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Tackling the Stubble Burning Crisis in India: A Pathway towards Cleaner Air

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Every year, with the arrival of winter, India's northern states, particularly Punjab, Haryana, and Uttar Pradesh, face the pressing problem of stubble burning. This agricultural practice, in which farmers set fire to crop residues left after harvesting paddy crops, has become a recurring contributor to severe air pollution levels, particularly in major cities such as New Delhi. The thick smoke emitted by burning fields not only envelops rural areas but also drifts to urban centers, forming a toxic blanket that causes public health emergencies and severely impairs air quality and visibility (Govardhan et al., 2023). Stubble burning contributes to North India's already alarming air pollution crisis, exacerbating smog, which worsens during the winter months due to temperature inversions (Parihar et al., 2023). Despite numerous government interventions, such as policies, subsidies for alternative technologies, and penalties for stubble-burning, the problem persists year after year. The reasons are deeply rooted in economic constraints, farming practices, and a lack of knowledge about sustainable alternatives. This article delves into the economic, social, and technical reasons why farmers continue to burn stubble, examining devastating effects on the environment and public health, and promising solutions also highlighting case studies from various regions of India where innovative practices and policies have made a positive impact on reducing this environmentally harmful activity.

Why Do Farmers Burn Stubble?

Farmers in northern states like Punjab, Haryana, and parts of Uttar Pradesh grow paddy crops during the Kharif season (June to October). After the crops are harvested, farmers face the challenge of dealing with the residual paddy straw or stubble that remains in the fields. Paddy residue is difficult to decompose naturally, and it must be removed to prepare the fields for the Rabi crop, typically wheat, which must be sown quickly (usually within 15 to 20 days of paddy harvest). Farmers face significant time pressure due to the narrow window between two cropping seasons (Singh et al., 2015). Several factors lead to the continued practice of stubble burning, despite growing awareness of its harmful effects:

1. **Time Constraints:** Farmers burn their fields because they don't have enough time to prepare for the next crop. Traditional methods of removing stubble, whether manually or with machines are time-consuming and labor-intensive. In contrast, burning the residue is a quick and easy way to clear the land in a matter of hours.
2. **Economic Constraints:** Most farmers in these areas have small to medium-sized farms and cannot afford mechanized solutions that allow for stubble management without burning. Machines such as the Happy Seeder, which can plant seeds without removing the stubble, and the Super Straw Management System (Super SMS), which chops and

evenly distributes the stubble, require a significant investment. Even with government subsidies, the initial cost of purchasing such machinery can be prohibitively expensive for many farmers, particularly those who rely on loans to fund their agricultural operations.

3. **Lack of Viable Alternatives:** Although there are other applications for paddy straw, such as the production of biofuel, animal feed, or mushrooms, these possibilities are still underdeveloped in many regions in terms of both infrastructure and market demand. Because facilities that may turn stubble into lucrative byproducts are typically difficult for farmers to access, burning is the most practical and easiest choice.
4. **Penalties and Government Policies:** Despite the introduction of penalties by state governments for burning stubble, enforcement is still uneven. Many marginal and small farmers contend that there are no other options available to them and that the imposition of fines will only make their financial situation worse. Furthermore, authorities find it logistically difficult to monitor and penalize individual farmers because of the size of the issue and the large area covered by paddy production.
5. **Cultural and Traditional Practices:** It takes time to change deeply rooted agricultural behaviors, such as the generations-long practice of stubble burning. Many farmers still believe that burning is the easiest and most efficient way to deal with crop leftovers, even in spite of increased understanding.
6. **Awareness and Technological Gaps:** A lot of farmers are not aware of newer methods or substitute technology that can cut down on burning. Although programs for awareness and training have been started, not every segment of the agricultural community has benefited from them yet. Because of this, customs still rule, especially in rural communities with little access to information and education.

Consequences of Stubble Burning

Beyond its immediate benefits for clearing fields, stubble burning has severe and far-reaching consequences:

1. **Air Pollution and Public Health:** Dangerous pollutants including as particle matter (PM2.5 and PM10), carbon dioxide (CO2), methane (CH4), and carbon monoxide (CO) are released when stubble is burned. These pollutants worsen the quality of the air and also help to create haze, which covers both urban and rural regions (Khan al., 2023). Long-term exposure to this air pollution leads to a variety of respiratory ailments, including lung infections, bronchitis, and asthma; the elderly, young children, and those with underlying medical disorders are most susceptible (Singh et al., 2023). The World Health Organization (WHO) claims that people who live in areas affected by stubble burning have much shorter life expectancies due to air pollution.
2. **Impact on Soil Fertility:** The soil loses vital elements like potassium, phosphate, and nitrogen when stubble is burned. Additionally, it eliminates helpful bacteria that support the health and productivity of the soil. As a result of this degradation, the land becomes less fertile over time, which makes farmers increasingly dependent on chemical fertilizers to sustain crop production and exacerbates environmental degradation.
3. **Contribution to Climate Change:** Burning stubble emits a lot of greenhouse gases (GHGs) into the atmosphere, which is one of the main causes of climate change and global warming. Strong greenhouse gases (GHGs) generated during burning, such as carbon dioxide and methane, trap heat in the atmosphere and cause temperature increases and more unpredictable weather. In addition to having an impact on the global climate, this also makes the local climate more unfavorable for farming, starting a vicious circle of environmental harm (Gulati et al., 2023).
4. **Economic Losses:** In the short run, stubble burning may appear like a cost-effective approach, but the long-term financial consequences are significant. Reduced soil fertility

results in a greater need for fertilizers, which drives up production costs. Furthermore, the negative health effects of pollution result in higher medical costs and decreased productivity, especially in cities where the harmful smog is present (Cusworth et al., 2023). The potential short-term gains for farmers from burning stubble are greatly outweighed by these hidden expenses.

Case Studies on Solutions to Stubble Burning

Despite the severity of the problem, several innovative solutions have emerged across India, driven by both government and community initiatives:

1. **Punjab's Happy Seeder Success Story:** With the use of the HS, a tractor-mounted device, wheat seeds may be seeded straight into fields without the need to remove paddy residue. The Happy Seeder was introduced under the "Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue" initiative, and its use is encouraged by government incentives. In Ludhiana, Punjab, 300 farmers formed a cooperative to purchase the Happy Seeder, eradicating stubble burning on over 1,000 hectares in two seasons. The retained paddy straw improved soil fertility, and wheat yields remained steady or slightly increased due to better soil moisture (Kaur et al., 2022)
2. **Bio-Decomposer Spray in Delhi NCR:** An innovative technique to break down stubble in the field is the Pusa Bio-Decomposer, developed by the Indian Agricultural Research Institute (IARI). The crop residue is sprayed with the bio-decomposer, which turns the straw into manure for the following crop in 20 to 25 days. *Case Study:* In 2020, a large-scale bio-decomposer trial on 4,000 acres near Delhi successfully broke down stubble without burning, enhancing soil nutrients and reducing the need for chemical fertilizers (Ministry of Environment, Forest and Climate Change, 2022). Positive feedback led to the method's expansion to new areas.
3. **Crop Diversification in Haryana:** Another long-term answer to the stubble burning problem is crop diversity. The Haryana government has been pushing the switch from rice to less residue-producing crops including cotton, maize, and pulses in partnership with agricultural colleges (Majumder, 2023). Case Study: In the district of Karnal, Haryana, the Mera Pani Meri Virasat plan incentivizes farmers to produce alternative crops that demand less water and do not contribute to stubble burning. Diversifying into pulses and maize allowed farmers to report cheaper production costs and less pressure to burn leftovers. In order to give farmers a stable market, the state also guaranteed purchase for these crops.
4. **Biomass Energy Plants in Punjab:** Stubble can be converted into biomass energy, providing a renewable energy source as an alternative to burning. Punjab has set up a number of biomass power plants that produce electricity from paddy straw, lessening the impact of crop residue on the environment (Kaur, 2020).Case Study: Nearly 100,000 tons of paddy straw are processed annually by the biomass facility operated by Satia Industries in Muktsar, Punjab. The plant has greatly decreased stubble burning in the surrounding areas by turning crop residue into energy. Farmers now have a way to make money since they can sell their straw rather than burning it. The company's initiatives have been praised for providing a long-term fix for the stubble burning issue.

Government Policies and Legislative Efforts

To address the issue of stubble burning, both state and central governments have implemented various policy measures:

1. **Subsidies for Farm Equipment:** The government has been providing subsidies of up to 50% for individual farmers and up to 80% for cooperative societies to purchase machinery like Happy Seeders, Super SMS, and mulchers. These machines help manage stubble in situ without burning.

2. **Penalties and Enforcement:** The National Green Tribunal (NGT) prohibited stubble burning in 2015 and imposed fines on farmers who persisted in burning. For small farmers, the fine is INR 2,500; for large farms, it is INR 15,000. Penalties are not always imposed consistently, and enforcement is still difficult.
3. **National Policy for Crop Residue Management:** In 2018, the Ministry of Agriculture introduced the National Policy for Crop Residue Management. The strategy describes a number of actions, such as the creation of other markets for crop residue, awareness campaigns, and financial support for farm equipment.

Recommendations

Recommendation	Details	Benefits
Scaling Up the Use of Happy Seeders	Increase adoption of Happy Seeders by expanding subsidies and raising awareness.	Reduces need for stubble burning by planting crops directly through residue, saving time and improving soil.
Expansion of Bio-Decomposer Usage	Promote the use of the Pusa Bio-Decomposer, which breaks down crop residue into compost.	Cost-effective and eco-friendly alternative to burning; improves soil health by adding organic matter.
Boosting Crop Diversification	Encourage farmers to grow less residue-intensive crops, such as pulses and cotton, with crop insurance and procurement support.	Reduces residue generation, thus minimizing the need for burning; enhances economic stability for farmers.
Public-Private Partnerships for Biomass Energy	Foster investment in biomass energy plants that convert crop residue into energy.	Provides a sustainable use for crop residue while generating renewable energy and offering extra income to farmers.
Farmer Training and Education	Conduct continuous education and training programs for farmers on sustainable agricultural practices and technologies.	Increases awareness and long-term adoption of environmentally friendly methods, reducing reliance on burning.

Way Forward

Stubble burning in India, driven by time and economic pressures, poses significant environmental challenges. However, innovative solutions offer hope for a cleaner future (Bhattacharyya et al., 2021). Technologies like the Happy Seeder, which allows wheat planting without removing stubble, and bio-decomposers such as the Pusa Bio-Decomposer, which turns residue into compost, have helped reduce burning (Zaidi, 2021). Biomass plants converting crop waste into renewable energy also provide an alternative use for stubble while generating farmer income. Scaling up these solutions, along with improving access, affordability, and addressing socio-economic barriers, can significantly reduce stubble burning (Dutta et al., 2022), improving air quality and enhancing soil health for sustainable agriculture.

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