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RESEARCH PAPER

A Garrett's Ranking Approach to Identifying Constraints in Sustainable Crop Residue Management in Central Uttar Pradesh

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ABSTRACT

Crop residue burning in the agricultural sector has emerged as a significant environmental and public health concern, contributing to air pollution, climate change, and various health-related issues. This study examines the challenges farmers face in adopting sustainable crop residue management practices (SCRMPs) in the Central region of Uttar Pradesh (U.P.), India, focusing on the districts of Hardoi and Lucknow. The research uses a multi-stage sampling method to collect data from 320 farmers across eight blocks and 32 villages. The study highlights the major constraints in adopting SCRMPs, including labour shortages during peak harvest periods, high labour and machinery costs, unpredictable weather patterns, and inadequate access to modern residue management equipment. Garrett's Ranking Technique was employed to prioritise the constraints based on farmers' perceptions, revealing that labour-related challenges and financial barriers are the most significant. The findings suggest that despite awareness of the negative effects of residue burning, farmers face substantial socio-economic and technical barriers to adopting more sustainable practices. The study calls for policy interventions to improve infrastructure, provide financial incentives, and raise awareness to support the widespread adoption of SCRMPs, thereby mitigating the environmental and health impacts of crop residue burning.

HIGHLIGHTS

- Labor shortages, high costs, and limited equipment hinder sustainable crop residue management in Uttar Pradesh.
- Policy interventions are needed to promote sustainable practices and overcome socio-economic and technical barriers.

Keywords: Crop residue burning, Sustainable crop residue management practices (SCRMPs), Environmental impact, Financial Barriers, Labour Shortage.

In the 21st century, addressing the challenges posed by global issues, whether related to foreign properties or domestic industries, requires the strategic use of farm outputs to ensure food security for a growing global population while mitigating climate change and promoting sustainable farming practices. Crop residue management has emerged as a critical concern at the intersection of agricultural productivity, environmental sustainability, and rural livelihoods. Crop residues, which are the by-products of crops after harvesting, constitute a significant but often underutilised resource. Global estimates suggest that crop residue production amounts to 3.8 billion metric tons annually, with cereals contributing 74% of this total (Bentsen *et al*. 2014). Effective management of crop residues has far-reaching impacts on soil health, water quality,

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and air pollution (Blanco-Canqui ; Lal, 2009). Traditionally, farmers have resorted to burning or incorporating crop residues into the soil, using them as animal feed, or diverting them for off-farm uses. However, the sustainability of these methods is increasingly questioned due to their environmental repercussions and the growing recognition of the potential value that residues hold for sustainable agricultural systems (Erenstein *et al*. 2015).

Crop residue emissions represent a major environmental issue in numerous regions, particularly in countries like China, India, and the United States, which contribute over 50% of all global crop residue emissions. Other top contributors include Brazil, Russia, France, Canada, Argentina, Indonesia, and Germany. Between 1990 and 2020, direct emissions (N_2O) from all crops increased from around 600 kilotonnes to 900 kilotonnes, with one of the primary drivers of this increase being the expansion of agricultural land. Over this period, the global agricultural area expanded by approximately 10%.

Global annual emissions from crop residues are approximately 100,000 metric tons. The three crop types responsible for the highest emissions are wheat (27.6%), maize (corn) (21.2%), and rice (16.7%), which together account for over 65% of total crop residue emissions. Other significant contributors include soybeans (9.7%), barley (6.2%), and sorghum (2.8%), accounting for an additional 18.7% of crop residue emissions. The remaining 16.1% of emissions stem from other crops such as potatoes, oats, and millet. Emissions from crop residues have shown an upward trend, increasing by approximately 10% between 1990 and 2020.

According to (Hiloidhari *et al*. 2014), India produces over 686 million tonnes (Mt) of crop residues each year, with 368 Mt originating from cereal crops. Among these, rice and wheat are the major contributors, generating 154 Mt and 131 Mt, respectively. In India, the primary uses for crop residues are as feed for livestock and as fuel for cooking. In contrast, countries such as China, Indonesia, Thailand, Bangladesh, and Sri Lanka utilize crop residues in various industries, including bioenergy production, organic fertilizers, and paper manufacturing.

In the Indo-Gangetic Plains of India, managing rice residue is particularly challenging due to the widely practised rice-wheat cropping system. The narrow window between rice harvesting and wheat sowing often leads farmers to burn rice residue, as they face difficulties accessing proper residue management machinery and contend with the labour-intensive nature of manual removal (Singh., 2020). India's surplus agricultural waste annually totals an estimated 178 million tons, of which 87 million tons are burned. Rice residue, the major portion of this waste, contributes significantly to the increase in CH_4, N_2O, and CO_2 emissions, exacerbating global warming potential each year.

This study explores the constraints farmers face when adopting crop residue management practices. Proper crop residue management is integral to soil health, environmental conservation, and sustainable farming practices. It aligns with the United Nations' Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land).

MATERIALS AND METHODS

Study Area

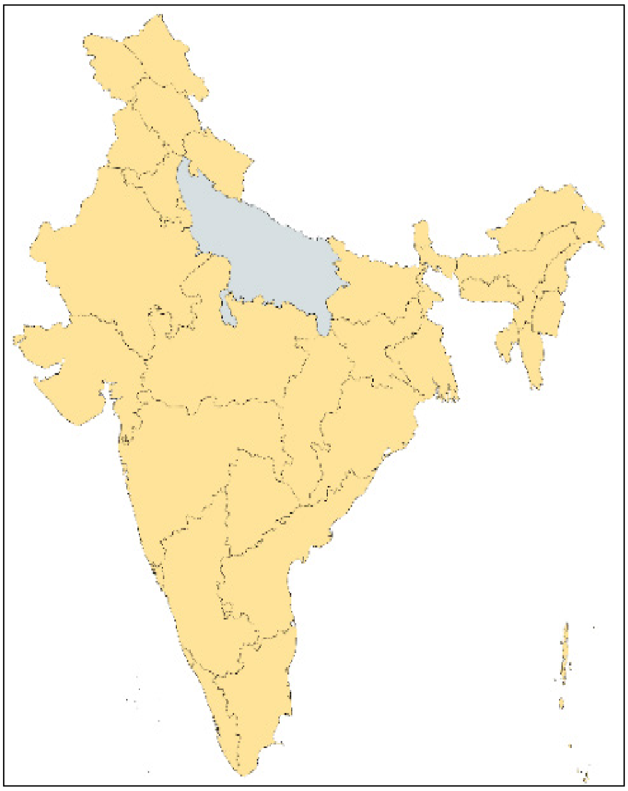

Fig. 1: Location of Uttar Pradesh within India

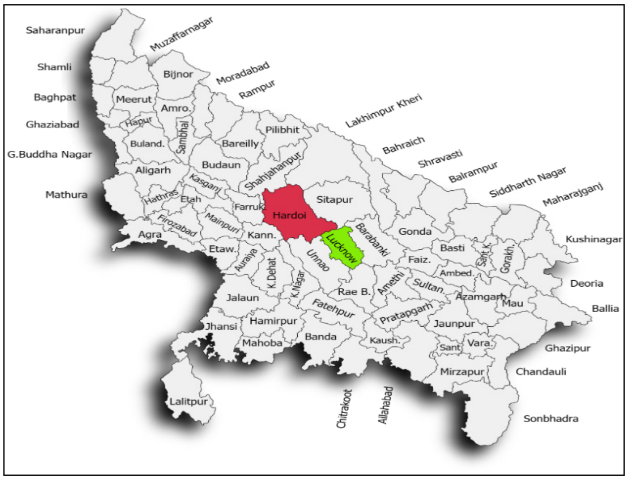

Fig. 2: Detailed map of Uttar Pradesh showing the selected districts of Hardoi and Lucknow

The study focused on the Central region of Uttar Pradesh (U.P.), specifically targeting the districts of Hardoi and Lucknow. Hardoi was selected for its high cereal production. At the same time, Lucknow was chosen for its relatively lower cereal production, offering a contrasting context for the study on Crop Residue Management (CRM) practices. The research aimed to explore farmers' challenges in adopting CRM techniques, considering various agro-climatic and socio-economic conditions in these regions. The study covered eight blocks in total, with four blocks from Hardoi (Sandila, Bilgram, Mallawan, and Pihani) and four from Lucknow (Malihabad, Mohanlalganj, Bakshi Ka Talab, and Kakori). Four villages were randomly chosen from each selected block, resulting in a total of 32 villages (8 villages from each of the 4 blocks). These villages were selected to ensure that the sample represented a broad range of agricultural practices and conditions, critical for understanding the diverse adoption of CRM techniques across the region.

Data Source

Primary data for this study were collected from 320 farmers (10 farmers from each village) through face-to-face interviews using a structured questionnaire. The questionnaire was designed to capture socio-economic, technical, and environmental factors that influence the adoption of CRM practices. In addition, the survey focused on the barriers farmers face in adopting these practices, such as financial constraints, social constraints, and technical difficulties. The methodology used a multi-stage sampling technique to ensure that the sample represented the diversity of the agricultural landscape in both districts. The first stage involved selecting the districts (Hardoi and Lucknow) and randomly selecting blocks, villages, and farmers. Data collection took place over several months, ensuring a comprehensive representation of the farmers' perspectives and experiences regarding CRM.

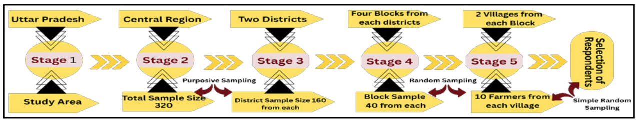

Fig. 3: Sampling Strategy

Data Analysis

Once data was collected, the responses were analysed using Garrett's Ranking Technique. This method helped prioritise the constraints based on the farmers' perceptions, allowing an in-depth understanding of the most significant barriers to adopting CRM practices. The study's findings provide valuable insights into the socio-economic and technical challenges that affect the adoption of CRM practices in the Central U.P. region, with implications for policy-makers and agricultural extension services to enhance the effectiveness of CRM strategies.

Garrett's Ranking Technique

Garrett's Ranking Technique was employed to prioritise the constraints faced by farmers in adopting Crop Residue Management (CRM) practices. The assigned rank was converted into the respective percentage position, which was subsequently transferred into Garrett's score using Garrett's table.

For each constraint, the individual respondent scores were aggregated, and the mean score for each constraint was calculated using the following formula:

$$Percent\ position = 100*(R_{ij} - 0.5)/N_j$$

Where R_{ij} = rank given for i^{th} constraint by j^{th} individual

N_j = Number of constraints ranked by a j^{th} individual.

These percent positions were then converted into points using Garrett's Table (Garrett & Woodworth, 1969) (Table 1). After converting the rankings to points, the mean score for each constraint was computed by adding these points for all respondents and dividing by the total number of respondents. The constraints were then ranked in descending order based on their mean scores, with higher mean scores indicating greater importance. This ranking approach allowed the study to prioritise the barriers to CRM adoption according to their relevance, ensuring a comprehensive understanding of the constraints.

Table 1: Conversion of Percent Position to Garrett's Score

Rank	Percent Position (%)	Garrett's Score
1	100 × (1 - 0.5) / 5 = 10	82
2	100 × (2 - 0.5) / 5 = 30	66
3	100 × (3 - 0.5) / 5 = 50	57
4	100 × (4 - 0.5) / 5 = 70	50
5	100 × (5 - 0.5) / 5 = 90	42

RESULTS AND DISCUSSION

The top five constraints highlighted in Table 2 are the most pressing challenges faced in crop residue management, primarily centred around labour shortages, high costs, and environmental factors. Labour shortages during peak harvest time (Rank I) emerged as the most significant barrier, severely hindering residue management, especially when timeliness is crucial. The scarcity of labour during peak periods leads to delays in residue handling, leaving farmers with limited options for disposal. High labour costs (Rank II) compound this issue, making it financially unfeasible for many farmers to hire the required workforce for residue management tasks. In addition, expensive labour during harvest periods (Rank III) further inflates operational costs, creating a financial strain on smallholder farmers. The persistent issue of unpredictable weather (Rank IV) adds another layer of complexity, as increasingly erratic weather patterns disrupt the timely management and decomposition of crop residues. Finally, the high costs of acquiring modern machinery (Rank V) remain a critical financial barrier. Many resource-constrained farmers cannot invest in technologies like Happy Seeders, making implementing efficient and sustainable residue management practices difficult. Similar results were found by Lin and Begho (2022), *Rani et al.* (2023), Kadango *et al*. (2023), Pradhan *et al.* (2024), and Sharma *et al*. (2021), who all highlighted labour unavailability, financial constraints, environmental unpredictability, and technological inaccessibility as key impediments to sustainable crop residue management.

Following the top five constraints, several other factors also significantly limit effective residue management. Conflict with other agricultural tasks (Rank VI) restricts the availability of labour for residue management. Farmers are often forced to prioritise other time-sensitive tasks, such as planting and harvesting, over residue management, further straining available resources. Resistance to change due to traditional farming methods (Rank VII) remains a significant cultural barrier, as many farmers continue to rely on conventional practices like residue burning, which are deeply ingrained in their routines. Limited access to modern residue management equipment (Rank VIII) remains a key technical constraint, with many farmers unable to afford or access the advanced tools needed for efficient residue handling. Similarly, poor soil fertility (Rank IX) limits the potential for effective residue incorporation into the soil, preventing the benefits of organic matter in improving soil health. The lack of effective residue-burning alternatives (Rank X) drives farmers toward harmful burning practices, as they lack viable alternatives for residue disposal. Climate variability (Rank XI) further complicates residue management, disrupting the natural decomposition of crop residues and often reducing the effectiveness of in-situ management practices. High maintenance and operational costs for equipment (Rank XII) discourage farmers from investing in modern machinery, particularly smallholders with limited capital. In addition, the limited availability of bio-decomposers or microbial agents (Rank XIII) curbs the adoption of biological methods for faster and eco-friendly decomposition of residues. The lack of adequate government support and weak policy enforcement (Rank XIV) highlights a major institutional gap, as farmers are neither incentivized nor adequately guided toward sustainable residue management solutions. High transportation and storage costs of residues (Rank XV) pose serious logistical challenges,

Table 2: Constraints faced by farmers in adopting CRM practices

Sl. No.	Constraints	Hardoi		Lucknow		Overall Rank
		Garrett Mean Score	Rank	Garrett Mean Score	Rank	
1. Technical Constraints						
1	Limited access to modern residue management equipment	83.03	I	79.06	I	VIII
2	Outdated machinery causes frequent breakdowns	66.01	IV	72.08	IV	XX
3	Lack of effective residue-burning alternatives	73.05	III	78.03	II	X
4	Inadequate infrastructure for residue collection and processing	61.04	V	74.09	III	XXIII
5	Limited availability of bio-decomposers or microbial agents	82.01	II	66.03	V	XIII
2. Financial Constraints						
6	High costs of acquiring modern machinery	83.09	II	90.09	II	V
7	High costs for transportation and storage of residues	63.02	IV	84.05	III	XV
8	High maintenance and operational costs for equipment	72.03	III	76.07	IV	XII
9	Expensive labor costs during harvest periods	96.02	I	92.06	I	III
10	Delayed or insufficient government subsidies	50.05	V	60.08	V	XXIX
3. Social and Cultural Constraints						
11	Cultural practices favor residue burning over management	72.04	II	65.06	V	XXI
12	Social norms and peer influence hinder the adoption of new practices	64.05	III	72.03	III	XXII
13	Limited awareness of residue management benefits	61.02	IV	78.04	II	XIX
14	Resistance to change due to traditional farming methods	80.06	I	84.08	I	VII
15	Insufficient agricultural extension services	47.01	V	70.07	IV	XXVIII
4. Environmental Constraints						
16	Unpredictable weather affects residue management timing	84.05	I	91.09	I	IV
17	Poor soil fertility limits effective residue incorporation	74.07	II	70.05	V	IX
18	Water scarcity affects composting and residue management	60.08	IV	83.05	II	XVI
19	Improper residue management increases pest and disease pressure	58.09	V	74.04	IV	XXV
20	Climate variability disrupts residue decomposition	72.09	III	78.02	III	XI
5. Labor Constraints						
21	Labor shortages during peak harvest time	96.09	I	93.07	II	I
22	High labor costs hinder residue management	92.07	II	96.02	I	II
23	Lack of skilled labor for machinery operation	65.03	IV	78.08	IV	XVII
24	Conflict with other agricultural tasks limits labor availability	82.06	III	89.05	III	VI
25	Skilled labor for specialized tasks is scarce	59.05	V	73.06	V	XXVI
6. Institutional and Policy Constraints						
26	Limited government support and weak policy enforcement	66.09	I	81.09	II	XIV
27	Ineffective enforcement of residue burning regulations	46.07	II	88.09	I	XXIV
28	Unclear policies on residue management create confusion	70.08	III	72.09	III	XVIII
29	Limited extension services to guide residue management	50.06	IV	68.03	IV	XXVII
30	Farmers lack representation in policy-making on residue management	17.02	V	22.08	V	XXX

Source: Authors.

especially for marginal farmers who lack access to infrastructure or aggregation support. Water scarcity (Rank XVI) affects composting processes and limits the effectiveness of decomposition techniques that require moisture, such as bio-decomposition. Lack of skilled labor for machinery operation (Rank XVII) further hinders the adoption of mechanized solutions, with many farmers dependent on untrained labor or hesitant to use the equipment themselves. Unclear policies on residue management (Rank XVIII) also contribute to confusion and non-compliance, as farmers receive mixed signals on what is permitted and supported. Limited awareness of residue management benefits (Rank XIX) reflects an information gap, wherein farmers are either unaware or unconvinced of the long-term benefits of sustainable practices. Outdated machinery and frequent breakdowns (Rank XX) represent another technical bottleneck, making even those with equipment reluctant to use it regularly due to performance issues. Cultural practices (XXI) favour residue burning, while social norms (XXII) and peer influence discourage adopting new methods. Limited extension services (XXIII) reduce guidance on effective residue management, and ineffective regulation enforcement (XXIV) undermines efforts to curb burning. Finally, the lack of farmer representation in policy-making (XXV) further limits the development of tailored solutions for residue management. Similar results were found by (Mungai *et al*. 2016), who reported that traditional practices, lack of tools, and poor soil fertility inhibit residue reuse; (Bechini *et al*. 2015), who identified policy gaps, labour constraints and unclear incentives as barriers to adoption; (Saral; Kukreja, 2020), who emphasised logistical and technical bottlenecks like transportation, outdated machinery, and cost; and (Divyabharathi *et al*. 2024) and (Kumar *et al*. 2023), who highlighted that climate variability, bio-decomposer unavailability, low awareness, and inadequate support systems critically undermine sustainable residue management efforts.

While ranked lower, the remaining constraints still present significant barriers to effective residue management. Water scarcity (Rank XVI) poses a major environmental challenge, particularly in areas where water is already in short supply. This issue affects composting processes and limits residue decomposition, further complicating residue management. Lack of skilled labour for machinery operation (Rank XVII) is another critical technical barrier, as advanced machinery requires trained personnel, and many farmers lack the resources to hire skilled workers or invest in training programs. Unclear policies on residue management (Rank XVIII) confuse farmers, leading to inconsistent application of residue management practices across regions. This lack of clarity further discourages farmers from adopting sustainable practices. Limited awareness of residue management benefits (Rank XIX) is a significant social constraint. Farmers may not fully understand the long-term advantages of sustainable residue management, such as improved soil health and reduced environmental impact. Finally, outdated machinery causing frequent breakdowns (Rank XX) continues to hinder progress. Many farmers rely on old equipment that frequently breaks down, resulting in inefficiencies and a greater reliance on manual labour, leading to further delays and increased costs. Similar findings have been noted by other studies, such as those by (Ramulu *et al*. 2018), (Saral ; Kukreja, 2020), and (Krishna; Mkondiwa., 2023).

CONCLUSION

This study provides a comprehensive analysis of the constraints farmers face when adopting sustainable crop residue management practices (SCRMPs) in the Central region of Uttar Pradesh, India. The findings indicate that labour-related issues, particularly shortages during peak harvest periods and high labour and machinery costs, are the most pressing barriers to adopting SCRMPs. In addition, unpredictable weather patterns, limited access to modern residue management equipment, and inadequate infrastructure further complicate the transition to more sustainable practices. These barriers highlight the need for a multifaceted approach to promote SCRMPs, including improved access to affordable technology, increased financial support, and enhanced farmer training.

The study also underscores the importance of addressing socio-cultural factors such as resistance to change due to traditional farming methods and insufficient awareness of the long-term benefits of residue management. Efforts to improve government support, strengthen policy enforcement, and develop clear guidelines for residue management are crucial to overcoming these challenges. Given the environmental and public health risks associated with crop residue burning, promoting sustainable practices is critical for achieving long-term agricultural sustainability, improving soil health, and mitigating climate change. In conclusion, this study emphasises the need for policy interventions that integrate technical, financial, and social support systems to facilitate the adoption of SCRMPs in Uttar Pradesh. These efforts will not only address the immediate challenges faced by farmers. However, they will also contribute to the broader goal of sustainable agricultural development, aligning with global environmental and health objectives.

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