
FROM STUBBLE TO SUSTAINABILITY: REFORMING CROP RESIDUE WASTE MANAGEMENT IN NORTH INDIA

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ABSTRACT

In the winter months of October to December, a recurring environmental and public health crisis is being witnessed in North India since last few years. The issue largely involves in-situ burning of the residue of paddy crop which contributes significantly to soil degradation, greenhouse gas emissions, air pollution which in turn adversely affects millions of people across the Indo-Gangetic Plains and the National Capital Region of Delhi. Crop residue burning, commonly referred to as stubble burning is the practice of burning the crop residue or stubble i.e. the waste left in the fields after harvesting paddy crop. The prime reasons for burning the crop residue by farmers involves economic constraints, minimal support from government, mechanized harvesting and the small interval between paddy harvesting and sowing of wheat.

This paper adopts an interdisciplinary approach to examine the 3Cs: Causes, Consequences and Challenges associated with crop residue burning. Analysis of constitutional and statutory framework governing environmental laws is done as well as role of key institutions like National Green Tribunal and the Commission for Air Quality Management in addressing the issue. A critical evaluation is conducted of the existing policies and initiatives like Crop Residue Management Schemes in Punjab and Haryana, Custom Hiring Centers and emerging technologies such as the Happy Seeder and Pusa Bio-Decomposer.

Best practices around the world are analyzed so that they may be adapted to the Indian context. It is argued that sustainable agriculture requires a shift from a penalty-based model towards an integrated framework which combines legal regulations, economic incentives, carbon-market development, technological innovation and farmer-centric governance. The paper concludes by recommending a timeline for reducing the stubble-burning incidents and transforming crop residue waste into an asset for the farmers.

Keywords: Stubble Burning, Air Pollution, Crop Residue Management, Delhi-NCR Smog, Climate-resilient Agriculture, Polluter Pays Principle, Biomass Utilisation, Transboundary Pollution, Inter-state Environmental Liability, Environmental Justice.

1. INTRODUCTION: THE RECURRING ISSUE OF CROP RESIDUE BURNING

Stubble burning or crop residue burning involves the burning of leftover crop residue by the farmers on the field itself, following the harvest of paddy. It is seen as a cheap and quick method of clearing the field for the next crop i.e. sowing of wheat. It has emerged as one of the most pressing environmental challenges faced in North India especially Delhi-NCR (National Capital Region) and the states of Punjab, Haryana and some parts of Uttar Pradesh. The immediate consequences witnessed are heavy smoke from burning which leads to air pollution, poor visibility, difficulty in breathing and soil degradation.

Over large parts of North India, a dense layer of smog is experienced because of burning the residue of crop. The resulting emissions of particulate matter (PM_{2.5} and PM₁₀), greenhouse gases and toxic pollutants create severe smog episodes, impair visibility and pose substantial health risks to millions of residents¹. What was once seen as a seasonal agricultural practice has evolved into a recurring environmental crisis over the last few years particularly after the enactment of Punjab Preservation of Subsoil Water Act, 2009 which fixed a date for sowing paddy in order to conserve groundwater and put a check on its over-utilization. What was meant to be a solution to the problem of groundwater depletion has in turn led to an increase in air pollution, thereby creating another problem.

1.1 The Green Revolution's Legacy and Issue of Stubble Burning

Green Revolution was introduced in North India considering the availability of fertile land and availability of canals. High-yield varieties of rice and wheat, heavy machines for harvesting, sowing etc. combined with intensive cropping patterns and use of fertilisers and pesticides led to increase in agricultural yield and also, crop residue. Punjab government in the year 2009 enacted the Punjab Preservation of Subsoil Water Act which reduced the interval between paddy harvesting and wheat sowing, leaving farmers with limited time to manage crop residue through alternative means.

The burning of crop residue elicits significant legal and constitutional inquiries regarding environmental protection and public interest. In response to the severity of this issue, a number

¹ Saifuddin M, Hussain T, Sidharth S and Manasa K, 'Stubble Burning in Northern India: Factors, Technological Solutions and Management Strategies—A Comprehensive Review' (2025) *Bhartiya Krishi Anusandhan Patrika* 3 <https://doi.org/10.18805/bkap837>, accessed 16 November, 2025.

of institutions have introduced regulatory measures and monitoring mechanisms in order to reduce crop residue burning, including the National Green Tribunal, State and Central Pollution Control Boards. Additionally, the Commission for Air Quality Management has implemented policy aimed at reducing crop residue burning². The persistence of the practice highlights the limitations of enforcement-focused approaches, which do not take into account the underlying economic and social constraints encountered by farmers³.

1.2 The Urgency for Sustainable Reform

In this context, this study takes an interdisciplinary legal-policy approach to examine the issue of crop residue burning in North India. This paper examines the impact of stubble burning on environment, economy and public health; evaluates the legal and institutional framework; identify implementation gaps and proposes sustainable reforms that reconcile environmental protection with agricultural realities. The study aims to integrate legal analysis with agricultural, economic and governance considerations to assist in the creation of a more efficient and sustainable crop residue management framework.

2. DIMENSIONS OF CROP RESIDUE BURNING IN NORTH INDIA

2.1 Evolution of the Problem of Stubble Burning

The Green Revolution of the 1960s and 70s transformed Indian agriculture, with Northern states becoming the wheat and rice basket of India. Enhanced agricultural productivity and national food security were achieved through the introduction of high-yielding wheat and rice varieties, as well as extensive irrigation infrastructure, chemical fertilizers and mechanized farming practices.

Even though machines reduced labour usage and improved efficiency and agricultural productivity, another issue cropped up - significant amount of crop residue left behind in the field after harvesting. In earlier times, agricultural residue was frequently utilized as a source of energy, raw materials or animal feed for household purposes. The accumulation of paddy

² Jain N, Bhatia A and Pathak H, 'Emission of Air Pollutants from Crop Residue Burning in India' (2014) 14 *Aerosol and Air Quality Research* 422, 3 <https://doi.org/10.4209/aaqr.2013.01.0031> accessed 16 November, 2025.

³ V. Venkatramanan, S Shah, AK Rai and R Prasad, 'Nexus between Crop Residue Burning, Bioeconomy and Sustainable Development Goals over North-Western India' (2021) 8 *Frontiers in Energy Research*, 4 <https://doi.org/10.3389/fenrg.2020.614212>, accessed 16 November, 2025.

straw became significant after harvest season due to changes in agricultural practices and traditional uses. The problem was exacerbated by the increasing dominance of the rice-wheat cropping cycle and nature of rice straw which had no potential uses. The short duration of preparation for the next crop, around two to three weeks, is limited due to paddy harvesting that occurs just before wheat sowing. Therefore, the quickest and most cost-effective way to clear crop residue from the field was through burning. Over a period of time, what initially appeared to be a localized agricultural practice evolved into a recurring environmental crisis.

2.2 From Seasonal Practice to Prolonged Environmental Crisis

Environmental damage caused by stubble burning has risen in recent years, with longer and more severe consequences. Burning incidents are also continuing to occur due the spread of paddy cultivation, increasing mechanisation and other factors such as climatic variation and growing residue volumes. During winter months, the smoke produced by burning activities often merges with adverse meteorological conditions, such as low wind speeds and temperature inversions. Therefore, pollutants are trapped near the surface, resulting in persistent levels of pollution leading to smog conditions throughout Punjab and Haryana as well as Delhi-NCR. It goes beyond agricultural management and has become a matter of environmental governance, public health protection and regional sustainability that requires judicial intervention.

2.3 Environmental and Public Health Dimensions

The combustion of crop residue results in the harmful emissions in the air, which is characterized by high levels of particulate matter (PM_{2.5} and PM₁₀), carbon monoxide, methane oxides and other harmful pollutants⁴. Severe air quality, reduced visibility and higher greenhouse gas concentrations are a consequence of crop residue burning. This practice affects soil quality by killing beneficial microorganisms, decreasing organic carbon content and disrupting nutrient cycles that are crucial for long-term agricultural productivity⁵.

The impact on public health is equally significant. Exposure to polluted air has been linked to various health issues, including respiratory illnesses, cardiovascular diseases, asthma, chronic

⁴ Jain N, Bhatia A and Pathak H, 'Emission of Air Pollutants from Crop Residue Burning in India' (2014) 14 *Aerosol and Air Quality Research* 422, 4 <https://doi.org/10.4209/aaqr.2013.01.0031> accessed 16 November, 2025.

⁵ A Kumar, KK Kushwaha, S Singh, YS Shivay, MC Meena and L Nain, 'Effect of paddy straw burning on soil microbial dynamics in sandy loam soil of Indo-Gangetic plains' (2019) 16 *Environmental Technology & Innovation* 100469, 5 <https://doi.org/10.1016/j.eti.2019.100469>, accessed 17 November, 2025.

obstructive pulmonary disorders and other health complications. During periods of high pollution, the risks become more significant for vulnerable groups such as children, elderly individuals and those with pre-existing medical conditions.

2.4 Economic and Social Dimensions

Agricultural choices are heavily influenced by economic realities. For many farmers, burning is the most practical option due to high costs of residue management machinery, labour shortages limited access to alternative technologies and uncertainty regarding economic returns⁶. National-level agencies' figures indicate significant GDP losses due to crop burning⁷.

Also, the ecological and healthcare implications of burning crops result in significant financial consequences for society. The impact of increased healthcare expenses⁸, reduced labour productivity, transportation disruptions and environmental degradation extends beyond farming communities⁹. Consequently, the burning of crop residue is a complex socio-economic issue that necessitates coordinated legal, institutional and policy responses¹⁰.

The labour-intensive and costly process of manual residue removal has prompted farmers to move towards mechanized agriculture. However, there are certain machineries that are required for sustainable residue management, i.e. Happy Seeder, demands high-horsepower tractors that are too expensive and cannot be afforded by many small and marginal farmers¹¹. Although Government provides subsidies but the operating costs such as fuel for machines and their

⁶ Behuria P, 'The trouble with stubble: The politics of cleaning India's air' (*Global Development Institute Blog*, 26 October 2017) <https://blog.gdi.manchester.ac.uk/trouble-stubble-politics-cleaning-indias-air/> accessed 22 November, 2025.

⁷ 'Air pollution from stubble burning costing India USD 30bn annually: Study' *The Economic Times* (New Delhi, 4 March 2019) <https://economictimes.indiatimes.com/news/economy/finance/air-pollution-from-stubble-burning-costing-india-usd-30bn-annually-study/articleshow/68251097.cms> accessed 22 November, 2025.

⁸ Sharma RK and Mishra A, 'Stubble burning in regions of Northern India: Causes, solutions & business opportunities' (2021) 9 *Journal of Pure and Applied Biosciences* 151, <https://semanticscholar.org/fff5/5b102397a146d1069dc7bbf421cfc420dd6b.pdf>, accessed 19 November, 2025.

⁹ International Food Policy Research Institute, 'Air pollution from India's stubble burning leads to USD 35 billion economic losses, poses significant health risk' (*Environmental News Network*, 4 March 2019) <https://southasia.ifpri.info/2019/03/04/new-study-air-pollution-from-indias-stubble-burning-leads-to-usd-35-billion-economic-losses-poses-significant-health-risk/> accessed 19 November, 2025.

¹⁰ International Food Policy Research Institute, 'Air pollution from India's stubble burning leads to USD 35 billion economic losses, poses significant health risk' (*Environmental News Network*, 4 March 2019) <https://southasia.ifpri.info/2019/03/04/new-study-air-pollution-from-indias-stubble-burning-leads-to-usd-35-billion-economic-losses-poses-significant-health-risk/> accessed 19 November, 2025.

¹¹ Khan S, 'Stubble burning in India: Causes, consequences and solutions' (*Observer Research Foundation – Expert Speak (Young Voices)*, 9 January 2025) <https://www.orfonline.org/expert-speak/stubble-burning-in-india-causes-consequences-and-solutions> accessed 21 November, 2025.

maintenance remain a deterrent factor.

If farmers opt for hiring equipment through Custom Hiring Centres, the rental charges and long waiting periods especially during peak season force the farmers to burn the stubble so that they do not miss the window of sowing wheat. For many farmers, the immediate savings from burning outweigh the long-term benefits of adopting new technologies. Therefore, if we need to opt alternatives to burning, such alternatives must not only be economical but also reliable and available as and when required.

2.5 Awareness Gaps and Access Barriers to Alternatives

The farmers are aware of the harmful side effects to both health and environment, but awareness alone cannot lead to behavioural changes. They even lack knowledge regarding handling of technology that is mainly required for sustainable residue management. In many regions there is insufficiency of infrastructure for ex-situ use that would help in bailing units or biomass processing plants that ultimately creates a hurdle in creating a stable market for collected straw¹².

Awareness campaigns also play a major role when it comes to overlooking social norms, financial realities and the practical concerns that help in guiding everyday decisions related to farms. There is a sort of disconnection between the long-term environmental benefits and their immediate financial needs¹³. To overcome this loophole, there must be options available which are accessible, affordable and compatible with the farmers undergoing existing practices.

These challenges indicate that institutional effectiveness depends not merely on the existence of regulatory bodies but also on their ability to coordinate actions, share information and align environmental objectives with agricultural realities. Consequently, an assessment of existing policies and management initiatives becomes necessary to evaluate whether current interventions are capable of addressing the root causes of crop residue burning.

¹² Ordóñez R, 'Happy Seeder can reduce air pollution and greenhouse gas emissions while making profits for farmers' (*International Maize and Wheat Improvement Center (CIMMYT*), 8 August 2019) 3 <https://www.cimmyt.org/news/happy-seeder-can-reduce-air-pollution-and-greenhouse-gas-emissions-while-making-profits-for-farmers/> accessed 22 November, 2025.

¹³ Kumar A, 'How can Punjab end stubble burning with crop residue management methods and tackle paddy stubble burning' (*Council on Energy, Environment and Water (CEEW)*, January 2025) 4 <https://www.ceew.in/publications/how-can-punjab-adopt-crop-residue-management-methods-and-tackle-paddy-stubble-burning> accessed 22 November, 2025.

2.6 Need for an Interdisciplinary Approach

At the intersection of environmental, agricultural, public health, economic and governance issues is the burning of crop residue. Attempts to address the issue using punitive legal measures or technological solutions have yielded minimal results. The most effective solution necessitates a balanced approach of environmental protection, agricultural sustainability and farmer welfare.

Any significant reform should encompass legal oversight, institutional coordination, financial incentives, technological advancement and civic engagement.

3. LEGAL, INSTITUTIONAL AND REGULATORY FRAMEWORKS GOVERNING CROP RESIDUE BURNING IN INDIA

The impact of stubble burning on public health, air quality and ecological sustainability is harmful and must be addressed through various constitutional statutes, environmental laws and regulatory mechanisms. A system has been established by Indian courts, environmental authorities and legislative bodies to ensure that environmental protection is in line with the needs of farmers' livelihoods. However, ongoing cases of crop residue burning highlight the considerable distance between legal requirements and practical implementation.

The success of environmental laws is largely dependent on the institutions that implement and enforce them. India has developed a complex institutional framework that includes judicial bodies, regulatory agencies and specialized authorities, in response to the mounting threat of crop residue burning. These institutions are essential in monitoring air quality, enforcing environmental regulations, coordination of inter-state responses and the promotion of practices for sustainable residue management. However, despite the existence of multiple institutions, recurring incidents of stubble burning highlight the challenges of coordination, enforcement and implementation.

3.1 Constitutional Framework

India's Constitution offers a solid legal basis for the protection of the environment. Even though there is no specific mention of a fundamental right to the protection of the environment in the Indian Constitution, the scope of Article 21 has been widened by way of judicial interpretation.

Article 21: Right to Life and Healthy Environment

Article 21 of the Indian Constitution states that every individual has the right to life and personal liberty. This article has been expanded to incorporate environmental rights through the judicial interpretations made by the Supreme Court. Air pollution resulting from crop residue burning directly threatens public health and therefore raises concerns under Article 21.

In *Subhash Kumar v. State of Bihar*¹⁴, the Supreme Court recognized that the right to life includes the right to enjoy pollution-free water and air. Similarly, in *M.C. Mehta v. Union of India*¹⁵, the Court emphasized the obligation of authorities to prevent environmental degradation and protect public health.

Article 48A: Protection and improvement of environment and safeguarding of forests and wildlife

As per Article 48A of the Constitution, it is the duty of the State to protect and improve the environment and safeguard forests and wildlife. This constitutional duty implies that the government, at both the central and state levels, must develop policies for the prevention of pollution due to crop burning and adopting climate-resilient agriculture.

Article 51A(g): Fundamental Duty of Citizens to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures

It highlights the collective social responsibility towards the environment as well as sustainable agriculture practices.

3.2 Air (Prevention and Control of Pollution) Act, 1981

This Act is the principal statutory provision regulating air pollution in India. It was promulgated after India ratified its obligations through the Stockholm Conference on Human Environment. This Act provides legal provisions for prevention, control and abatement of air pollution. Under this Act, the powers to control air pollution have been vested in the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs), who are authorized to regulate and control activities resulting in air pollution. While the Act does not address stubble burning

¹⁴ AIR 1991 SC 420 at page no. 8.

¹⁵ AIR 2020 SC 27 at page no. 21.

explicitly, the emissions that result from stubble burning are encompassed within the definition of air pollutants provided under the Act.

As per the provisions of this Act, the Pollution Control Boards can conduct inspections, issue directions and impose fines on farmers. However, given the widespread nature of agricultural activities and the socio-economic conditions prevailing among farmers, it becomes a challenge to enforce this provision.

3.3 Environment (Protection) Act, 1986

This Act serves as umbrella legislation for environmental governance in India. The Act gives wide powers to the central government to take actions essential for environmental protection and improvement. Many notifications and directives that deal with issues related to air pollution and residue management find backing in this Act. The Act is also useful in helping coordinate environmental policies among various sectors of economy, which makes this Act pertinent in solving problems arising out of residue burning.

3.4 Bharatiya Nyaya Sanhita, 2023; Section 270: Public Nuisance

The Bharatiya Nyaya Sanhita, 2023, contains provisions on public nuisance and acts that endanger public health and safety. The burning of vast amounts of crop residue can have detrimental effects on public health, as it releases pollutants into the air and creates perilous environmental conditions. Environmental regulation is primarily enforced by specific environmental statutes, but the BNS can be utilized as an extra legal framework in certain situations where pollution causes harm, inconvenience or danger to society. The inclusion of public health considerations within criminal law reflects the growing recognition of environmental harm as a societal concern rather than merely an agricultural issue.

3.5 Environmental Principles Developed Through Judicial Interpretation

Polluter Pays Principle, under it the people who cause environmental harm are required to pay for the costs of prevention, mitigation and restoration. The Supreme Court affirmed this principle in *Vellore Citizens Welfare Forum v. Union of India*¹⁶. In the context of crop residue

¹⁶ AIR 1996 SC 2715 at page no. 10.

burning, fines imposed on small and marginal farmers by the respective State governments reflects this principle.

Precautionary Principle mandates action in situations where there is a risk of environmental harm. As crop residue burning poses considerable risks to the environment and public health, precautionary actions must be taken in line with this principle.

The idea of sustainable development entails balancing development with environmental conservation. The solution to the problem of crop residue burning must therefore consider environmental sustainability and agricultural productivity.

3.6 Institutional Framework for Addressing Crop Residue Burning

The National Green Tribunal (NGT) is India's apex environmental adjudication body and it was established under the National Environmental Tribunal Act, 2010. The Tribunal's recognition of stubble burning as a significant cause of air pollution in North India and the need for preventive measures have made it an essential factor in addressing crop residue burning. It also directed local authorities to establish monitoring systems and punish those who violated the law. To enhance accountability among public authorities and private actors, the NGT has incorporated principles such as sustainable development, the precautionary principle and the polluter pays principle. The ongoing issue of stubble burning is a clear indication that the administration requires administrative and policy assistance before judicial actions can be taken.

In India, the Central Pollution Control Board (CPCB) is accountable for overseeing air quality across the nation, devising national regulations to manage pollution, coordinating State Pollution Control Boards policies and providing guidance to the Central Government on matters related to pollution. In the case of crop residue burning, the CPCB regularly monitors air quality levels in affected areas and measures how stubble burning affects seasonal pollution episodes. The Board provides scientific evidence by means of satellite data, field reports and environmental monitoring systems to guide policy decisions and regulatory intervention. State Pollution Control Boards serve as the main enforcement mechanism at the state level. Pollution Control Boards are responsible for enforcing environmental regulations in Punjab, Haryana, Uttar Pradesh and Rajasthan regarding the burning of crop residue.

The Commission for Air Quality Management Act, 2021 was established by Parliament as a means of monitoring air pollution in North India, which is transboundary and affects all regions. It was established with the aim of coordinating efforts among states and agencies responsible for air quality management. Its jurisdiction covers the entire territory of Delhi-NCR and its surrounding areas. Among the Commission's significant duties are devising extensive action plans to enhance air quality, providing guidance to governments and authorities, advocating for sustainable crop residue management strategies and coordinating inter-state pollution control measures. The CAQM offers a single-source solution for regional environmental issues, setting it apart from earlier fragmented approaches. In-situ and ex-situ residue management techniques have been actively promoted, along with mechanized alternatives to burning, by the Commission. Nevertheless, effective coordination between central and state administrations is still the foundation for its success.

Research, technological innovation and farmer training programmes are among the contributions made by institutions like the Indian Council of Agricultural Research (ICAR) and the Indian Agricultural Research Institute (IARI). District administrations, village panchayats, Farmer Producer Organizations and Custom Hiring Centres work together to ensure compliance, increase in access to machinery and promote sustainable alternatives at the local level. Their involvement is particularly important because residue management decisions are ultimately implemented at the farm level.

3.7 Limitations of the Existing Legal Framework

Despite constitutional safeguards, environmental laws and legal statutes in place to prevent it, the burning of crop residue remains a persistent problem. Punitive enforcement and other measures that focus on imposing fine on farmers do not address the economic and technological challenges faced by farmers.

Lack of implementation is worsened by inadequate coordination among agencies, fragmented institutional responsibilities are not fully recovered and environmental penalties are poorly recovered. Consequently, the effectiveness of the legal framework depends not only upon regulatory prohibitions but also upon complementary measures such as institutional coordination and farmer participation.

4. CURRENT POLICY FRAMEWORKS AND MANAGEMENT INITIATIVES

Several strategies have been proposed by the Government of India and the State Governments in an attempt to resolve the problems arising due to crop residue burning. Despite having the political commitment to overcome the problem, these strategies lack implementation and reforms are necessary.

4.1 Regulatory and Legal Intervention

The National Green Tribunal issued an order on the 10th of December, 2015¹⁷, wherein it banned the practice of burning agricultural waste within the National Capital Territory of Delhi and its surrounding regions including Punjab, Haryana, Uttar Pradesh and Rajasthan. Alongside this ban is attached a fine ranging from ₹2,500 to ₹15,000, depending upon the area of landholding¹⁸. The main object behind it is to create a sense of deterrence-based framework which would discourage the burning of paddy stubble.

In the year 2020, the Commission for Air Quality Management (CAQM) was established to strengthen regional coordination. It came into being by an Act of Parliament having its jurisdictional cover up to National Capital Region and its adjoining areas¹⁹. Mandatory duties have been imposed upon CAQM to formulate action plans, supervise inter-state coordination and monitor implementation of programmes targeting air quality improvement. It also consists of strategies related to stubble management including ex-situ and in-situ residue utilization²⁰, monitoring mechanisms and awareness campaigns. Enough powers have been given to the Commission so as to impose environment related penalties on the offenders²¹. Despite so many efforts, all things go in vain as the compliance of it remains weak. Merely 11%²² of the fines

¹⁷ *National Green Tribunal*, Order dated 10 December 2015 (Stubble Burning Matter).

¹⁸ *Ibid*; Penalty slabs issued under the NGT's environmental compensation regime

¹⁹ The Commission for Air Quality Management in National Capital Region and Adjoining Areas Act 2021.

²⁰ Sharma RK, 'Stubble Burning in Regions of Northern India – Causes, Solutions & Business Opportunities' (2021) 9 *Indian Journal of Pure & Applied Biosciences* 151, 7 <https://doi.org/10.18782/2582-2845.8617>, accessed 20 November, 2025.

²¹ *Ibid* s 12–14.

²² Commission for Air Quality Management in National Capital Region and Adjoining Areas, 'The Commission for Air Quality Management in National Capital Region and Adjoining Areas (Imposition, Collection and Utilization of Environmental Compensation for Stubble Burning) Amendment Rules, 2024' (Press Release, 7 November 2024, Press Information Bureau, Ministry of Environment, Forest and Climate Change, Government of India).

https://sansad.in/getFile/rsnew/Committee_site/Committee_File/ReportFile/12/204/254_2025_2_11.pdf?source=rajyasabha, accessed 23 November, 2025.

imposed for burning the stubble in the year 2024 has been collected so far²³. This low recovery rate has diluted the deterrent effect of punitive measures²⁴. As a result, penalty-based approach has been proven to be inadequate in altering farmer behaviour without addressing underlying economic pressures and providing alternatives²⁵.

4.2 Government Schemes for Crop Residue Management (CRM)

It is recognized that penalties alone cannot stop the practice, therefore the Union Government has come up with a series of financial and mechanisation-based interventions. The Central Sector Scheme on Promotion of Agricultural Mechanisation for In-Situ Management of Crop Residue, was initiated in the year 2018-19, where ₹1151.80 crore was allocated in its first phase. In between 2018 and 2024, Between 2018 and 2024, Punjab, Haryana, Uttar Pradesh and Delhi altogether received approximately ₹3698.45 crore under the CRM programme.²⁶

Under this scheme, individual farmers were given an opportunity to receive a 50% subsidy for purchasing residue management tools and equipment while on the other hand Custom Hiring Centres (CHC) and Farmer Producer Organizations (FPO) will receive a subsidy up to 80% for projects valued for a price of Rs 30 lakh. In 2024 CRM guidelines were issued which revised subsidy-sharing to a ratio of 60:40 between centre and state, in the same way 80% subsidy was introduced for high-horsepower tractors²⁷ for CHCs and it also established a credit-linked capital mechanism to ensure that there is equitable allocation. Additional objectives also catered which include promoting ex-situ utilization through biofuels such as CNG, bio-ethanol and biomass-based energy generation.

Between the year 2022 and 2023²⁸, it is seen that that fire counts have been declined in Punjab

²³ Commission for Air Quality Management (CAQM), Fine Collection Report (2024).

²⁴ Press Information Bureau (Government of India), 'Ban on crop residue burning' (Press Release, 21 June 2019) <https://www.pib.gov.in/newsite/PrintRelease.aspx?relid=190615>, accessed 22 November, 2025.

²⁵ D Jha, 'Why behaviour matters more than bans: Reimagining solutions to stubble burning' (PANJ Foundation, 30 April 2025) <https://www.panj.org.in/why-behaviour-matters-more-than-bans-reimagining-solutions-to-stubble-burning/>, accessed 19 November, 2025.

²⁶ Government of India, Ministry of Finance, Department of Economic Affairs, 'Lok Sabha Unstarred Question No 1737: Imposition, collection and utilization of environmental compensation for stubble burning' https://sansad.in/getFile/loksabhaquestions/annex/184/AU1737_KJNMaf.pdf?source=pqalsm, accessed 19 November, 2025.

²⁷ Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture and Farmers Welfare, 'Rajya Sabha Unstarred Question No 2119: [Subject matter – stubble burning and crop residue management]' https://sansad.in/getFile/annex/266/AU2119_jpiCv9.pdf?source=pqarss, accessed 19 November, 2025.

²⁸ Press Information Bureau, Ministry of Agriculture & Farmers Welfare, 'Government revises the Crop Residue Management guidelines enabling efficient ex situ management of paddy straw generated in the States of

by 27% but as usual the adoption of CRM equipment remains far from universal. Many farmers are of the view that it is convenient and preferable to own a personal machinery rather than relying upon CHCs because there are chances that these machineries would be available on time when required, staff shortages and maintenance deficiencies²⁹. All these inconsistencies and non-reliance weaken the trust towards shared-equipment models which eventually forces the farmers towards faster and unsustainable practices.

4.3 Technological Solutions Promoted

In government's residue management strategies technology forms a core pillar. Technologies such as Happy Seeder, which is a tractor-mounted implement, enables the farmers in easy and direct drilling of wheat seeds. Studies conducted shows that as compared to conventional burning, the Happy Seeder- based systems are more profitable and aids in reducing the emission of greenhouse-gases by more than 78%, thereby reducing the demand for water, fuel and labour³⁰.

Apart from Happy Seeder, there is other equipment called the Super Seeder which performs multiple functions such as residue cutting, soil preparation, seed placement and fertiliser application in a single pass, improving sowing efficiency and reducing emissions. Another one in the list of promoted innovation is the Pusa Bio-Decomposer, developed by the renowned Indian Agricultural Research Institute (IARI). It is microbial formulation which accelerates the decomposition of paddy straw within a span of 20 days, supported by lignocellulosic enzymes active at temperatures typical of the rice-wheat transition period³¹. This process of decomposition enriches the soil fertility, decreases dependency on fertilizer and thereby offers a cost-effective alternative to stubble burning. Delhi is one of a state which has promoted the adoption of it by providing free spraying services to farmers. But despite the fact that such

Punjab, Haryana, Uttar Pradesh and Delhi' (Press Release, 1 July 2023, Press Information Bureau, Government of India) <https://www.pib.gov.in/PressReleaseDetail.aspx?PRID=1936626>, accessed 20 November, 2025.

²⁹ Centre for Study of Science, Technology and Policy (CSTEP), 'Stubble management: Harnessing ex situ options and market mechanisms' (*Policy Brief*, 28 August 2024) <https://cstep.in/drupal/sites/default/files/2024-08/Stubble%20Management%20Harnessing%20Ex%20Situ%20Options%20and%20Market%20Mechanisms.pdf> accessed 24 November, 2025.

³⁰ Keil A, Krishnapriya PP, Mitra A, Jat ML, Sidhu HS, Krishna VV and Shyamsundar P, 'Changing agricultural stubble burning practices in the Indo Gangetic plains: Is the Happy Seeder a profitable alternative?' (2021) 19 International Journal of Agricultural Sustainability 128 <https://doi.org/10.1080/14735903.2020.183427>, accessed 24 November, 2025.

³¹ Bishnoi R, Kumar V, Bishnoi DK and Meena MS, 'Economic viability analysis of Super Seeder machine adoption in wheat cultivation: A case study in Haryana' (2024) 63 Annals of Arid Zone 55 <https://doi.org/10.56093/aaz.v63i2.144989>, accessed 24 November, 2025.

technology offers demonstrated environmental and economic benefits, there are many constraints in its widespread adoption such as high upfront investment, maintenance challenges and delays in machine access during peak periods.

4.4 Role of Custom Hiring Centres (CHCs) and Farmer-Producer Organisations (FPOs)

In order to overcome the high cost involved in specialized machinery, the government has come up with the idea of incentivising the establishment of Custom Hiring Centres (CHCs) by offering subsidies of up to ₹15 lakh, covering 80% of project costs. Approximately 41,900 CHCs and 3.23 lakh CRM machines have been deployed across the four-key residue-burning states³². Farmer Producer Organisations (FPOs) acts as a collective platform that helps small and marginal farmers access inputs, machinery and markets by instituting leverages in economies of scale³³. Participation is also facilitated by way of organised value chains and which in turns improve bargaining power³⁴. However, there are certain drawbacks of CHCs wherein they frequently underperform due to poor equipment maintenance, understaffing and late service delivery.

5. ASSESSMENT OF EXISTING POLICY FRAMEWORKS AND CROP RESIDUE MANAGEMENT INITIATIVES

During the last ten years, several policy decisions and monetary incentives have been launched by the Government of India as well as by several state governments to tackle crop residue burning. It is evident that such policies and decisions were taken due to the realization of the negative implications of crop residue burning. However, although there is some success in terms of decreasing the frequency of burning incidents, the fact that burning continues to happen shows that the policies have led to inconclusive results.

³² Press Information Bureau, Ministry of Agriculture and Farmers Welfare, 'Stubble burning' (*Press Release*, Press Information Bureau, Government of India, April 2025)
<https://www.pib.gov.in/PressReleasePage.aspx?PRID=2112397> accessed 23 November 2025.

³³ *Where There's Smoke, There Was Stubble: Applying behavioural insights to design a sustainable solution to the problem of stubble burning in Punjab, India* (London School of Economics and Political Science)
<https://www.lse.ac.uk/PBS/assets/documents/PEL-coursework/2023-24/group-5-where-there-is-smoke-there-was-stubble.pdf>, accessed 25 November, 2025.

³⁴ Gorai SK, Wason M, Padaria RN, Rao DUM, Paul S and Paul RK, 'Factors contributing to the stability of the Farmer Producer Organisations: A study in West Bengal' (2022) 58 *Indian Journal of Extension Education* 91
<https://doi.org/10.48165/IJEE.2022.58218> accessed 24 November, 2025.

5.1 Crop Residue Management Scheme

Among the most important interventions taken by the government has been that of the Central Sector Scheme on Promotion of Agricultural Mechanisation for In-Situ Management of Crop Residue, also known as Crop Residue Management Scheme. Launched in the year 2018, the objective of the scheme has been to discourage the burning of agricultural waste through the use of modern machinery.

Government provides monetary support to individuals, Custom Hiring Centres, Farmer Producer Organizations and cooperative societies in the acquisition of machinery like Happy Seeders, Super Seeders, Rotavators, Straw Balers and Mulchers. This scheme has led to the procurement of several thousands of machines in Punjab, Haryana and Uttar Pradesh.

The program has enabled access to mechanized means as well as made farmers aware about other alternatives to burning of stubble. However, the impact of the program has been limited due to non-uniform access to machinery, difficulty in maintaining and using these machines and failure of smaller landowners to use modern equipment on their own.

5.2 Promotion of In-Situ Residue Management Technologies

In-situ management practices ensure that the crop residues are retained in the field and not taken burnt. The Happy Seeder is a technology which facilitates the process of sowing wheat directly in the fields having residues of paddy crops. The technique helps in avoiding burning of residues while helping in improving soil moisture content. The Pusa Bio-Decomposer developed by the Indian Agricultural Research Institute facilitates faster decomposition of paddy straw using micro-organisms. It results in conversion of the agricultural waste into organic substances improving soil fertility levels and decreasing the reliance on chemical fertilizers. Even though these techniques have many environmental advantages, their usage has been inconsistent owing to economic barriers and lack of awareness particularly among small and marginal farmers

5.3 Promotion of Ex-Situ Utilization of Crop Residue

In recent times, policy measures have been directed at converting agricultural residue into an economic asset via ex-situ usage. Agricultural residue may be used for production of Bio-ethanol, Compressed Bio-Gas, electricity from biomass, packaging and paper industry.

Government has facilitated private sector involvement in biomass utilization as well as encouraged investments in bio-fuels and renewable energy projects. This could help generate extra revenue streams for farmers while minimizing pollution levels.

Yet, poor logistics, high transportation costs, limited storage facilities and undeveloped biomass markets have remained a challenge.

5.4 Custom Hiring Centres and Farmer Producer Organizations

Acknowledging the fact that some farmers do not have the money to purchase costly residue management machines, the government has come up with institutions like Custom Hiring Centres (CHCs) and Farmer Producer Organizations (FPOs). The custom hiring centres offer farmers machine facilities on rent in crucial sowing periods, whereas FPOs encourage group ownership and sharing resources and negotiating power³⁵.

Though such institutions have made technology easily accessible to some extent, yet certain problems persist. There are complaints from farmers regarding late arrival of machines, poor maintenance of machines, shortage of skilled drivers and non-availability of machines in peak agricultural periods³⁶. This results in many farmers choosing to burn crops in fields since it is more convenient. Initiatives in machinery subsidies, research works and renewable energy ventures show that there is a move towards adopting sustainable methods for residue management rather than enforcement measures alone.

5.5 Persistent Policy Gaps and Limitations

Evaluation of the existing initiatives suggests that crop residue burning cannot be handled by regulation alone or through subsidy schemes and technology. The existing policies have been successful to some extent, however, they fall short of fully ensuring a ban on residue burning. However, the above-mentioned success is accompanied by certain limitations. Firstly, almost all initiatives are oriented towards managing residue after its creation and not preventing it.

³⁵ Mid Sweden University and Indian Institute of Technology Ropar, *Insights and realism of stubble burning in India: Health economics analyses* (Research Report, December 2024) <https://www.miun.se/globalassets/institutioner/hov/forskning/insights-and-realism-of-stubble-burning-in-india--health-economics-analyses--isbn-978-91-89786-94-3.pdf>, accessed 19 November, 2025.

³⁶ Press Information Bureau, 'Centre aims to work towards achieving zero stubble burning in current season: Shri Narendra Singh Tomar' (Press Release, 1 November 2024, Ministry of Information and Broadcasting, Government of India) <https://www.pib.gov.in/PressReleasePage.aspx?PRID=1945674>, accessed 18 November, 2025.

Secondly, subsidies play a crucial role in many policy frameworks, which raises issues of their sustainability over a long period. Enforcement measures are based mostly on penalties but not farmers' economic problems. Thirdly, there is a lack of cooperation between different institutions that are responsible for various issues related to residue burning. Finally, political sensibility towards farmers makes the enforcement of such initiatives very difficult. The issue would only be solved when farmers start treating residue as a product and not as agricultural waste.

6. PATHWAYS TOWARDS SUSTAINABLE CROP RESIDUE MANAGEMENT: POLICY REFORMS

The continued burning of agricultural residues in spite of stringent legal and other efforts shows that the current strategies have failed to tackle the underlying structures behind the issue. This would mean that sustainable reforms should focus on moving from a regime based primarily on enforcement towards one that considers environmental issues, agricultural sustainability and farmer welfare as well.

6.1 Reorienting Policy from Punitive Measures to Incentive-Based

While the current policy measures are necessary for ensuring accountability, excessive dependence on punitive action often generates resistance among farmers who already face economic and operational constraints, hence, applicability of Polluter Pays Principle on small and marginal farmers is not an effective measure. On the contrary, a balance is required by coupling the system of regulations with incentives. The government ought to use direct economic incentive packages and performance based incentives for encouraging farmers to engage in sustainable residue management.

6.2 Strengthening In-Situ Residue Management

Managing and discarding the left-over crop residue within the fields remains a challenging pillar for sustainable agriculture. Such policies should be framed, adopted and implemented which would help in prioritizing consistent use of established in-situ technologies. In-situ management still stands out among one of the best ways to minimize the burning of crop residue and enhance the health of the soil. The government should increase the backing towards

the use of technologies like Happy Seeder, Super Seeder and Pusa Bio-Decomposer.³⁷

A cost-effective biological method called Pusa-Bio-Decomposer is evolved in order to break down paddy straw within a span of roughly 20-25 days. Instead of burning, farmers can opt other alternatives in the form of converting residue into nutrient-rich compost which increases the level of nutrition of soil and reduces the dependency on chemical fertilizers. Zero tillage, residue mulching, and crop rotation can aid in promoting the conservation of agricultural practices along with ensuring better soil quality. Small and marginal farmers need special consideration because their major concern is the availability of modern tools which may come at a cost. Thus, subsidies must cover not only the cost of buying the machines but also repairing and maintaining them.

6.3 Scaling Up Ex-Situ Utilization: Value Chain Development

Ex-situ residue management can transform stubble from an agricultural burden into an economic asset. For realising this potential strengthening market linkages and developing efficient value chains are essential.

6.3.1 Bioenergy Production

Residue can be used for the bioenergy production in several forms of renewable energy, including bio-ethanol, bio-compressed natural gas (CNG), biomass pellets for thermal power stations and production of energy through biomass. Studies report shows that bio-fuels can reduce harmful emissions by up to 2750kg CO₂ per ton, whereas bioethanol production can reduce emissions at the rate of 2549 kg CO₂ per ton.³⁸

6.3.2 Supply Chain Infrastructure

One of the major drawbacks of ex-situ expansion is that there is lack of a reliable supply chain for residue collection, its processing and transportation. There are certain facilities which are essential and need to be installed near the field for smooth functioning such as the establishment

³⁷ Jain S, Arya H and Sarao NS, 'How crop residue management guidelines aim to curb farm fires and stubble burning' (*Council on Energy, Environment and Water (CEEW)*, 18 September 2024) <https://www.ceew.in/blogs/how-crop-residue-management-guidelines-aim-to-curb-farm-fires-and-stubble-burning> accessed 24 November, 2025.

³⁸ *Sustainable bio energy production models for eradicating open field burning of paddy straw in Punjab, India* (Mongabay) 8 <https://imgs.mongabay.com/wp-content/uploads/sites/30/2023/03/01073939/Sustainable-bio-energy-production-models.pdf>, accessed 24 November, 2025.

of additional bailing units, storage depots, straw banks and palletization facilities. Despite this, there are current situations where most of the farmers receive little or no compensation for their residue. Data shows that only 3% received payment (around ₹1,200 per acre), 69% gave straw away for free and 28% even paid for removal³⁹.

6.4 Developing a Circular Economy for Crop Residue

Crop residue must be seen as an asset instead of a waste product. This is possible by adopting a circular economy approach that will see the utilization of agricultural biomass. Crop residue can serve as a raw material for Bio-ethanol and biofuel production, biomass-based electricity generation, biochar and organic compost production. Creation of effective value chains will offer farmers other sources of income besides offering a solution to environmental pollution. Government needs to promote private sector investment in renewable energy plants.

6.5 Introducing Market-Based Economic Incentives

In order to alter behaviour significantly there has to be changes in economic policies which must be extended beyond conventional subsidies and create periodic income opportunities linked to sustainable residue management. Economic considerations significantly influence farmers' decisions regarding residue disposal. Therefore, sustainable reform requires the creation of market mechanisms that generate direct financial benefits from residue management. One proposed measure is the introduction of an MSP-like pricing mechanism for paddy straw⁴⁰. A guaranteed minimum price would incentivize farmers to sell their crop residues instead of burning. This model would help develop a sustainable biomass business as well as benefit the rural economy.

Moreover, carbon credit systems can also prove to be beneficial in managing crop residue as carbon trading would yield extra income for the farmers. Farmers who refrain from burning crop residues can earn carbon credits by reducing greenhouse gas emissions. Market mechanisms are able to create a lasting behavioural shift since they make environmental

³⁹ Jain S, Arya H and Sarao NS, 'How crop residue management guidelines aim to curb farm fires and stubble burning' (*Council on Energy, Environment and Water (CEEW)*, 18 September 2024) <https://www.ceew.in/blogs/how-crop-residue-management-guidelines-aim-to-curb-farm-fires-and-stubble-burning> accessed 24 November, 2025.

⁴⁰ Press Trust of India, 'Stubble burning: Parliamentary Panel calls for MSP like pricing for paddy residue' *Deccan Herald* (11 February 2025) <https://www.deccanherald.com/india/stubble-burning-parliamentary-panel-calls-for-msp-like-pricing-for-paddy-residue-3401027>, accessed 25 November, 2025.

responsibility economically beneficial.

6.6 Enhancing Institutional Coordination and Governance

As air pollution is trans-boundary in nature, there is need for coordination among various institutions and governments. Despite improvement in regional cooperation through the Commission for Air Quality Management, there are still deficiencies in coordination. Different policies should be framed with the aim of integrating fragmented sectoral policies which works as a cross-purpose. For instance, water irrigation and conservation regulation might delay the paddy sowing, inadvertently affecting the crop window for wheat sowing, thereby leaving them with no other option but to burn it. An integrated governance framework should facilitate regular collaboration among various Ministries and State governments. Different ministries working in their respective spheres should collaborate their efforts as it is crucial for infrastructure development and coordinated enforcement.

A dedicated inter-ministerial task force could improve policy coherence, reduce duplication of efforts and ensure that environmental and agricultural policies operate in a complementary manner rather than at cross purposes.

6.7 Promoting Crop Diversification and Sustainable Agriculture

One of the primary structural factors behind the generation of residues is the reliance on the monoculture cycle of cultivation involving rice-wheat crops. Any sustainable change necessitates moving away from the monoculture cycle of cropping. The government needs to promote crop diversification by offering specific incentives, procurement facilities and extension services. Diversification towards crops like maize, pulses and oilseeds can not only help minimize residue formation, save ground water and increase agricultural resilience but can also facilitate the adoption of various conservation agriculture techniques like zero-tillage, residue mulching and precision farming.

6.8 Strengthening Farmer-Centric Approaches

It is not possible for any reforms to be successful without involving farmers. In most cases, reforms have been conducted using a top-down strategy whereby they focus on achieving regulatory goals without paying much attention to local conditions. It will therefore be

necessary for any future reform to take into consideration the interests of farmers. Farmers are more willing to change their farming behaviours when they see tangible rewards.

6.9 Towards a Sustainable and Integrated Framework

Awareness programs should be conducted to highlight not only the negative impact of fires on the environment but also economic benefits of sustainable methods like soil fertility, lower costs of inputs and increased productivity⁴¹. The chances of farmers using modern techniques increase significantly when they see positive outcomes by their farmer counterparts. Progressive farmers can act as role models and hence promote CRM techniques⁴².

Farmer Producer Organisations can also support the farmers by enabling cooperative machinery ownership, easing the accessibility of machines and helping farmers get the subsidies. In an integrated framework, following principles must be taken into consideration, firstly, environmental conservation should be an important goal since it is entrenched in the constitution. Secondly, the wellbeing of farmers and viability of agriculture should not be overlooked in designing such a framework. Thirdly, rather than regarding the agricultural residue as waste, it should be treated as a resource that can be tapped for generating renewable energy.

The complex issue of crop residue burning exemplifies how fragmented policies may be inadequate when addressing certain environmental issues. To achieve any reform in this regard, the policy must combine all of the relevant components, i.e., legislation, economics, technology and cooperation. Only through a holistic approach we can move from recurring cycles of crop residue burning towards a more sustainable, resilient and environmentally responsible agricultural future.

7. LESSONS FROM GLOBAL BEST PRACTICES IN CROP RESIDUE MANAGEMENT

The challenge of crop residue burning is not unique to India as several nations have faced similar environmental and agricultural problems. Crop residue is common in all countries but

⁴¹ The United Indian, 'Environment: Innovative solutions to stop the stubble burning impact' (2024) <https://theunitedindian.com/news/blog?stubble-burning-India&b=353&c=1>, accessed 23 November, 2025.

⁴² Roots Foundation, *Project Bhoomi – Crop Residue Management Initiative* (<https://rootsfoundation.in/projects/project-bhoomi-crop-residue-management-initiative/>), accessed 23 November, 2025.

its management varies from country to country. Varied regulatory measures and market-based strategies have been adopted by countries to deal with the issue of crop residue burning without affecting agricultural productivity.

A variety of approaches have been adopted by different countries to manage the crop residue burning, so that a mixture of achievable results can be availed depending on enforcement capacity and the availability of practical alternatives. If strict bans are accompanied by strong institutional oversight and accessible alternatives, they can be effective.

7.1 United Kingdom: Strict Regulatory Prohibition

A stringent system of regulations has been implemented in the UK with regard to crop residue burning with the help of the enactment of the Crop Residues (Burning) Regulations of 1993. This Act severely curtailed crop residue burning and provided for very strong enforcement procedures. The success of the British system of regulation in combating crop residue burning is due to proper monitoring, stringent regulations and easy access to alternatives. While the British system may provide a viable model for preventing crop residue burning, it is unlikely that it can be directly applied to India because there are vast differences between the two countries in terms of agricultural practices.

7.2 European Union: Integrating Environmental Sustainability with Agricultural Policy

In European Union, under the Common Agriculture Policy, environmental regulation is tied with the payments made to farmers. According to EU Regulation 1306/2013, promotion of renewable energy, specifically biofuels, has led to reduction in crop residue burning as the residue is used in generating energy⁴³.

Such an approach motivates the farmers to adopt climate-resilient agricultural practices as the subsidy is contingent upon adherence to the environmental requirements. Economic incentives must be aligned with environmental objectives instead of relying exclusively on punitive measures. One important takeaway from the European Union experience for India is that sustainable agricultural practices will have better success when the economic value is evident.

⁴³ Sander A, 'Parliamentary question E-001847/2020: Stubble burning (Question for written answer to the Commission under Rule 138)' (European Parliament, 25 March 2020) https://www.europarl.europa.eu/doceo/document/E-9-2020-001847_EN.html, accessed 20 November, 2025.

7.3 United States: Controlled Burning and Localized Regulation

The United States adopts a more decentralized approach to residue management. Stubble burning is entirely prohibited in different states of USA like Oregon and Idaho; however, some exceptions can be made via the permit system⁴⁴. The matter of when and where to allow such stubble burning rests in the hands of the local administration, who takes into consideration the weather forecast and air quality standards to avoid smoke dispersal and its impact on health. Such an adaptive policy takes into consideration the fact that the situation may differ from region to region and hence the solution must be found differently as well. The USA provides a lesson that needs to be considered by India regarding residue management.

For India's residue-management policies, regional variations in cropping patterns, resource availability and institutional capacity must be taken into account.

7.4 China: Transition from Punitive Measures to Incentive-Based Policies

China experienced a similar challenge of crop residue management that is currently being faced in North India. Similar to Indian government's approach of applying Polluter Pays Principle on farmers, Chinese authorities relied on bans, fines and enforcement mechanisms to curb agricultural residue burning. However, it did not help as without viable alternatives, farmers are left with only one option which is to burn the residue⁴⁵.

To address the issue of stubble burning at the root level, China decided to adopt an incentive scheme in which both farmers and corporations received money as support to recover the straw i.e. crop residue. Money was provided not only for straw recovery but also for technology and investments related to biomass products. This approach succeeded in reducing the burning incidents by an estimated 233 cases annually, because of which there is improvement in air quality by nearly 5 $\mu\text{g}/\text{m}^3$ and credited with the achievement of preventing tens of thousands of premature deaths each year⁴⁶.

⁴⁴ Oregon Department of Environmental Quality, *Burning 101*, <https://www.oregon.gov/deq/aq/Pages/Burning-101.aspx>, accessed 21 November, 2025.

⁴⁵ J Ren, P Yu and X Xu, 'Straw utilization in China—Status and recommendations' (2019) 11 *Sustainability* 1762 <https://doi.org/10.3390/su11061762>, accessed 22 November, 2025

⁴⁶ G He, T Liu and M Zhou, 'Straw burning, PM_{2.5} death: Evidence from China' (2020) 145 *Journal of Development Economics* 102468, 5 <https://doi.org/10.1016/j.jdeveco.2020.102468>, accessed 22 November, 2025

There has been decrease in number of stubble burning incidents coupled with economic benefits as a result of using straw. The Chinese experience shows that people are more likely to change their behaviour sustainably when the environment and economy are on the same side.

7.5 Adaptability and Applicability to Indian Context

By assessing the crop residue management practices in the above countries, the important takeaways applicable in the Indian context are that regulation alone is insufficient, economic value must be attached to crop residue and farmer participation must be central to sustainable reform. These must be adapted as per India's unique agricultural, economic and social conditions. In India, we must adopt the strong legal enforcement similar to the United Kingdom, incentive-based mechanisms inspired by China, environmental-agricultural integration comparable to the European Union and localized implementation strategies resembling those adopted in the United States.

However, such an approach not only incorporates the environmental concerns enshrined within the constitution but also will address the challenges faced by the farmers. By implementing such a framework that integrates the best practices adopted by other nations, India will be able to build an effective framework for managing its crop residue.

The development of an elaborate policy framework must be embraced in India through ensuring adequate regulatory supervision, economic motivation and market development of residues usage. The use of circular economy policy whereby the agricultural wastes are recycled and used in production of biofuels, composites, papers and textiles amongst others, would have great prospects.

8. RECOMMENDATIONS AND CONCLUSION

Environmental degradation is an amalgamation of institutional failure, human greed, policy lapse and unsustainable technological changes. As the issue of crop residue burning still persists even after the implementation of policies and initiatives, it requires more than fragmented efforts. The compressed window between harvesting and sowing along with rising labour costs, mechanised harvesting and limited finances force the farmers to burn the crop residue rather than to look for alternatives.

Applying Polluter Pays Principle on the small and marginal farmers is not a viable method to stop the practice of crop residue burning. Even the legal prohibitions and fines imposed have not been able to decrease the incidents of stubble burning. Officials at the local level tend to manipulate the number of burning incidents to put up a false picture of reduced stubble burning instances. The socio-economic realities faced by farmers must be considered before applying the Polluter Pays Principle on them as this Principle was not meant to penalise the downtrodden and vulnerable but was intended towards the big industries who wilfully pollute the environment.

India has legal and institutional framework in place to address the problem of stubble burning. Even Indian judiciary has played an important role by issuing directions to the State governments. The initiatives like Crop Residue Management Scheme, Custom Hiring Centres providing machines like Happy Seeder on rent, Pusa Bio-Decomposer, subsidies have proved to be of little success, as the efforts are fragmented, accessibility of machines is uneven, farmers are constrained by economic barriers and there is absence of viable alternatives of utilizing the crop residue. Government tries to intervene when the burning incidents start, whereas it should have worked around the year trying to solve the issue of farmers and listening to their problems.

Taking inspiration from the best practices around the world to manage crop residue, in the Indian context, the most suitable strategy would be an integrated approach involving subsidies for farmers, participation of private sector and effective laws and regulations. The farmers are aware about the harmful consequences of stubble burning but the sustainable behavioural change in them can only come when they are provided with better alternatives to burning the crop residue. If the crop residue can be a source of extra income for the farmers, why would they burn it.

A farmer-centric policy framework involving all the stakeholders is required instead of focussing on imposing fines and merely adopting policies on paper. In alignment with Sustainable Development Goals, the government needs to develop a circular economy utilizing the waste into asset for renewable energy plants. International efforts are ongoing for promoting carbon-credit markets to reduce Greenhouse Gas emissions, similarly, Indian government must push for expansion of robust carbon-credit market to curb stubble burning incidents. This would reduce environmental pollution and also create economic opportunities for the farmers.

The success of the transition of crop residue from waste to asset will depend upon the ability of policymakers to combine climate-resilient agriculture with economic progress and food security. Hence, this paper suggests a timeline for sustainably managing the crop residue.

8.1 Short-Term Priorities (1–3 Years)

As the issue of stubble burning is seasonal in nature, the government should start preparing for managing the crop residue before the harvesting of paddy starts. Accessibility of machines (Happy Seeder, Super Seeder) and their timely availability must be ensured by strengthening the Custom Hiring Centres. Monitoring of stubble burning incidents through satellite surveillance should be enhanced so that correct number of incidents are reported which will help in formulating the policy for managing crop residue. Farmers must be provided subsidies for crop diversification and managing the stubble. Awareness must be raised among the farmer community regarding the alternatives available to stubble burning. Along with building confidence among farmers, the above measures will also help in reducing the burning incidents.

8.2 Medium-Term Priorities (3–7 Years)

In the medium-term, the strategy will be to develop an enabling environment that adds economic value to crop residue while also reducing instances of crop residue burning. A policy framework at the national level must be framed that will integrate the fragmented efforts of various institutions, state governments and laws and regulations. It must provide for a proper allocation of duties within the institutions, coordination between states and integration of environmental policies with those of agriculture and energy. Private-sector participation can be encouraged by providing tax incentives for setting-up renewable energy plants which would utilize crop residue as raw material.

8.3 Long-Term Priorities (Viksit Bharat@2047)

As we move forward towards the goal of Viksit Bharat @ 2047 (Developed India @ 2047), the focus must be on sustainable development accompanied with economic progress. This vision entails zero occurrences of crop residue burning along with adopting climate resilient agriculture and productive use of crop residue for energy generation. This would not only serve the purpose of environmental protection but would also be beneficial for India in fulfilling its obligations related to sustainability and climate change mitigation.

8.4 Future Outlook

The future is sustainability and for agriculture, climate-resilience is vital considering the changes in soil and consumption patterns. Government should promote crop diversification in addition to implementation of policy for management of crop residue. Agricultural practices must ensure environmental sustainability without harming the interests of farmers. The shift from crop residue burning to energy generation proves that environmental conservation and economic development can co-exist. Ultimately, whether crop residue remains a persistent environmental catastrophe or becomes the catalyst for achieving progressively greener and more resilient future depends on the success of this transition.