CEEW
THE COUNCIL

Why Paddy Stubble Continues to be Burnt in Punjab?

Meeting Challenges with Solutions

L. S. Kurinji and Srish Prakash

Issue Brief | October 2021

Image: Niti Gupta/CEEW

Overview

Millions of people living in the Indo-Gangetic Plains (IGP) bear the brunt of the decades-old stubble burning practice[1] in Punjab, which jeopardises their health in multiple ways. The economic and health impacts of this practice has led to the formulation of an array of policy measures targeted at reducing crop residue burning (Balakrishnan et al. 2020). These policies range from subsidising crop residue management (CRM) machines to incentivising small farmers who do not burn to an outright ban on crop residue burning (MoAFW 2018; Rambani 2019; PTI 2019). Despite efforts for several years by various arms of the government, the farm fires have spiked in 2020, as residue burning was reported from more than 50 per cent of the area sown under paddy (CREAMS 2020). Therefore, this issue poses a serious concern.

With yet another stubble burning season not very far away, we reflect on the state's residue generation and preparedness for managing residue from paddy

1. We use stubble burning and crop residue burning synonymously.

in the upcoming season. To gain an understanding of the scenario, we interviewed a host of stakeholders across 17 districts in Punjab and gathered insights on the accessibility and affordability of crop residue management solutions and farmers' preferences for the available solutions. Besides generating primary data from stakeholders, we used secondary data from government reports, parliamentary questions, and newspaper articles to assess the implication of changes in the notified date of sowing, the area under paddy, the number of in-situ CRM machines, and ex-situ utilisation capacity.

Key findings

Area under paddy continues to dominate the Kharif crop mix, leading to enormous paddy residue generation

Despite Punjab government's efforts to diversify the Kharif crop mix, paddy remains the dominant Kharif crop in the state (ESOPB 2020). This year, the state's area under paddy was 30.66 lakh hectares, declining marginally by 2.63 per cent from 2020 (31.49 lakh hectares). In addition, despite a gradual decline over the last five years, the late-maturing high-profit PUSA 44 variety of paddy remains the dominant seed variety (Nibber 2020, 2021a). Further, this year's notified date of paddy transplantation was the 10th of June (*The Tribune* 2021a). This should theoretically provide farmers with ample time to manage the residue. However, the same was true last year (transplantation date was 13th June), and yet the number of fire events in 2020 was the highest in the last four years (Joshi 2021; PRSC 2021).

Teething problems with in-situ crop residue management remain

Despite an increase in the number of in-situ crop residue management (CRM) farm implements deployed, their adoption remains limited. According to government records, by 2020, 76,626 CRM machines were deployed in Punjab, which includes 13,316 Happy Seeders and 17,697 Super Seeders. Sangrur district has the maximum number of Happy and Super Seeders, followed by Muktsar, Bathinda, and Mansa.

The state though is still short of CRM machines to cater to the large area under paddy (*Hindustan Times* 2021a). The current penetration of these machines in a few high-burn districts such as Amritsar, Patiala, and Ludhiana is far below the ideal requirement and therefore needs to be scaled up significantly. The existing stock, if deployed at full capacity, is estimated to cover only 17 lakh hectares in Punjab, which corresponds to 66 per cent of area sown under non-basmati variety in 2021. In addition, a majority of these machines remain underutilised. Farmers' misperceptions of the impact of the Happy Seeder on the productivity of wheat sown using this machine is a cause of its low popularity. The custom hiring centre (CHC) system, which was meant to improve access to these machines, has not achieved the expected rates of adoption. The rental model is plagued with delays and sees poor uptake as a significant proportion of farmer's desire to own a CRM machine. The awareness of FARMS App, which was aimed to popularise the CHC model and create an online marketplace for renting CRM machines, is quite poor among the farmers. Further, diesel price hikes in 2021 have led to the operational cost of Happy Seeder and Super Seeder going up, respectively, by 8.25 and 5.25 per cent, compared to 2019 price levels, reducing their appeal among the farmers.

> **Sangrur district has the maximum number of Happy and Super Seeders, followed by Muktsar, Bathinda, and Mansa.**

Ex-situ utilisation capacity has stalled in the state

and continues to remain below 1 million tonnes, which is less than 6 per cent of the paddy residue generated in the state. The high cost of densified biomass and lack of supply chain actors like biomass aggregators, processors, and storage facilities have made the existing ex-situ ecosystem a laggard. The state's recent policy measure allowing industries to use crop residue in their boilers is a step in the right direction (DIPR Punjab 2021). However, this policy is expected to take time to mature and may have only a little impact on the forthcoming season.

The PUSA decomposer could become a game changer, but it has a long way to go

A recent addition to the suite of in-situ CRM is the PUSA decomposer, which manages crop residue within two to three weeks of application (*The Hindu* 2021). A single packet, costing INR 20, mixed with 25 litres of water can be used for residue generated from one hectare of land (Mohan 2021b). The PUSA decomposer thus presents an economically viable and time-efficient solution to stubble burning. Still, the development and adoption of the decomposer are at a nascent stage. In 2020, its use was limited to 200 hectares across five villages in Punjab (PIB 2021). While the decomposer might be economically viable and eco-friendly, its potential needs to be demonstrated at a large scale for improving farmers' awareness and finding their acceptance.

> While the PUSA decomposer might be economically viable and eco-friendly, its potential needs to be demonstrated at a large scale for improving farmers' awareness and acceptance.

Famers' sentiment significantly impacts crop residue burning

The prevailing sentiments due to the recent agricultural reforms have had an undesired impact on stubble burning. The *Commission for Air Quality Management in National Capital Region and Adjoining Areas Act, 2021* empowers the commission to levy an environmental compensation on farmers for stubble burning, adding momentum to the prevailing sentiments (MoL&J 2021; Mohan 2021a). The persistence of these sentiments poses a major barrier to the efforts in reducing crop residue burning.

Recommendations

Given that the situation is not conducive at present and the harvesting season is just weeks away, we make the following recommendations to the Punjab government:

- Ensure that CRM machines that are to be provided this year are handed over well before the commencement of the residue burning season.
- Engage with relevant stakeholders to popularise the CHC model and dispel the misconceptions about the use and impact of options such as the Happy Seeder.
- The central government should use the funds earmarked publicising its flagship CRM scheme to create awareness of the FARMS and i-Khet apps designed to facilitate the CHC system.
- As an immediate measure, we recommend that the state government should use social networking platforms such as text messages, WhatsApp, Facebook, and other avenues to share the details of the CHCs at the block level to increase their reach beyond their immediate social networks.
- The state government's rental rate advisory must be revised to reflect the increasing cost of residue management machines and should be made legally enforceable.
- Farmers who use CRM machines should be provided financial assistance to compensate for the increase in operational cost of these machines vis-à-vis the rising fuel prices.
- The central government should also geotag the CRM machines provided under its subsidy scheme to understand their usage and ensure that they are utilised to their maximum capacity.
- The effectiveness of the PUSA decomposer should be extensively studied in Punjab. Farmers should be made aware of its efficacy both in terms of managing crop residue and reducing costs.
- The state should ensure that all the existing ex-situ end-users are operating at their maximum capacity. In addition, the government must ensure that the plants that were or are to be commissioned this year initiate biomass procurement and storage.
- The state government can use its punitive tool of imposing fines on stubble burning as a last resort to particularly discourage protest burning.

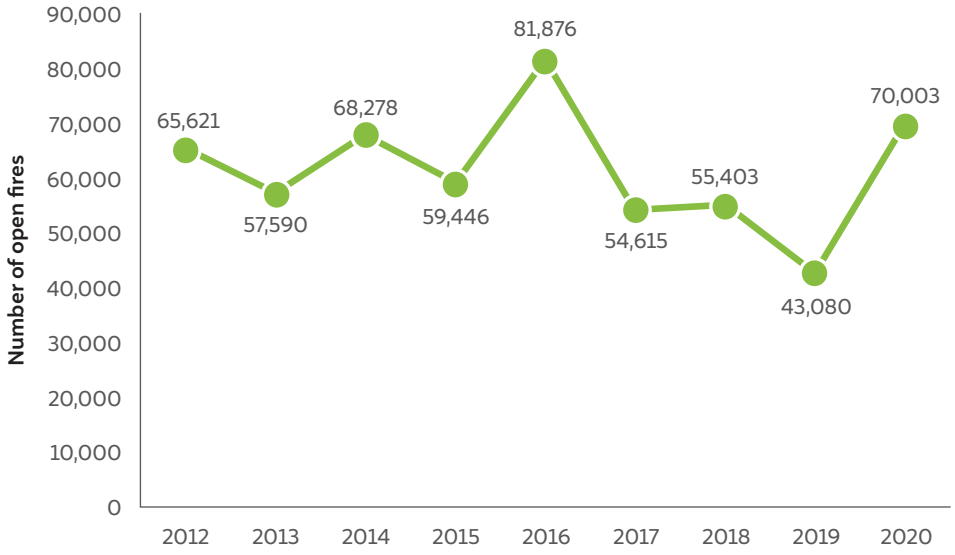
1. Background

Crop residue burning incidents commence every September with unfailing regularity in Punjab and rise steadily as the weeks pass. This well-established pattern leads to an 'airpocalypse', paralysing northern India with the onset of winter every year (Kurinji 2019; Kurinji, Khan, and Ganguly 2021; Jethva et al. 2019). Multiple factors, such as the paddy–wheat cropping system and consequent mechanised harvesting that leaves behind residue in the field, delayed sowing to conserve groundwater, labour scarcity, and the lack of viable markets for residue, are responsible for stubble burning in Punjab (Gupta 2019; Kurinji 2019).

In recent years, the health and economic impacts of stubble burning have gripped the attention of citizens, the media, the government, and the judiciary. The central and state governments have implemented various policy measures ranging from subsidising crop residue management (CRM) machines to providing cash incentives for small farmers who do not burn and an outright ban on crop residue burning (MoAFW 2018; Rambani 2019; PTI 2019). Despite the government's intent and efforts at mitigating this menace, stubble burning presents an important public policy conundrum. This was evident from the sharp rise in stubble burning incidents in 2020 (Figure 1), as residue burning was reported from more than 50 per cent of the area sown under paddy (CREAMS 2020).

> In Kharif 2020, Crop residue burning was reported in more than 50% of the area sown under paddy in Punjab.

Figure 1 Punjab recorded over 70,000 farm fires during Kharif 2020, the second highest in the last decade



Source: Authors' compilation using data from NASA VIIRS 375 m accessed via NASA FIRMS

Note: High and nominal fire events observed between 1 September and 30 November across years were used.

With yet another stubble burning season looming large in Punjab, we realise that a business-as-usual approach would prove to be detrimental and timely access to alternatives is needed to mitigate the crisis. In this study, we synthesise and assess the variables that impact stubble burning, identify gaps in the existing alternatives, and discuss approaches that could lead to better residue management. The main objective of this study is to aid the Punjab government in identifying pitfalls in the existing policy landscape and ensuring timely access to CRM alternatives to farmers.

2. Data and approach

We employed a mixed-methods approach in this study. We conducted telephonic interviews with relevant stakeholders across 17 districts (74 per cent of the districts) between July and August 2021 (Figure 2). Our interviewees included officials from the Department of Agriculture in the Punjab government and Krishi Vigyan Kendras (KVK),[2] operators of custom hiring centres (CHCs), representatives from farm unions, and manufacturers of CRM machinery (the details of the interviewees are listed in Annexure 1). Officials of the Department of Agriculture were selected through snowball sampling, and operators of custom hiring centres were identified using a stratified random sampling method.[3] Data on CHCs for sampling was accessed from the FARMS app developed by the Ministry of Agriculture and Farmers' Welfare (MoAFW) (MoAFW, n.d.). The survey covered the following themes:

1. The operating cost of in-situ CRM machines vis-à-vis the rising fuel cost
2. Farmer's preferences among these machines
3. Influence of farmers' sentiments on crop residue burning.

Besides generating primary data from stakeholders, we used secondary data from government reports, parliamentary questions, and newspaper articles to assess the change in the notified date of sowing and transplantation, the area under paddy, the number of in-situ CRM machines, and ex-situ utilisation capacity.

> **The objective of this study is to aid the Punjab government in identifying pitfalls in the existing policy landscape and ensuring timely access of crop residue management options to farmers.**

2. Our interactions with officials of KVKs were limited due to their busy schedules.

3. Stratified random sampling was used to choose CHCs to ensure that the sample is derived from multiple districts despite retaining the properties of random sampling. Snowball sampling was used for selecting the officials of the Department of Agriculture as their contact details were not available publicly.

Figure 2 Profile of our interviewees

8 Officials from the Department of Agriculture, Punjab

Amritsar, Bathinda, Faridkot, Ferozepur, Gurdaspur, Ludhiana, Moga, Muktsar, & Sangrur.

13 Custom Hiring Centres

Bathinda, Faridkot, Fazlika, Hoshiarpur, Jalandhar, Patiala, & S.B.S. Nagar.

5 Farm unions

Bathinda, Barnala, Fatehgarh Sahib, Fazlika, Ferozepur, Hoshiarpur, Mansa, Moga, Muktsar, Kapurthala, Ludhiana, Jalandhar, S.A.S. Nagar, S.B.S. Nagar, & Sangrur.

4 Crop residue management machine manufacturer

Amritsar & Sangrur

2 Officials from Krishi Vigyan Kendra

Bathinda & Sangrur

Source: Authors' compilation

Note: The mismatch between the numbers and the district names is reflective of the fact that single individuals/unions cater to multiple districts.

3. No change in Punjab's Kharif crop mix

In this section, we pay attention to the variables such as the area sown under paddy, the prevalent varieties of paddy, and the mandated date of transplanting that determine Punjab's residue generation and the choice of residue management.

3.1 Punjab missed its crop diversification target in Kharif 2021, leading to enormous paddy residue generation

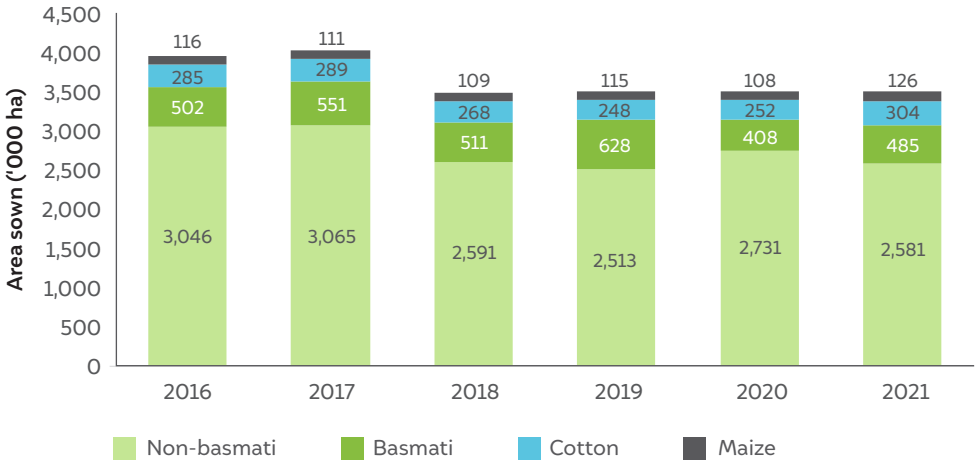
Owing to water scarcity in the state, the Punjab government has consistently stressed the need for crop diversification (ESOPB 2020). However, against the state's 2021 diversification target of 3.25 lakh hectares under cotton, 5.37 lakh hectares under basmati, and 1.50 lakh hectares under maize, the state could only achieve 3.04 lakh hectares for cotton, 4.85 lakh hectares for basmati, and 1.26 lakh hectares for maize (Chaba 2021; Kamal 2021). Though the targets have been very modest and not really followed up with matching incentives like those in the rice–wheat system, it is encouraging to note that diversification has indeed taken place, albeit slowly.

The area under paddy in Punjab this year is 30.66 lakh hectares, which is only 2.6 per cent lower than 31.49 lakh hectares in 2020. Of the sown area this year, 25.81 lakh hectares were devoted to the non-basmati variety (Kamal 2021) (Figure 3). This implies that this year, similar to last year, the state will generate nearly 16 million tonnes[4] of residue. This enormous quantum of stubble is bound to make its management a logistical nightmare.

> **Punjab will generate nearly 16 million tonnes of paddy residue in Kharif 2021.**

4. Assuming an average yield of 4,034 kg rice per hectare (based on projections for FY 2019–20) and a straw-to-grain ratio of 1.5, the state will generate 15.62 million tonnes of non-basmati paddy residue in 2021.

Figure 3 Area under non-basmati paddy in 2021 in Punjab declined by 5.5 per cent compared to 2020

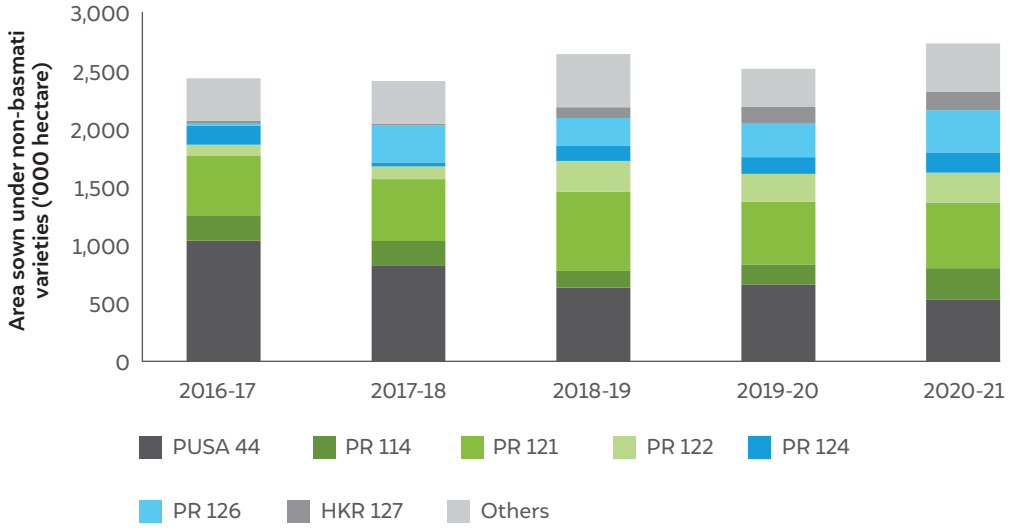


Source: Authors' compilation from Agricultural Statistics of Punjab (2020); All India Crop Situation (2021); and Neel Kamal. 2021. 'Area under Water-Guzzling Paddy Falls by 4 Lakh Acres in Punjab'. The Times of India.

3.2 PUSA 44, with a longer gestation period, remains a dominant variety in high-burn districts in Punjab

The varieties of paddy that are sown have a direct relationship with stubble burning. The high-yield, high-profit PUSA 44 variety is infamous for its long gestation period and enormous residue generation (Nibber 2020, 2021a). The long gestation period leaves farmers with little time to manage the vast quantities of residue this variety of paddy generates (MoAFW 2019). The state government has been promoting short-duration varieties like PR 121 and PR 126, which mature in 140 and 123 days, respectively, while PUSA 44 matures in about 160 days after seeding (*The Tribune* 2021b). PR 121 has now become popular among the farmers due to its yield stability across environments (NGT 2019). However, despite a gradual decline in area under PUSA 44, it remains the dominant variety in Punjab and is likely to add to the problem of crop residue burning (Figure 4). Both government records and responses from the state agriculture department confirm PUSA 44 to be the dominant paddy variety for this season as well (MoAFW 2021b). Our interviews revealed that PUSA 44 is one of the most dominant varieties in the districts of Barnala, Bathinda, Ludhiana, Patiala, and Sangrur, which are also among the high-burn districts in the state (Kurinji 2019). Secondary data from the MoAFW also indicate a high prevalence of PUSA 44 in these districts (MoAFW 2021b).

Figure 4 Long-duration PUSA 44 remains a dominant paddy variety in Punjab



Source: Authors' compilation; MoAFW.2021. Cultivation of Paddy. New Delhi: Ministry of Agriculture and Farmers Welfare.

3.3 Notified date of transplantation is similar to last year

Another variable that influences stubble burning is the notified date of sowing. Being a water-intensive crop, paddy has already made a significant dent on Punjab's water table (CGWB 2020). To arrest the declining groundwater levels, the state enacted the *Punjab Preservation of Subsoil Water Act, 2009*, prohibiting paddy sowing and the subsequent transplantation before the respective notified dates in May and June (Dept. of Legal & Legislative Affairs 2009). This delayed date is intended to synchronise transplantation with the onset of monsoon. However, this creates a time crunch for eco-friendly residue management and contributes to residue burning. This year, as paddy transplantation commenced on 10 June, it should ideally result in an early harvest (The Tribune 2021a). An early harvest should, therefore, provide farmers with extra time to manage the stubble. However, the same was true last year (transplantation date was 13th June), and yet the number of fire events was the highest in the last four years (Figure 1) (Joshi 2021; PRSC 2021).

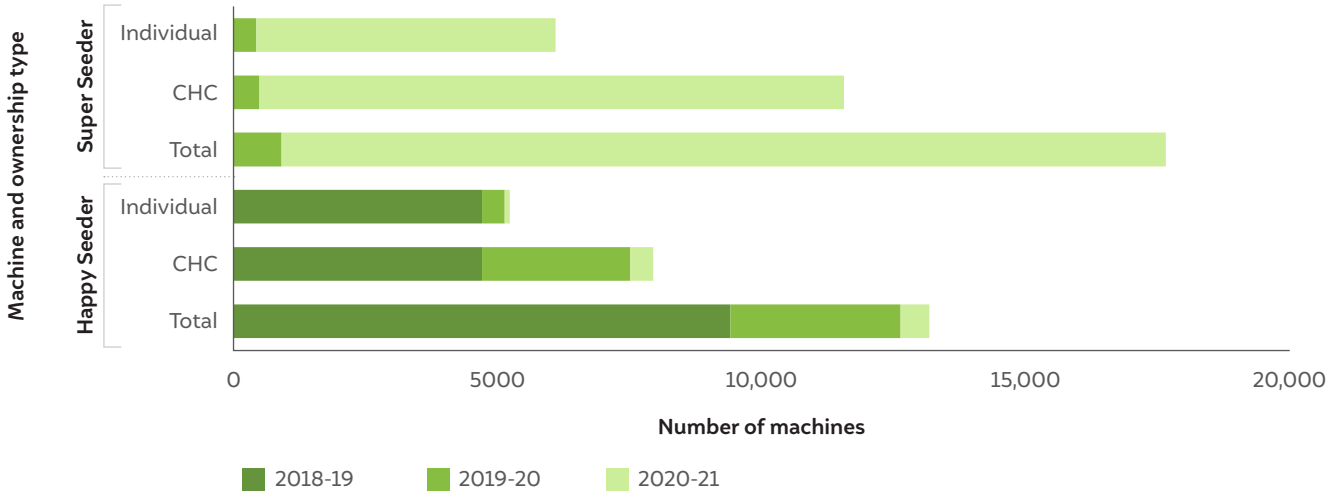
4. Punjab's CRM solutions: hits and misses

Crop residue can be managed in two ways. The residue left after the crop harvest can either be incorporated back into the soil, or collected and supplied for other applications as boiler fuel in industries and power plants and in packaging materials, among others. These management practices are referred to respectively as in-situ and ex-situ. Over the last few years, both the central and the state governments have been recommending the in-situ method as the ideal solution for residue management.

In 2018, the central government launched its flagship CRM scheme, *Promotion of Agricultural Mechanization for In-situ Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi*, to subsidise the cost of CRM machines like the Happy Seeder. Under the scheme, Punjab received INR 810 crore between 2018 and 2020 and an additional INR 235 crore in 2021–22 (Nibber 2021b). The deployment of in-situ CRM machines has received a major boost in Punjab due to the subsidy scheme. By 2020, the state had established 19,834 Custom Hiring Centres and received 76,626 CRM machines (Annexure 3) (*Hindustan Times* 2021a). The most popular of these machines are the Happy Seeder (HS) and the Super Seeder of which the state has 13,316 and 17,697 respectively (Figure 5). For FY 2021–22, Punjab's Department of Agriculture has sanctioned an additional 31,970 farm machines under the aforementioned central government's flagship scheme (*Hindustan Times* 2021b).

> **Punjab received INR 810 crore between 2018 and 2020 and an additional INR 235 crore in 2021-22 to support insitu crop residue management methods in the state.**

Figure 5 By 2020, 13,100 Happy Seeders and 17,600 Super Seeders were deployed in Punjab



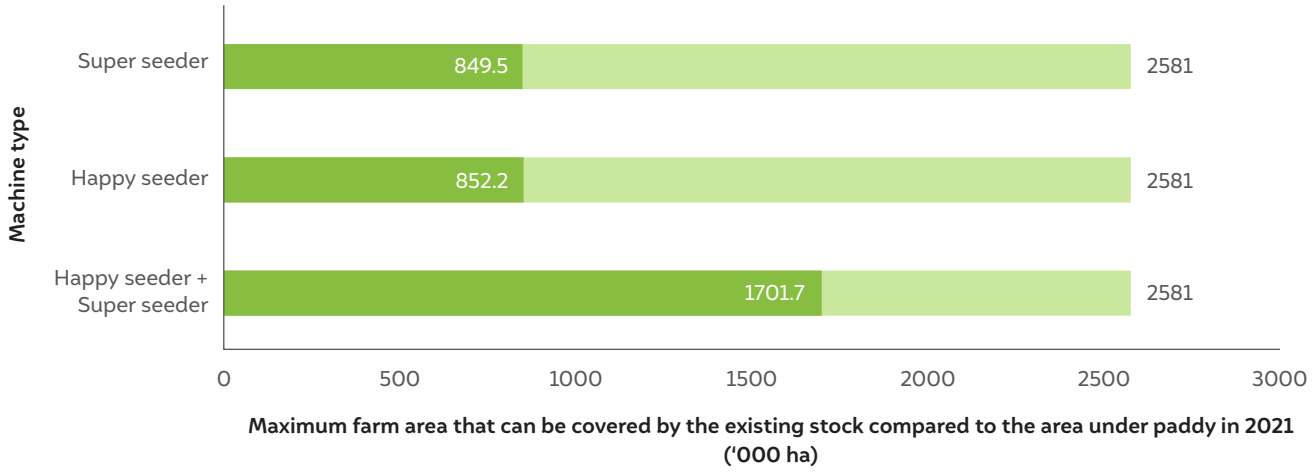
Source: Authors' compilation; MoAFW. 2021a. 'Agriculture Mechanisation for In-Situ Management of Crop Residue'. Parliament of India.

4.1 Existing stocks of CRM machines are highly underutilised

While the numerical growth of CRM machines is commendable, we ask if Punjab has enough machines to cover the total area under paddy. Our interviews with agricultural officers, operators of CHCs, and CRM machine manufacturers included a question on the time these machines take to manage the residue covering one hectare of land. We understand that the time taken depends on the size of the machine, the capacity of the tractor it is attached to, and the speed at which the implement is run through the field. Based on the responses, we arrived at an average time of 150 minutes per hectare for the Happy Seeder and 200 minutes per hectare for the Super Seeder, which was found to be in agreement with the data published by the MoAFW (Sharma et al. 2019; MoAFW 2021a).

Assuming a maximum daily run time of eight hours, a Happy Seeder can cover 3.2 hectares in a day, whereas the Super Seeder can work through 2.4 hectares. Assuming a maximum window of 20 days between the harvest of paddy and the sowing of wheat, we estimate that one Happy Seeder can cover a maximum of 64 hectares of farmland in a season. A single Super Seeder, in contrast, can cover 48 hectares of land in one season. Multiplying the total number of machines with the area a single machine can cover in one season (20 days), we found that the existing stock of Happy and Super Seeders can be used to manage 8.52 lakh hectares and 8.49 lakh hectares, respectively. Both add up to 17 lakh hectares, which corresponds to 66 per cent of the total area sown under non-basmati paddy in 2021 (Figure 6).

Figure 6 Over 66 per cent of the non-basmati farms can be managed by Happy and Super Seeders if deployed at maximum capacity



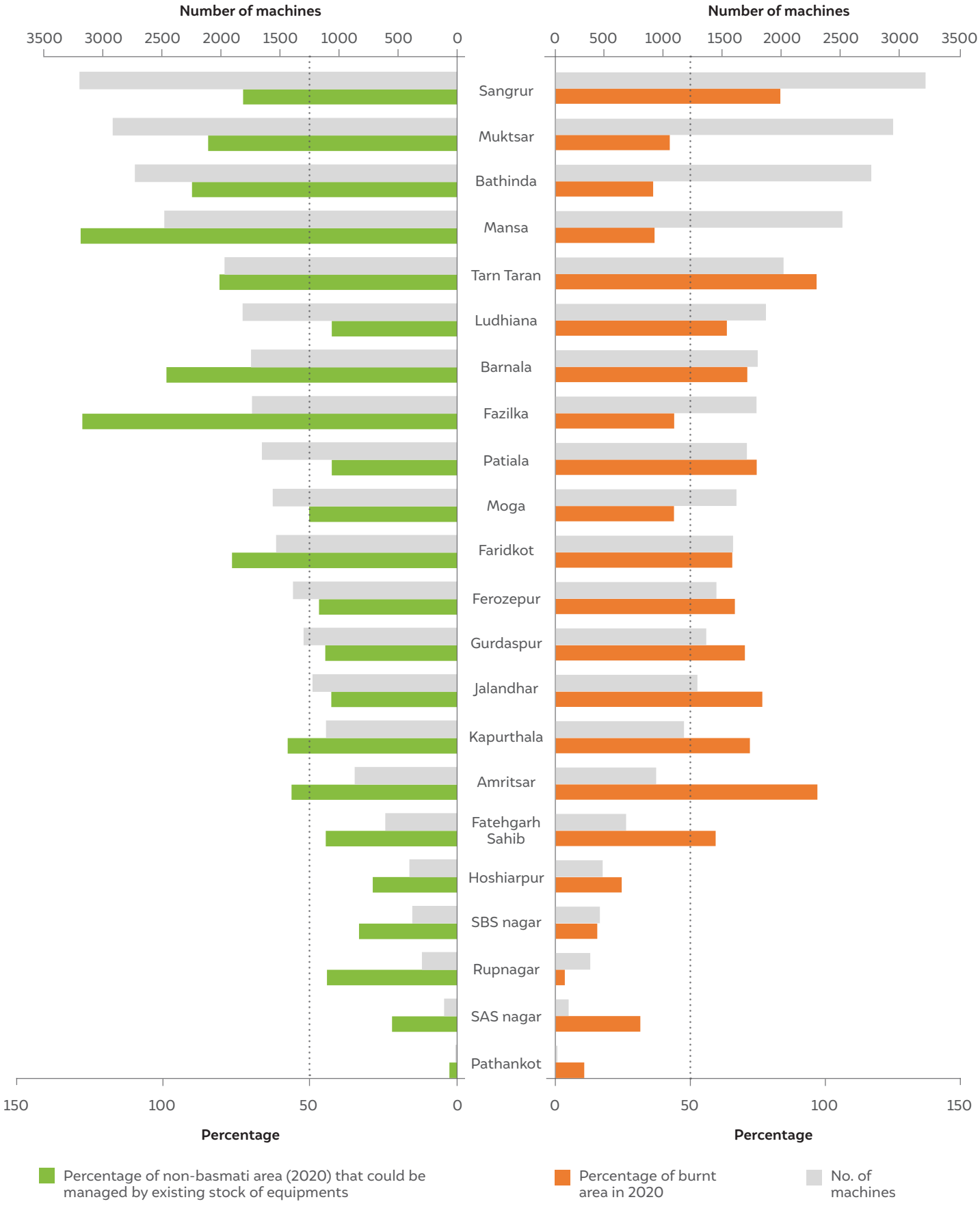
Source: Authors' analysis

Note: It is important to note that we assumed a daily run time of eight hours for each machine and the availability of 20 days for CRM. It is unlikely that the machines are used at their maximum capacity and for the assumed maximum run time.

District-level stats reported by the MoAFW indicate that Sangrur has the maximum number of Happy and Super Seeders, followed by Muktsar, Bathinda, and Mansa (MoAFW 2021a). If utilised at full capacity, the current stock of machines could be used to manage more than 80 per cent of the non-basmati paddy farms in the districts of Fazilka, Bathinda, Barnala, Mansa, and Muktsar. However, their penetration in a few high-burn districts such as Amritsar, Patiala, and Ludhiana is far from the ideal requirement and for realising maximum benefit, the number of machines deployed in these districts needs to be scaled up significantly.

> **Penetration of Happy Seeders and Super Seeders in a few high-burn districts such as Amritsar, Patiala, and Ludhiana is far from the ideal requirement.**

Figure 7 **Punjab burnt residue on more than 50 per cent of farmland in Kharif 2020 despite higher penetration of CRM machines**



Source: Authors' analysis

Going by our calculations, the existing stock of seeders can be used to manage nearly 66 per cent of the non-basmati farmland, but in reality most machines remain underutilised. For instance, in 2020, 12[5] out of 22 districts in Punjab burnt crop residue on more than 50 per cent of their land (CREAMS 2020). However, all these districts had a stock of CRM machines that could be used to manage more than 40–50 per cent of the non-basmati farms.

We performed a correlation analysis to examine if the increased equipment supply has contributed to a reduction in stubble burning. We inspected the link between 'the number of Happy and Super Seeders supplied till 2020 per 1,000 ha of non-basmati area' and 'area burnt in 2020' at the district level. We observed a negative relation between the two variables (Annexure 4), and the correlation coefficient turns out to be very low (–0.14). This makes it difficult to conclusively claim that the increased supply of CRM machines has resulted in reduced stubble burning.

Our interviews suggest farmers' apprehensions towards wheat crop yields sowed by these seeders as a major reason for the lower adoption of these machines. Furthermore, the lack of a standard operating procedure listing changes needed in terms of fertiliser and irrigation application in areas sown under seeders acts a key barrier to their adoption. This problem can be solved only through extensive training and handholding in the early stages of adoption (Sharma et al. 2019). Our interviews also indicated private ownership of these machines as a stumbling block to their optimal use. **Around 40 and 35 per cent respectively of the existing stock of Happy and Super Seeders in Punjab are privately owned** (Figure 5). The average size of farmland in Punjab is below 4 hectares, which can be covered by a single Happy Seeder in a little over a day and by a Super Seeder in a little under two days (MoAFW 2016). The fragmented nature of landholding in the state implies that CRM machines under private ownership are unlikely to be operating at their maximum capacity. In the absence of data that ties individual land records of those who own seeder machines in a private capacity, it is impossible to determine if privately owned machines are being used optimally.

> Around 37% of the existing stock of Happy and Super Seeders in Punjab are privately owned.

4.2 The CHC (rental) model has not caught the farmers' attention yet

The aforementioned central government scheme is designed to promote the CHC (rental) model to improve accessibility of CRM machines for the farmers. By extending the capital subsidy available for farmers' groups to 80 per cent compared to the 50 per cent available for individuals, the scheme nudges buyers to operate CHCs. This arrangement can be used to overcome two barriers. First, it cuts down the unit cost, which ranges between INR 2 and 3 lakh for the Super Seeder and between INR 1.5 and 1.8 lakh for the Happy Seeder (IndiaMart 2021). The high cost of these machines makes it unaffordable for small farmers despite the availability of the 50 per cent subsidy. Second, it promotes optimum utilisation of a machine. The use of these machines is limited to the paddy harvest season, making them redundant for the rest of the year. This makes it impossible to achieve breakeven cost and utilise them to their maximum capacity. The CHC model is meant to overcome these barriers. *But does it?*

We asked agricultural officers and operators of CHCs if the CHC model is popular among the farmers. Agricultural officers repeatedly pointed out that farmers in Punjab do not like renting these machines for two reasons. The first is the logistical problem of timely access. The CHC model is plagued by delays due to inefficient logistical management and delays in transport and operation. Farmers are often unsure of the rented machines arriving on time. This bumps up their desire to own a machine. The second is a behavioural issue. Ownership of CRM machines is associated with prestige. Farmers are often reluctant to request others to rent out a CRM machine. Our interviewees suggest that the scope of the CHC model is restricted to small and marginal farmers who cannot afford the seeder machines despite the availability of subsidies.

We also observed a limited use of the FARMS app developed by the MoAFW to increase access to farm

5. The 12 districts are Barnala, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Jalandhar, Kapurthala, Ludhiana, Moga, Patiala, Sangrur, and Tarn Taran.

implements and popularise the CHC model (MoAFW, n.d.). The app aims to inform farmers of their closest CHCs and facilitate renting (or buying) farm implements similar to renting cabs using the Ola or Uber app (*Economic Times* 2019). The app contains a range of farm implements, including CRM machines, that can be rented or bought. Data from the FARMS app indicates that while Punjab leads other states in the number of CHCs registered on the app, only 21 implements were hired between September 2019 and September 2021 using the app (Annexure 5). During our interactions, **only two of the 13 CHC operators said they were aware of the FARMS app**. Of the two, only one had downloaded the app but had never rented out any equipment using it, while the other was simply aware of the app. Despite the availability of the app, our interviewees (CHCs) stated that they relied on local social networks to rent out their implements.

Digitisation of the entire CHC system could improve the CHC model in Punjab, as the state has a literacy rate of 76.7 per cent and a rural internet subscription rate of 47.96 per cent (MHA 2011; TRAI 2020). There is thus an urgent need to popularise this app and leverage its capabilities for the optimum utilisation of CRM machines available with the CHCs.

4.3 Happy Seeder is losing its popularity among farmers in Punjab

Data on the number of subsidised in-situ machines in Punjab suggests that the Super Seeder is the most sought-after residue management machine in Punjab (Figure 5 and Annexure 3). The farmers' overwhelming preference for this machine is reflected in the fact that the number of Super Seeders in Punjab has eclipsed every other in-situ machine despite the machine only being introduced in 2019 (MoAFW 2021a). The dominance of Super Seeders was also confirmed by all 10 of our interviewees from the Department of Agriculture. Despite its higher cost, tractor power and diesel consumption (Figure 8 and Annexure 6), the Super Seeder became popular among the farmers as it cuts and incorporates the stubble with soil more efficiently than the Happy Seeder.

Super Seeder trumps the Happy Seeder in terms of farmers' acceptability.

In terms of preference for other in-situ machines, our interviewees identified the Happy Seeder as the second most popular machine in Punjab.

A major component of the crop residue burning conundrum is the farmer's preferences. CEEW's research suggests that the farmers are acutely aware of the negative impact of stubble burning and are open to using CRM machines provided they fulfil the criteria of availability, affordability, and not damaging the wheat crop (Gupta 2019). However, satisfying these criteria alone does not translate into farmers developing a liking for the machines. The Happy Seeder is the most definitive example of this trend. It sows wheat without removing the paddy stubble, which results in the field looking yellow and the farmer is gripped with anxiety about the health of the wheat crop. Thus the Happy Seeder poses a major psychological barrier for the farmers. Despite some of our interviewees stressing the fact that the Happy Seeder is one of the best machines for the conservation of agriculture, its popularity has nose-dived due to farmers' poor understanding of the Happy Seeder's impact on wheat crop yields. The carefully built support and investments for Happy Seeder may be in vain as the farmers prefer newly launched machines like the Super Seeder. Our interviewees also indicate that the Super Seeder trumps the Happy Seeder in terms of farmers' acceptability.

4.4 Increasing fuel prices can prove to be a significant barrier to crop residue management

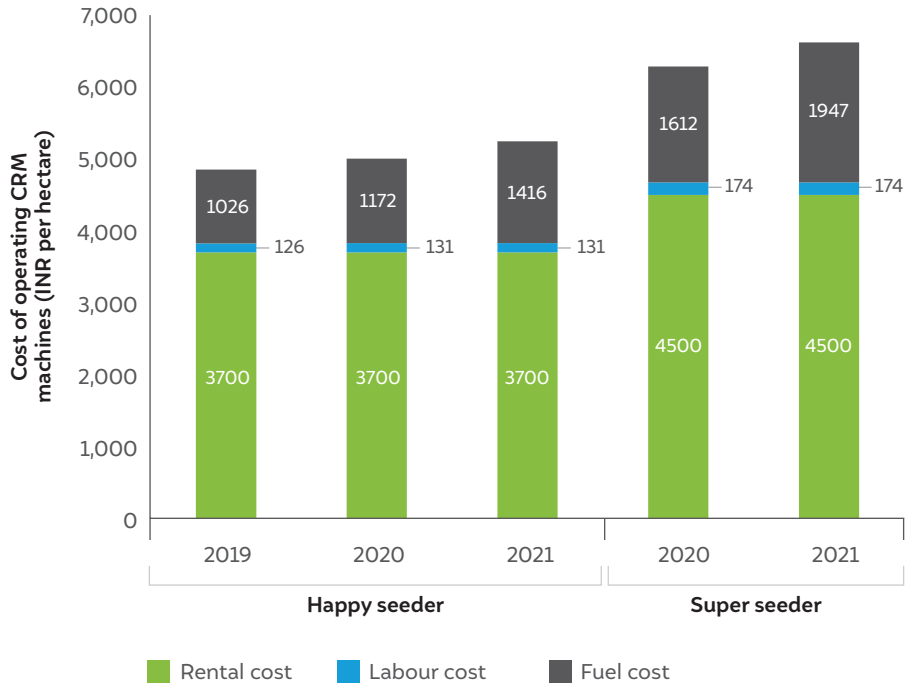
The Happy Seeder and the Super Seeder are tractor-towed implements. Our interviewees stated that the diesel consumption of these machines is influenced by the tractor and machine size and their operating speed. The Department of Agriculture recommends a forward speed of 3.5 km/hr for the Happy Seeder and 2 km/hr for the Super Seeder (Singh, Gautam, and Yadav 2017). However, to save time, farmers operate

them at greater speeds, which causes fuel inefficiency. Our interviewees mentioned that, on average, the Happy Seeder consumes 16 litres of diesel per hectare (or 6.5 litres per acre). In contrast, Super Seeder consumes 22 litres of diesel per hectare (or 9 litres per acre).

On average, the fuel cost accounts for 25 per cent of the cost associated with the operation of the two machines. In the last two years, diesel prices had shot up from INR 64.12 per litre in September 2019 to INR 73.26 per litre in September 2020 and to INR 88.52 per litre in September 2021 (Bank Bazaar 2021). In relation to price levels of 2019, the diesel cost of these machines jumped 14 per cent in 2020 and 38 per cent in 2021. This has led to an increase in the operating cost of the Happy Seeder from INR 4,850/ha in 2019 to INR 5,250/ha (an increase of 8.25 per cent) in 2021. For the Super Seeder, the cost has increased from INR 6,290/ha in 2020 to INR 6,620/ha (an increase of 5.25 per cent) in 2021 (Figure 12). The high operating costs remain a significant barrier to the sustained use of these machines.

> **On average, the fuel cost accounts for 25% of the cost associated with the operation of the Happy Seeder and Super Seeder.**

Figure 8 Fuel price hike has significantly increased the operating cost of the CRM machines



Source: Authors' analysis

4.5 Ex-situ utilisation capacity has not picked up while several plants are yet to be commissioned

Ex-situ crop residue management[6] is highly acceptable among farmers as it does not alter their farmland and provides additional income. **Three of the five 'Kisan' union leaders interviewed identified ex-situ management as an appropriate way of dealing with the paddy stubble.** However, the current ex-situ capacity pales in comparison to the quantum of residue generated in Punjab (DIPR Punjab 2021).

The state has 11 biomass-based power plants with a capacity to manage 0.88 million tonnes of residue annually. Since 2019, the state's ex-situ capacity

6. Ex-situ management refers to the utilisation of crop residue outside the farm. It entails transforming the crop residue into value-added goods such as paper, cardboard, or fuel (Kurinji and Kumar 2021).

> **Since 2019, the state's ex-situ capacity addition has stalled and has not increased beyond 0.88 million tonnes/year.**

addition has stalled and has not increased beyond 0.88 million tonnes/year (EPCA 2020). The state was to commission two biomass power plants and two bio-CNG plant in the current year, and one bio-ethanol and four bio-CNG plants in late 2022 and 2023 (EPCA 2020; Kurinji and Kumar 2021). Upon execution, these projects would have increased the crop residue utilisation capacity to 1.33 million tonnes/year (EPCA 2020). Still, ex-situ management would only account for 8.5 per cent of the estimated 15.62 million tonnes of non-basmati residue to be generated in 2021. There are no updates though on the execution and commissioning of additional projects.

Apart from the installed capacity, our interviewees highlighted several local-level problems with ex-situ management. These include the following:

- Lack of an adequate base of biomass end-users in each district
- Current end-users are buying residue from areas outside the district they are located in
- The existence of a single or limited number of end-users in a district, which creates a monopsony and gives rise to price manipulation
- Low availability of ex-situ machines such as balers and storage infrastructure

Ex-situ management in Punjab also suffers from other drawbacks beyond limited utilisation capacity. The state does not have enough balers, storage capacity, supply chain actors, and skilled workforce to aggregate, store, and efficiently supply the residue it generates. Further, the high delivered cost of biomass supplies and low demand for biomass make it an economically unattractive proposition for entrepreneurs in the supply chain (Kurinji and Kumar 2021).

Augmenting the ex-situ ecosystem in Punjab requires concerted action from the state government, private sector entities, and farmers. While this has been missing historically, the state government has recently announced policy measures to enable the expansion of ex-situ management. In August 2021, the state permitted certain industries such as sugar mills and pulp and paper mills to use paddy stubble as fuel for boilers with a steam-generating capacity of 25 tonnes per hour (TPH) and above (Vasudeva 2021). The government also announced fiscal and non-fiscal incentives to promote the industrial utilisation of paddy stubble. These include the following:

- A cumulative fiscal incentive of INR 25 crore to the first 50 industries that opt in to use paddy stubble as the fuel
- Ensuring availability of panchayat land for residue storage with a lease agreement of up to 33 years with a 6 per cent increase in lease per annum
- Prioritising the availability of balers in areas where paddy residue is used as the boiler fuel (DIPR Punjab 2021)

Further in September 2021, the Commission for Air Quality Management (CAQM) directed 11 NCR coal-fired thermal power plants to co-fire biomass pellets with coal for this season which could potentially consume 1.3 million tonnes of residue (Rajpurohit 2021).

While the recent measures for enabling ex-situ options for CRM are to be welcomed as steps in the right direction, they only give a semblance of half-hearted steps that may not yield the desired results, perhaps even in the medium or long term. Until a comprehensive ex-situ policy covering capacity addition and supply chain development is implemented, the ex-situ options would remain inadequately addressed though they hold great promise to tackle the stubble burning issue.

> **Until a comprehensive ex-situ policy covering capacity addition and supply chain development is implemented, the ex-situ options would remain inadequately addressed.**

4.6 The PUSA decomposer could become a game changer, but it has a long way to go

A recent addition to the suite of in-situ CRM is the PUSA decomposer. This capsule-based microbial decomposer developed by the Indian Agricultural Research Institute (IARI) accelerates the decomposition process of crop stubble using which the stubble can be managed within two to three weeks of application (Chakrabarti 2020; *The Indian Express* 2021; *The Hindu* 2021). A single packet consisting of four capsules mixed with 25 litres of water can be used to treat the residue on one hectare of land at the cost of just INR 20 (Mohan 2021b). This presents an economically viable and time-efficient solution to stubble burning. But the development and adoption of the decomposer are at a nascent stage. In 2020, its use was limited to 200 hectares across five villages in Punjab (PIB 2021). At present, the decomposer technology has been licensed to 12 companies to facilitate its mass adoption and wider reach (PIB 2021). Even though the decomposer might be an economically viable and eco-friendly method of CRM, its potential needs to be demonstrated on a large scale for improving farmers' awareness and winning their acceptance.

4.7 Farmers' sentiment also plays a significant role in stubble burning

The Farmers' Produce Trade and Commerce (Promotion and Facilitation) Act, 2020, Farmers (Empowerment and Protection) Agreement of Price Assurance, Farm Services Act, 2020, and the Essential Commodities (Amendment) Act, 2020 passed by the Parliament in September 2020 triggered widespread protests among farmers across Punjab and other north-western states. Researchers and the media have identified the sentiments against the three acts as a factor contributing to higher residue burning in Punjab in 2020 (*The Hindu* 2020; CERCA 2020; Schmall 2020).

We discussed this prospect with farm unions, officials of the Department of Agriculture (Punjab), and operators of CHCs. **Twelve of our 28 respondents agreed that farmers' sentiments against the proposed reforms led to higher stubble burning**. Eleven negated this view and five of our respondents chose not to comment. Interestingly, officials from the Department of Agriculture and KVKs were more in agreement with the view that the protests led to higher stubble burning than leaders of farm unions and CHC operators. **Eleven of our respondents suggested that protest burning is likely to continue in the Kharif season 2021**.

The enactment of *The Commission for Air Quality Management in National Capital Region and Adjoining Areas Act, 2021* has added to the prevailing sentiments against agricultural reforms. Section 15 of the Act empowers the commission to "impose and collect environmental compensation from farmers causing air pollution by stubble burning, at such rate and in such manner, as may be prescribed" (MoL&J 2021). Farm unions have previously expressed displeasure over the provision of fines for stubble burning (Mohan 2021a). The persistence of these sentiments is a major barrier to the efforts undertaken to reduce crop residue burning.

5. Recommendations

Recognising the seriousness of the stubble burning issue in Punjab, we interacted with relevant stakeholders to identify the variables that influence stubble burning, understand how they have changed in recent times, and the implication of these changes. Our assessment indicates that it is unlikely that there will be a significant reduction in crop residue burning in the Kharif season 2021 in Punjab. The silver lining though is the increasing stock of CRM machines and the emergence of the Super Seeder, which despite its high operational cost, has become a farmer's favourite. Better logistical management and targeted outreach can lead to reduced crop residue burning. For this statement to hold, we recommend the following five E's:

- **Ensure the economic viability of in-situ crop residue management machines**: The per hectare operating cost of the Happy Seeder has increased from INR 4,850 in 2019 to INR 5,250 (an increase of 8.25 per cent) in 2021 due to fuel price hike. For the Super Seeder, the same cost has increased from INR 6,290 in 2020 to INR 6,620 (an increase of 5.25 per cent) in 2021. The rising cost would prove to be a hurdle to the sustained use of these machines. Given the state government's inability to alter fuel prices,

we suggest direct benefit transfers to the users of these machines to compensate for the rising fuel prices. The government should use its existing system of agricultural officers, the panchayat network, and specially designated nodal officers to identify the users of these machines and quantify their use. In addition to these steps, the state government should test the PUSA decomposer for its effectiveness in residue management and economic viability. The use of the decomposer should be demonstrated on a large scale to ensure farmers' awareness and acceptance.

- **Ensure timely delivery of new residue management machines**: Our interviewees point to delays in the deliveries of CRM machines in the previous years. These delays contribute to the inefficient utilisation of these machines and this problem has been flagged previously. The agricultural engineering wing of the Department of Agriculture in Punjab must track the delivery of these machines and ensure that they are deployed well before the start of the harvest season.

- **Ensure functionality of the CHC model**: The state government should initiate campaigns to reduce the apprehensions attached with the rental model. In addition to this step, information campaigns covering the benefits of the Happy Seeder should be initiated to ensure that the existing stock of Happy Seeders does not become redundant. The state government's rental advisories for CRM machines have not been revised since 2019. We recommend annual revision of these rates to reflect ground realities and make these rates legally enforceable. As an immediate measure, we recommend that the state government uses social networking platforms such as text messages, WhatsApp, Facebook, and other avenues to share the details of these CHCs at the block level to increase their reach beyond their immediate social networks. The state is also launching its own farm machinery rental app called i-khet. The government should launch campaigns to popularise the app and familiarise farmers with its interface and services (Hindustan Times 2021c).

The central government has earmarked INR 10 crore in 2021 for publicising its flagship CRM scheme. These funds must be utilised effectively to create behavioural change among the farmers and to promote the FARMS and i-khet apps. In addition, the central government should geotag the CRM machines provided under its subsidy scheme to understand their usage and ensure that they are being utilised up to their maximum capacity.

- **Ensure full utilisation of the existing ex-situ management options**: The state government should verify and ensure that all the existing biomass-based power plants are operating at their maximum capacity. The government had plans to commission two biomass-based power projects and two bio-CNG projects across three districts in the current financial year (EPCA 2020). However, it is not clear whether these plants have been operationalised yet. It is imperative that these plants become operational at the earliest. At the minimum, the state government should ensure that these plants initiate biomass procurement and storage. Besides, the government should also ensure access to ex-situ machines and panchayat lands for handling and storing the residue that these plants can utilise. The central government should also include ex-situ machines under its flagship CRM scheme to enhance their availability.

- **Enforce the ban on burning**: The state government has previously penalised crop residue burning (Sally 2020). Given the current state of the political economy, enforcing this punitive measure would be difficult in the forthcoming season. However, the state government can use this tool as a last resort to particularly discourage protest burning.

The central government should geotag the CRM machines provided under its subsidy scheme to understand their usage and ensure that they are being utilised up to their maximum capacity.

6. Conclusion

The decades-old practice of stubble burning in Punjab has been resulting in a serious air pollution crisis in northern India. Despite a slew of policy measures and judicial directives, the practice continues to persist. We interacted with relevant stakeholders from 17 districts across Punjab to examine the factors contributing to continued burning in the state and their influence on the current Kharif season. Our discussions suggest that farmers' choice of CRM depends on the quantum of residue generation (a function of paddy variety and area sown), accessibility, and affordability of CRM solutions.

Despite Punjab government's effort to diversify crops, paddy remains a dominant crop in the state. In 2021, over 30.66 lakh hectares were sown under paddy, of which 25.81 lakh hectares were under the non-basmati variety. Despite displaying a declining trend in the sown area, the long-duration, high-residue PUSA 44 remains a dominant variety of paddy, at least in the high-burn districts. The lack of significant changes in the area under paddy and continued cultivation of the dominant paddy variety makes it evident that the state has missed out on controlling the quantum of residue that will be generated in the forthcoming season.

Importantly, the state's ex-situ residue management capacity has also remained stagnant for the last three years. Several projects that were to be commissioned this year have missed their commissioning deadlines. The only development in the ex-situ front has been the state government announcing the policy on allowing

Farmers' choice of CRM depends on the quantum of residue generation (a function of paddy variety and area sown), accessibility, and affordability of CRM solutions.

and incentivising the use of crop residue in industries in NCR power plants. However, this policy is likely to take time to mature and yield results.

In-situ management remains the most viable CRM option this year. However, our analysis has identified several problems with its adoption at a large scale. These include the inadequacy of the existing stock of the seeder machines, poor utilisation of the available machines, the dismal performance of custom hiring centres, the high operational cost of these machines vis-à-vis the rising diesel price, and farmers' perceptions in light of the recently enacted farm laws.

Our assessment concludes that Punjab has a long way to go to eliminate crop residue burning. The reduced area under non-basmati paddy and the rising stock of the Happy Seeders and the Super Seeders presents an opportunity to control burning in the forthcoming season. However, grasping this opportunity requires augmenting the supply of CRM machines, better logistical management of the existing stock of CRM machines, ensuring the financial viability of using these machines, increasing ex-situ utilisation capacity, and dedicated outreach to farmers to bring about their behavioural change.

Ensure financial viability, better logistics management of existing CRM options and targeted outreach to reduce stubble burning in Kharif 2021.

CEEW's Srish Prakash (l) in the field interviewing a faculty member of KVK Amritsar.

Image: L.S. Kurinji/CEEW

References

Balakrishnan, Kalpana, Sagnik Dey, Tarun Gupta, R. S. Dhaliwal, Michael Brauer, Aaron J. Cohen, Jeffrey D. Stanaway, et al. 2020. 'The Impact of Air Pollution on Deaths, Disease Burden, and Life Expectancy across the States of India: The Global Burden of Disease Study 2017'. *The Lancet Planetary Health* 3 (1). Elsevier: e26–39. doi:10.1016/S2542-5196(18)30261-4.

Bank Bazaar. 2021. 'Diesel Price in Punjab Today, Diesel Rate in Punjab - BankBazaar'. https://www.bankbazaar.com/fuel/diesel-price-punjab.html.

CERCA. 2020. 'CERCA Annual Report'. Centre of Excellence for Research on Clean Air. https://cerca.iitd.ac.in/app/assets/images/cerca-report/Annual%20Report%202020.pdf.

CGWB. 2020. 'Block Wise Ground Water Resource Assessment-2020'. Cental Ground Water Board. http://cgwb.gov.in/GW-Assessment/2021-08-02-GWRA-2020-BLOCKWISE%20MASTER-SHEET.pdf.

Chaba, Anju Agnihotri. 2021. 'Punjab to Miss Crop Diversification Target Again This Year'. *The Indian Express*. July 9. https://indianexpress.com/article/cities/chandigarh/punjab-to-miss-crop-diversification-target-again-this-year-7395963/.

Chakrabarti, Angana. 2020. 'Pusa Tablets — the Microbial Cocktail That Gives Farmers an Alternative to Stubble Burning'. *The Print*, November 19. https://theprint.in/india/pusa-tablets-the-microbial-cocktail-that-gives-farmers-an-alternative-to-stubble-burning/546786/.

CREAMS. 2020. 'Monitoring Paddy Residue Burning in North India Using Satellite Remote Sensing During 2020'. Indian Agricultural Research Institute. http://creams.iari.res.in/pdf/bulletin_sp_20/04_RiceResidue_BurnStatistics_2020.pdf.

Dept. of Legal & Legislative Affairs. 2009. 'THE PUNJAB PRESERVATION OF SUBSOIL WATER ACT, 2009'. Chandigarh: DEPARTMENT OF LEGAL AND LEGISLATIVE AFFAIRS, PUNJAB. https://dswcpunjab.gov.in/contents/docs/Pb-preservation-of-Subsoil-Act,2009.pdf.

DIPR Punjab. 2021. 'Punjab Permits Industry To Use Paddy Straw As Fuel in Boilers To Claim Incentives | Directorate of Information and Public Relations, Punjab, India ਸੂਚਨਾ ਤੇ ਲੋਕ ਸੰਪਰਕ ਵਿਭਾਗ ਪੰਜਾਬ ,ਭਾਰਤ'. http://www.diprpunjab.gov.in/?q=content/punjab-permits-industry-use-paddy-straw-fuel-boilers-claim-incentives.

Economic Times. 2019. 'Govt Launches Mobile App for Farmers to Hire Tractor, Farm Machineries - ET Auto'. ETAuto.Com. https://auto.economictimes.indiatimes.com/news/automotive/farm-equipment/govt-launches-mobile-app-for-farmers-to-hire-tractor-farm-machineries/71291438.

EPCA. 2020. 'EPCA Report No 117 Special Report on Implementation of Hon'ble Supreme Court Directions on Stubble Burning before the Onset of the Season 2020'. 'ENVIRONMENT POLLUTION (PREVENTION & CONTROL) AUTHORITY'. https://www.epca.org.in/EPCA-Reports1999-1917/EPCA-Report-no-117-Crop-burning.pdf.

ESOPB. 2020. 'Economic Survey'. Chandigarh: Economic and Statistical Organisation, Government of Punjab. https://esopb.gov.in/Static/PDF/EconomicSurvey-2020-21.pdf.

Gupta, Niti. 2019. 'Paddy Residue Burning in Punjab Understanding Farmers' Perspectives and Rural Air Pollution'. Council on Energy, Environment and Water. https://www.ceew.in/publications/paddy-residue-burning-punjab#:~:text=In%20the%20state%20of%20Punjab,National%20Capital%20Region%20(NCR).

Hindustan Times. 2021a. '25,000 Agri-Machines to Be Subsidised for Paddy Stubble Management in Punjab'. Hindustan Times. August 2. https://www.hindustantimes.com/cities/others/25000-agri-machines-to-be-subsidised-for-paddy-stubble-management-in-punjab-101627845144465.html.

Hindustan Times. 2021b. '31,970 Machines Sanctioned for Crop Residue Management in Punjab'. Hindustan Times, September 15. https://www.hindustantimes.com/cities/chandigarh-news/31970-machines-sanctioned-for-crop-residue-management-in-punjab-101631659718178.html.

Hindustan Times. 2021c. 'Ludhiana: Now, Book Machinery for in-Situ Stubble Management on i-Khet App'. Hindustan Times. September 19. https://www.hindustantimes.com/cities/others/ludhiana-now-book-machinery-for-in-situ-stubble-management-on-i-khet-app-101631990315837.html.

IndiaMart. 2021. 'Happy Seeder at Best Price in India'. IndiaMART. September 10. https://dir.indiamart.com/impcat/happy-seeder.html.

Jethva, Hiren, Omar Torres, Robert D. Field, Alexei Lyapustin, Ritesh Gautam, and Vinay Kayetha. 2019. 'Connecting Crop Productivity, Residue Fires, and Air Quality over Northern India'. Scientific Reports 9 (1): 16594. doi:10.1038/s41598-019-52799-x.

Joshi, Vishal. 2021. 'Paddy Sowing Begins Early in Southern Punjab'. Hindustan Times. June 7. https://www.hindustantimes.com/cities/chandigarh-news/paddy-sowing-begins-early-in-southern-punjab-101623086980477.html.

Kamal, Neel. 2021. 'Area under Water-Guzzling Paddy Falls by 4 Lakh Acres in Punjab | Chandigarh News - Times of India'. The Times of India. September 1. https://timesofindia.indiatimes.com/city/chandigarh/area-under-water-guzzling-paddy-falls-by-4l-acres-in-pb/articleshow/85816807.cms.

Kurinji, L S. 2019. 'Alternative Methods to Monitor Air Pollution: A Study of Crop Residue Burning in Punjab'. New Delhi: Council on Energy, Environment and Water. https://www.ceew.in/sites/default/files/CEEW-Pollution-Monitoring-Methods-Punjab-Issue-Brief-08Apr19.pdf.

Kurinji, L S, Adeel Khan, and Tanushree Ganguly. 2021. 'Bending Delhi's Air Pollution Curve: Learnings from 2020 to Improve 2021'. New Delhi: Council on Energy, Environment and Water. https://www.ceew.in/sites/default/files/ceew-study-on-controlling-delhi-air-pollution-2021.pdf.

Kurinji, L.S., and Sankalp Kumar. 2021. 'Is Ex-Situ Crop Residue Management a Scalable Solution to Stubble Burning? A Punjab Case Study.' https://www.ceew.in/publications/ex-situ-crop-residue-management-scalable-solution-stubble-burning.

MHA. 2011. 'CENSUS 2011 PUNJAB DATA SHEET'. Ministry of Home Affairs. https://www.censusindia.gov.in/2011-prov-results/data_files/punjab/Final%20Data2.pdf.

MoAFW. 2016. 'State Wise Agricultural Census Data: Average Size of Holding by Size Class (Punjab)'. https://agcensus.dacnet.nic.in/SL/StateT1sizetable4.aspx.

MoAFW. 2018. 'OPERATIONAL GUIDELINES of THE CENTRAL SECTOR SCHEME ON PROMOTION OF AGRICULTURAL MECHANIZATION FOR IN-SITU MANAGEMENT OF CROP RESIDUE IN THE STATES OF PUNJAB, HARYANA, UTTAR PRADESH AND NCT OF DELHI'. Ministry of Agriculture & Farmers Welfare.

MoAFW. 2019. 'Report of The Committee on Review of The Scheme "Promotion of Agricultural Mechanisation for In-Situ Management of Crop Residue Management in States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi"'. Delhi: Ministry of Agriculture and Farmers Welfare. https://farmech.dac.gov.in/revised/1.1.2019/REPORT%20OF%20THE%20COMMITTEE-FINAL(CORRECTED).pdf.

MoAFW. 2021a. 'Agriculture Mechanization for In-Situ Management of Crop Residue'. Parliament of India. https://pqars.nic.in/annex/254/AU1297.pdf.

MoAFW. 2021b. 'CULTIVATION OF PADDY'. Parliament of India. https://pqars.nic.in/annex/254/AU2095.pdf.

MoAFW. n.d. 'FARMS (Farm Machinery Solutions) Mobile App | Govt of India'. https://agrimachinery.nic.in/Index/farmsapp.

Mohan, Vishwa. 2021a. 'Bill Tabled in Lok Sabha to Form Air Quality Management Panel in Delhi-NCR | Delhi News - Times of India'. July 31. https://timesofindia.indiatimes.com/city/delhi/bill-tabled-in-ls-to-form-air-quality-mgmt-panel/articleshow/84909239.cms.

Mohan, Vishwa. 2021b. '25k Farmers to Use Stubble Solution | India News - Times of India'. The Times of India. August 28. https://timesofindia.indiatimes.com/india/25k-farmers-to-use-stubble-solution/articleshow/85703839.cms.

MoL&J. 2021. 'THE COMMISSION FOR AIR QUALITY MANAGEMENT IN NATIONAL CAPITAL REGION AND ADJOINING AREAS ACT, 2021'. New Delhi: Ministry of Law and Justice. https://prsindia.org/files/bills_acts/bills_parliament/2021/The%20Commission%20for%20Air%20Quality%20Management%20in%20National%20Capital%20Region%20and%20Adjoining%20Areas%20Act,%202021.pdf.

NGT. 2019. 'NOTE ON PADDY TRANSPLANTION DATE'. National Green Tribunal. https://greentribunal.gov.in/sites/default/files/all_documents/541-2019.pdf.

Nibber, Gurpreet Singh. 2020. 'Discontinue Sowing Oldest Paddy Variety to Check Stubble Burning: Centre to Punjab'. Hindustan Times. March 19. https://www.hindustantimes.com/cities/discontinue-sowing-oldest-paddy-variety-to-check-stubble-burning-centre-to-punjab/story-MQw5GGGw4sf9TYw7XoKlEO.html.

Nibber, Gurpreet Singh. 2021a. 'PUSA-44 Paddy Variety an Environmental Hazard, Need to Discontinue Its Sowing: Punjab to Centre'. Hindustan Times. May 26. https://www.hindustantimes.com/cities/chandigarh-news/pusa44-paddy-variety-an-environmental-hazard-need-to-discontinue-its-sowing-punjab-to-centre-101621974913035.html.

Nibber, Gurpreet Singh. 2021b. 'Punjab Receives ₹235 Crore from Centre for Paddy Stubble Management'. Hindustan Times. July 3. https://www.hindustantimes.com/cities/chandigarh-news/punjab-receives-rs-235-crore-from-centre-for-paddy-stubble-management-101625256292187.html.

PIB. 2021. 'Steps Taken by the Government for Awareness about the New Low-Cost Capsule Which Can Convert the Paddy Stubble into Bio-Manure'. August 10. https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1744517.

PRSC. 2021. 'Crop Residue Burning Information and Management System'. Crop Residue Burning (CRB) Information and Management System. https://gis-prsc.punjab.gov.in/residue/index.aspx.

PTI. 2019. '29,000 Punjab Farmers Get Rs 2500 per Acre for Not Burning Crop Residue'. Business Standard India, November 15. https://www.business-standard.com/article/pti-stories/29-000-punjab-farmers-who-did-not-burn-crop-residue-compensated-119111501440_1.html.

Rajpurohit, Shivnaryan. 2021.'To Cut Coal, Thermal Plants Told to Use Paddy Straw Pellets too. The Indian Express, September 22. https://indianexpress.com/article/cities/delhi/to-cut-coal-thermal-plants-told-to-use-paddy-straw-pellets-too-7525878/

Rambani, Vishal. 2019. 'Why Ban on Stubble Burning Has Gone up in Smoke in Punjab'. Hindustan Times. November 1. https://www.hindustantimes.com/cities/why-has-the-ban-on-stubble-burning-gone-up-in-smoke/story-KQP95IsdTVCzQHScnpkcuI.html.

Sally, Madhvi. 2020. 'Punjab, Haryana Begin Penalising Farmers for Stubble Burning - The Economic Times'. https://economictimes.indiatimes.com/news/politics-and-nation/punjab-haryana-begins-penalising-farmers-for-stubble-burning/articleshow/78684425.cms?from=mdr.

Schmall, Emily. 2020. 'Indian Farmers' Protests Spread, in Challenge to Modi'. The New York Times, December 4, sec. World. https://www.nytimes.com/2020/12/04/world/asia/india-farmers-protest-pollution-coronavirus.html.

Sharma, Mohit, Ishan Sahajpal, Aditya Bhuyan, and Akansha Chauhan. 2019. '"Cleaner Air - Better Life" Initiative Impact Assessment Report for Crop Residue Management Project'. CII foundation. https://ciifoundation.in/document/NewsLetter/CII-Final-CRM-Impact-Assessment-Report-05Aug2019.pdf.

Singh, Prashant, Balvindra Singh Gautam, and Rahul Kumar Yadav. 2017. 'Performance Evaluation of Happy Seeder for Sowing Wheat Crop in Combined Harvested'. International Journal of Agricultural Engineering 10 (2): 645. doi:10.15740/HAS/IJAE/10.2/643-646.

The Hindu. 2020. 'Stubble Burning | Maximum Cases in Punjab; Anger over Farm Laws among Major Reasons', November 15, sec. Other States. https://www.thehindu.com/news/national/other-states/stubble-burning-maximum-cases-in-punjab-anger-over-farm-laws-among-major-reasons/article33101909.ece.

The Hindu. 2021. 'Centre Should Direct States to Use Bio-Decomposer: CM', September 14, sec. Delhi. https://www.thehindu.com/news/cities/Delhi/centre-should-direct-states-to-use-bio-decomposer-cm/article36443326.ece.

The Indian Express. 2021. 'Farmers Happy with New Technique to Tackle Stubble Burning, Others States Should Use Too: Kejriwal'. The Indian Express, September 14. https://indianexpress.com/article/cities/delhi/stubble-burning-farmers-delhi-pollution-7506244/.

The Tribune. 2021a. 'Paddy Transplantation Advanced to June 10'. Tribuneindia News Service. https://www.tribuneindia.com/news/punjab/paddy-transplantation-advanced-to-june-10-253005.

The Hindu. 2021b. 'Short-Duration Paddy Varieties Can Turn the Tide'. Tribuneindia News Service. June 7. https://www.tribuneindia.com/news/features/short-duration-paddy-varieties-can-turn-the-tide-264670.

TRAI. 2020. 'The Indian Telecom Services Performance Indicators'. Telecom Regulatory Authority of India. https://www.trai.gov.in/sites/default/files/Report_09112020_0.pdf.

Vasudeva, Vikas. 2021. 'Punjab Package to Spur Industrial Use of Paddy Stubble'. The Hindu, September 4, sec. Other States. https://www.thehindu.com/news/national/other-states/punjab-package-to-spur-industrial-use-of-paddy-stubble/article36290751.ece.

Annexures

Annexure I List of stakeholders interviewed

Table A1.1 Custom hiring centres

S. No.	Name	District
1	Kissan Friends Sway Sahayeta Group	Bathinda
2	Uddham Kheti Sewa Society	Faridkot
3	Gurmeet Singh Sekhon CHC	Fazlika
4	Salechan Kissan Club	Jalandhar
5	New Maan Khetibadi Help Group	Bathinda
6	Kissan Ekta Kheti Sewa Society	Faridkot
7	Sant Brar Kheti Sewa Society	Faridkot
8	Kang Agriculture Welfare Society	Patiala
9	Khalsa Kisan Society	Hoshiarpur
10	Vilas Agriculture Welfare Society	Bathinda
11	Jagjit Kheti Sewa Society	Faridkot
12	Singara Singh CHC	S.B.S. Nagar
13	Dhillon Agriculture Swasahayta Group	Faridkot

Source: Authors' compilation

Table A1.2 Farm unions

S. No.	Name	District
1	Bharti Kisan Union Mansa	Mansa
2	Bharti Kisan Union Doaba	Multiple
3	Kissan Bachao Morcha	Multiple
4	Lok Bhalai Insaaf Welfare Society	Multiple
5	Punjab Kisan Union	Multiple

Source: Authors' compilation

Table A1.3 Government departments

S. No.	Department/Organisation	District
1	Agriculture Engineering Wing	Ferozepur
2	Agriculture Engineering Wing	Bathinda
3	Agriculture Engineering Wing	Faridkot
4	Agriculture Engineering Wing	Ludhiana
5	Agriculture Engineering Wing	Amritsar
6	Agriculture Engineering Wing	Gurdaspur
7	Agriculture Engineering Wing	Sangrur
8	Agriculture Engineering Wing	Sri Muktsar Sahib
9	Agriculture Engineering Wing	Moga
10	Krishi Vigyan Kendra	Bathinda
11	Krishi Vigyan Kendra	Sangrur

Source: Authors' compilation

Table A1.4 Crop residue management machine manufacturers

S. No.	Name	District
1	Saron Mechanical Works	Sangrur
2	Thind Mechanical Works	Amritsar
3	Satwant Agro Engineers	Sangrur
4	KSD Agro Engineers	Sangrur

Source: Authors' compilation

Annexure II Questionnaires administered to various stakeholders

Questionnaire 1: Custom Hiring Centres

1. How much do you charge to rent out your Happy Seeder/Super Seeder?
2. What is the per acre diesel consumption of your machine?
3. How much time does your machine take to cover 1 acre of land?
4. Do farmers prefer buying the machine or do they prefer renting the machine? Why?
5. Can you use a smartphone?
6. Do you or does anyone in your family own a smartphone with an active data connection?
7. Are you aware of the FARMS app?
8. How did you get to know about the 'FARMS' App?
    a. Through the workshop carried out by KVKs
    b. Through social media
    c. Others (Please specify)
9. Have you ever used the app?
    a. Yes
    b. No
10. Have you successfully rented out/sold machinery using the app?
11. Did you encounter any problems while using the app?
12. What can be done to improve the user experience of the app?
13. What do you think needs to be done to improve the access and adoption of crop residue management machines?
14. Did the farmer's protest affect burning last year? If so, how?
15. What will be its impact this year?

Questionnaire 2: Government Officials

1. What is the dominant crop residue management practice followed in your area?
    a. Removal of residue and use it for ex-situ application
    b. Removal of plural and burning the lower part of the stem
    c. Removal of plural and incorporation of the lower part of the stem
    d. Complete burning
2. What is the most dominant variety of paddy in your district?
3. Do farmers burn the residue of varieties other than PUSA 44?
4. Do farmers burn the residue of basmati?
5. Do farmers burn the residue of crops other than paddy?
6. Was sowing delayed in your district and will this lead to higher burning?
7. What is the dominant crop residue management machine in your area?
    a. Happy Seeder
    b. Super Seeder

c. Super straw management system
d. Hydraulic Reversible M.B. Plough
e. Rotary mulcher
f. Shrub Master
g. Paddy straw chopper
h. Rotavator
i. Zero till Seed Cum Fertiliser Drill

8. Do farmers prefer buying the CRM machines or do they prefer renting them?
9. Are prices of CRM machines fixed? If so, can you share a list of the prices?
10. How has the rental cost of the preferred machine changed? (Increase/decrease)
11. What are the main barriers to adoption of CRM machines?
12. Did the farmer's protest affect burning last year? If so, how?
13. What will be its impact this year?

Questionnaire 3: Farm Unions

1. What is the dominant crop residue management practice followed in your area?

a. Removal of residue and use it for ex-situ application
b. Removal of plural and burning the lower part of the stem
c. Removal of plural and incorporation of the lower part of the stem
d. Complete burning

2. What is the most dominant variety of paddy in your district?
3. Do farmers burn the residue of varieties other than PUSA 44?
4. Do farmers burn the residue of basmati?
5. Do farmers burn the residue of crops other than paddy?
6. Was sowing delayed in your district and will this lead to higher burning?
7. What is the dominant crop residue management machine in your area?

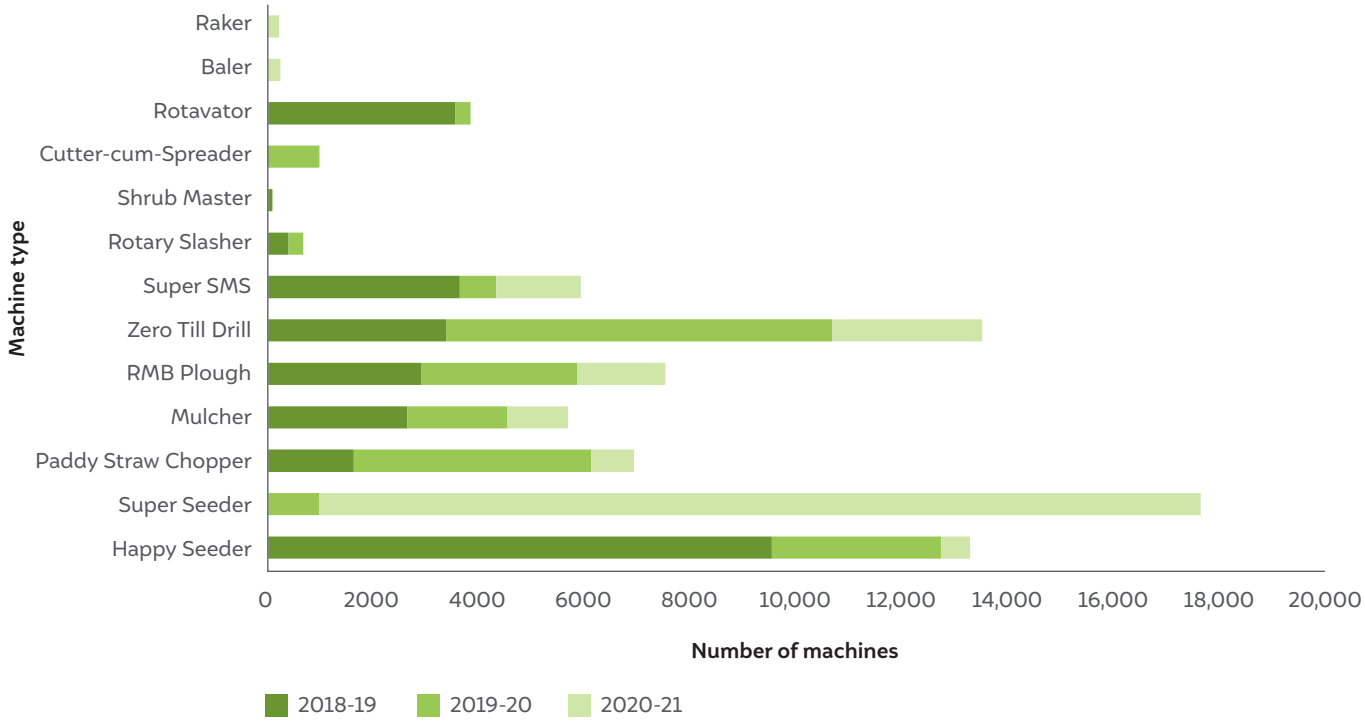
a. Happy Seeder
b. Super Seeder
c. Super straw management system
d. Hydraulic Reversible M.B. Plough
e. Rotary mulcher
f. Shrub Master
g. Paddy straw chopper
h. Rotavator
i. Zero till Seed Cum Fertiliser Drill

8. Do farmers prefer buying the CRM machines or do they prefer renting them?
9. Are prices of CRM machines fixed? If so, can you share a list of the prices?
10. How has the rental cost of the preferred machine changed? (Increase/decrease)
11. What are the main barriers to adoption of CRM machines?
12. Did the farmer's protest affect burning last year? If so, how?
13. What will be its impact this year?

Questionnaire 4: CRM Machinery Manufacturers

1. What CRM machines do you manufacture?
2. What is the most popular CRM machine at the moment?
3. How has the price of this machine changed?
4. What is the per acre diesel consumption of this machine?
5. How much time does it take to cover 1 acre of land?

Annexure III By 2020, over 76,626 CRM machines were deployed in Punjab[7]



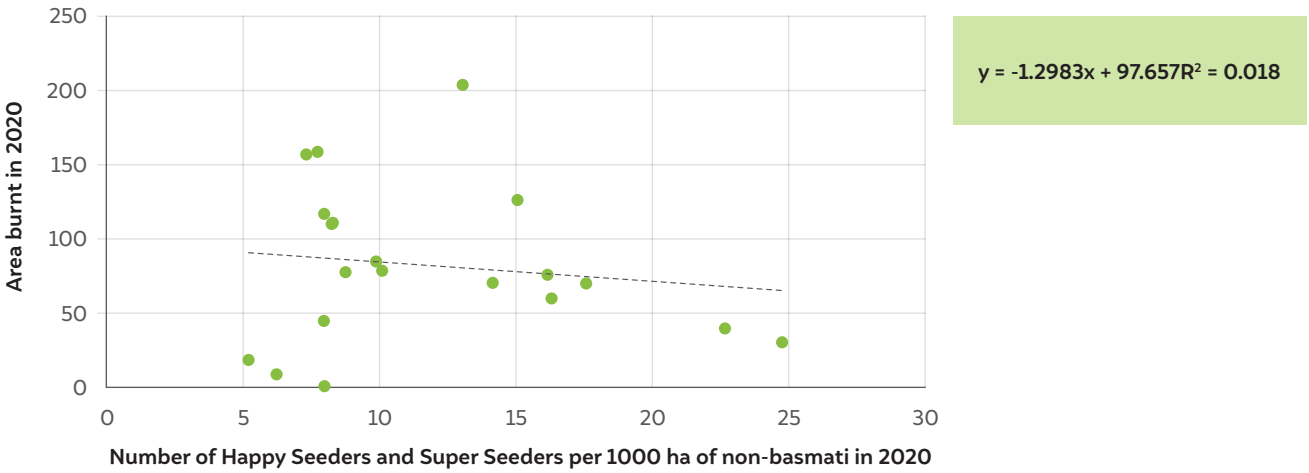
Source: Authors' compilation; MoAFW. 2021a. 'Agriculture Mechanisation for In-Situ Management of Crop Residue'. Parliament of India.

Annexure IV Does higher penetration of CRM machines lead to lower burning in 2020?

We conducted a correlation analysis to examine if the increased equipment supply has led to reduced crop residue burning. We inspected the link between 'number of HS and SS supplied till 2020' and 'area burnt in 2020' at the district level. In order to normalise the variations in non-basmati sown area across the districts, we correlated 'number of HS and SS supplied per 1000 ha of non-basmati area' with 'area burnt in 2020'. While we observe a negative relation between the two variables (Figure A4), the correlation coefficient turns out to be very low (−0.14). This makes it difficult to conclusively claim that the increased supply of CRM machines has resulted in reduced burning.

7. This does not include the machines that are to be provided in the current financial year. The application process for availing subsidies is underway and data for 2021–22 will only be available in late 2021 or early 2022.

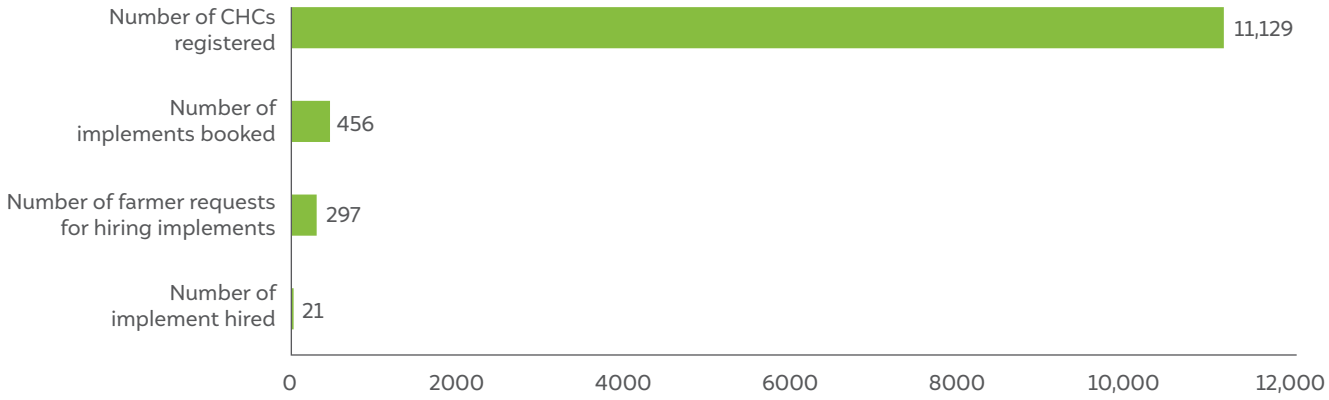
Figure A4 No conclusive evidence to claim that the increased supply of CRM machines has resulted in reduced burning



Source: Authors' compilation

Note: We ignored two districts (Pathankot and SAS Nagar) as the area under non-basmati paddy in these districts were low.

Annexure V Only 21 implements were hired using the FARMS app in Punjab between September 2019 and September 2021



Source: Authors' compilation; MoAFW n.d. 'FARMS (Farm Machinery Solutions) Mobile App | Govt of India'. https://agrimachinery.nic.in/Index/farmsapp.

Note: This plot includes all types of farm implements, including CRM machines.

Annexure VI A comparison of Happy Seeder and Super Seeder

	Happy Seeder	Super Seeder
Year of development	2002	2018
Number of machines supplied till 2020	13,316	17,697
Field capacity	150 minutes per hectare (or 60 minutes per acre)	200 minutes per hectare (or 85 minutes per acre)
Cost of the machine (INR)	1.5–1.8 lakh	2–3 lakh
Tractor power requirement (horse power)	Above 50 hp	Above 60 hp
Diesel consumption (litre/hectare)	16	22
Rental cost (INR/hectare)	3,700	4,500

Source: Authors' compilation; Data collated from stakeholder consultation and existing literature

The authors

L. S. Kurinji
kurinji.selvaraj@ceew.in | @KurinjiSelvaraj

Kurinji, a Programme Associate at CEEW's Risks and Adaptation team, focuses on devising efficient methods to monitor and control air pollution sources in India.

Srish Prakash
srish.prakash@ceew.in

Srish, a consultant at CEEW, focuses on conducting and supporting policy research on crop residue burning in Northern India.

Suggested citation: Kurinji, L. S., and Srish Prakash. 2021. *Why Paddy Stubble Continues to be Burnt in Punjab? Meeting Challenges with Solutions.* New Delhi: Council on Energy, Environment and Water.

Disclaimer: The views expressed in this report are those of the authors and do not reflect the views and policies of the Council on Energy, Environment and Water.

Acknowledgments: We thank our reviewers—Dr Niraj U. Joshi, Senior Research Affiliate, Global Economic Dynamics and the Biosphere Programme, The Royal Swedish Academy of Sciences; Sakshi Balani, Team Lead, Air Pollution Action Group (A-PAG); Ritesh Bhatia, CEO, India Paryavaran Sahayak Foundation; Shruti Jindal, Programme Associate, CEEW, and Harsimran Kaur, Research Analyst, CEEW—for providing critical feedback and insightful comments to refine this report. We also thank Karthik Ganesan, Director, Research Coordination, CEEW; Tanushree Ganguly, Programme Lead, CEEW, and T. Satyateja Subbarao, Research Analyst, CEEW, for providing us their valuable inputs throughout the study. We express our sincere gratitude to our interviewees from the Department of Agriculture in Punjab and Krishi Vigyan Kendras (KVKs), operators of custom hiring centres (CHCs), leaders of farm unions, and manufacturers of crop residue management (CRM) machinery for providing information relating to the accessibility and affordability of crop residue management solutions in Punjab. We appreciate the efforts of Harsimran Kaur (CEEW) for supporting the authors in carrying out the interviews in the regional language (Punjabi) in Punjab. Finally, we thank our outreach team for enabling the publication and dissemination of this study as per CEEW's quality standards. Authors' take full responsibilities for any errors in the document.

Peer reviewers: Dr Niraj U. Joshi, Senior Research Affiliate (Global Economic Dynamics and The Biosphere Programme), The Royal Swedish Academy of Sciences; Sakshi Balani, Team Lead, Air Pollution Action Group (A-PAG); Ritesh Bhatia, CEO, India Paryavaran Sahayak Foundation; Shruti Jindal, Programme Associate, CEEW and Harsimran Kaur, Research Analyst, CEEW.

Organisation: The **Council on Energy, Environment and Water (CEEW)** is one of Asia's leading not-for-profit policy research institutions. The Council uses data, integrated analysis, and strategic outreach to explain – and change – the use, reuse, and misuse of resources. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with wider public. In 2021, CEEW once again featured extensively across ten categories in the *2020 Global Go To Think Tank Index Report.* The Council has also been consistently ranked among the world's top climate change think tanks. Follow us on Twitter @CEEWIndia for the latest updates.

For queries contact

COUNCIL ON ENERGY, ENVIRONMENT AND WATER (CEEW)

Sanskrit Bhawan, A-10, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi - 110067, India
T: +91 (0) 11 4073 3300

info@ceew.in | ceew.in | @CEEWIndia | ceewindia