www.strijournal.wordpress.com

SCIENCETECH REPORTS INTERNATIONAL
Volume 1 Issue 1, 2025

SHORT COMMUNICATION OPEN ACCESS

Crop Residue Management Initiatives: A Comprehensive Analysis of Government of India and Punjab's Strategies

Gurbir Singh*
Department of Agriculture, Khalsa College Amritsar, Punjab, India - 143001
*Correspondence for materials should be addressed to GS (email: gurbirrattan@khalsacollege.edu.in)

Received
2025/04/07
Accepted
2025/06/03
Published
2025/06/05

Abstract
Crop residue burning (CRB) in India poses a severe environmental and public health challenge, particularly in the agricultural heartlands of Punjab, Haryana, Uttar Pradesh, and the National Capital Territory (NCT) of Delhi. Driven primarily by the narrow window between successive crop cycles, this practice leads to significant air pollution, soil degradation, and economic losses. In response, both the Government of India (GoI) and the Government of Punjab have implemented a multifaceted array of initiatives, evolving from general farm mechanization support to highly specialized crop residue management (CRM) schemes.

Keywords: Crop residue; Management; Analysis; Initiatives; Punjab; Environment; Health

Introduction

The GoI's approach, spearheaded by the dedicated Central Sector Scheme on Crop Residue Management (CRM), has seen substantial financial commitments and continuous policy refinement. The 2024 CRM Operational Guidelines mark a pivotal shift, introducing critical reforms such as subsidizing high-horsepower tractors for Custom Hiring Centres (CHCs), empowering biomass aggregators with greater independence, and implementing a credit-linked capital subsidy mechanism to enhance accountability. These changes aim to address historical inefficiencies and accelerate the adoption of both in-situ (on-field incorporation) and ex-situ (off-field utilization) residue management practices. Punjab, as a focal state, has demonstrated significant state-level ownership through its own ambitious action plans, including a ₹ 500 crore initiative for FY 2025-26. The state has actively promoted a diverse range of CRM machinery, supported bio-decomposer technologies, and increased ex-situ utilization targets. Concurrently, stringent enforcement measures, including hiked environmental compensation rates and police action, have been put in place to deter burning. These concerted efforts have yielded tangible results, with Punjab reporting a notable 70 % reduction in farm fire incidents in 2024 compared to the previous year.

Despite this progress, significant challenges persist. Behavioural resistance, rooted in farmer misconceptions and the economic realities of a tight sowing window, continues to drive partial or complete burning. Issues such as the underutilization of certain CRM machines, dissatisfaction with ex-situ payment models, and limitations of digital platforms like the i-Khet app underscore the need for more farmer-centric and market-driven solutions. Furthermore, the absence of a structured end-of-life management plan for agricultural machinery poses a growing concern.

Moving forward, the effectiveness of CRM initiatives hinges on a holistic strategy that combines robust financial support and technological dissemination with targeted outreach, market development for biomass, and adaptive policy frameworks. Addressing the socio-economic realities of farmers, ensuring the optimal utilization of subsidized machinery, and fostering a sustainable biomass value chain will be crucial for achieving a permanent cessation of crop residue burning and securing long-term environmental and agricultural benefits.

Crop residue burning (CRB) is a pervasive agricultural practice in India, primarily employed by farmers to swiftly clear fields following harvest, particularly paddy, in preparation for the subsequent crop, such as wheat. This practice is often necessitated by a very short window—sometimes as little as 15 to 20 days—available for sowing the next crop, making rapid field clearance a logistical imperative for farmers. While offering immediate convenience, CRB inflicts profound and widespread damage across environmental, public health, and agricultural domains.

The act of burning one tonne of paddy straw releases a significant cocktail of pollutants into the atmosphere. This includes approximately 3 kg of particulate matter (PM), 60 kg of carbon monoxide (CO), 1460 kg of carbon dioxide (CO_2), 199 kg of ash, and 2 kg of Sulphur dioxide (SO_2). On a national scale, India's crop residue burning is estimated to generate around 150 million tonnes of CO_2, over 9 million tonnes of CO, and a quarter-million tonnes of SO_2 annually. It is further estimated that approximately 92 million tonnes of crop waste are burned across India each year. These emissions contribute substantially to severe air pollution, which in turn exacerbates respiratory ailments, aggravates eye and skin conditions, and can worsen chronic heart and lung diseases among the populace. A striking illustration of this impact is the observation that the PM emitted from crop residue burning in Delhi is reported to be 17 times higher than that from all other pollution sources combined. Beyond atmospheric contamination, Crop Residue Burning inflicts considerable harm on soil health and fertility. The burning process leads to a substantial loss of vital nutrients; one tonne of paddy straw, for instance, contains approximately 5.5 kg of nitrogen (N), 2.3 kg of phosphorus (P_2O_5), 25 kg of potassium (K_2O), 1.2 kg of Sulphur (S), and 50-70 % of the micro-nutrients absorbed by rice, along with 400 kg of carbon, all of which are lost to the atmosphere. This destructive practice also adversely alters critical soil properties, including temperature, pH levels, moisture content, available phosphorus, and overall soil organic matter. Despite the clear detrimental effects and its classification as a crime under Section 188 of the Indian Penal Code (IPC) and the Air and Pollution Control Act (APCA) of 1981, consistent enforcement and implementation of these legal provisions have been observed to be lacking across the country.

The fundamental conflict between the short-term logistical needs of individual farmers and the long-term environmental and societal costs of stubble burning is a critical aspect of this challenge. Farmers, operating within a tight agricultural calendar, perceive burning as the most expedient and economical method to prepare their fields for the subsequent crop. This individual economic rationality, however, directly contributes to widespread environmental degradation and public health crises. A purely punitive approach, without adequately addressing the underlying farmer compulsion and providing viable, accessible, and economically feasible alternatives, is therefore unlikely to achieve sustainable behavioural change. The cumulative and transboundary nature of the pollution burden further complicates the issue. The detailed per-tonne emissions and aggregate national figures highlight that the problem extends far beyond the individual farm. The significant contribution of agricultural burning in northwest India to the overall national emissions of organic and elemental carbon, coupled with its disproportionate impact on Delhi's air quality, demonstrates that localized burning creates a shared atmospheric burden that transcends state boundaries. This interconnectedness underscores the necessity for coordinated national responses and justifies central government intervention, as the environmental consequences are not confined to the point of origin but affect broader regions, particularly the densely populated National Capital Region (NCR).

The states of Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, and the National Capital Territory (NCT) of Delhi are the primary geographical focus of the Union government's Crop Residue Management Operational Guidelines, reflecting their significant contribution to the stubble burning phenomenon. Among these, Punjab, a leading agricultural state, stands out as a major contributor to the issue, largely due to its prevalent paddy-wheat cropping cycle. The state recorded over 35,000 Kharif farm fires in 2022 alone. Recognizing the scale of the problem, Punjab has set an ambitious target to manage 100 % of its estimated 20 million metric tonnes of paddy residue in 2024. While the overall estimated paddy straw generation is projected to slightly decrease from 19.52 million tonnes in 2024 to 19.32 million tonnes in 2025, the challenge of comprehensive management remains substantial. Recent reports indicate significant progress in reducing farm fires in Punjab, with incidents decreasing by 70 % from 36,663 in 2023 to 10,909 in 2024.

Despite these overall reductions, certain districts continue to be persistent hotspots for stubble burning. Sangrur, for instance, consistently reports the highest number of cases, with 5,613 incidents in 2023 and 1,725 in 2024. This highlights that even with broad progress, specific regions

or farmer demographics may face unique challenges or exhibit greater resistance, necessitating more granular and targeted interventions. The severity and persistent nature of the issue have drawn judicial scrutiny, with the Supreme Court admonishing Punjab and Haryana in October 2024 for their handling of farm fires and urging more stringent action.

The "short window" for Rabi crop wheat sowing after paddy harvest is a primary driver of the burning practice. Farmers face immense pressure to clear their fields quickly within this critical 15 to 20-day period. This logistical constraint, coupled with the limited availability of appropriate machinery during this peak demand period, explains why farmers often resort to burning despite the associated penalties. Policies must therefore prioritize solutions that are either time-efficient and readily available within this narrow window or strategies that extend this window, such as promoting short-duration paddy varieties.

The persistence of "hotspots" like Sangrur, even amidst an overall decline in farm fires, suggests that a uniform, blanket policy approach may not be sufficient. These areas likely harbour specific socio-economic conditions, farmer demographics, or infrastructural gaps that require tailored strategies. Understanding the unique challenges faced by farmers in these persistent burning zones, potentially through detailed socio-economic profiling, is crucial for designing effective, localized interventions that can address the root causes of continued burning in these areas.

Table 1. Key Provisions of Government of India's CRM Operational Guidelines (Pre-2024 vs. 2024)

Area of Intervention	Pre-2024 Guidelines	2024 Guidelines
Subsidizing Tractors for CHCs	No specific subsidy for tractors for CHCs.	Introduced 80% subsidy on tractors (60 HP and above), allowing one subsidized tractor per CHC.
Empowering Biomass Aggregators	Aggregators established business through agreements with industries (Industry: 25%, Govt: 65%, Aggregator: 10%).	New option: Government contributes 65%, Aggregators contribute 35% of the cost, fostering greater independence from industries.
Financial Assistance Mechanism	Direct Benefit Transfers (DBT) to beneficiaries.	Replaced by a credit-linked capital subsidy mechanism, with subsidy paid directly to financial institutions after verification.

Punjab has demonstrated a robust commitment to addressing crop residue burning, setting an ambitious target to manage the entirety of its paddy residue in 2024, estimated at approximately 20 million metric tonnes. This proactive stance is underscored by the formulation of a comprehensive action plan valued at ₹ 500 crore for the fiscal year 2025-26. This substantial state-level investment is specifically earmarked for providing farmers with the latest CRM machinery at subsidized prices and for implementing effective strategies for paddy straw management. The plan operates within the framework of the centrally-sponsored CRM Scheme, adhering to a funding pattern where the Central government contributes 60 % and the state government contributes 40 %. This significant state investment indicates a strong sense of ownership and urgency in tackling the stubble burning crisis, likely driven by the direct and severe impacts on its own population and the broader National Capital Region. It also suggests a recognition that central funds alone may not be sufficient, and additional, dedicated state resources are crucial for addressing the problem's scale and local context.

In-situ crop residue management involves retaining, incorporating, or mulching crop residues directly within the field. This method, often aided by microbial consortia, facilitates the decomposition of residues, thereby helping to retain essential nutrients in the soil and preventing burning. Punjab has been at the forefront of promoting such practices through the consistent introduction of new CRM machines under its subsidy scheme. This includes Super Seeders (introduced in 2020), Smart Seeders (2022), and Surface Seeders (2023). Furthermore, the Punjab Agricultural University (PAU) initiated field trials for a new machine, the Mittal Seeder, in late 2024, aiming to identify a cost-effective solution for residue management. This continuous technological innovation and diversification of in-situ solutions reflect a commitment to providing farmers with a range of options to suit their specific needs and farm conditions. To encourage adoption, subsidies are provided at a rate of 50 % for individual farmers and a higher 80 % for farmer groups, cooperative societies, and gram panchayats for the purchase of a wide array of CRM machines. These machines include, but are not limited to, Super Straw Management Systems (SMS), Happy Seeders, Super Seeders, Smart Seeders, Zero Till Drills, Mulchers, Paddy Straw Choppers, Hydraulic

Reversible Mould Board Ploughs, Balers, and Rakes. In the previous season, the state distributed 17,600 subsidized CRM machines. Cumulatively, under the centrally-sponsored CRM scheme, 1,48,451 subsidized CRM equipment units have been provided to farmers and Custom Hiring Centres (CHCs) in Punjab up to 2024-25. For the 2025-26 fiscal year, the plan includes providing an additional 4,367 subsidized equipment units to farmers and 1,500 to CHCs.

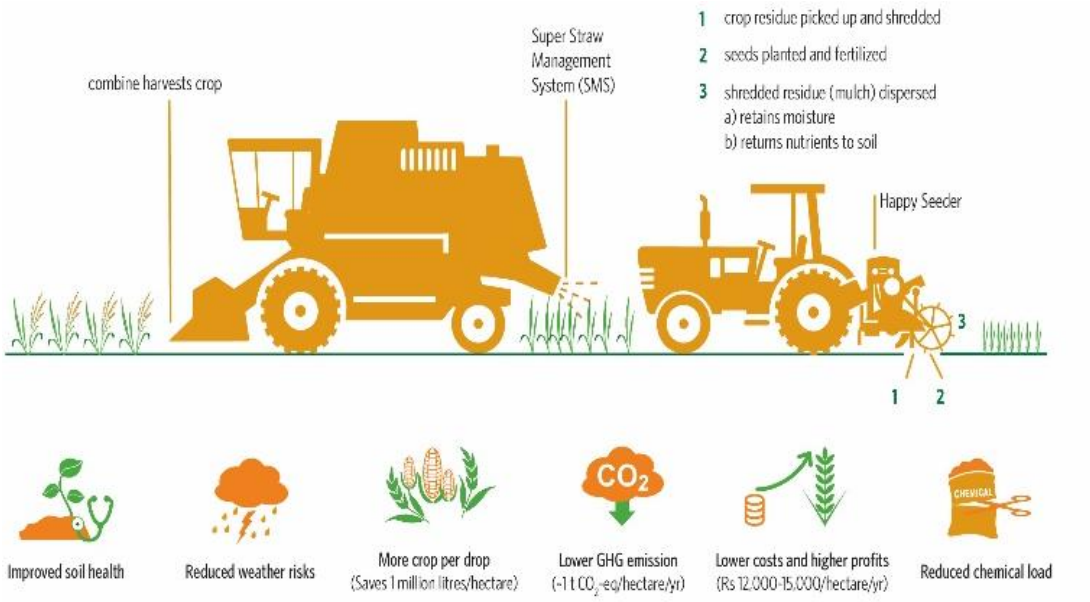

Figure 1. Happy seeder and its benefits (Source: The Nature Conservancy, 2025)

Beyond mechanical solutions, Punjab has also promoted the use of Pusa Decomposer, a microbial consortium developed by the Indian Council of Agricultural Research (ICAR), which has proven effective for rapid in-situ decomposition of paddy straw. In 2021, this bio-decomposer was utilized across approximately 5.7 lakh hectares in Punjab, Haryana, Uttar Pradesh, and NCT of Delhi, managing about 3.5 million tonnes of straw, with satellite monitoring indicating that 92 % of the sprayed plots were managed through decomposition. To further promote this technology, the CRM Scheme's Operational Guidelines were revised in August 2022 to include provisions for large-scale demonstrations of bio-decomposers on farmers' fields. Punjab's 2025-26 action plan incorporates the use of bio-decomposers on 2.5 lakh acres. However, a pilot project in 2022 on 5,000 acres faced limited acceptance from farmers, who were often in a rush to clear their fields for the next crop.

Ex-situ management of crop residue involves baling and transporting the straw away from the fields for various off-farm uses, such as the creation of biofuels and briquettes for power generation. Punjab is actively working to significantly increase its ex-situ utilization efforts, with a targeted rise from an estimated 5.96 million tonnes in 2024 to 7.06 million tonnes in 2025. This expansion is driven by increased consumption across various industrial sectors, including industrial boilers (targeting nearly 35 lakh tonnes in 2025), compressed bio-gas plants, bio-ethanol plants, thermal power plants, and brick kilns.

This approach aims to expand the economic value chain for crop residue, transforming a waste product into a valuable resource and thereby creating a market-driven incentive for its removal from fields. In parallel with ex-situ management, the Punjab government is also making concerted efforts to diversify the area under paddy cultivation towards other crops. This strategy is intended to reduce the overall volume of paddy straw generated, thereby lessening the burden of residue management. As part of this diversification, the state plan supports providing financial assistance of ` 1,500 per acre for direct seeding of rice (DSR), with a target of 5 lakh acres under this scheme. This promotes more sustainable agricultural practices that inherently reduce stubble generation.

A project named PRANA started in June 2022 – Promoting Regenerative And No-burn Agriculture (PRANA) is a four-year project focused in the state of Punjab in Northwest India that aims to deliver the following outcomes:

Eliminating burning of one million hectares of cropland

Getting at least 250,000 farmers to adopt a no-burn cropping system
Preventing at least six million tonnes of CO_2 emission from entering the atmosphere
Saving 500 billion litres of water from enhanced soil health and agronomy
Piloting financial instruments that incentivize farmers to adopt no-burn practices

Conclusions and Recommendations

The collective efforts by the Government of India and the Government of Punjab in crop residue management represent a significant and evolving policy response to a critical environmental and agricultural challenge. The transition from general farm mechanization to dedicated CRM schemes, coupled with substantial financial commitments, underscores a growing recognition of the problem's urgency. The 2024 CRM Operational Guidelines signify a crucial adaptive shift, directly addressing previous inefficiencies by subsidizing tractors for CHCs, empowering biomass aggregators, and implementing a credit-linked subsidy mechanism to enhance accountability. These policy refinements, alongside Punjab's ambitious state-specific action plans and stringent enforcement measures, have yielded tangible results, notably a 70 % reduction in farm fire incidents in Punjab in 2024. However, despite this progress, the persistence of stubble burning points to deeply rooted behavioural, economic, and systemic challenges. The "short window" for sowing, farmer misconceptions about CRM technologies, market failures in ex-situ residue utilization, and gaps in machinery lifecycle management continue to impede comprehensive adoption. The observed underutilization of certain machines, the limited reach of digital platforms like i-Khet, and the continued cultivation of high-residue paddy varieties further complicate the issue. By integrating these strategies, the Government of India and Punjab can build upon their existing progress, fostering a sustainable agricultural ecosystem that eliminates crop residue burning while ensuring farmer livelihoods and environmental health.

References

Crop Residue Management – Operational Guidelines (2025) Government of India Ministry of Agriculture & Farmers Welfare, Department of Agriculture & Farmers Welfare Available at: https://farmech.dac.gov.in/Content/New_Folder/Revised_CRM_Guidelines_2025.pdf (accessed 6 July 2025).

Punjab reports 70 per cent reduction in stubble burning (2025) Highlights Ex-Situ management efforts, Available at: https://www.newindianexpress.com/nation/2024/Nov/29/punjab-reports-70-per-cent-reduction-in-stubble-burning-highlights-ex-situ-management-efforts (accessed 6 July 2025).

The Nature Conservancy (2025) Promoting Regenerative and No-burn Agriculture (PRANA) to Tackle Climate Change in Northwest India Available at: https://www.nature.org/en-us/about-us/where-we-work/india/our-priorities/prana/ (accessed 6 July 2025).

Author Contributions

GS conceived the concept, wrote and approved the manuscript.

Acknowledgements
Not applicable.

Funding
Not applicable.

Availability of data and materials
Not applicable.

Competing interest
The author declares no competing interests.

Ethics approval
Not applicable.

Citation: Singh G (2025) Crop Residue Management Initiatives: A Comprehensive Analysis of Government of India and Punjab's Strategies. ScienceTech Reports International 1(1): 9-14.