

Paper number: 970

The Green Shift: Tackling Stubble Burning for a Sustainable Tomorrow

Track: Sustainable and Responsible Business

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## Introduction

The agricultural sector has consistently played a vital role in ensuring the sustainable growth and development of the Indian economy. The advent of the Green Revolution marked a significant turning point, with the introduction of high-yielding variety (HYV) seeds leading to a substantial rise in agricultural productivity, increased cropping intensity, and improved per capita income for farmers (Pingali, 2012; Sharma, 2011). Agricultural emissions pose significant health risks. Stubble burning has many environmental impacts compared with alternatives such as ploughing stubble back in the field or harvesting it for industrial purposes. Farmers burn crop residues, mainly after harvesting paddy, to clear fields for the next sowing season due to the lack of affordable. This practice has severe environmental, economic, and health implications, contributing to air pollution, greenhouse gas emissions, and soil degradation (Gupta et al., 2021). Basically, Stubble burning is the practice of setting fire to the crop residue left in the field after harvesting, primarily associated with rice and wheat crops. This method is used by farmers to clear the field for the next planting season quickly. However, it has significant environmental and health impacts. The burning of stubble releases large quantities of pollutants, including carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and particulate matter (PM<sub>2.5</sub>), which contribute to air pollution and climate change. Additionally, it causes the loss of soil nutrients and organic matter, reducing soil fertility and increasing the need for chemical fertilizers. Rice, paddy and wheat cropping patterns are among the extensive farming practices in the states of Haryana, Punjab, Rajasthan, and western Uttar Pradesh (Shaik et al., 2019). These regions are very famous for burning the straw and stubble after the harvesting season. The United Nations Sustainable Development Goals (UNSDGs) provide a global framework for addressing pressing challenges such as poverty, inequality, health, and environmental degradation. Among these, goals like SDG 13 (Climate Action), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land) are directly relevant to tackling the issue of stubble burning in India. Stubble burning, a common agricultural practice in states like Haryana and Punjab, contributes significantly to air pollution, greenhouse gas (GHG) emissions, and soil degradation. In India, the National Green Tribunal (NGT) has prohibited the practice of straw and stubble burning in the highly polluted city of New Delhi and its neighboring states—Haryana, Punjab, Rajasthan, and Uttar Pradesh—due to its significant contribution to deteriorating air quality. In response to the escalating environmental and health concerns associated with crop residue burning in these regions, various policy measures and management strategies have been introduced to promote sustainable residue disposal practices.

Farm Stubble burning is prevalent in about 10,000 villages in North-western States – Punjab and Haryana mainly, but also in UP, Rajasthan, and MP. It leads to massive air pollution problems in pre-winter and winter months in the region - Delhi NCR is worst affected, where life comes to a standstill year after year. Farmers mostly complain about the lack of viable alternatives. Open-field burning of residual biomass is considered a convenient method of its disposal.

In last few years, the Government of India and concerned State Governments have launched many initiatives and policy measures to curb the problem – including (b) Subsidy Scheme for

farmers/cooperatives on Farm Machineries used in stubble management (launched in 2018, Rs3000 Cr has been already spent) (b) Subsidy for entrepreneurs for establishment of stubble processing/value addition (Ex-situ) units, launched in 2023 (c) notification to make bio-pellets mixing with coal (5 to 10%) mandatory for all industries operating in the region (2022) (d) Establishment of large industrial ventures by PSUs for industrial use of biomass (such as Bio CNG plant by IOCL). In spite of all such efforts, stubble burning incidents and air pollution was witnessed at an unprecedented level in 2023 season, although year on year there is a slow decline in burning cases. Corporate Social Responsibility (CSR) initiatives can play a pivotal role in addressing this issue by promoting sustainable solutions for the farming community. The burning of stubble contributes to deterioration in air quality that sometimes resulted in skin irritation and dryness of the eye, allergies, coughing, to the nearby community (Raza et al., 2022).

In Haryana (India), particularly in Fatehabad district, stubble burning has been a persistent issue, contributing to poor air quality and associated health problems.

## **Literature Review**

Stubble burning, particularly of paddy residues, has emerged as a serious environmental and public health issue in India. Despite legal bans and technological interventions, farmers continue to engage in this practice, largely due to economic and logistical constraints (Kumar et al., 2020). The environmental implications—air pollution, greenhouse gas emissions, and soil degradation—have been well-documented (Cusworth et al., 2018; Sidhu et al., 2015). However, limited attention has been paid to multi-sectoral solutions, particularly the role of Corporate Social Responsibility (CSR) in addressing this crisis. According to a report by the Centre for Science and Environment (2023), stubble burning contributes up to 30–40% of Delhi's air pollution during peak harvest seasons.

Economic factors play a crucial role in the persistence of this practice. Mechanized harvesters such as combine machines leave behind long stalks, which farmers are unable to manage manually or economically (Jain et al., 2014). The high cost of eco-friendly alternatives such as Happy Seeders, Super Straw Management Systems (SMS), and decomposer sprays remains a deterrent for small and marginal farmers (Kaur et al., 2022). Additionally, a lack of adequate extension services and delayed or insufficient subsidy disbursement further hinder adoption. The National Green Tribunal (NGT) has prohibited residue burning in Delhi and its neighboring states (NGT, 2015), but enforcement is weak, and punitive approaches often alienate farmers rather than encourage sustainable alternatives (MoEFCC, 2022).

## **Technological and Policy Approaches**

Over the years, several policy frameworks have attempted to tackle the problem. The National Policy for Management of Crop Residue (2014) and the Central Sector Scheme on Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue (2018–19) aimed to promote machinery and practices that reduce stubble burning. However, evaluations have shown that the reach of such schemes is limited. Innovations like microbial decomposer solutions developed by the Indian Agricultural Research Institute (IARI) offer promise but have faced implementation challenges, including inadequate training and awareness campaigns (IARI, 2021). Thus, while technological solutions exist, their diffusion and acceptance remain constrained because of the institutional gaps.

## Crop Residue Burning & Air Pollution Crisis in Northwest India

In spite of enormous media coverage and hue and cry about the stubble burning crisis in recent years, the problem remains deep rooted and persists at a large scale. Punjab & Haryana are the two hotspot states of crop residue burning incidents (Refer Table 1). The number of fire counts in Punjab in 2022 was 49,922, and 71,304 in 2021. <https://pib.gov.in/PressReleasePage.aspx?PRID=1880978>

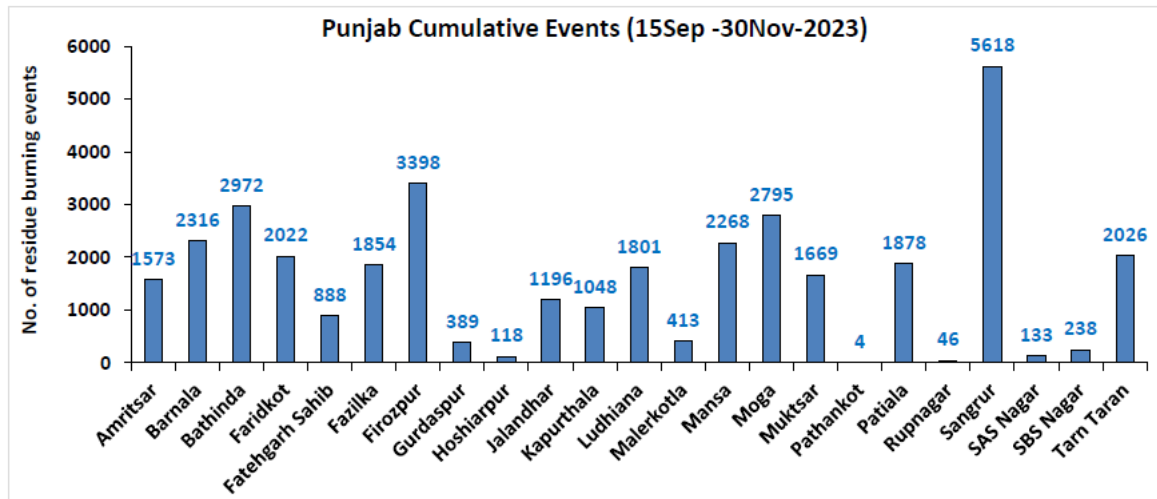


Table : 1 (District-wise Stubble Burning Incidents in Punjab, 2023)

Despite the growing concern around stubble burning, several critical gaps remain in both academic and policy literature. First, there is a limited focus on multi-stakeholder collaboration, as most existing studies tend to examine technological or regulatory solutions in isolation, without exploring the synergistic roles that government, communities, and corporate entities—particularly through CSR—can play in a coordinated response. Secondly, smallholder constraints are often overlooked, as many policies and technologies are based on uniform assumptions, ignoring the socio-economic diversity and resource limitations among marginal farmers. Lastly, the behavioral dimensions of stubble burning—including farmer perceptions, risk attitudes, and entrenched social norms—remain underexplored, thereby limiting the design of context-sensitive, culturally appropriate solutions.

### The Intervention and scope of the study

Recognizing the urgency of this issue, Cadence, which is a leading EDA and Intelligent System Design provider, delivering hardware, software, and IP for electronic design companies in India as a part of their CSR and Sustainability initiatives (Biswas and Das, 2023), plans for an intervention. They approached an implementation partner, i.e. CII Foundation, to undertake the project to address these challenges by promoting alternative, sustainable stubble management practices. In Haryana, particularly in Fatehabad district, stubble burning has been a persistent issue, contributing to poor air quality and associated health problems. The Cadence and CII Foundation project seeks to address these challenges by promoting alternative, sustainable stubble management practices.

About Cadence: Cadence is a market leader in AI and digital twins, pioneering the application of computational software to accelerate innovation in the engineering design of silicon to systems. Their design solutions, based on Cadence's Intelligent System Design strategy, are essential for the world's leading semiconductor and systems companies to build their next-generation products from chips to full electromechanical systems that serve a wide range of markets, including hyperscale computing, mobile communications, automotive, aerospace, industrial, life sciences and robotics.

About CII Foundation: It was set up by CII in 2011 to undertake a wide range of developmental and charitable activities and initiatives pan India by enabling Industry for infusing inclusive development. CII Foundation works towards inclusive development by providing a meaningful bridge between marginalised communities and donors, specially the Corporate Sector.

This study tries to fill the critical gaps by stating the potential of CSR as a catalyst for sustainable stubble management in India. Unlike prior research, which is either techno-centric or policy-oriented, this work takes a systems perspective, integrating environmental science, rural livelihoods, and corporate engagement.

## **Objectives**

The primary objectives of the project are:

- To Implement Alternative Crop Residue Management Techniques.
- To promote sustainable agricultural practices among farmers.
- How CSR can be strategically aligned with state and central policies to support scalable models of residue management.
- What role do community participation and trust-building play in ensuring the acceptance and sustainability of CSR-led initiatives.
- To Conduct Awareness and Training Programs

The adoption of technology has been planned in the intervention to seek the solutions of the problem and challenges. The technology such as Super Seeder, Smart Seeder, Surface Seeder, Baler & Raker has been used.

## **Research Methodology**

Cadence, in collaboration with the CII Foundation, has embarked on a project to curb stubble burning in the Fatehabad district of Haryana. The initiative targets a cluster of 10 villages, encompassing 6232 hectares and engaging a farmer population of 1,520. The target sample was around 300 farmers. The baseline emissions assessment has been conducted. Data collection has been done through stratified random sampling of farmer households at the village level. Selected interviews have been conducted with the farmers and other affected communities. A geo-tagging mobile application was employed as a tool for the digital survey. Additionally, the Government reports and agricultural statistics were used for the cultivated area estimates. The

adoption of technology has been planned in the intervention to seek the solutions of the problem and challenges.

Past government data has shown that two states of India namely Haryana and Punjab have scored the highest when it comes to crop residue burning. Furthermore, the reason of choosing Fatehabad is the very fact that among all the districts of Haryana, Fatehabad has been worst performing when it comes to crop residue management or crop residue burning (Refer Table:2)

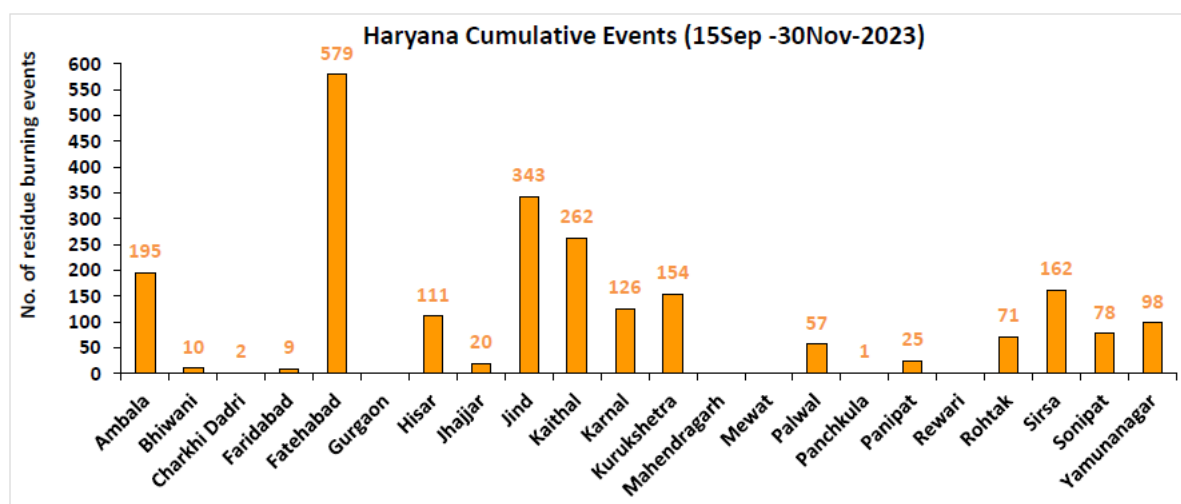


Table:2

### Monitoring Survey Parameters

The monitoring survey for the project, to be carried out, involving the collection of extensive data across several categories to assess the agricultural practices, land management, and residue management of the farmers participating in the initiative. The data collection process has been structured in several key sections (Meul et al. 2008). Farmer Details, a comprehensive list of participating farmers, was gathered from ten villages in Fatehabad district, Haryana.. The data collection process was structured in several key sections:

- 1 Farmer Details
- 2 A comprehensive list of participating farmers was gathered from ten villages in Fatehabad district, Haryana.
- 3 Key details recorded
- 4 Name of the farmer
- 5 Gram Panchayat/Village
- 6 Block

### Land Mapping Details

- Geo-coordinates were recorded using GIS and Remote Sensing (Sentinel 2 & Sentinel 5p) technology to accurately map the project intervention area.
- Coordinates were collected at each corner and one point at the center of the field
- Photographs of the field were taken to visually document the land conditions
- The amount of residue generated per hectare and its usage (cattle fodder, mulching, burning, etc.) was documented.

- 1 Land and Crop Details
- 2 Crop-related data collected:
- 3 Type of crop grown within the project area.
- 4 Crop yield (t/ha)
- 5 Crop cycle (Sowing and harvesting dates were recorded)
- 6 Harvesting details:
- 7 Duration of harvesting (number of days).
- 8 Time period of harvesting (approximate dates).
- 9 Method of Harvesting (manual, mechanical or other)
- 10 Post-harvest residue management:
- 11 Method of residue extraction (manual, machinery, or other).
- 12 Amount of residue generated per hectare.
- 13 Usage of residue (for cattle, mulching, burning, etc.)
- 14 If the residue was burnt, the quantity or percentage burnt was recorded.



Image :1 From the field: Discussion with the community

## Result and Discussion

The district of Fatehabad (Haryana), encompassing 10 villages and spanning a total area of approximately 6232 hectares (2023), serves as the focal point of the study. Satellite imagery analysis reveals that around 997.12 hectares (2024), within this area are affected by stubble burning through Satellite imagery analysis. This highlights the significant scale of the issue in the surveyed region. However, the extent of stubble burning may fluctuate annually due to factors such as climate conditions, variations in crop yields, and the frequency of burning practices across different areas.

In 2023, the baseline report indicated that approximately 3,490 hectares, or 56% of the total 6,232 hectares of cropland in Fatehabad, were affected by stubble burning for rice straw management. This widespread practice contributed to the burning of a significant portion of farmland. However, following a monitoring survey in 2024, after various interventions were implemented and advanced monitoring techniques like GIS and remote sensing (Sentinel 2 & Sentinel 5p) were utilized, a substantial reduction in the burned area was observed. The latest data shows that only 997.12 hectares, representing 16.04% of the total cropland, are now subjected to burning. This decline reflects a positive shift toward more sustainable and environmentally friendly residue management practices. The change is likely due to increased awareness among farmers, stronger policy enforcement, and the gradual adoption of alternative, sustainable methods for managing paddy straw. This trend demonstrates a growing commitment to reducing environmental impacts and promoting more efficient farming practices.



Image:2 – Researchers Team with the farmers

To calculate the reduction in emissions:

- Emissions before intervention (2023): 28,482.35 tonnes Co<sub>2</sub>eq from 3,490 hectares.
- Emissions after intervention (2024): 8,137.81 tonnes CO<sub>2</sub>eq from 997.12 hectares.
- The difference in emissions can be calculated by subtracting the post-intervention emissions from the pre-intervention emissions, which indicates how much reduction occurred.

Furthermore, significant challenges are preventing the widespread adoption of sustainable alternatives:

- Lack of Awareness: Many farmers are not fully aware of the benefits of in-situ and ex-situ practices, or they may lack the knowledge or resources to implement them effectively.
- High Cost of Equipment: The cost of machinery for in-situ practices, such as the Happy Seeder, may be prohibitive for smallholder farmers.
- Labor Constraints: In rural areas, the availability of labor at critical times, such as during the harvest season, can drive farmers to choose the quicker method of burning.

- **Infrastructure and Market Limitations:** For ex-situ practices like baling, a lack of local infrastructure for storage or a reliable market for straw could deter farmers from using these methods.

#### Environmental Impact

- **Impact on Soil health and biodiversity:** Paddy and wheat cropping is a widespread agricultural practice in the northwestern regions of India, particularly in the fertile riverine plains of Haryana and Punjab. These regions are renowned for their extensive agricultural fields but are equally notorious for the burning of paddy and wheat straw by farmers following the harvest season. Haryana and Punjab collectively contribute 48% of the total straw produced in the country, and alarmingly, nearly half of this straw is burned directly on farmlands.

According to a 2012 study by the Indian Agricultural Research Institute (IARI), Punjab alone generates approximately 40 million metric tonnes of farm residue annually. Nationally, the production of agricultural remains was reported as 253 million tonnes in 2010, increased to 352 million tonnes in 2012 (IARI, 2012), and further to 500 million tonnes by 2016 (Government of India, 2016). Paddy straw production, particularly in the Rice-Wheat 17 | Baseline Report 2024. Cropping System (RWCS), constitutes the largest agricultural production system globally, covering approximately 12.3 million hectares in India<sup>3</sup>.

The practice of stubble burning has profound adverse effects on soil health and agricultural sustainability. Burning crop residues results in the significant loss of organic matter, essential nutrients, and beneficial soil microorganisms, all of which are critical for maintaining soil structure, fertility, and productivity. Research has shown that stubble burning adversely impacts soil organic matter quality, reducing levels of organic carbon, nitrogen, and phosphorus. Additionally, vital nutrients such as potassium, sulphur, and carbon are also depleted. The elevated soil temperatures caused by burning can kill or displace important microorganisms, disrupting the soil's carbon-to-nitrogen ratio and overall ecological balance. Biodiversity is also negatively impacted by stubble burning. The practice destroys habitats for various wildlife species, including insects, birds, and small mammals that rely on crop residues for food and shelter. The destruction of these habitats disrupts local ecosystems and contributes to a decline in biodiversity. Furthermore, the intense heat kills soil-dwelling organisms, which are crucial for maintaining ecological balance and supporting soil health.

- **Contribution to air pollution and health hazards:**

Stubble burning significantly contributes to air pollution by releasing large amounts of particulate matter (PM<sub>2.5</sub>, PM<sub>10</sub>), carbon dioxide, carbon monoxide, and other harmful pollutants, leading to poor air quality and severe respiratory health issues, especially for individuals with pre-existing conditions. PM<sub>2.5</sub> levels can increase by 50–75%, while PM<sub>10</sub> levels rise by 40–45% during burning events. Additionally, toxic substances like benzene, soot particles, nitrogen oxides, sulfur dioxide, and aromatic hydrocarbons are emitted, further degrading air quality. Depending on residue composition, stubble burning can release around 13 tonnes of carbon dioxide per hectare, posing significant risks to both human health and the environment.

## Conclusion

The current development study on greenhouse gas (GHG) emissions from rice stubble burning in Fatehabad District, Haryana, has been studied using key parameters related to crop residue generation, burning percentage, and emission factors for CH<sub>4</sub>, CO<sub>2</sub>, and N<sub>2</sub>O. The findings of this intervention brings the significant environmental impact of rice stubble burning and

underline the necessity for mitigation strategies to reduce emissions and promote sustainable residue management. The major intent of crop residue management projects in Punjab and Haryana was to mitigate air pollution from burning crop residue, promote sustainable agricultural practices, and enhance soil health. These projects aim to reduce greenhouse gas emissions, improve air quality, and prevent the loss of essential nutrients and soil microorganisms. Additionally, they seek to encourage the adoption of technologies and machinery for in-situ and ex-situ crop residue management, as well as create awareness among farmers about the benefits of these practices. The study demonstrates a significant positive shift towards sustainable practices. However, continuous financial support, policy enforcement, and farmer engagement are essential for long-term success in managing crop residue sustainably.

### **Suggested mitigation strategies**

Some mitigation strategies that can help reduce greenhouse gas emissions from rice stubble burning include adopting no-burn farming practices, promoting Alternative Uses of Rice Straw, and encouraging farmers to explore alternative uses for rice straw can mitigate the negative impacts of burning, among others.

In conclusion, the pollutants released from stubble burning pose serious health risks to exposed populations, contributing to a range of respiratory and cardiovascular ailments, and in extreme cases, even mortality. Beyond its impact on public health, the practice significantly contributes to atmospheric pollution, accelerates climate change, and depletes essential soil nutrients. Given these far-reaching consequences, there is an urgent need for comprehensive and well-enforced policies that address the root causes of stubble burning and promote sustainable residue management practices.

### **Implications**

The promotion of sustainable crop residue management (CRM) practices holds significant policy implications with direct relevance to India's environmental, agricultural, and socio-economic priorities. These interventions align with multiple Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 2 (Zero Hunger), by addressing the environmental degradation caused by stubble burning and promoting sustainable agriculture. Mechanized in-situ residue incorporation helps preserve soil nutrients and microbial life, reducing dependence on chemical inputs and enhancing long-term productivity.

The establishment of Farm Machinery Banks (FMBs) supports SDG 8 (Decent Work and Economic Growth) and SDG 10 (Reduced Inequalities) by making advanced technologies accessible to small and marginal farmers through affordable custom hiring. Moreover, CRM interventions generate co-benefits by facilitating income diversification through alternative uses of biomass (e.g., fodder, fuel, bioenergy), contributing to SDG 12 (Responsible Consumption and Production). Awareness creation and capacity building among farmers through targeted IEC strategies are critical for behavioral transformation and link directly to SDG 4 (Quality Education). Integrating CSR funding into CRM policy frameworks can catalyze innovation, infrastructure development, and community engagement. CSR can bridge financial and institutional gaps, enabling corporations to contribute meaningfully to climate-

resilient agriculture and rural sustainability. Strategic CSR investments, aligned with national and state CRM missions, can ensure long-term impact, scalability, and inclusive development.

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