ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2025): 4.69
IJAN 2025; 7(9): 48-55
www.agriculturejournal.net
Received: 19-07-2025
Accepted: 21-08-2025

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Harvest to haze: Unraveling the impact of stubble burning

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DOI: https://www.doi.org/10.33545/26646064.2025.v7.i9a.286

Abstract
Stubble burning, the deliberate setting fire to crop residues after harvest, is a prevalent agricultural practice in several regions of India, particularly Punjab, Haryana, and western Uttar Pradesh. Farmers often adopt this method to quickly clear fields for the next sowing season, especially in intensive cropping systems like rice-wheat. While cost-effective and time-saving in the short term, stubble burning has severe environmental, economic, and health consequences. It releases large amounts of particulate matter ($PM_{2.5}$ and PM_{10}), greenhouse gases (CO_2, CH_4, N_2O), and toxic pollutants, contributing to poor air quality, smog formation, and respiratory illnesses. The practice also leads to the loss of soil organic matter, depletion of beneficial microorganisms, and long-term decline in soil fertility. Despite existing regulations and penalties, enforcement remains a challenge due to socio-economic constraints faced by farmers. Sustainable alternatives such as in-situ residue management using Happy Seeder, mulching, bio-decomposition, and promoting crop diversification have shown promise in reducing stubble burning. Addressing the issue requires an integrated approach involving technological interventions, farmer incentives, awareness programs, and strong policy support to achieve environmentally sustainable agriculture while safeguarding farmer livelihoods.

Keywords: Stubble burning, crop residue management, air pollution, soil health, sustainable agriculture

Introduction

What is stubble burning?

According to Technical Bulletin 6 prepared by International Competence Centre for Organic Agriculture, stubble burning is a method of removing crop residues (leftover) from the field to sow crop for the next season. Stubble burning is a process of setting on fire the straw stubble, left after the harvesting of grains.

- It is usually a practice in the areas that use combined harvesting method, which leaves crop residue behind. As a result of the lack of infrastructure for waste management, farmers set almost 15.4 million metric tons (out of the 19.7 MMT) on fire in open fields (Punjab government 2017).
- Stubble burning is practiced majorly in the Indo-Gangetic plains of Punjab, Haryana, and western Uttar Pradesh and in north India and is a major cause of air pollution in National Capital Region.

Farm fire cases and penalties in Punjab have declined from 2020 to 2022, indicating progress in curbing stubble burning. In 2023, cases slightly rose to 7,061 with Rs 1.9 crore in penalties, suggesting the need for continued efforts.
In 2020, Haryana imposed Rs 86 lakh in penalties for 464 cases amid 4,202 farm fires, with no verified data available for later years. Research shows stubble burning can contribute up to 30% of PM levels in Delhi-NCR. (Source: Business Standard, 6th December, 2024)
As per the news article “Stubble burning contributed 10.6% to Delhi’s PM 2.5 levels in late 2024: Centre’s data”, between 2020 and 2024, stubble burning contributed significantly to Delhi's PM2.5 levels during the post-harvest season, with average contributions ranging from 9% to 13% and peak daily contributions reaching up to 48%. In 2024 alone, stubble burning accounted for an average of 10.6% of PM2.5 in Delhi. Punjab reported 10,909 stubble

burning incidents during the 2024 paddy season (Sept 15-Nov 30), and ₹1.48 crore was collected as environmental penalties. (Source: The Times of India, 10 March, 2025)

Importance of stubble burning issue in Haryana

Stubble burning in Haryana is significant due to its detrimental impact on air quality, public health, and the environment. It contributes to air pollution, especially during winter months, and exacerbates respiratory and skin infections. The practice also harms soil fertility, depletes vital nutrients, and increases soil temperature, negatively impacting agricultural productivity. Additionally, stubble burning contributes to greenhouse gas emissions, further impacting the climate.

Causes of stubble burning

As per the article "Bureaucrat incentives reduce crop burning and child mortality in South Asia"

1. Burning is used as a fast and inexpensive method for clearing crop residue after harvest and before the next cropping cycle. Farmers echo this sentiment: "If I can clear my farm using a one-rupee matchbox, why will I spend thousands?"
2. First, the Green Revolution spurred the 'rice-wheat cropping system', which is characterized by rapid harvest and sowing cycles so that crops can catch prime conditions for their growth. Second, burning increased by 39% after the introduction of water conservation legislation that compressed the harvest period for rice.
3. Greater use of mechanization technologies produced larger crop residues that needed to be cleared. Finally, a high labor wage due to sustained out-migration from rural areas further increased the use of these mechanized tools

As per working paper "Causes of Emissions from Agricultural Residue Burning in North-West India: Evaluation of a Technology Policy Response"

a) 90% of the respondents, when asked about the basis of variety choice, cited the price and yield of various varieties during the previous growing season as the key factors in arriving at this decision.
b) Rice residue is largely burnt because it is of limited value to the farmers both as livestock feed and non-feed use. Since the machinery for planting wheat into loose rice residue was hitherto unavailable, farmers burnt the rice residue.
c) Singh *et al.* (2006) [16]., suggest that the yield of the wheat crop may also be negatively impacted if the loose residue is unevenly spread on the field.

(Singh, R; Dhaliwal, H; Singh, TH (2006) [16] 'A financial assessment of the Happy Seeder for rice-wheat systems in Punjab, India', Permanent Beds and Rice- residue Management for Rice-Wheat Systems in the Indo-Gangetic Plain 7:182)

As per Observer Research Foundation research on "Stubble burning in India"

- Paddy farming, whose production soared due to many policies, including subsidized fertilizers, a guaranteed minimum support price (MSP), and free electricity, is responsible both for a significant amount of crop residue and groundwater scarcity. In India, paddy farming constitutes 41 percent of the total grain food production [8].
- A water conservation legislation called the Punjab Preservation of Subsoil Water Act 2009, enacted in Haryana and Punjab, has also contributed to incidents of stubble burning.
- Under this act, paddy sowing can only be carried out in monsoon months as water-intensive crops such as rice refrain from sucking groundwater during this period.
- One of the challenges faced by farmers who use CRM, such as happy seeder and supper seeder, is that both require an expensive 60 horsepower (HP) tractor to run, which stands useless much of the time. Even on rent, it typically costs a farmer INR 10,000. Moreover, hiring a stubble removal machine for a four-acre farm requires a waiting time of nearly two weeks.

According to "COVID-19 pandemic and sudden rise in crop residue burning in India: issues and prospects for sustainable crop residue management"

a) From 2012, since when the fire counts data of the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor of NASA's Suomi NPP satellite is available, the highest fire counts were recorded in 2016 as 100029.
b) However, an unexpected increase in paddy residue burning activities was noted in the year 2020, having around 80889 fire counts observed over the two major agricultural states (Punjab and Haryana).
c) Residue burning in 2020 increased by 18.9%, 23.0%, and 60.2% from 2017, 2018, and 2019, respectively.
d) Amid the COVID-19 pandemic, the sudden increase in crop residue burning activities and related increases raises a human health concern as air pollution is a major risk factor for COVID-19 and may increase the related mortality in neighboring cities and megacity New Delhi
e) During harvesting season, there was a scarcity of workforce to manage the crop residue, possibly leading to increased paddy residue burning activities.

Research paper on "Assessment of Farmers' Perception about Crop Residue Burning in Haryana"

Crop residue burning is an economically viable option for the farmers followed by the farmers for efficient straw management statement had the highest weighted mean percentage followed by every farmer is not able to use happy seeders because it requires very high-power tractors for functioning with comprising of 89.33 per cent and 85.89% respectively. Moreover, farmers perceived that weeds can be controlled by open straw burning. (Source: Indian Journal of Extension Education)

Research paper "Farmer perspectives on crop residue burning and sociotechnical transition in Punjab, India"

1. Medium/large farmer Focused Group Discussions (FDG) differed from small farmer FGDs.
2. Medium/large farmers often discussed the expense of not burning, identifying the prohibitive role of no-burn Crop Residue Management cost for small farmers.
3. Though FGDs with small farmers also reported the importance of cost, they were more likely to cite a lack of access to other options for CRM.
4. Alternatively, responses from key informants indicate the cost, both for diesel and machine rental, is most important to farmers deciding whether to practice crop residue burning

Research paper "Farmers' Perspective to Mitigate Crop Residue Burning in Haryana State of India"

The major problems are less time availability between the harvesting of rice and showing of wheat crop, followed by cost of cultivation increases, if machinery is used, and lack of cost-effective & viable technologies.

Research paper "A state of the art review in crop residue burning in India: Previous knowledge, present circumstances and future strategies"

- Labor scarcity
- Farm mechanization and use of combine harvester
- Short window for sowing wheat
- Lack of acceptance as fodder
- Management of weed and pest

Research paper "Reasons and awareness levels of farmers on residue burning in Indo-Gangetic Plain of India: An exploratory research"

- The study depicts that short window time between paddy harvesting and showing wheat was a primary reason for stubble burning.
- Research also shows that harvesting is expensive and time-consuming, causing farmers to burn.
- Most farmers were aware of the various adverse effects of burning on soil health, air health, and human health.
- Everybody was aware of the ban on crop residue burning and other government measures, but they have no other viable options other than burning.

Impact of stubble burning

Research paper on "Assessing People's Awareness of Environmental and Health Impacts of Straw Burning in Southeast Vietnam through Factor Analysis and Proposing Sustainable Solutions"

Table 1: Environmental impacts

Impact	Details
Air Pollution	Emission of CO_2, CH_4, NO_x, SO_x, VOCs, SOAs (Secondary Organic Aerosols)
Smog Formation	Caused by SOAs from VOCs; reduces air quality
Soil Degradation	Loss of nutrients (N, P, K, S), reduced fertility, and poor soil structure
Loss of Biodiversity	Kills beneficial insects and microorganisms
Ecological Imbalance	Disrupts local ecological balance in rice fields
Climate Change Contribution	Greenhouse gas emissions enhance global warming

Table 2: Chemical Pollutants Released

Pollutant	Source/Effect
PM10 and PM2.5	Fine particulate matter causing respiratory and cardiovascular health issues
Polycyclic Aromatic Hydrocarbons (PAHs)	Carcinogens like benzo[a]pyrene; persistent environmental toxins
Phosphine (PH_3)	Toxic gas harmful in enclosed/poorly ventilated areas
Volatile Organic Compounds (VOCs)	Contribute to formation of SOAs and smog

Table 3: Health impacts

Health Impact	Cause
Respiratory diseases	Inhalation of PM10, PM2.5, toxic gases
Cardiovascular diseases	Fine particulate matter entering the bloodstream
Cancer risk	Long-term exposure to PAHs (Polycyclic Aromatic Hydrocarbons) and carcinogenic smoke
Eye and skin irritation	Exposure to smoke, soot, and chemicals

Table 4: Agricultural impacts

Impact	Details
Loss of Soil Nutrients	Burning destroys organic matter and essential nutrients
Reduced Crop Productivity	Long-term damage to soil structure affects future yields
Wasted Resource Potential	Straw could be reused as animal feed, compost, biofuel, or for other uses

Table 5: Lost Opportunities (If Not Burned)

Alternative Use of Straw	Benefits
Compost/Fertilizer	Improves soil health and reduces need for chemical inputs
Animal Feed	Low-cost feed option for livestock
Mushroom Cultivation	Substrate for straw mushroom farming
Bioenergy (biogas, bioethanol)	Renewable energy, reduces emissions
Roofing/Packaging Material	Industrial raw material

Research paper "Adoption Pattern of Farm-Machinery based Solutions for In-situ Paddy Straw Management in Punjab"

Negative Impacts of Stubble Burning

1. Environmental Degradation

- **Air Pollution**

a) Burning ~23 million tonnes of paddy straw in Punjab, Haryana, and UP contributes to severe air pollution.
b) Air Quality Index (AQI) improved from 'poor' (201-300) to 'moderate' (101-200) as burning decreased from 2016 to 2022.

- **Greenhouse Gas Emissions**

Releases carbon dioxide, methane, and nitrous oxide, contributing to climate change.

- **Loss of Biodiversity**

Burning destroys beneficial soil microbes, insects, and fauna.

2. Soil Health Deterioration

- **Nutrient Loss**

a) 1 tonn of straw contains
b) 5.5 kg Nitrogen
c) 2.3 kg Phosphorus
d) 25 kg Potash
e) 1.2 kg Sulphur
f) 400 kg Organic Carbon
g) Burning causes a 50-70% loss of micronutrients, costing over ₹200 crores annually.
h) **Soil Organic Carbon:** Burning leads to depletion of organic carbon, reducing soil fertility and structure.

- **Decline in Soil Health**

a) Continuous burning reduces soil organic carbon and increases soil compaction.
b) It negatively impacts soil structure, porosity, and moisture retention.

- **Weed and Pest Resistance**

a) While some farmers burn residues to control weeds and pests, over time this leads to the emergence of resistant weed species, such as Phalaris minor.

Socio-economic impacts

- **Health Hazards**

a) Causes respiratory issues, eye irritation, and other health problems in rural and urban populations.
b) Especially harmful to children and elderly.

- **Resource Waste**

Burning wastes valuable biomass that could be used for mulching, bioenergy, fodder, or compost

- Pressure on Small Farmers

Limited time between harvesting and sowing prompts small/marginal farmers to burn due to lack of access to timely mechanized solutions.

As per research article "High PM2.5 Levels in Delhi-NCR Largely Independent of Punjab-Haryana Crop Fires an Analysis of Observations across a Network of 30 Sites"

a) Crop Residue Burning (CRB) is a major source of PM2.5 pollution in Delhi-NCR, particularly in late autumn.
b) The pollution spike correlates closely with the timing of paddy harvesting and widespread stubble burning in northwestern India.
c) Atmospheric and meteorological conditions (e.g. low wind, temperature inversion) in this period trap pollutants, worsening air quality.

Health Implications

- High PM2.5 exposure is associated with a surge in respiratory and cardiovascular ailments.
- Children, elderly, and vulnerable individuals suffer the most during peak burning periods.

Environmental Impact

a) Results in hazardous smog, reduced visibility, and public safety risks.
b) Triggers frequent health emergencies and policy responses in NCR (e.g. school shutdowns, construction bans).
c) The study underscores the urgent need for effective alternatives to stubble burning, such as in-situ residue management, stricter enforcement, and policy-level intervention.
d) Reducing CRB is critical to improving air quality and protecting public health in Delhi-NCR.

As per DAY-NRLM technical bulletin-6

- **Nutrient Loss**

Burning one tonne of straw leads to significant loss of essential nutrients—5.5 kg Nitrogen, 2.3 kg Phosphorus, 25 kg Potassium, 1.2 kg Sulphur, and organic carbon, directly affecting soil fertility.

- **Soil Health Damage**

High temperatures during burning kill beneficial microbes and degrade soil structure, leading to reduced nitrogen and carbon in the topsoil layer (0-15 cm), thereby hampering root growth and crop productivity.

- **Greenhouse Gas Emissions**

Stubble burning releases large quantities of CO_2, CH_4, CO, N_2O, and NOx, contributing significantly to climate change and air pollution.

- **Human Health Hazards**

Toxic gases from burning cause severe air pollution, triggering respiratory issues such as asthma, Chronic Obstructive Pulmonary Disorder (COPD), bronchitis, and even cancer. Vulnerable groups like children and the elderly are especially at risk.

Legal framework governing stubble burning

1. Statutory Prohibitions and Regulations

- Stubble burning is explicitly prohibited under the Air (Prevention and Control of Pollution) Act, 1981 and the Environment (Protection) Act, 1986. Violators face fines and possible imprisonment-Section 15 of the Environment (Protection) Act, 1986, prescribes penalties of up to five years in prison and fines up to ₹1 lakh for environmental harm caused by such activities.
- The National Green Tribunal (NGT) has banned stubble burning and imposes fines ranging from ₹2,500 to ₹30,000 depending on the scale of the offense.

As per new article "Stubble burning and rights to healthy environment"

- The Supreme Court of India has repeatedly intervened, directing state and central governments to enforce bans, provide reports, and consider the fundamental right to a healthy environment under Article 21 of the Constitution.
- The Court has also noted the gap between reported cases and actual penalties imposed, highlighting enforcement challenges.

State level actions

- Punjab and Haryana have introduced schemes to incentivize alternative residue management, such as direct cash transfers (e.g., ₹1,000 per acre in Haryana) and subsidized machinery like Happy Seeders.
- Despite these efforts, machinery availability and suitability remain inconsistent across regions.

Policy Initiatives and Economic Instruments

1. Financial Incentives and Subsidies

- Both central and state governments have rolled out subsidies for alternative residue management equipment and direct cash incentives to discourage burning.
- Financial incentives are often insufficient to offset the perceived cost and convenience advantages of burning, especially for small and marginal farmers.

2. Penalties and Enforcement
- Penalties for stubble burning have recently been doubled by the central government, with fines now reaching up to ₹30,000 under new Environment Protection Act rules.
- However, collection of fines and actual enforcement remain weak due to administrative and political reluctance, especially during periods of farmer unrest.

3. Monitoring and Technology
- The use of remote sensing and satellite monitoring has been adopted to detect and track incidents of stubble burning, aiding enforcement efforts.
- The Commission for Air Quality Management (CAQM) is tasked with coordination and monitoring, but its effectiveness has been questioned by the judiciary.

Recommendations from economic model
A Keynesian economic model suggests the following policy mix for effective mitigation:
- Increase penalties to make burning financially unattractive.
- Enhance subsidies and financial incentives for sustainable alternatives.
- Lower interest rates to facilitate investment in residue management technologies.
- Integrate environmental and health costs into fiscal policy to reflect the true social cost of burning.
- Promote trade policies that favor sustainable agricultural practices.

Alternative solutions
As per the research paper "The effects of agricultural machinery services and land fragmentation on farmers' straw returning behavior"

1. Straw Returning (Main Alternative Studied)
Involves crushing crop residues and incorporating them into the soil using tractors and tillage tools.
- **Benefits**

a) Enhances soil fertility.
b) Increases crop yield.
c) Improves soil carbon sequestration.
d) Reduces open-field pollution.

2. Use of Agricultural Machinery
- Self-owned or outsourced machinery for shredding and incorporating straw into the soil.
- Mechanization helps manage straw efficiently without burning.

3. Policy Interventions and Support
- Government subsidies for purchasing or renting agricultural machinery.
- Bans and regulations against open burning.
- Promotion of socialized services: Facilitating access to shared or village-level mechanization services.

4. Land Consolidation
Reducing land fragmentation to make machinery use more efficient, thus facilitating straw management without burning.

- **Implied or Related Alternatives (from referenced studies and context)**

a) Composting crop residues.
b) Biomass energy generation (e.g., using straw for electricity or biofuel).
c) Animal fodder (in suitable regions and seasons).
d) Mushroom cultivation substrates.

Research paper "Farmers' Perspective to Mitigate Crop Residue Burning in Haryana State of India"
1. Straw Returning to Soil
a) Incorporating the residue back into the soil using machines like rotavators, mulchers, and Happy Seeder.
b) Improves soil fertility and reduces pollution.

2. Biomass-Based Power Plants
a) Promoted by 94.44% of farmers in Haryana as per the second study.
b) Crop residues are used to generate electricity or heat, providing income and reducing burning.

3. Industrial Use of Straw
a) 96.66% of farmers suggested creating industrial demand (e.g., for cardboard, paper, biofuel, packaging, and brick kilns).
b) Encourages farmers to sell rather than burn residues.

4. Custom Hiring Centers (CHCs)
a) Access to machinery like Happy Seeder, Super Seeder, Baler, etc.
b) CHC services need improvement as 92% of farmers reported poor functioning.

5. Crop Diversification
a) Shifting from rice-wheat to alternative crops (e.g., pulses, oilseeds) that generate less residue.
b) 70.54% of farmers supported this, especially if supported with higher MSPs.

6. Community-Based Management
83.88% of farmers suggested community-level straw collection and management to reduce costs and improve efficiency.

7. Availability of Machinery at Panchayat Level
79.44% suggested making crop residue management machines available at village-level for collective use.

8. Low Horsepower-Driven Machinery
a) Many machines (like the Happy Seeder) need high-power tractors, which small farmers lack.
b) 11.36% suggested developing efficient, light machinery suitable for all farmers

9. Government Incentives
Subsidies based on farmers' financial condition for purchasing or renting machinery.
Suggested by 81.66% of farmers.

10. Awareness and Training
a) Conduct campaigns and training to promote sustainable residue management practices.
b) Address the gap in technical knowledge and extension contact.

Research paper "Farmers' Cognition of and Satisfaction with Policy Affect Willingness of Returning Straw to Field: Based on Evolutionary Game Perspective"

1. Straw Returning to the Field (Main Solution)

- Treated as the preferred, sustainable alternative to open burning.
- Benefits include

a) Soil enrichment (fertility, structure, disease resistance).
b) Environmental protection (less pollution).
c) Long-term agricultural productivity.

2. Policy-Based Incentives and Reforms

a) Cash and Comprehensive Subsidies
b) Cash alone is insufficient.
c) Comprehensive subsidies (cash + technical + machinery + service support) are more effective in changing farmer behaviour.
d) Technical Services & Machinery Subsidies
e) Offering machinery (e.g., for straw shredding and tilling) and training is crucial.
f) Reduces the economic and knowledge gap that leads to burning.

3. Enhance Farmer Cognition

Positive effects

Farmers believing that straw returning improves disease resistance and yield → more likely to adopt it.

Negative effects

a) Farmers associating straw returning with increased fertilization costs or no visible environmental improvement → less willing.
b) Improving education and awareness campaigns about actual benefits is key to behaviour change.

4. Strengthening Policy Satisfaction

Even when subsidies exist, if farmers are dissatisfied with policy clarity or delivery, they may still burn straw

Suggestions

a) Clearer policy communication.
b) Local (village-level) outreach via extension agents or cooperatives.
c) Trust-building through consistent, transparent subsidy delivery.

5. Local Governance and Demonstration

a) Engage village leaders, cooperatives, and model farmers to:
b) Demonstrate benefits of straw returning.
c) Help others navigate services and subsidies.

Success story of farmers

Case study "Gurpreet Singh Kuthala-A Successful Farmer Who Adopted a Stubble Burning Alternative"

- Gurpreet, educated up to Class XII and managing 40 acres (10 owned, 30 leased), took advantage of government subsidies to purchase ex-situ crop residue management machines-specifically, a Straw Rake and a Baler. These machines allowed him to efficiently collect, bale, and transport paddy straw, transforming it from a liability into a valuable commodity.

Business model and achievements

- **Contract with Biofuel Companies:** Gurpreet signed a contract with the Sangrur RNG Bio Gas Plant to supply 12,000 quintals of paddy straw bales, earning around ₹16 lakh in a single season.
- **Expansion:** Gurpreet partnered with a friend to invest in more machines, aiming to supply 18,000 quintals of paddy straw for over 1 crore revenue .
- **Profitability:** After deducting expenses, Gurpreet reported a net profit of ₹7-8 lakh in a season, with plans to further increase his profits by storing bales to sell during periods of higher demand.
- **Community Impact:** By collecting stubble from his own and neighbouring villages, Gurpreet prevented crop residue burning on over 600 acres last year, with plans to expand this to 2,000 acres.

Environmental and Social Impact

- **Reduction in Stubble Burning:** Gurpreet's initiative contributed to a significant reduction in stubble burning incidents in Malerkotla, with many local panchayats passing resolutions against the practice.
- **Inspiration for Others:** His success has inspired other farmers to view stubble as a source of income rather than waste, encouraging wider adoption of sustainable practices.
- **Recognition:** The Punjab Agriculture and Farmers Welfare Minister commended Gurpreet for his dedication to environmental conservation and for supporting government efforts to combat crop residue burning.

Key takeaways

- **Innovation and Support:** Access to government-subsidized machinery was crucial for Gurpreet's transition to sustainable stubble management.
- **Economic Viability:** Selling paddy straw as an industrial input can generate substantial income, making the alternative both environmentally and financially attractive.
- **Scalability:** Gurpreet's model demonstrates the potential for scaling up such initiatives across Punjab, benefiting both farmers and the environment.

2. Success story: Virender Yadav- Transforming stubble management in Haryana

Background and motivation

- Virender Yadav, a 32-year-old farmer from Farsh Majra village near Kaithal, Haryana, returned to India from Australia in 2015. Upon his return, he was alarmed by the severe air pollution caused by the widespread practice of stubble burning, which not only affected the environment but also led to health issues for his family, including his mother, wife, and daughters

Innovative approach to stubble management

- Recognizing that simply avoiding stubble burning on his own four-acre farm would not be enough, Virender sought a scalable solution. In late 2018, he approached the agriculture department and learned about stubble management equipment available with government subsidies. He invested in saw balers-machines that collect stubble and compress it into bales

Turning Waste into Wealth

- Instead of burning the stubble, Virender began selling the compressed bales to local paper mills and agro-industries. In 2019, he expanded his efforts by forming a network with farmers from eight neighbouring villages. Together, they collected and sold tens of thousands of quintals of stubble, covering 5,500 acres of land. The stubble was sold at around Rs 135 per quintal.

Economic and Environmental Impact

- In just two years, Virender sold stubble worth over Rs 2.5 crore, earning a profit of approximately Rs 45-50 lakh after expenses.
- His initiative eliminated stubble burning in his village and surrounding areas, significantly reducing air pollution and improving public health.
- The project benefitted around 200 farmers, who also earned additional income by selling their stubble instead of burning it.

Recognition and role model status

Virender's success was recognized at the national level, with Prime Minister Narendra Modi mentioning his achievements in the 'Mann Ki Baat' radio program. The agriculture department also highlighted his work as a model for other farmers. Virender is now invited to speak at government outreach programs to motivate others to adopt sustainable stubble management practices.

Recent Policy Initiatives and Roadmap

- In 2024, the Government of India updated its Crop Residue Management (CRM) guidelines to address previous inefficiencies, focusing on improving farmer access to CRM solutions, ensuring efficient use of machinery, and enhancing the profitability of biomass aggregators. These guidelines aim to increase the adoption of crop residue management and reduce farm fires, especially in Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, and Delhi.
- The Commission for Air Quality Management (CAQM) has introduced a 19-point plan that includes mapping each farm with a proposed stubble management mode, promoting both in-situ (on-field) and ex-situ (off-field) solutions, and strengthening monitoring and enforcement through dedicated task forces and nodal officers.
- The Supreme Court has mandated the formation of state-level committees led by Chief Secretaries to monitor implementation, with monthly progress reports to the CAQM starting June 2025.
- Real-time online platforms for tracking residue generation and utilization, as well as pilot industrial projects using paddy straw, are part of the roadmap.

Technological and Market-Based Approaches

- In-situ solutions (like mulching and decomposers) have been promoted through subsidies and machinery banks, but ex-situ solutions are also necessary for surplus straw.
- Ex-situ strategies include baling, biomass co-firing in thermal power plants (with a government mandate for at least 5% pellet use), compressed biogas (CBG) plants, and industrial uses such as packaging or brick kilns.
- The government has launched the SAMARTH mission to promote biomass co-firing in coal-based power plants.

Conclusion

A sustainable resolution requires a multi-pronged approach: promoting crop diversification away from high-residue crops, ensuring fair pricing and market access for alternative crops and stubble-based products, strengthening support for sustainable residue management technologies, and addressing the underlying policy and market failures that lock farmers into unsustainable cycles. Only with coordinated policy reforms, robust enforcement, and genuine economic incentives for farmers can India effectively tackle the stubble burning crisis and its environmental fallout.

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