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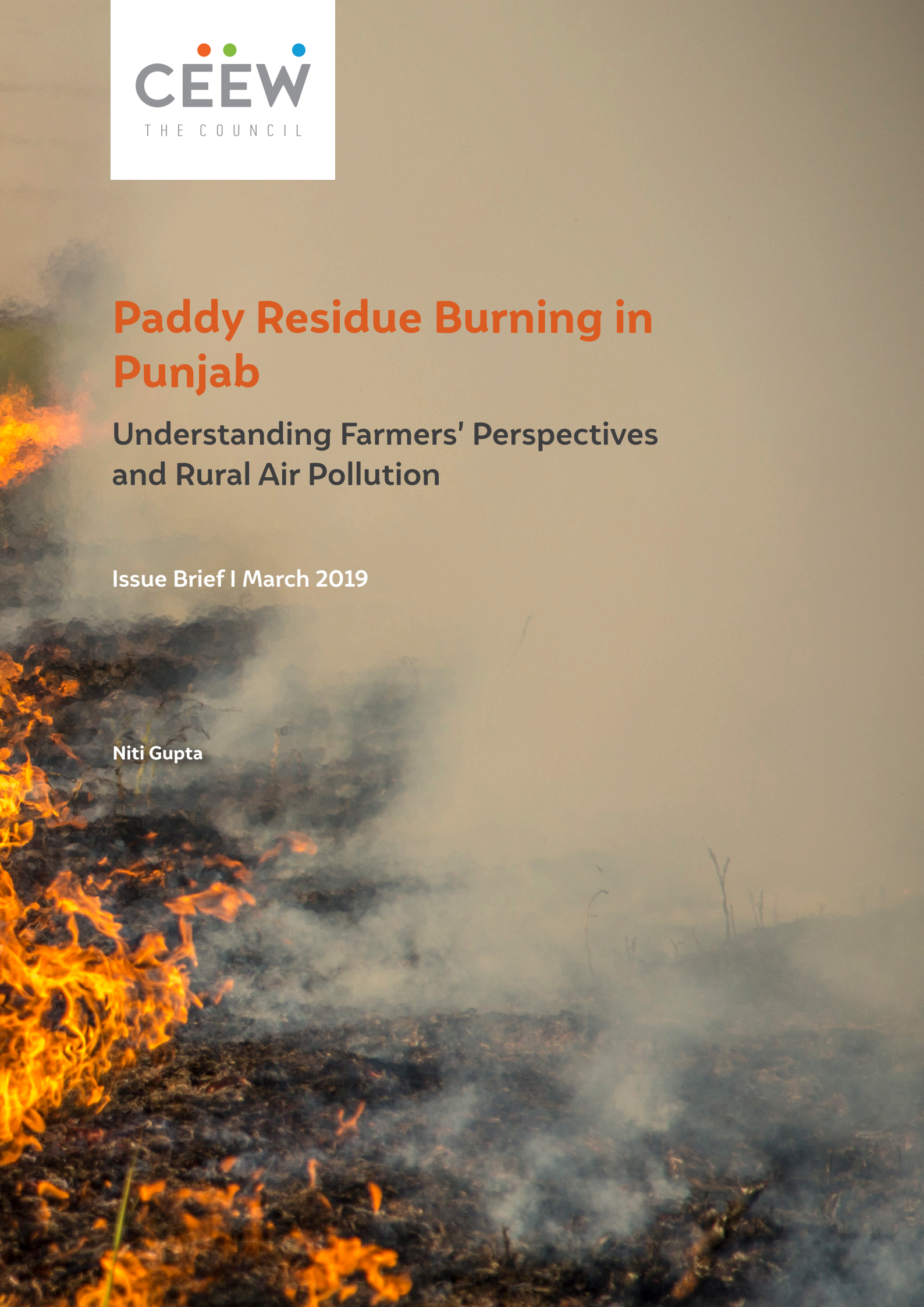
Paddy Residue Burning in Punjab

Understanding Farmers' Perspectives and Rural Air Pollution

Issue Brief I March 2019

Niti Gupta



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I thank CIMMYT (International Maize and Wheat Improvement Center) and Borlaug Institute for South Asia (BISA) for their support on the ground and valuable insights and inputs, and Mr Manish Kumar at CIMMYT for his technical expertise and guidance throughout the study. I also thank the peer reviewers of this issue brief for their comments and suggestions on improving its content and structure.

I thank all the farmers who participated in the interviews and agreed to install sensors in their fields. The economic evaluation of Happy Seeder, and the challenges and solutions identified in the brief, were informed by structured and semi-structured interviews with various group stakeholders, including farmers, members of Noorpur Farmers' Cooperative Society in Ludhiana, Amrinder Singh of S.N. Paper Mills, manufacturers of agricultural implements, and custom hiring centres (CHC). I thank them for their valuable insights on the document.

I would also like to thank my colleague Kurinji L.S. for her contribution to the report. Her work on sensor data analysis and monitoring fire counts is an important and valuable addition to the study.

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Niti is a Research Analyst at CEEW. Her work focusses on climate risk and adaptation strategies; improving air quality to meet India's ambient air quality standards; tackling crop residue burning in Punjab by promoting conservation agriculture for stubble management; using low-cost sensors for monitoring and regulation; and assessing and scaling sustainable agriculture practices. Her research interests lie in the field of behavioural and experimental economics, and using evaluation studies to critically examine public policies in developing countries. Niti holds a Master's degree in development studies, with a major in the economics of development, from the International Institute of Social Sciences, Erasmus University and a BA (Hons) degree in economics from Daulat Ram College, University of Delhi.

"In the dominant narrative around crop residue burning, farmers are always painted as the main culprits and Delhi is the victim. Seldom have we paused to reflect on farmers' challenges. Through this report, discussing the complex cross-cutting linkages of the agriculture-water-air nexus, we try to bring in farmers' voices from the field."

Image: Kurinji LS/CEEW

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ABBREVIATIONS

CO	carbon monoxide
CO_2	carbon dioxide
CPCB	Central Pollution Control Board
CBG	Compressed biogas
CIMMYT	International Maize and Wheat Improvement Center
CH	combine harvester
CHC	custom hiring centre
CNG	compressed natural gas
EPCA	Environment Pollution (Prevention & Control) Authority
FICCI	Federation of Indian Chambers of Commerce & Industry
FCI	Food Corporation of India
FPO	farmer producer organisation
FIRMS	Fire Information for Resource Management System
GBD	global burden of disease
GoI	Government of India
HS	Happy Seeder
IIT	Indian Institute of Technology
MSP	minimum support price
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NGT	National Green Tribunal Act
NASA	National Aeronautics and Space Administration
NCR	National Capital Region
NSSO	National Sample Survey Organisation
PAU	Punjab Agricultural University
PACS	Primary Agriculture Cooperative Societies
PM	particulate matter
SO_2	sulphur dioxide
SATAT	Sustainable Alternative Towards Affordable Transportation
Super SMS	Super Straw Management System
SHG	self-help group
VIIRS	Visible Infrared Imaging Radiometer Suite

Majority of the rice crop, in Punjab, is harvested using combine harvesters, which leaves behind large amounts of rice residue in the fields.

Image: Niti Gupta/CEEW

Executive Summary

In Punjab, India, it is common to burn paddy residue. Crop waste burning emits aerosol particles - coarse particles (PM_{10}) and fine ($PM_{2.5}$) - and greenhouse gases (GHG). These emissions aggravate the poor air quality in Delhi and the National Capital Region (NCR) and constitute a serious environmental challenge. To address it, many policies have been mandated in the past few years, and resource conservation technologies - such as Happy Seeder and Super Straw Management System (Super SMS) for direct incorporation of seeds are promoted. But these alternatives have not been adopted widely, and the practice of burning crop waste persists.

This issue brief aims to examine the impact of paddy residue burning on local air quality; evaluate the economic feasibility of alternative insitu solutions, with a focus on Happy Seeder; and understand from farmers their challenges in adopting alternative methods of managing paddy residue and,also, find viable solutions.

The study employed a mixed methods approach. We installed low-cost sensors across four districts in Punjab to monitor $PM_{2.5}$ emissions; interviewed farmers to understand their challenges and what they see as the solution; and collected and analysed satellite information to understand the trend of paddy residue burning in Punjab.

In the peak burning season, we observed deterioration in air quality in the rural areas of the study area and higher emissions of $PM_{2.5}$ from paddy-intensive regions than from regions where less paddy is cultivated.

An economic evaluation indicates that using the Happy Seeder can prove a cost-effective and viable alternative to burning, but uptake is constrained by high prices - there is no standard rental rate - and innovative business models are needed to facilitate it. In the medium and long term, short-duration varieties of rice need to be promoted, along with fresh incentives for farmers to move away from rice-wheat rotation. Farmers require a well-established paddy residue collection mechanism; they also need training to understand the agro-economic benefits of alternatives given to them.

Low-cost sensors were installed across four districts in Punjab to monitor $PM_{2.5}$ emissions; farmers were interviewed to understand their challenges and understand what they see as the solution

Low cost sensors are emerging as an alternative means to monitor air quality and to create awareness on air pollution.

Image: Niti Gupta/CEEW

1. Introduction

In Indian agriculture, the state of Punjab holds an important place - it occupies only 1.53 per cent of India's geographical area but contributes the most to the central rice procurement pool. In the 2017- 18 kharif season, about 11.83 metric tons(MT) of rice was procured from Punjab, about a third of the 36.18 million MT procured by various agencies, according to data from the Food Corporation of India (FCI). Haryana contributed 3.99 MT and Andhra Pradesh 3.87 MT.[1]

Farming practices for harvesting rice and wheat are highly mechanised. These practices leave a huge amount of scattered, root-bound paddy straw in the field after the harvest. Much of the wheat straw is collected and used as cattle fodder. Rice straw, which has high silica content, is considered to be poor feed; it has no other local economic use. Farmers have only 10-15 days between harvesting paddy and planting the next crop (wheat, for example). Since that is not enough time to clear and prepare the fields,and removing the rice straw left in the field is a labour-intensive exercise, they burn the paddy residue (stubble) in situ. It is a common residue management practice among farmers in the state of Punjab. The time constraint and the labour-intensive nature of removing the rice straw has led to the mechanisation of harvesting, which has in turn aggravated the paddy residue management issue.

1.1 Genesis of the problem

Punjab witnessed massive progress in food grain production after the green revolution. Among Indian states, Punjab had the best infrastructure, high level of mechanisation, and advanced irrigation facilities. This made the state suitable for the introduction of photo period non-sensitive short-duration varieties of wheat and rice - required then for increasing the production of food grains in India and reducing the dependence on import of American wheat under the Public Law 480 (PL -480), also known as "Food for Peace". PL-480 was a funding avenue through which US food could be used for overseas aid. It was then possible to grow high yielding 120-130 days rice crop (June-July to October-November) followed by a high yielding 110-120 days wheat crop (November-December to March-April).[2]
Advanced irrigation facilities were a crucial prerequisite in this agricultural growth. There was a quantum jump in the area under groundwater irrigation - from 1.7 million hectares in

1 Department of Food & Public Distribution, GoI (2018), "Annual Report 2017-18", Available at https://dfpd.nic.in/

2 Kumar P., Kumar S. & L. Joshi (2015), "Socioeconomic and Environmental Implications of Agricultural Residue Burning - A Case study of Punjab, India"- Springer.

1966 to 3 million hectares in 2012 - changing the structure of irrigation in the state (Sarkar & Das 2014).[3] Punjab experienced a major shift from canal irrigation to deep tube well irrigation, which together provides 99.75 per cent of the irrigation in the state. This transition was rapid after 1997, when electricity was made free for agriculture. In southern Punjab, until the mid-1990s, farmers were dependent mostly on canal irrigation to grow cotton and wheat. However, with the announcement of free electricity in 1997 and the simultaneous large-scale adoption of submersible pumps after the mid-1990s, the state underwent a shift from cotton to rice cultivation and saw a significant increase in deep tube well irrigation. Northern Punjab saw the emergence of tube well irrigation in the early 1980s (Sarkar & Das 2014).

Under the free electricity regime, groundwater irrigation replaced surface water irrigation, and the spread of tube well technology brought a larger area under assured cultivation. The farmers were better insulated against production risks, which further encouraged crop activity and crop intensification throughout the year (Dhawan 1982).[4] It took no time for the semi-arid state of Punjab to shift from the traditional maize-wheat cropping pattern to the water intensive rice-wheat cropping rotation.

1.1.1 Shifts in cropping pattern

With the adoption of the rice-wheat cropping pattern, the area under low-input crops (like maize and bajra) and pulses (gram, urad, mung bean, etc.) in Punjab decreased over the years. On the other hand, rice production increased more than 15 times in 40 years - from 6.88 lakh MT in 1970-71 to 105.42 lakh MT in 2011-12, and wheat production jumped from 51.45 lakh MT to 179.82 lakh MT.[5]

Crop	1970-71 (%)	1980-81 (%)	1990-91 (%)	2000-01 (%)	2010-11 (%)
Rice	6.87	17.49	26.86	32.89	35.85
Wheat	40.49	41.58	43.63	42.92	44.72
Cotton	6.99	9.60	9.34	5.97	6.49
Maize	9.77	5.65	2.51	2.08	1.69
Pulses	7.29	5.04	1.91	0.68	0.25
Sugarcane	2.25	1.05	1.35	1.52	0.89

TABLE 1:
Shifts in cropping pattern (percentage)

Source: Statistical Abstract, Government of Punjab, 2012

3 Sarkar A. & A. Das (2014), "Groundwater irrigation-electricity-crop diversification nexus in Punjab: trends, turning points and policy initiatives", Economic and Political Weekly.

4 Dhawan B.D (1982), "Development of Tube well Irrigation in India". Agricole Publishing Academy. New Delhi.

5 Economic Adviser, Government of Punjab "DISTRICT WISE MAJOR CROPS IN PUNJAB (June 2010 to May 2011)" - Publication No. 943 < Available at http://www.pbplanning.gov.in/pdf/Major%20Crops%20of%20 Punjab%20june%202,010%20to%20may%202,011.pdf>

By procuring 80 per cent of the rice produced in Punjab in the 1980s, the state government promoted the shift towards the rice-wheat cropping pattern. The minimum support price (MSP) policy also supported the cultivation of non-basmati high yielding varieties of rice. Owing to the higher returns in rice and wheat, assured market structures, and the MSP programme, agriculture in Punjab has become a rice-wheat monoculture.[6]

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1.1.2 Groundwater depletion

The nexus of the wheat-rice cropping pattern, groundwater extraction, free electricity for agriculture, and food procurement policy came at a high ecological cost, however - the excessive production of rice resulted in massive depletion of groundwater in Punjab.

Paddy requires at least 18 mm of water per day for almost 100 days, while the requirement for wheat is about 500 mm during the growth period. For paddy grown in an area of one hectare, the depth of water required is almost 1,600 mm. Punjab's average annual rainfall is nearly 650 mm, of which less than 500 mm falls during the rainy season, from July to September;[7] the remaining 1,100 mm comes from groundwater. One kilogram of rice consumes 3,000 - 5,000 litres of groundwater[8] (Kaur et al., 2015). If the rice-wheat monoculture remains, the water table in central Punjab is expected to fall below 70 feet in 66 per cent of the area by 2023, below 100 feet in 34 per cent of the area, and much below 130 feet in 7 per cent of the area (Sidhu et al., 2010).[9]

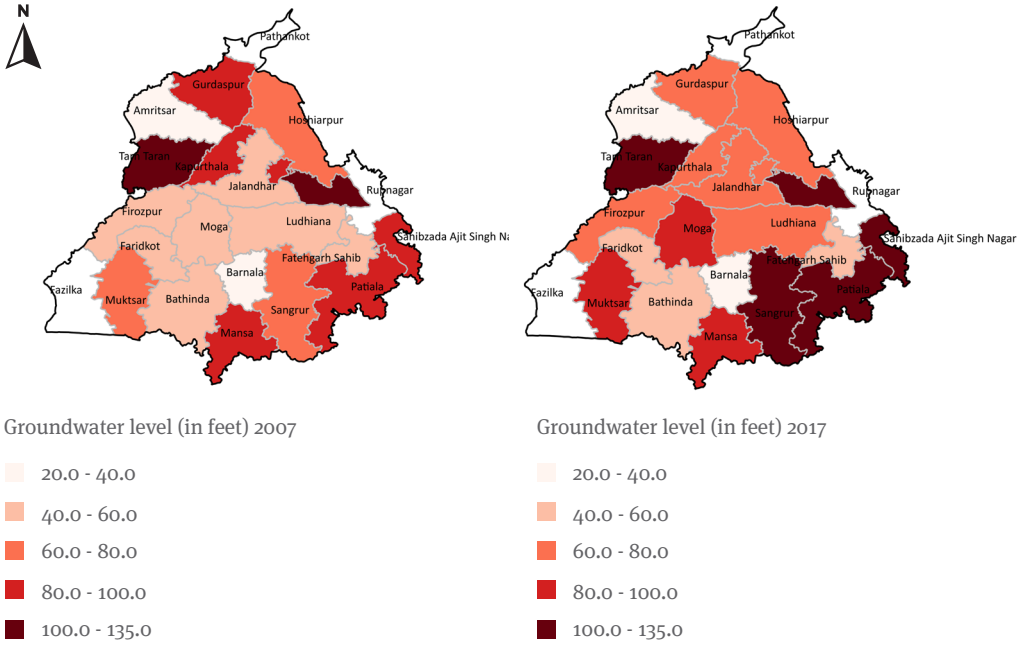

FIGURE 1: Change in groundwater level from 2007 to 2017

Source: CEEW analysis, 2018

6 Shergill H.S., "Wheat and Paddy Cultivation and the Question of Optimal Cropping Pattern for Punjab" - Punjab University, Chandigarh.

7 Chaba A.A., "Punjab: Decade's heaviest pre-monsoon rainfall lifts paddy hope", The Indian Express, 30 June 2018. Available at <https://indianexpress.com/article/cities/chandigarh/punjab-decades-heaviest-pre-monsoon-rainfall-lifts-paddy-hopes-5239333/>

8 Kaur B., Vatta K. & Sidhu R.S. (2015), "Optimising Irrigation Water Use in Punjab Agriculture: Role of Crop Diversification and Technology", Indian Journal of Agricultural Economics, Vol.70, No.3, July-September

9 Sidhu, R.S., K. Vatta and H.S. Dhaliwal (2010), "Conservation Agriculture in Punjab – Economic Implications of Technologies and Practices", Indian Journal of Agricultural Economics, Vol 65, No. 3, July-September, pp. 413-427.

Of the 138 blocks of the state, 103 blocks are overexploited, five blocks are critical, and four blocks are in the semi-critical category, according to the latest data provided by the Central Groundwater Board (Government of India 2011) and the Department of Irrigation, Punjab.[10] The groundwater development stage in Punjab is now 172 per cent,[11] which indicates that annual water consumption in Punjab is very high as compared to its annual recharge. It has the highest stage of all the states in India.

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The growing concerns over the depleting water table compelled the government to pass the Punjab Preservation of Subsoil Water Act in 2009. The act prohibited paddy transplantation before a notified date in June. Violators were liable to a penalty of INR 10,000 per hectare per month for the period of violation continues. The act permitted agricultural officers to destroy the nursery of paddy or the sown transplanted plant before the notified date at the expense of such farmer (Punjab Government, 2009).[12] In 2018, the date notified under this act for paddy transplantation was 20 June; in 2017, the date was 15 June.[13]

1.1.3 Mechanisation of agriculture and shortage of labour

The major causes of paddy residue burning in Punjab are the introduction of mechanised harvesting, in the form of combine harvesters; the depleting water table; and the shortage of agricultural labour.

Under rice-wheat rotation, rice is grown during the warm and humid season between June and October; wheat is grown between November and March. Any delay in sowing wheat adversely affects the crop yield. The crucial time for wheat harvest is 10-30 April, when the temperature is about 30-35°C. The paddy transplantation date, 20 June, leaves farmers a shorter turnaround window, of 20-25 days, between rice harvesting and planting of wheat.

Manual harvesting, the traditional practice, is not an economical option for farmers now - labour wages have increased, and there is a labour shortage. The size of the workforce in agriculture declined by around 30.57 million between 2004-05 and 2011-12 despite an increase in the total workforce, according to employment data from the National Sample Survey Organisation (NSSO) and FICCI research.[14]

10 Available at < http://cgwb.gov.in/gw_profiles/st_Punjab.htm>, last accessed 21st January 2019.

11 The groundwater development stage of 100 per cent indicates that groundwater consumption is equal to groundwater recharge; groundwater development stage of above 100 per cent indicates that the annual groundwater consumption is more than the annual groundwater recharge.

12 Punjab Government Gaz. (2009), "The Punjab Preservation of Subsoil Water Act, 2009 (Punjab Act No.6), Department of Legal, and Legislative Affairs, April 28. Available at <http://agripb.gov.in/abt_deptt/pdf/Pb%20preservation%20of%20Subsoil%20Act,2009.pdf>.

13 Directorate of Information and Public Relations, Punjab. Information available at <http://diprpunjab.gov.in/?q=content/punjab-announces-paddy-transplantation-june-20>, last accessed 18 January 2019.

14 FICCI and KPMG (2015), "Labour in Indian Agriculture: A growing challenge", Available at <http://ficci.in/spdocument/20550/FICCI-agri-Report%20093–2015.pdf>, last accessed 18 January 2019.

With the implementation of rural income schemes like the MGNREGA, labourers from Bihar and Uttar Pradesh prefer working in their own states. Better remuneration and growth opportunity in other sectors attract the workforce away from agriculture and lead to labour shortages. Labour charges for sowing paddy have increased from INR 1,500 per acre in 2017 to INR 2,000-2,500 per acre in 2018.

In Punjab, almost 80 per cent of the rice crop is harvested using combine harvesters, which leaves behind large amounts of rice residue - almost 19.7 million metric tons of paddy straw on average, of which almost 15.4 million metric tons are set on fire in open fields (Punjab Government 2017).

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1.2 Emissions and impacts

Paddy residue burning negatively impacts the environment and also farmers' health. Biomass burning is a major source of gaseous pollutants such as carbon monoxide (CO), methane, nitrous oxides, and hydrocarbons in the troposphere (Tripathi et al. 2012).[15] Paddy residue burning, particularly, is an important source of aerosol particles, such as coarse particles (PM_{10}) and fine particles ($PM_{2.5}$). Various studies have found that the fine particles released due to agricultural crop burning easily enters into the lungs, causing heart problems.[16]

Burning one tonne of straw releases 3 kg of particulate matter (PM), 60 kg CO, 1,460 kg CO_2, 199 kg ash, and 2 kg of SO_2 (Gupta et all. 2004).[17] According to the Global Burden of Disease (GBD) study, which estimates ground level $PM_{2.5}$ concentrations from 1998 to 2015, mortality estimates for India in 2015 attributable to $PM_{2.5}$ were dominated by mortality estimates for the rural population. Since about two-thirds of Indian population lived in rural areas in 2015, about 75 per cent of the deaths in India occurred among the rural population. Of the total deaths attributable to exposure to $PM_{2.5}$ emissions, the deaths of 66,200 were attributed to exposure to $PM_{2.5}$ from open burning in 2015, of which 50,500 were in rural areas and remaining 15,700 in the urban areas.

There is strong scientific evidence that crop residue burning by farmers in Punjab in the months of October and November aggravates the poor air quality in Delhi and the NCR.[18] Most paddy residue burning takes place during these two months, which coincides with post-monsoon conditions when the probability of inversion condition is also the maximum. Winter brings the double whammy of more pollutants being trapped in more moisture and less dispersion due to wind conditions. In November, the contribution of biomass to PM_{10} could be as high as 140 microgram per cubic metre; to $PM_{2.5}$, about 120 microgram per cubic metre, according to the IIT Kanpur study on source apportionment.[19] The mean contribution

15 Tripathi S., Singh R N, and Sh. Sharma (2012), "Emissions from Crop/Biomass Residue Burning Risks to Atmospheric Quality", International Research Journal of Earth Sciences, Vol.1(1), 24–30, April.

16 American Thoracic Society, Committee of the environmental and occupational Health (1996), "Health effects of outdoor pollution", Am J Respir Crit Care Med, 15, 3–50.

17 Macnee W. and Donaldson K. (2003), "Mechanism of lung injury caused by PM10 and ultra-fine particles with special reference to COPD", Eur Respi Journal, 21, 47–51.

18 Lee J.T., Son J.Y. and Cho Y.S. (2007), "The adverse effects of fine particle air pollution on respiratory function in the elderly", Sci Tot Environ., 385, 28–36.

19 Gupta P. K., Sahai, S., Singh, N., Dixit, C. K., Singh, D. P., Sharma, C. (2004). Residue burning in rice-wheat cropping system: Causes and implications. Current Science, 87(12), 1713–1715.

in the entire winter season is 97 microgram per cubic metre for PM_{10} and 86 microgram per cubic metre for $PM_{2.5}$.

Of late, researchers and policymakers have focused their attention on air quality in urban areas only. Air quality in rural areas remains a largely neglected issue so far. The Central Pollution Control Board (CPCB) has installed more than 700 air quality monitoring stations in over 300 cities and towns across India, but rural areas lack air quality monitoring networks, and there is little data. Contrary to popular belief, rural areas suffer both from outdoor and indoor air pollution. One of the major sources of outdoor air pollution in rural areas is also the burning of paddy and wheat straw.

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1.3 Policy mandates to reduce paddy residue burning

Several mandates have been taken so far to address the paddy residue problem.

The National Policy for Management of Crop Residue, 2014 (NPMCR) was prepared by the Ministry of Agriculture and Farmers' Welfare, Government of India. The NPMCR lists policies to reduce the incidence rate of paddy residue burning. The document listed interventions such as 'use of satellite based remote sensing technologies to monitor crop residue management' and 'development of appropriate and cost-effective farm machinery to facilitate collection, volume reduction, transportation and application of residues',etc.[20] Although these interventions have been enforced to some extent, these have not eliminated the burning incidence.

The National Green Tribunal, 2015 (NGT) provides many directives. One imposes a fine, in the form of environmental compensation,on farmers who burn crop waste. Small farmers with a landholding of less than 2 acres (0.81 hectares) pay environmental compensation of INR 2,500 per incident; those with a landholding of more than 2 acres but less than 5 acres (2.02 hectares) pay INR 5,000 per incident; and farmers with a landholding of more than 5 acres pay INR 15,000 per incident.[21] However, CEEW research and interviews with farmers suggest that none of this has reduced fire counts; farmers continue to burn residue. The financial condition of farmers, especially of small landholders, is such that they can afford neither expensive agricultural implements nor expensive labour; paying the fine cheaper.

The Environment Pollution (Control and Prevention) Authority (EPCA), set up by the Prime Minister's Office, coordinates with state governments (Punjab, Haryana, and Uttar Pradesh) to review the status of problems and implementation of solutions.

The Sustainable Alternative Towards Affordable Transportation (SATAT) initiative was launched by the Ministry of Petroleum and Natural Gas on 1 October 2018. The SATAT aims to setup compressed biogas (CBG) production plants and make CBG available in the market for use in automotive fuels. Compressed biogas can be produced from various biomass/ waste sources, including agricultural residue, municipal solid waste, sugarcane press mud, distillery spent wash, cattle dung, and sewage treatment plant waste. Through the initiative,

20 Government of India, Ministry of Agriculture (2014), "National Policy for Management of Crop Residue", Department of Agriculture & Cooperation, November. <http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf>.

21 Available at <http://www.agripb.gov.in/pdf/NGT%20judgement.pdf> last accessed 16th January 2019.

the government aims to 'boost availability of more affordable transport fuels, better use of agricultural residue, cattle dung and municipal solid waste, as well as to provide an additional revenue source to farmers.[22]

A new central sector scheme, 'Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh and NCT of Delhi', was approved in 2018 to 'address air pollution and to subsidize machinery required for in-situ management of crop residue' for the period from 2018-19 to 2019-20.[23] A provision of INR 1,151.80 crore has been made under this scheme, of which Punjab will receive INR 695 crore. The scheme is implemented to promote the 'usage equipment and machines for in-situ management of crop residue'. It has three major components:

1. establish farm machinery banks or CHCs of in situ crop residue management machinery;
2. procure agricultural machinery and equipment for in situ crop residue management; and
3. conduct information, education, and communication (IEC) programmes through demonstrations, trainings, advertisement, and publicity to raise awareness on in situ crop residue management.

The Happy Seeder Machine

Image: Niti Gupta/CEEW

Happy Seeder is a tractor-powered machine that cuts and lifts rice straw, sows wheat into the bare soil, and deposits the straw over the sown area as mulch. It is attached to a 45-50 horse power (hp) tractor and works with a spreader called the Super Straw Management System (Super SMS). The machine cuts slits in the field, about 4-5 centimetre (cm) deep and drops the seeds for the next crop.[24]

Using Happy Seeder has potential agronomic benefits. The mulch suppresses weeds, reducing soil evaporation and the need for control measures (Sidhu et al. 2007, 2008).[25] Other advantages of using Happy Seeder, include improved soil health, and enhanced nutrient use efficiency (by 10-15 per cent) and water savings (up to 1.45 million litre per hectare) through reduced evaporation and elimination of pre-sowing irrigation. In the conventional approach (of burning straw), it takes about 10 days to prepare the fields; using Happy Seeder, the farmer can mulch and seed the next crop in three or four days.

Happy Seeder is currently priced at INR 1.15 lakh. Individual farmers receive a subsidy of 50 per cent, and farmers' cooperatives, groups, and CHCs receive 80 per cent. The cost of using Happy Seeder includes the cost of hiring the machine and the cost of the diesel needed to operate it. A prerequisite for using this machine is that loose rice straw should be spread uniformly on the field. This can be done using the Super SMS, at additional cost.

22 Available at <http://pib.nic.in/newsite/PrintRelease.aspx?relid=183,787> last accessed 16th January 2019.

23 Available at <https://www.agrimachinery.nic.in/Files/Guidelines/CRM.pdf> last accessed 16th January 2019.

24 Singh R.P., Dhaliwal H.S., Humphreys E., Sidhu H.S., Singh M., Singh Y. and Blackwell J. (2008), "Economic evaluation of the Happy Seeder for rice-wheat systems in Punjab, India", AARES 52nd Annual conference, Canberra, ACT, Australia.

1.3.1 The policy and subsidy to procure agricultural machinery and equipment for in situ crop residue management

Under the 2108 centre scheme, the government will provide 80 per cent financial assistance of project cost to cooperative societies of farmers, farmer producer organisations (FPO), self-help groups (SHG), registered farmers' societies, private entrepreneurs, and groups of women farmers. It will also provide 50 per cent financial assistance to the farmers for procurement of agricultural machinery. The financial assistance is limited to 50 per cent of cost of the machine or the maximum permissible subsidy per machine, whichever is lower.

The agriculture department has been promoting implements like Happy Seeder, mulcher, and Reversible MB Plough, which can be attached to mechanised harvesters to shred the residue and eliminate the need for burning paddy straw. Farmers and farmers' cooperatives are offered a 50-80 per cent subsidy on the price of these implements.

Name of the machine	Description of machine	Equipment cost (lakh INR)	Rate of financial assistance (for individuals)	Maximum permissible subsidy per machine (INR)
Super SMS to be attached with combine harvester	Ensures that the loose straw thrown by the combine is cut and evenly spread in the fields. It facilitates the use of a zero-till with Happy Seeder.	1.12	50%	56,000
Happy Seeder	Cuts the straw, spreads it evenly in rice fields, cuts 4-5 cm deep slits in the field, and sow's wheat seeds along with the fertilisers.	1.51	50%	75,600
Paddy mulcher (7 ft)	Cuts the residue and mixes it in the soil.	1.57	50%	78,400
Reversible MB Plough (3 bottom)	Mostly used for potato. It mixes the residue by cutting them in small pieces and bury it in the soil.	1.79	50%	89,500

TABLE 2:
Subsidies available for various agricultural implements

Source: Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare, Government of India, 2018
Note: The financial assistance will be limited to 50% of the cost of the machine or the maximum permissible subsidy per machine as indicated above, whichever is lower.

25 Sidhu H.S., Manpreet-Singh, Blackwell J., Humphreys E., Bector V., Singh Y., Malkeet Singh, and Sarbjit Singh. (2008), "Development of the Happy Seeder for direct drilling into combine harvested rice, In 'Permanent beds for rice-wheat cropping systems and direct drilling into rice residues" ed. by E. Humphreys and C. Roth. ACIAR Proceedings No. 127.

Sidhu H.S., Manpreet-Singh, Humphreys E., Singh Y., Singh B., Dhillon S.S., Blackwell J., Bector V., Singh M. and Sarbjeet S. (2007), "The Happy Seeder enables direct drilling of wheat into rice stubble", Australian Journal of Experimental Agriculture 47.

1.4 About the study

Despite policy mandates and the promotion of new, alternative technologies, adoption has been low, and burning of waste persists. According to the satellite data from NASA (VIIRS), there was an increase in open fire counts during October and November in 2018 compared to the previous year.

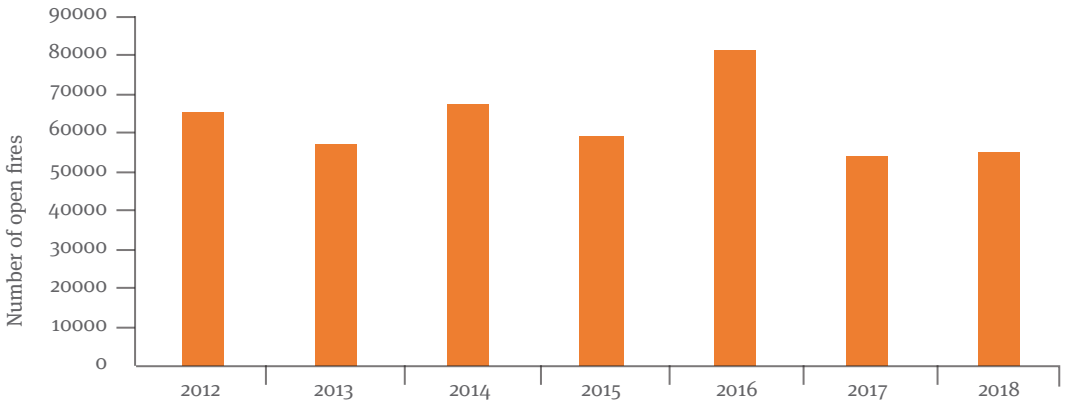

FIGURE 2:
Historical trend of aggregate open fires in Punjab during paddy burning season (Oct-Nov)

Source: NASA NRT VIIRS 375 m
**open fires from any burning detected by the satellite*

Against this background, this issue brief set out to understand:

1. How is burning impacting pollution locally?
2. Is the Happy Seeder, an alternative in situ solution to paddy residue burning, an economical option for farmers?
3. What are the challenges faced by farmers in adopting alternative methods of paddy residue management? What do farmers see as solutions?

Technicians installing sensors close to a paddy field in Hoshiarpur district.

Image: Niti Gupta/CEEW

2. Data and Methodology

We employed a mixed methods approach to answer the questions posed. The approach included

- installation of low-cost sensors across four districts in the state of Punjab to capture $PM_{2.5}$ emissions and understand how burning impacts pollution locally;
- the use of NASA (VIIRS) satellite for information on fire counts in Punjab; and
- interviews with farmers to collect primary data on the challenges farmers are facing and what they see as solutions to the issue.

2.1 Sensor installation

Research on the accuracy and reliability of low-cost sensors is underway, but these are emerging as an alternative for air quality monitoring and as a first step to fill data gaps and create awareness on air pollution. Purelogic Labs manufactures low-cost sensors that measure $PM_{2.5}$, PM_{10}, humidity, temperature, and noise. We procured 48 low-cost sensors from them and installed these across four districts of Punjab in October 2018. We measured $PM_{2.5}$ of the ambient air hourly from 19 October 2018 to 15 January 2019.

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Of the 48 sensors, 16 sensors were installed in Ludhiana, 12 in Sangrur, 8 in Hoshiarpur, and 12 in Pathankot. With the help of Kheti Virasat Mission,[26] we selected villages in each of the four districts; in each village, we selected farmers who agreed to have sensors installed in their field. The sensors were installed close to paddy fields. The researcher selected the site using these criteria:

- it is not adjacent to buildings or trees that distort air flow;
- emissions from other sources (standby generators, chullahs, etc.) will not affect monitoring;
- the power supply is available round the clock;
- the mobile phone network is strong for un-interrupted data transmission; and
- there is no physical interferences from children, etc.

26 A local, non-profit, civil society action group that works in the fields of sustainable agriculture, conservation of natural resources, environmental health, and eco-sustainable technologies.

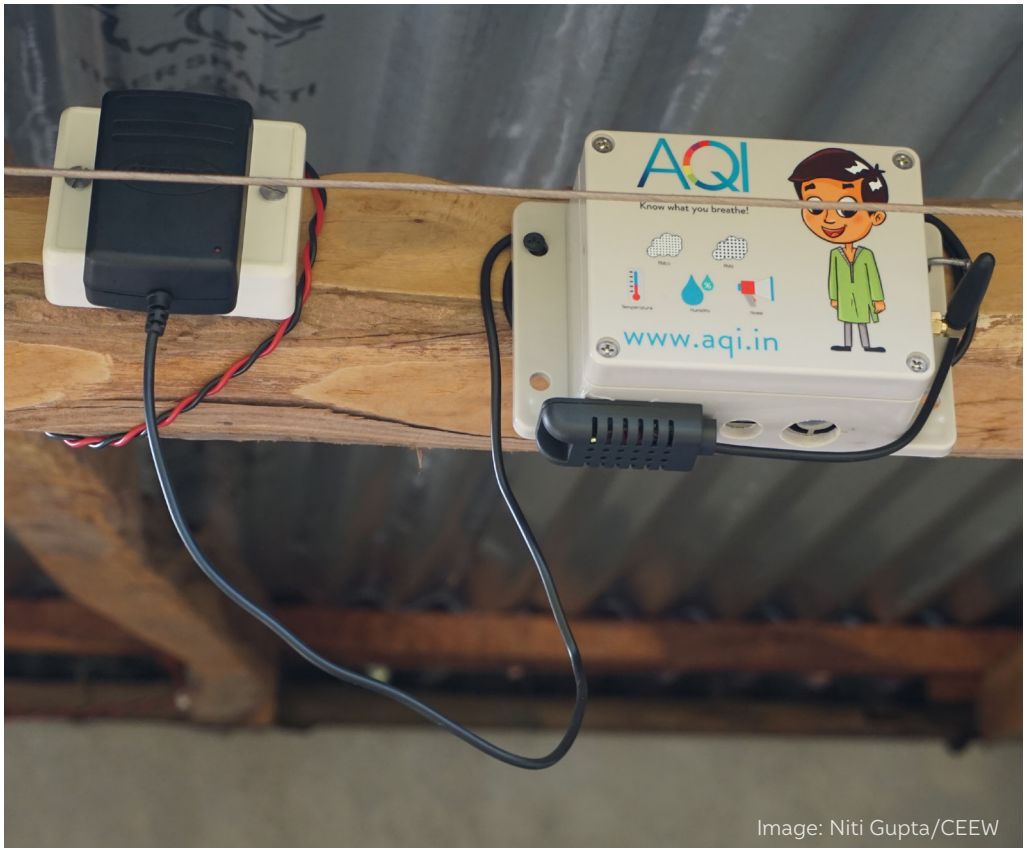

Image: Niti Gupta/CEEW

Sensors from Purelogic Labs installed at homes near farms

Image: Niti Gupta/CEEW

2.2 Farmers' interviews


Image: Kurinji L.S./CEEW

The first set of interviews gathered information on current residue management practices and on the challenges, farmers face in adopting alternative paddy residue management practices

We carried out two sets of semi-structured interviews across four districts in Punjab - Ludhiana, Sangrur, Hoshiarpur, and Pathankot. The first set of interviews with 41 farmers gathered information on current residue management practices and on the challenges, they face in adopting alternative paddy residue management practices. The farmers who expressed their willingness to install the sensors in their fields were also selected. The second set of interviews with eight farmers collected information on the economic assessment of the Happy Seeder machine. The selection of villages and farmers for this set of interviews was done with on-ground support from CIMMYT-BISA.

Our questionnaire focused on farmers'

1. current paddy residue management practices;
2. perception of alternative paddy residue management options provided by the government; and
3. challenges in the uptake of these alternatives and the solutions they see.

2.3 Use of NASA (VIIRS) satellites for fire counts

Data on fire counts is accessed from the Visible Infrared Imaging Radiometer Suite (VIIRS) Fire Product L2 data from NASA Fire Information for Resource Management System (FIRMS). Based on secondary literature, in this study, we used the detected fire pixel with calculated confidence value of greater than 30 (C > 30) to assure fewer false detection for fire pixels (Jethva, et al. 2018).

Traditionally, manual harvesting was done which left less crop residue in the fields. With an increase in labour costs, this is no more an economical option for farmers.

Image: Kurinji L.S./CEEW

3. Key Findings

3.1 Poor rural air quality

Analysis of data from the deployed sensors indicates that the air quality in rural areas of Ludhiana and Sangrur worsened during the peak burning time (25 October 2018 to 15 November 2018). As against the daily standard of 60 microgram per cubic metre for $PM_{2.5}$ in Sangrur, $PM_{2.5}$ levels in November ranged between 219 microgram per cubic metre and 630 microgram per cubic metre.

Another interesting observation was the difference in air quality among paddy-intensive regions (Ludhiana and Sangrur) and Pathankot and Hoshiarpur, where less paddy is cultivated. During the peak burning season, the average $PM_{2.5}$ value for Pathankot ranged from 32 microgram per cubic metre to 114 microgram per cubic metre; for Hoshiarpur, it ranged from 50 microgram per cubic metre to 155 microgram per cubic metre. The analysis clearly indicates that air quality is better in districts where less paddy is cultivated and less paddy residue burned.

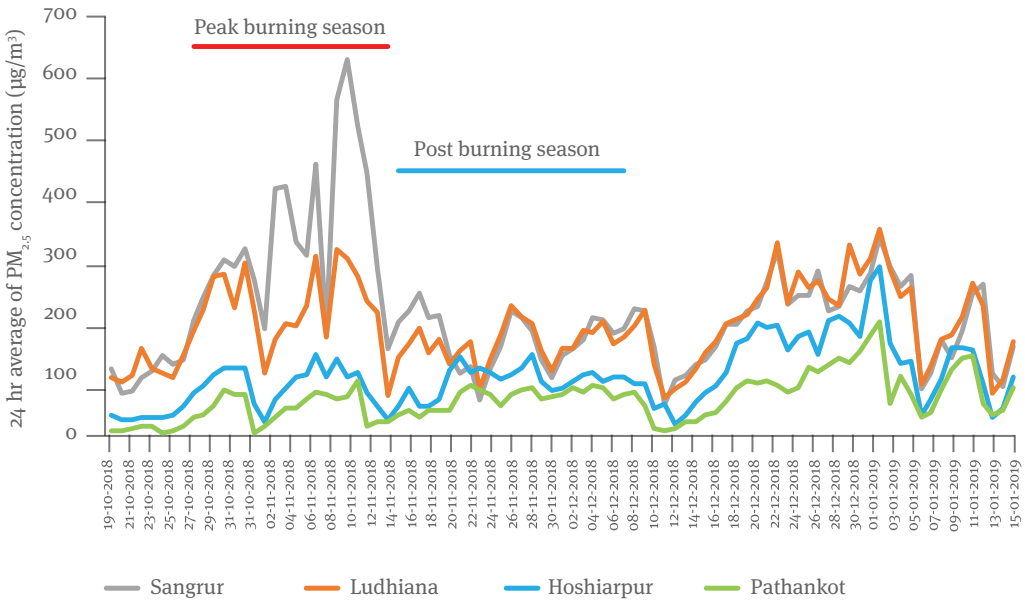

FIGURE 3:
$PM_{2.5}$ level across Ludhiana, Sangrur, Hoshiarpur, and Pathankot

Source: CEEW analysis, 2018

3.2 Happy Seeder is more economical than conventional farm equipment

Farm operations include a combination of rice residue treatments (mulch, bale, incorporate, and burn), land preparation (zero-till,rotavate, plough, and harrow), and seeders (broadcast, zero-till, and Happy Seeder). Traditionally, the burn option and mechanised broadcaster dominate the wheat sowing practice in the region.

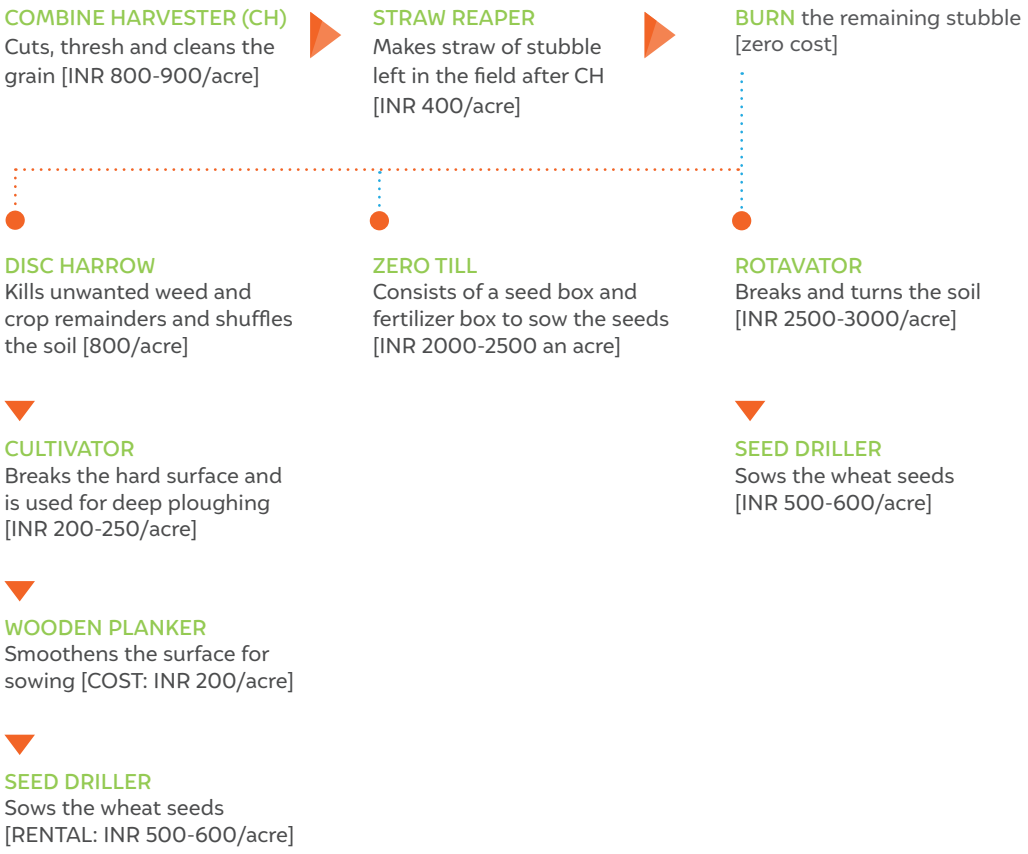

FIGURE 4: Conventional methods of rice residue removal and wheat sowing

Source: CEEW analysis, 2018

We find that the Happy Seeder can be an economically viable alternative to burning paddy residue - farmers can save about INR 1,000- 1,100 per acre on average in field preparation cost. Since the machine can be brought into the field immediately after the rice harvest, it also gives farmers more time.

The farmers who took part in the second survey and who employed the Happy Seeder used the machine in a limited area while also using conventional practice in remaining land. This allowed us to compare the costs of both approaches.

Details	Conventional method - burn straw in the field	Zero burn approach - use Happy Seeder
Process/machines used	CH + burn + disc harrow + cultivator + seed drill	CH + Super SMS + Happy Seeder
Cost (INR per acre)	INR 3,000/acre (CH cost INR 800/acre + reaper INR 400/acre + harrow 800/acre + cultivator INR 200s/acre + planker INR 200/acre + seed driller INR 600/acre)	INR 2,000-3,000/acre (CH with SMS INR 1,500/acre + Happy Seeder INR 500-1,500/acre)
Time required	6-10 days	2-3 days

TABLE 3:
Burning straw vs Happy Seeder

Source: CEEW analysis, 2018

3.3 Farmers' voices and challenges

Despite the advantages of the Happy Seeder, uptake has not been widespreadso far. In 2013, the Punjab government distributed 200 Happy Seeders to Primary Agriculture Cooperative Societies (PACS). Eighty machines were given free and the remaining 120 at a 50 per cent subsidy. The expenditure was financed by grants from the state agriculture department.[27]

Prior to 2017, around 1,000 Happy Seeders were sold in Punjab and Haryana. Now, the central government supports the Happy Seeder, and it is being promoted in Punjab and Haryana. Almost 8,000 machines are reported to have been sold last year.[28] Based on the current capacity, an estimated 35,000 Happy Seeders would cover the entire area, in Punjab.

Based on the discussions with farmers and other stakeholders, such as manufacturers of the Happy Seeder, three main issues constrain uptake.

27 Roy V.C. (2013), "Happy Seeder machines by govt to tackle paddy problem", Available at <https://www.business-standard.com/article/economy-policy/-happy-seeder-machines-by-govt-to-tackle-paddy-problem-110062300002_1.html>

28 Bhattacharya A. (2018), "8-fold rise in Happy Seeder sales raises hope", Available at <https://timesofindia.indiatimes.com/city/delhi/8-fold-rise-in-happy-seeder-sales-raises-hope/articleshow/66077515.cms>

Image: Kurinji L.S./CEEW

Over 50 farmers were interviewed between October and December 2018 by CEEW researchers to understand their paddy residue management challenges.

3.3.1 Manufacturing output of Happy Seeder was lagging behind demand

Each year stubble is burned on around 5.683 million acres of land in Punjab. Based on the available machinery and its capacity, it is estimated that around 35,000 Happy Seeders would be needed to cover the entire area in Punjab. Although 2018 saw a tremendous increase in sales, it was not enough. This was partially due to delay in sending out tenders for the manufacturers. The manufacturers got roughly three months for implementation of the order, which was not enough to meet the demand. Currently, there are 3,200 farmers' cooperative societies in Punjab and 12,000 villages. The availability of machines in CHCs was also observed as limited and inaccessible to farmers.

The agriculture department, however, has already started accepting applications from farmers and manufacturers for the season forthcoming in June and July 2019. For the manufacturers, the tender process is expected to be initiated from June 2019 onwards to avoid delay.

3.3.2 No standard rate for renting Happy Seeder

The rental cost of implements such as Happy Seeder remained prohibitive for some farmers, especially those with small land holdings. There was no standard rental rate. While some farmers' cooperatives charged INR 500 per acre, others charged as much as INR 1,500 per acre, making it unviable for some farmers. Even though much emphasis has been given to IEC - as raising awareness about Happy Seeders is part of the objective of the central scheme - there was still a wide perception gap observed among farmers on the pricing of such implements.

3.3.3 Fragmented market for paddy residue management

Custom rates for baling and hauling rice straw to a storage area or a paper and cardboard mill range from INR 1,100-1,400 per acre for a farmer. Together, the seven biomass power plants in Punjab consume 1 million metric tons of paddy straw annually; they currently lack the capacity to consume the entire 19.7 million metric tons generated.

In the long-term, it is important that Punjab breaks out of the wheat-paddy rotation and shifts to other crops.

Image: Niti Gupta/CEEW

4. Conclusion

Any real solution for paddy residue burning in Punjab involves an in-depth understanding of the agriculture-water-air nexus. It is imperative for Punjab to move towards sustainable agricultural practices that can conserve both depleting groundwater and soil health.

Based on our discussions with farmers and relevant stakeholders, we make the following key recommendations to address the paddy residue burning problem.

4.1 Make paddy residue management technologies available

The Happy Seeder technology coupled with Super SMS-mounted combine harvesters are an innovative and potential scalable solution to manage paddy residue. To widen use, a careful assessment is needed of farm-level constraints to scaling up, of trade-offs, and of viable business models.

There are 1,200 PACS in Punjab. Custom hiring agricultural implements through PACS can be a financially viable option for farmers. These institutions have experience with leasing and renting out equipment and strong linkages with farmers. Under the central scheme, the PACS have the advantage of buying the agricultural implements at 80 per cent subsidy (with direct benefit transfer). However, it is important to fix a uniform rental rate. Promotion of farm mechanisation through CHCs, private entrepreneurs, and farmers' organisations can also benefit farmers, especially small and marginal farmers.

In addition, to improve the efficiency of usage and even pricing, app-based rental models can be promoted. If the machine is being used by a farmer in the vicinity, another farmer should be able to get it for a lower price. Lowering the rental rate during hours when demand is low will help in demand management and also give data on the actual unmet demand.

A careful assessment is needed of farm-level constraints to scaling up, of trade-offs, and of viable business models

4.2 Promote short-duration rice varieties

Punjab Agricultural University (PAU) has developed early-maturing varieties of rice, like PR 126 and PR 127. The PR 126 matures in about 123-125 days after seeding and PR 127 in about 137 days. Both the varieties yield around 30 quintals per acre and consume less water than late-maturing PUSA varieties that require more water and also leave heavier stubble.

A shift to early-maturing rice varieties will allow farmers more time for clearing and preparing fields for sowing wheat. These varieties have a higher yield, consume less water, and resist diseases better; therefore, they can prove more profitable.

A shift to early-maturing rice varieties will allow farmers more time for clearing and preparing fields for sowing wheat

4.3 Raise farmer awareness

Misperceptions of practices or of cost of alternative technologies of residue removal and other in situ practices seriously constrain uptake. Better residue management practices need to be demonstrated through more, better awareness campaigns and design information tools.

In evaluating any farming practice, farmers usually consider total yield only, not input cost or input-output price structure. Awareness programmes should explain that using agricultural implements such as Happy Seeder or practising in situ treatment saves input costs, as less fertiliser and water is needed, and improves soil health.

4.4 Monitor fire counts and rural air quality

Advanced technologies and remote sensing data are required to strengthen monitoring mechanisms. Monitoring should be local. Mobile-based applications can raise farmers' awareness and enable reports of burning in the field.

Mobile-based applications can raise farmers' awareness and enable reports of burning in the field

4.5 Give farmers incentives to move away from the rice-wheat cultivation cycle

In the long term, Punjab needs to shift away from rice-wheat rotation. Current price signals or marketing and procurement policies of crops other than paddy do not offer farmers at-par incentives to shift away from paddy cultivation. Even if MSPs are announced (for pulses, for example), procurement is still an issue. In choosing between the labour and mechanisation options of managing straw, farmers prefer cash incentives to subsidies.

4.6 Set up mechanisms to collect paddy residue

Enterprises such as paper plants can recycle paddy residue; but, to run economically, a plant needs residue from 60-70 acres of land daily, along with six months of storage infrastructure. Currently, there is no uniform mechanism to collect, store, or transport paddy residue; since supply is not assured, industry lacks an incentive to invest in additional plants. Assigning economic value to the residue and to burning it should incentivise the building of this mechanism.

4.7 Use paddy residue to produce biofuels

Paddy straw can be used to produce biogas, bioethanol, or bio-CNG. The Punjab government has entered into agreements with companies (like Hindustan Petroleum Corporation, Indian Oil, Verbio, and Rika Biofuel Development) to produce these biofuels. Hindustan Petroleum targets the use of about 500 metric tons of paddy straw daily for generating 100 kilolitres of bioethanol. Similarly, Verbio targets the use of 300 metric tons of paddy straw daily to produce 33.23 metric tons of bio-CNG. The state government should formulate a policy to set up the infrastructure to create biofuel supply and demand.

4.8 Strengthen MSP operations

'As per NSSO data for 2012-13, all farmers, who reported sale of paddy during July-Dec 2012, only 13.5 per cent households sold it to procurement agencies and for wheat (Jan-June, 2013), 16.2 per cent households sold it to the procurement agencies.' Over a third of rice and wheat farmers know of the MSP, but very few know that the government sets an MSP for crops like pulses and oilseeds, too, according to NSSO data.[29] The NSSO report suggests that the government set MSPs for crops other than rice and wheat, and publicise these widely. Agricultural marketing for crops other than wheat and rice should be promoted. Punjab was the first state to offer a well- established marketing infrastructure for paddy. Other crops lack that incentive.

Agricultural marketing for crops other than wheat and rice should be promoted

Farmers are equally the victims of complex cross-cutting linkages of the agriculture-water-air nexus, which compels them to burn their fields and inhale toxic fumes. In the trade-off between breathing fresh air and burning fields, we have forced farmers to choose the latter.

29 Available at <https://cacp.dacnet.nic.in/ViewReports.aspx?Input=2&PageId=39&KeyId=598>

Annexure

Paddy residue burning in Punjab – CEEW Questionnaire October 2018

District _____
Block _____
Village _____
Full Address _____
Mobile Contact Number _____
GPS Latitude _____
GPS Longitude _____

Basic Information -

Farmer name _____
Farmer mobile phone no. _____
Age _____
Education _____

1. How much land do you OWN IN TOTAL? (in respondent's stated land unit) ___ __ [NUMBER]

2. How much land do you CULTIVATE in? _____[NUMBER]

3. Information on Plot Size and Crops:

	Plot area			Unit	What is the primary crop sown?			What was the secondary crop sown?		
	Natural	Transitional	Conventional		Natural	Transitional	Conventional	Natural	Transitional	Conventional
Kharif 2018										
Rabi 2017–18										
Spring/ summer 2018										

4. According to you, what percentage of people in your village burns the crop residue?

5. According to you, what percentage of people in your village or in your neighbouring areas burns the crop residue?

6. Normally during the year, how would you rate air quality in your area?

- Very good
- Good
- Acceptable
- Poor
- Very poor

7. During the burning season, how would you rate air quality in your area?

- Very Good
- Good
- Acceptable
- Poor
- Very Poor

8. What is your view on paddy residue burning?

- completely acceptable
- somewhat acceptable
- somewhat unacceptable
- completely unacceptable

9. Do you think the paddy residue burning has any impact on health?

- Yes
- No

10. How frequent are visits from monitoring agencies in PPCB or other government bodies during the burning season?

- Very infrequent
- Infrequent
- Neither
- Frequent
- Very Frequent

11. Do you know about the fines in the event of cropresidue burning?

- Yes
- No

12. What is the fine, in your understanding? ---------- (ask for a monetary value or other metrics)

13. What is your view on fines for paddy residue burning?

- completely acceptable
- somewhat acceptable
- neither
- somewhat unacceptable
- completely unacceptable

14. Are the fines being levied without exception?

- Yes
- No

15. If No – Who doesn't pay the fine? -------- (open ended)

16. Do you think there are alternative ways of handling the residue?

- Yes
- No

17. If yes, then what alternative technique do they think is appropriate?

- Composting or mushroom cultivation
- Biofuel extraction
- Biomass power plant
- Incorporation or mulching

18. If no, what do you think will be the solution to the issue of burning?

19. On your farm, do you still burn any crop residue?

- Yes
- No

20. How do you manage the paddy straw in your fields?

21. If no to 19: What were the reason for you to stop paddy residue burning?

- 0= I want to comply with the law
- The fine is too high and I cannot afford it
- 1= Not burning improves yield for the next crop
- 2= Not burning means reduced fertiliser requirement in the next cycle
- 3= Not burning is a way of conserving soil health
- 5= My own Health concerns
- 6=Other (specify)

22. Have you considered moving away to cultivate crops other than rice and wheat?

23. Are you aware about the subsidies on machinery provide by the state government for processing the crop residue instead of burning?

24. Do you face any barriers with these new alternatives available provided for paddy residue management?

25. If yes to 23: can you please explain in details?

Image: Kurinji L. S./CEEW

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