Assessing bottlenecks in the rice straw value chains in Punjab

Abstract

The sustainable management of rice straw and the efficient cultivation of wheat crops are integral components of agricultural practices in the Punjab region, where rice and wheat are staple crops. However, the management of rice straw remains a persistent challenge, it is estimated that about 20 million tonnes of rice straw left in the field after the combine harvesting. As wheat straw is preferred for dry fodder or *Bhusa* for feeding the animals. The farmers of Punjab do not find a ready economic use of rice straw. The traditional practice of open-field burning of rice straw due to time constraints, adversely affects air quality, soil health, and ecosystem sustainability. Various methods have been employed to address the straw management issue, including rice straw incorporation, mulching, baling and partial burning. Different machines are available for timely management of rice straw includes Super SMS, Happy seeder, Paddy straw Chopper/mulcher, Hydraulic Reversible MB plough, Rotary slasher, Zero Tillage drill and Rotavator, Rotary till-drill, Strip till seeder, Straw baler. However, their adoption remains inconsistent across the region. Understanding the bottlenecks and constraints associated with these methods is essential for devising effective solutions. Therefore, a farmers survey was conducted in this study to find out the major constrains to adopt these technologies. It was found that the soil type, rice variety, weather condition, limited financial resources and awareness are the major driven reason for the low adoptability of the technology. Assessing the economic viability of these technologies is vital for informed decision-making by farmers and policymakers. The economics of wheat crop sowing using happy seeder was found to be the cheapest (costing 1300 Rs/acre) among all the tested methods. This research aims to provide valuable insights into sustainable agricultural practices in Punjab, fostering a transition toward more environmentally friendly and economically viable straw management and rice wheat cultivation strategies.

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Keywords: Straw Management, Machines, Constrains, Rice Wheat, Economic

Introduction

The sustainable management of rice straw and the efficient cultivation of wheat crops are integral components of agricultural practice. In the Punjab region, where rice and wheat are

staple crops, about 20 million tonnes of rice straw per annum left in the field after the combine harvesting (Singh *et al.* 2020; Singh *et al.* 2023). Due to highly mechanised system, a huge chunk of straw is left over the combine harvested field. After combine harvesting, usually a considerable amount of loose straw along with standing stubble are left in the field (Sidhu *et al.* 2007). These trail of loose residues and standing stubbles interfere with the land preparation and seeding of the wheat crop. For wheat crop, straw combines are the mechanical option available and normally used after combine harvesting of wheat for cutting, bruising and blowing the wheat straw as *bhusa* into the trailer. However, the management of rice straw remains a persistent challenge to the farmers because farmers does not find a ready economic use of rice straw, whereas wheat straw is preferred for dry fodder or *Bhusa.* Hence, most of wheat straw is utilized but rice straw is not preferred as animal fodder because high silica content (Thakur *et al.* 2018). The rice straw needs to clear the field to allow for wheat sowing within 2-3 weeks of rice harvest. This has led farmers to resort to open burning of rice straw in the field (Parihar *et al.* 2023).

Burning rice straw in field is quick and cheap option for the farmers. Therefore, it is a common and cost-effective practice for farmers in Punjab. About 80% of rice straw is burnt by the farmers in the field (Roy *et al.* 2018). In the Indo-Gangetic Plains (IGP) of India, rice-wheat is the predominant cropping system where 80% of rice and 48% wheat is straw produced is born and only 7% of rice and 45% of wheat is straw is used as fodder (Singh *et al*. 2023). Open air burning of the high moisture rice residue in a short span of time causes both health and environmental hazards. Moreover, burning of rice residues also compromises soil health by adversely impacting the beneficial micro-flora and fauna (Mehta *et al.* 2013). For highly fertile agricultural region with little soil nutrient cycling contributing 85% of the grain produce for national food security needs, nothing could be worse than losing organic carbon and nutrients from the residue as well (Dahal *et al.* 2016).

Presently, to sow wheat in the field with retained rice residue, multiple tillage operations (2-3 times harrow/tiller, or rotavator and planker) are carried out, resulting in higher cost of cultivation and delay in the sowing (Pandey 2020). When conventional seed drills are used for direct drilling of wheat, they do not perform as desired. There are different machineries available for direct sowing of the wheat in the rice residue ridden field. These machines include Super SMS, Happy Seeder (HS), Rice Straw Chopper/Mulcher, Hydraulic Reversible MB plough, Rotary Slasher, Zero Till Drill (ZT) and Rotavator, Rotary Till-Drill with DTFO (disc type furrow openers), Strip Till Seeder, Straw Baler, MB plough. However, their adoption remains inconsistent across the region (Thakur *et al.* 2018).

To understand the bottlenecks and constraints associated with these methods it is essential to devise effective solutions. Therefore, a farmer's survey was conducted it to find out the major constrains in adoption of these technologies. Moreover, the economic viability of these technologies is vital for informed decision-making by farmers and policymakers. Assessing the economic viability of these technologies is vital for informed decision-making by farmers and policymakers.

1. Methodology and Data Collection for Assessing Bottlenecks

Study area

A survey to understand farmers' adoption of straw management by different methods like use of Happy Seeder, Super Seeder, Mulcher, Baler and other no-burn technologies in five blocks, including two villages in each block. In each selected village, 8-12 farmers were identified under coarse (non-basmati) rice varieties during the rabi season of 2022. All data were collected from farmers through structured interviews.

Data collection

Data collected were stratified into four wheat establishment methods (burning of rice stubble residues and conventional sowing of wheat, burning of rice stubble residues and zero till sowing of wheat, incorporation of rice stubble residues and conventional sowing of wheat, and partial/complete burning of residue and super seeder sowing of wheat) after rice harvest. Data collected from the farmer surveys include a range of household characteristics, farm and plot level information, adoption of HS, ZT, credit access, decision making influencers, household head's attitudes and beliefs, etc.

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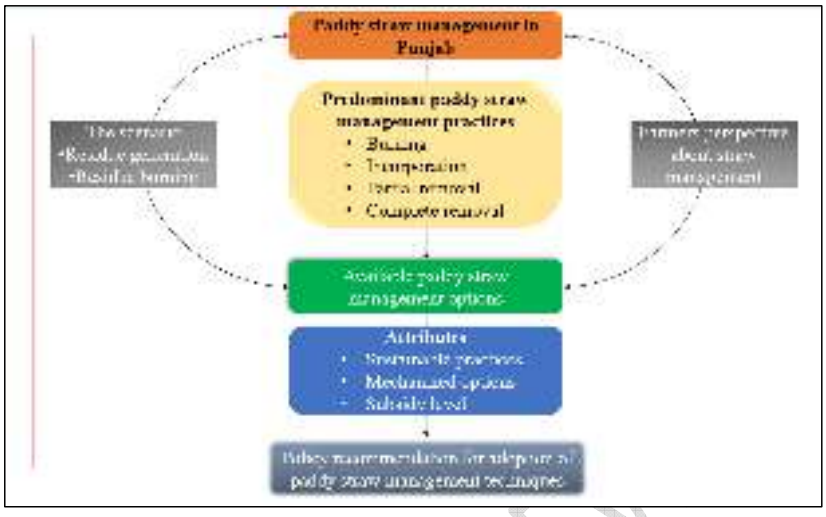

Fig 1 Analytical Framework for Bottleneck Identification

2. Prevalent methods of the straw management in the area

The highly mechanized rice-wheat cropping system prevalent in Northern India leads to a huge amount of straw left over in the field after harvesting. Moreover, due to the short window between rice harvesting and wheat sowing, and a lack of adequate management tools, farmers opt burning as a convenient disposal method of the rice straw (Parihar *et al.* 2023).

Farmers generally rely on various techniques for straw management, which include using straw as cattle bedding, animal fodder, thatching for rural home roofs, soil mulching, straw incorporation and fuel for domestic and industrial use. It is important to note that wheat straw may be utilized to feed domestic animals and does not require any specific disposal stratagy, while rice straw is a poor feed for livestock due to its high silica content and requires various management/disposal methods (Thakur *et al.* 2018). However, the limited period between rice harvesting and wheat sowing usually hampers the proper implementation of the straw disposal strategies.

Rice straw burning is most common in combine-harvested fields because loose straw and standing stubbles (25–30 cm height) remain in the field after the operation of the harvester. Burning of straw is assumed to be a simple, inexpensive, and speedy technique for residue management, which is regularly adopted by farmers to clear the field for the sowing of next crop (Singh *et al.* 2014). The common straw management practice performed in Punjab are given below.

Complete burning

Complete burning is a prevalent straw management practice in Punjab, India, where entire fields are set ablaze after harvest to swiftly dispose of crop residues. While this method offers a quick solution to residue removal and mitigates the risk of pest and disease carry-over to the next crop, it entails significant drawbacks. The process releases greenhouse gases like carbon dioxide and methane, contributing to air pollution and global warming climate change (Gadde *et al.* 2009). Moreover, it leads to a depletion of organic matter in the soil, negatively impacting soil health, and poses risks to human health due to the release of harmful particulate matter and other pollutants.

Fig. 2 Complete burning of rice straw

Partial burning

Another option that is popular among the farmer is partial burning of rice straw, which involves only burning loose straw anchored on the standing stubbles. Because loose straw interferes with the wheat sowing operation of seed drill, farmers manage this problem by partially burning straw, with only standing stubbles remaining on the field. After partial burning farmers operate their conventional seed drill or zero till drill to sow the wheat crop. In their perception, partial burning helps to manage the residue timely but also kills the pathogenic insects, pest and weeds of the previous crop.

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Fig. 3 Partial burning of rice straw (Source: Das 2023)

Mulching

Mulching is a sustainable alternative to burning, where chopped or shredded rice residues are spread across the soil surface as a protective covering. This practice offers a range of benefits, including the conservation of soil moisture, moderation of soil temperature, and prevention of erosion. Mulching acts as a physical barrier against wind and water, benefiting both soil health and crop growth (Parihar *et al.* 2022). However, efficient mulching may necessitate specialized equipments (Super SMS, Mulcher and Stubble Shaver) and it may not entirely eliminate challenges like weed growth and disease carry-over. After mulching the straw in the field, various sowing methods can be employed for wheat sowing, including the Happy Seeder, conventional Seed cum Fertilizer Drill, Spatial Seed Drill, and Zero Till Drill.

Fig. 4 Mulching of rice straw

Incorporation

Incorporation entails the mechanical mixing of crop residues into the soil using tillage equipment. This practice enhances soil structure and fertility by increasing the organic matter content in the soil. It promotes vital processes like nutrient cycling and microbial activity, reducing the reliance on external inputs such as fertilizers. However, straw incorporation may demand specialized machinery and additional labour. Mould Board plough, Rotavator, Roto Till Drill, and Super Seeder are generally used for the incorporation of the rice straw in the field. Intensive energy requirement is one of the major drawbacks of the incorporation method of straw management.

Fig. 5 Incorporation of rice straw

Baling

Baling is a method where rice residues are collected, compressed, and tied into compact bundles for easier handling and transport. This practice not only provides an additional source of income for farmers through the sale of straw but also offers an efficient means of storage and transportation.

Fig. 6 Baling of rice straw

The choice of straw management practices to a particular farmer takes into account different factors such as farm size, available resources, equipment, and environmental considerations.

3. Findings and Analysis: Key Bottlenecks in the Rice Straw Value Chains

Farmers of different areas were asked about the different practices for rice straw management in selected districts many farmers incorporated the straw in the farms. Other management practices used were mulching, baling, partial burning and complete burning.

Mansa:

Diverse and compelling patterns emerge in straw management before sowing wheat. Around 50% of farmers adhere to the tradition of complete rice straw burning, a common practice in Punjab. Concurrently, 5% farmers adopt the more advanced and efficient approach of utilizing a baler for rice straw removal. The remaining 10% of farmers strike a balance by opting for a partial burn, demonstrating consideration of both tradition and scientific practice in their wheat sowing. The investigation in Buchhaona villege, situated in Block Budladha of Mansa district revealed a distinct pattern in wheat sowing practices in the region. As demonstrated in Figure 7, a substantial 32% of the surveyed farmers persisted in use of Seed cum Fertilizer Drill for wheat crop sowing. Meanwhile, a similar 19% have adopted the Zero Till Drill and 25 % farmers used Super Seeder for wheat sowing. Furthermore, 12 %, 7 % and 5 % opt for the Roto Till Drill, Happy Seeder and Baler respectively.

Barnala:

In the investigation, came to know that different practices for rice straw management were performed in village Sekha of Barnala district. A significant number of farmers are still adherence to traditional rice straw management methods. Notably, 80% of surveyed farmers used to follow rice straw burning because they found it as a cheap and quick straw management option (Singh *et al.* 2020). In contrast, 18 % of farmers opted for partial burning, indicating a awareness regarding the environment and soil. Figure 7 presents a discerning insight into the techniques employed for wheat crop sowing in Sekha village. Evidently, 31 % of farmers opt for the utilization of Super Seeder, demonstrating a conservation agriculture approach. In parallel, 28% elect to employ the traditional Seed cum Fertilizers Drill. On the other hand, 14%, 13% and 12 % of the farmers embrace the Zero Till Drill, Happy Seeder and Roto Till Drill respectively for the wheat crop establishment. Interestingly, only 2% of farmers uphold the balers for straw removal from the field.

Shri Muktsar Sahib:

The Butter Barkha village, situated within Gidderbaha block of Shri Muktsar Sahib district, predicting a diversified agricultural approximately 3318 acre area, include as at 1200 acres under and rice encompassing 1500 acres under rice. Significantly, 425 acres area has been sown by Happy Seeder additional, and an additional baler is used for the removal of the loose straw from 550 acres. In the region Happy Seeder, conventional Seed cum Fertilizer Drill and Roto Till Drill is popular among the farmers. Happy Seeder shares around 32% of the total sown area which is followed by Seed cum Fertilizer Drill (22%), Roto Till Drill

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(15%), Super Seeder (13%) and Zero Till Drill (10%). Whereas only 8% of the farmers use the Baler for removing straw prior sowing of the wheat (Fig. 7).

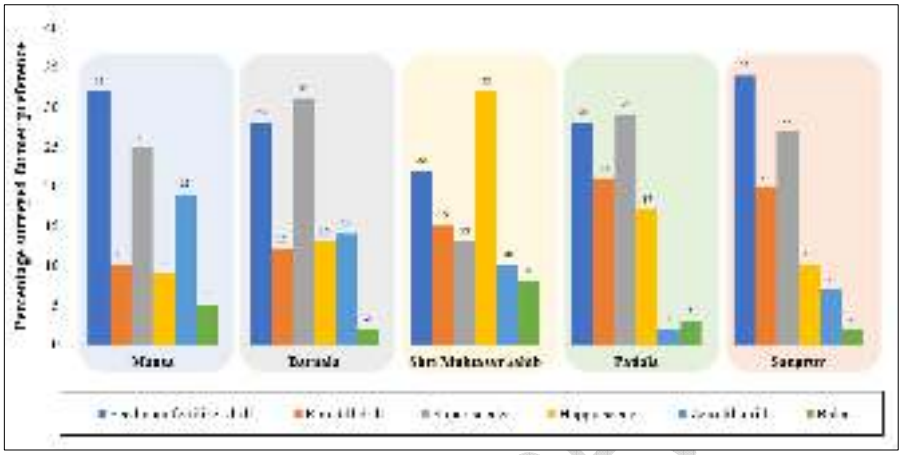

Fig. 7: Different machinery adopted for wheat sowing in different district of Punjab

Patiala:

In the Malikpur village, of Patiala district, a comprehensive insight was observed for different rice straw management practices. The findings are delineated in Figure 7, providing a quantitative representation of these practices. Remarkably, a significant majority of farmers, constituting (29 %), opt for the super seeder for sowing of wheat crops. Followed by, 20% of farmers using Seed cum Fertilizer Drill, and 21% farmers adopting Roto Till Drill, demonstrating a discerning inclination towards conservation agriculture practices. Among the farmers utilizing the Super Seeder and Roto Till Drill, a prevalent practice involves the burning of loose straw. However, 30% farmers are engaged in the incorporation of rice straw in soil, while 3-5%, opt for straw removal using Baler. A notable 40% of farmer choose to complete burning of rice straw, marking a distinctive divergence in rice straw management approaches.

Sangrur:

A comprehensive overview of the straw management practices employed by farmers in Bir Kalan village, situated within the Sunam block of Sangrur district is presented in Fig 7. The study specifically focuses on the methods utilized for sowing wheat crops. The Seed cum Fertilizer Drill emerges as the predominant choice among farmers, commanding a significant 34 % adoption rate for wheat sowing. The super seeder is embraced by 27% of farmers, indicating to its popularity as an alternative technology for rice straw incorporation.

Additionally, 20% of farmers opt for the Roto Till Drill, while a 10% and 7 % employs the Happy Seeder and Zero Till Drill technology, respectively.

Ludhiana:

In the Ludhiana district, a diverse practice is employed by farmers for rice straw management. The findings (Figure 8), revealed that 38-40% of farmers opt for the practice of straw incorporation in soil, employing implements such as mulcher, rotavator and disc harrow. This method serves as an effective means of returning organic matter to the soil, enriching its fertility and structure (Kumar *et al.* 2023). A significant number of farmer, (10-13%), use straw as cattle feed, showcasing a resourceful approach to livestock management. Additionally, 19-23% of farmers choose to convert straw into bales, thus contributing to fodder preservation and storage. Another 8-10% farmersemploy straw as mulch in wheat crop, a practice recognized for its efficacy in moisture conservation and weed suppression. However, 20-24% of farmers, still resort to complete straw burning. While this method offers quick means of straw disposal, it raises ecological concerns due to associated emissions and depletion of soil organic matter (Bhavaneshwari *et al.* 2019).

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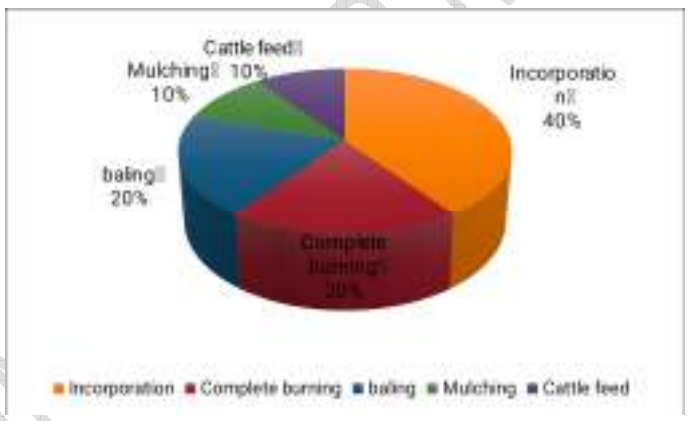

Fig. 8: Adoption of rice straw management in Ludhiana

Economics of wheat crop establishment in rice straw fields:

The economics of wheat crop establishment in rice straw fields in Punjab holds significant importance due to several interrelated factors. However, there are several machineries available for direct wheat sowing in the rice residue field which include Happy Seeder, Super Seeder, Zero Till Drill, Roto Till Drill and Smart Seeder. The economics of these machine may vary according to availability in the region as well as time available for the wheat sowing (Jat *et al.* 2016). Fig. 9 shows the different options of wheat sowing by rice

straw management. The combine harvester charges for the harvesting rice with Super SMS combine were Rs 500 more than the combine harvester without super SMS. The function of Super SMS is that the rice straw coming at the back of combine is chopped and spread in the field which is a pre-requisite for Happy Seeder, Super Seeder and Chopper. The most economical method of sowing with Happy Seeder was costed Rs. 1300/- per acre. The straw incorporation in soil (dry mixing) costs around Rs. 5100/- per acre, because it includes one pass of MB plough to bury the crop residue in the soil, then mixing it with 2-3 passes of disc harrow and rotavator for fine seedbed preparation. To conduct this long series of event it takes around 10-15 days' therefore, can be achieved with short duration of rice varieties.

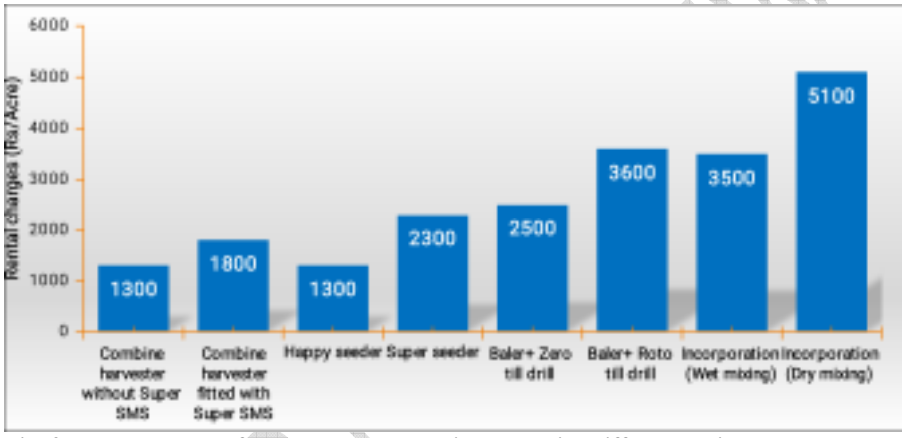

Fig. 9: Rental charges for wheat crop establishment with different residue management option

Identified bottlenecks

These findings underscore the diversity and adaptability of rice straw management practices in the selected district of Punjab. The prevalence of the Seed cum Fertilizer Drill reflects its widespread acceptance and efficacy in the rice-wheat cropping system. Meanwhile, the emergence of alternative technologies such as the Super Seeder, Zero Till Drill, and Happy Seeder point towards a dynamic agricultural ecosystem responsive to evolving technological advancements.

Farmers in Punjab face several significant hindrances in the adoption of scientifically proven straw management practices. Labour shortage is a pressing concern, with many farmers expressing anxiety over the lack of available labour to effectively execute these techniques. Economic constraints also play a pivotal role, as the high initial costs associated with advanced straw management practices act as a deterrent for many. Additionally, a

limited window of time between rice harvest and wheat sowing is a critical bottleneck, leaving farmers with little room for adopting time-intensive straw management practices. The region's highly mechanized farming system is another challenge, with existing machinery often incompatible with modern straw management techniques, necessitating additional investments. Finally, a considerable percentage of respondents emphasized the lack of awareness about scientifically proven straw management practices, indicating a pressing need for educational outreach and knowledge dissemination in this regard.

Policy Recommendations and Interventions

There are a few key issues, recommendations, lessons learned and follow-up actions identified. A range of opportunities for accelerating the adoption of straw management technologies are listed as-

1. Overcapitalization in the farming sector is a serious problem in Punjab. All agencies should encourage and promote rice straw management machinery usage through cooperatives or custom hiring to avoid indebtedness in the farming sector.
2. Majority of the farmers surveyed are aware of the problem and have taken significant steps to stop stubble burning. However, awareness strategy includes innovative digital media approaches that support the adoption of rice straw management machinery should be developed and implemented as a long-term opportunity to create positive motivation for on-farm adoption.
3. The environmental, agronomic and economic benefits of these approaches need to be highlighted, in addition to addressing common farmer misconceptions that a well cultivated soil (often using a rotavator) free of stubbles and plant residues leads to higher crop yields.
4. Farmers need to be technically equipped to adopt the recommended practices. They need to be trained on the machine operation and maintenance, besides changes required in agronomical practices.
5. Villages adoption program under Corporate Social Responsibility (CSR) be promoted so that impact of the village development will be better in curbing the problem of rice straw burning. The coordination between village and different departments in the village to be increased so that the schemes available for the villages and farmers be properly implemented.

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6. The existing farm machinery apps for hire in and hire out to be popularized among the farmers and CHC, so that machinery be optimally utilized and made available to the farmers.

Conclusion

In conclusion, our comprehensive survey across selected villages in Mansa, Sangrur, Patiala, Sri Muktsar Sahib, Ludhiana, and Barnala districts of Punjab sheds light on the prevailing straw management and wheat crop establishment practices in the region. The findings reveal a discernible trend towards the adoption of modern straw management machinery, including the Super Seeder, Happy Seeder, SMS, and Zero Till Drill. This signifies a positive stride towards more sustainable and efficient agricultural practices. However, it remains a concern that a significant proportion of farmers still resort to the traditional practice of burning rice straw in the fields. The reason for the less adoption of these technologies are different, such as labour shortages, high initial costs, short window periods, mechanization issues, cheap and quick way and limited awareness towards benefits of straw management. Therefore, it is imperative to further promote and facilitate the adoption of advanced straw management techniques to mitigate environmental impact and enhance overall agricultural productivity. Additionally, targeted awareness and education programs could play a pivotal role in fostering sustainable practices among the farming community. This study provides a valuable foundation for informed policy-making and interventions aimed at promoting sustainable agriculture in the region.

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