et al., 2011). Using rice straw as mulch reduced agricultural water consumption by 3-11% and increased wheat production as compared to non-mulched crops.

iii.) Happy Seeder: This device cuts standing rice straw, sows wheat seeds, and utilizes the straw as mulch. This mulch helps to retain soil moisture, reduce erosion and limit weed development. Furthermore, the Happy Seeder decreases the work required for residue collecting and seeding. When combined with a simple straw spreading mechanism, it functions effectively as the 'Super Straw Management System' (Lohan et al., 2018).

5. Environmental Laws, National Schemes, and Policies:

Stubble burning carries both apparent and hidden expenses. The Indian Constitution imposes 11 regulations aimed at decreasing anthropogenic pollution. Stringent measures have been imposed under Section 144 of the Civil Procedure Code to reduce paddy straw burning (Jat et al., 2009). Several significant legislations have been passed to decrease pollution and safeguard biodiversity, including:

1. The Environment (Protection) Act, 1986
2. The National Environmental Tribunal Act, 1995 (Amendment 2010)
3. The National Environment Appellate Authority Act, 1997
4. The Environment (Siting for Industrial Projects) Rules, 1999
5. The National Green Tribunal Act, 2010

The Ministry of Agriculture and Farmer's Welfare (Government of India) took a big step in 2014 by implementing the National Policy for Management of Crop Residue (NPMCR), which has main objectives such as:

1. Promoting sustainable crop residue management through advancements in machinery and various industrial sectors.
2. Raising awareness among farmers through capacity building and extension activities.
3. Providing financial support to the farming sector for feasible crop residue management.
4. Developing and enforcing appropriate laws, acts and policies for managing crop residue.

NPMCR'spilot projects in collaboration with states focus on developing farm machinery, modifying combine harvesters for better straw collection and using remote sensing technology to monitor crop residue management, with support from the Central Pollution Control Board in New Delhi. However, progress has been modest, with substantial results notably in agricultural residue monitoring by satellite in Punjab and Haryana (Datta et al., 2020).In 2018, the Cabinet Committee for Economic Affairs allocated Rs. 1152 crores for farm mechanization in the NCR region to manage surplus residue and minimize pollution levels (Datta et al., 2020). The National Green Tribunal (NGT) has enforced a strict prohibition on crop residue burning in India's northwestern states, with fines of up to INR 15,000 for farmers caught burning stubble (Jitendra et al., 2017).

Beyond the agricultural sector, the Central Electricity Authority, Ministry of New and Renewable Energy and Ministry of Petroleum and Natural Gas are exploring the use of rice residue for power generation. Public sector such as Indian Oil and Hindustan Petroleum are developing 2G ethanol power plants in Punjab and Haryana (MoPNG, 2018). The Government of India has also authorized the National Thermal electricity Corporation to combine agricultural residue pellets (about 10%) with coal for electricity generation, providing farmers with a return of around Rs. 5500 per ton.

Although these initiatives appear promising, they have yet to be completely implemented and potentially deliver major economic benefits to farmers.

6. Conclusion and Future perspective:

Stubble burning is a complicated issue in India, affecting air quality, soil health, and farmer livelihoods. Despite current management methods and government legislation aimed at reducing the problem, stubble burning remains widespread owing to economic and logistical restrictions. Stubble burning is a major environmental concern in India, driven by factors such as labor shortages, automation, and the short period between crop cycles. While several management strategies, including as in-situ integration, mulching, and off-farm usage, provide feasible options but their acceptance is restricted. Government programs, such as the National Policy for Crop Residue Management (NPMCR) and legislative measures, have made progress in tackling the issue, but further implementation and public participation are required.

Future efforts should focus on improving the economic viability of residue management options, expanding the availability of supporting technologies and increasing farmer engagement through targeted incentives and education. In order to successfully address the issues associated with stubble burning, India should progress toward a more resilient and sustainable agricultural framework by promoting a collaborative approach including policymakers, researchers and agricultural communities.

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