Addressing Air Quality Spurts due to Crop Stubble Burning during COVID-19 Pandemic: A case of Punjab

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1. Background

World over the headlines are centred on COVID-19. The World Health Organisation (WHO), various subject experts, and governments across the world see this pandemic sticking around in some measure until a cure or a vaccine has been found. In view of this, there is an urgent need that all stakeholders – governments, industry, people, and civil society – shift their strategy from largely reactive, so far, to proactive.

COVID-19 has been termed as an "Anthropocene Disease" and a response to the pandemic focused purely on human health will be near-sighted, and there is a need to look at COVID-19 from the perspective of Planetary Health (O'Callaghan-Gordo and Antó 2020). Thus, the response to the pandemic must not only consider humans but also the Planet. COVID-19 and many other infectious diseases of recent times have the same origin as environmental degradation and climate change.

However, in the short to medium run, while the industry needs to develop an understanding of the implications of the current disruptions and the future threats and risks and accordingly develop a plan to totally avoid / minimise the impacts of these on their businesses; the governments have a duty to: (i) develop and implement the measures that would minimise the risks to the economic recovery and (ii) focus on all possible measures to arrest critical events (such as crop stubble burning in north India) that may cause poor air quality (AQ)[2] thus further aggravating this unprecedented health crisis in at least three

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[2] In Delhi-NCR, about half the air pollution on some winter days can be attributed to agricultural fires, when air quality level is 20 times higher than the safe threshold levels defined by the WHO (PTI (i), 2019)

ways:

i. One, poor AQ poses additional risk to people getting infected by Covid-19. Available information shows that management of COVID-19 in persons with weak respiratory system is much harder and tricky and is associated with high mortality rates (Chen et al 2020). A growing body of evidence suggests increase in cases related to respiratory illness increase in Delhi NCR and other cities in Punjab, Haryana and Uttar Pradesh in winter competing with cases of other illness for the poor/modest health infrastructure and other support systems in these states (Gupta el al 2016; Gupta 2019). The extent to which the COVID-19 virus induces respiratory stress in infected individuals is also influenced by the extent to which an individual's respiratory system is already compromised due to other factors such as co-morbidities and pollution linked pulmonary conditions;

ii. Two, it is likely that poor AQ (high SPM) might aid human-to-human transmission of COVID-19. According to Qu (2020), inhaling of virus-laden fine particles could transport the virus into deeper alveolar and tracheobronchial regions and further increase chances of infections. A recent source apportionment study says, open burning emissions in Punjab, Haryana, and the northwest of Uttar Pradesh accounted for 15% to 35% of ambient PM2.5 concentrations (GBD MAPS Working Group, 2018).; and

iii. Three, with COVID-19, existing health infrastructure is already under severe stress, and additional pollution related infections will only serve as a stress multiplier.

This clearly means that in 3-4 months we have a huge imperative to address the annual disaster of AQ in Delhi NCR and other cities of Punjab, Haryana and Uttar Pradesh in India.

Come winter, Delhi NCR AQ (sudden worsening in AQ due to paddy stubble burning in Punjab, Uttar Pradesh, and Haryana) becomes a hot topic for the media, government, political circles, and elite sections. The concern and anger of people is also due to the

delayed or missed flights. AQ in Delhi NCR or AQ in general in other urban hot spots in India has not been a serious election issue so far. This can to a large extent be explained by the fact that vulnerable people including children, elderly and the poor bear the large brunt of health issues due to poor AQ. The poor also have many other serious issues like poverty, employment and livelihood to deal with, and also lack full understanding and awareness of the implications of poor AQ.

In this paper, we focus on the issues in poor AQ due to crop stubble burning in Punjab. What solutions can we find now, to avoid the disaster in October - December 2020? The analysis in the paper brings to the fore some short term practical measures and underlines that a medium to long term solution lies, among others, in making food production in Punjab efficient in resource use and resilient to environmental and climate changes.

2. Some Attributes of Agriculture in Punjab which have a bearing on crop Stubble Burning

Punjab has been and is still seen as the bread basket of the country. Comparative advantages of good soil, availability of sub-surface and surface water, hardworking and enterprising farmers, and knowledge of nuanced farming and other supporting infrastructure developed over the years especially since the green revolution, has contributed to growth in agriculture in Punjab in the last few decades. Productivity growth supported by government policies and technology has played a major role in influencing crop specialisation strategies in agriculture in Punjab over the years.

Following the success of the high yielding varieties in Punjab, there was introduction of rice-wheat cropping rotation. This has led to extreme specialisation of rice-wheat cropping system, covering 81% of the gross cropped area of the state in 2013 (Grover at al 2017). With the adoption of the rice wheat cropping pattern in the state, crop diversity has decreased considerably owing to a decrease in area under crops like, gram, pulses, groundnut, which have a positive impact on soil quality. Further, area under low input crops, like maize, bajra, jowar etc., has also decreased. Field experiments conducted by

the Indian Agricultural Research Institute have shown that a rice-wheat cropping system is no longer sustainable for the Indo-Gangetic Plain (IGP) region (Sharma et al 2010). Following scientific calls, the Indian government introduced the Crop Diversification Program in Haryana, Punjab & Western Uttar Pradesh was introduced in 2013 recognizing that continuous cultivation of water guzzling crops like paddy due to frequent flood irrigation has resulted into depletion of ground water in the original Green revolution States namely; Punjab, Haryana and Western Uttar Pradesh (MOA 2013).

Under the rice-wheat cropping system, with the availability of short duration varieties of wheat and rice it became possible to grow high yielding rice crop (June/July to October/ November), followed by a wheat crop (November/December to March/April). With the adoption of these varieties rice-wheat crop rotation became popular in areas which earlier produced only wheat or rice in any one farming year.

An important feature and limitation – also seen as the main factor responsible for stubble burning – of the rice wheat cropping cycle is the available short time between rice harvesting and sowing of wheat. A delay in sowing wheat adversely affects the wheat crop. Farmers get less than 20-25 days between two crops, and hence the quickest and easiest solution is to burn the crop residue (Jitendra, et al., 2017). According to (DTE, 2019), over 20 million tonnes of rice stubble is produced every year in Punjab; out of which 80% is burnt on the farm. Based on a survey of 625 farmers in Punjab a study (Kumar et al., 2015) shows that 41% farmers attributed crop stubble burning to short window of time available between harvesting paddy and sowing wheat, while 48% said that burning is more economical and faster. Diversification of rice-wheat cropping system areas is necessary not only because of burning of paddy straw but because of other adverse impacts on water tables, stagnancy in crop yield and depletion of natural resources (Kedia 2017).

The short window of time available between rice and wheat crops can also be attributed partly to the Punjab Preservation of Subsoil Act, 2009 (Jain 2019). As per the Act, farmers are prohibited from sowing paddy seeds in nurseries before May 10 and transplanting the seedlings before June 10. The objective of the Act is to delay the sowing of paddy seeds so that the water used for harvesting these seeds can be reduced. This legislation did produce

the desired results. Before the Act, farmers used to harvest paddy seeds in April. It was found that 4500 litres of water are required to grow 1 kg of rice when it is sown in April-May. But when the sowing is done in mid-June, water requirement is significantly reduced to 1500-2000 litres. Once the Act was enforced, the average annual rate of decline in the water table reduced from 0.9m (2000-2008) to 0.7m (2008-2012). But there was a negative externality associated with the Act. Rice is a 120-days crop. Thus by the time rice was harvested, it was already time for the next crop cycle (Rabi season). Since farmers did not have enough time to prepare the field between two crop cycles, they were forced to burn the rice-straw. However, more research is required to understand the impact of this legislation on the practice of rice straw burning.

Shortage of labour could also be a factor contributing to burning of rice straw. With the enactment of the Punjab Preservation of Subsoil Act, 2009, harvesting of rice and sowing of Rabi gets pushed to October/November. Cultural factors during the festive season (Dushehra, Deepawali, and Chatth) in October/November in north India impact availability of labour which is critical input in management of rice straw and preparation of field for the next crop. This issue is also under researched to be able to understand the extent of the impact and potential solutions.

Preparation of the field for the sowing of wheat crop involves removal or utilization of rice straw left in the field. Over the years, various technology solutions have been introduced and used in Punjab to harvest the rice crop within the available short period of time. One such solution has been use of the combined harvester. Almost 80 % of the rice crop is harvested using this in Punjab. However, use of combined harvester leaves behind a large amount of rice residue in the fields, which is difficult to collect manually.

According to Shyamsundar et al (2019), Happy Seeder is a profitable and scalable rice residue management solution to the farmers and its use has the potential of generating Rs 6,000-Rs 11,500 profits per hectare for the average farmer. The study states that "*a key reason why burning continues in northwest India is the perception that profitable alternatives do not exist*". The Government of India subsidy in 2018 for onsite rice residue management has partly addressed a major financial barrier for farmers, which has resulted in an increase in use of Happy Seeder. However, other barriers still exist, such as lack of

knowledge of profitable no-burn solutions and impacts of burning, uncertainty about new technologies and burning ban implementation, and constraints in the supply-chain and rental markets (CIMMYT, 2019).

Apart from this, farmers can manage crop residues effectively by employing agricultural machines like the Rotavator, which is used for land preparation and incorporating crop stubble in the soil; Hay Baler, used to compress a cut crop so that it is easy to handle and store; and the Reaper Binder, used for harvesting paddy stubble and making it into bundles, and zero till seed drill, used for land preparations to directly sow seeds in a crop stubble (DTE, 2019).

3. Examining crop stubble burning in north India through the lens of promoting efficient and resilient agriculture and management of externality

Agriculture is an essential driver of economic growth and helps ensure food and nutritional security which is crucial for sustainable development particularly in developing countries like India. However, agriculture exerts a considerable impact on the environmental resources (FAO, 2012) especially land, water, biodiversity, and atmosphere (local and regional pollution and greenhouse gases). Food production, in turn, is impacted by poor quantity and quality of natural resources and climate change. Even though the current agricultural policies in Punjab have played a significant role in contributing to the economy of the state these do create externalities in terms of ecological and natural resource crises in the state and seasonal spurts in atmospheric pollution in the region. Thus, there is a need to make food production more efficient in resource use and more resilient to environmental changes and shocks. However, this would involve addressing multiple, complex and intertwined policy, technology, and regulatory issues in a multi-stakeholder setting. Given the COVID-19 shock, ensuring food security should be built on large scale reforms making it more ecologically resilient, while viewing it as an opportunity to put India's agri-marketing and PDS system more efficient (Gulati 2020). To guide such transformation there is need for a paradigm shift from the conventional development approach.

3.1 Balancing efficiency and resilience

Specialized systems are often presented as being more efficient from an economic point of view, as they generate more income. These systems often benefit from price and income support from governments which, in turn, encourages relatively greater research and technological advancements providing further support to specialised systems (Martin, 2019). The pursuit of efficiency is a reasonable goal and thus is both supported and encouraged/rewarded by the governments through various policies (largely guided by neoclassical economics which ignores environmental factors). However, it does not come free. Some of the costs of efficiency in agriculture can be environmental unsustainability and loss of resilience in the medium to long –run (loss of nutrients in soil, loss of biodiversity, increase in input costs, stress on water resources, and off-farm externalities).

Resilience in agriculture can be described as the capacity of farmers, systems, communities, or individuals to prevent, mitigate or cope with risk and recover from shocks (climate change, pests, diseases, invasive species and so on). Essential to building resilience is reducing exposure, reducing the sensitivity of systems to the changes and shocks, and increasing adaptive capacity (Martin, 2019).

Being efficient without being resilient will not be helpful over the long term, and being resilient without being efficient or without allowing for an increase in production, will pose problems for ensuring food security over the long term and for supporting livelihoods. In the pursuit of these two goals, there might be trade-offs, but there can also be synergies. For instance, there is evidence that crop diversification (genetic variety, species, structural) contributes to a significant reduction in downside risk exposure (Di Falco et al. 2007). Whereas, agriculture systems providing more diverse types of food can facilitate nutritional security and promote ecosystem services for pest and disease control and resilience to climate change variability (Lin 2011). Resilient agriculture, in turn, contributes to productivity growth (Di Falco and Chavas 2008).

Although it is being increasingly recognized that diversity can improve the resilience of agricultural systems and promote ecosystem services; economic policy incentives and

other types of support (MSP, input subsidies, biotech solutions, and support for other expensive and intensive forms of risk management) can out-weigh the incentives to implement diversified farming systems. A clear understanding of the potential of increasing diversity within farm systems is essential in designing the appropriate policy responses.

3.2 The issue of externality in crop stubble burning

Stubble burning creates externality in the form of emissions with implications for climate change and health costs to people in affected region, disruptions in economic activity (cancellation/delays in flights and trains, and slow road traffic and accidents). The Coase theorem states that externality management requires some coordination schemes among the individuals affected by the externalities, and this can be done through private contracts when the number of individuals is small. Alternatively, when the number of individuals is large, more centralised coordination (through some form of governance institution) schemes may be needed (Carriazo, 2016). Since air quality is a public good, the role of central coordination /government becomes even more important. Which would imply that the government would need to either share the cost of compensation or the cost of abatement (reducing stubble burning), or both in different measures. Broadly, the application of incentive-based regulation can be a potential cost-effective way to control air pollution.

Agricultural policy and environmental policies can play important role in designing such an instrument. The challenge is that agricultural policy often has multiple objectives such as ensuring food security, supporting farmers' incomes, managing price volatility, managing local and off-farm externalities (disease, invasive species). It becomes problematic when the objective of managing local and regional externalities due to crop stubble burning conflict with other objectives of agricultural policy. Environmental policy on the other hand has limited jurisdiction as well as limited resources and resulting policy options available. A well-coordinated and participatory approach is thus called for.

Nonetheless, agricultural policy which has incentivised specialisation in rice-wheat cropping cycle practiced in Punjab cannot completely absolve itself from the on-farm and

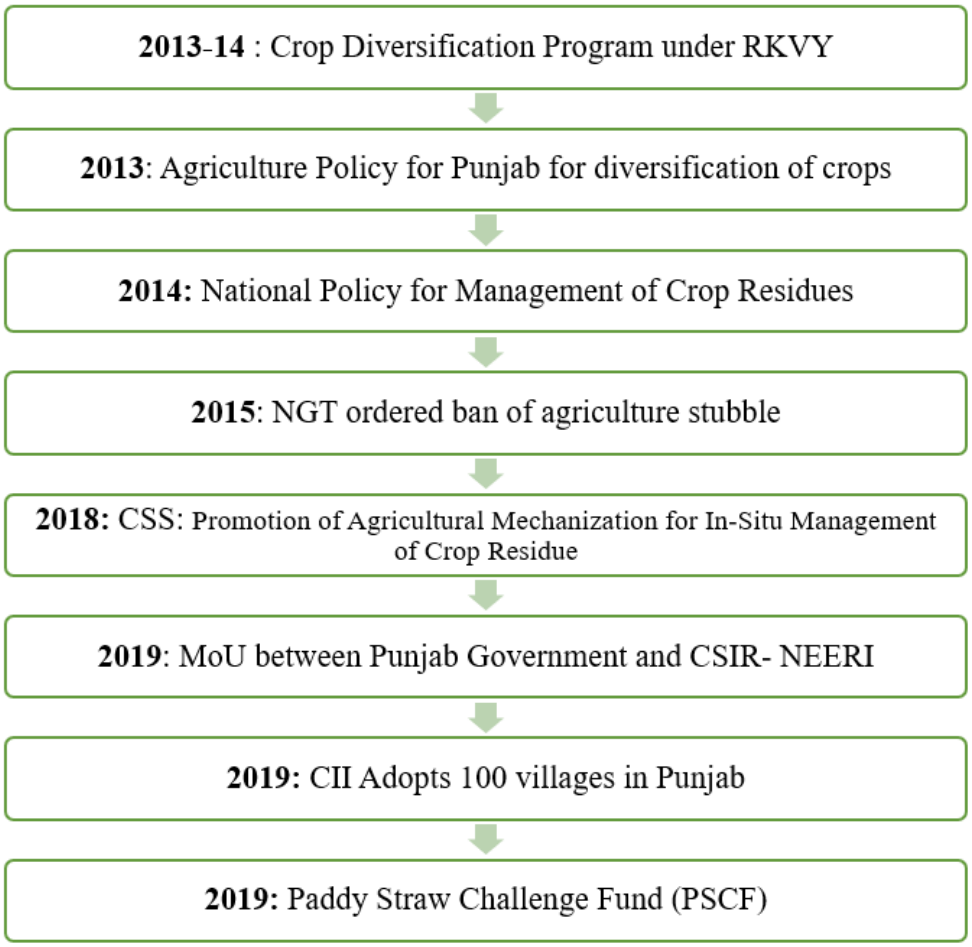
off-farm costs of this cropping system. There is no denying that the specialisation in agriculture being promoted in Punjab has impacted the resilience to adapt (crop diversification) to innovate (technological and enterprise innovation) and transform the state into low agricultural waste, and water efficient through water conservation practices. To large extent stubble burning is done by farmers to achieve economic efficiency by hastening the harvesting of Kharif crop so the farm can be quickly readied for the Rabi crop. A delay in sowing of Rabi crop has implications for the yield and quality.

Rice residue burning results in extensive on and off farm impacts, e.g., losses in soil nutrients, soil organic matter, production and productivity, air quality, biodiversity, and water and energy efficiency and on human and animal health. Burning 1 tonne of rice accounts for a loss of nitrogen (5.5 kg), phosphorous (2.3 kg), potassium (25 kg), and sulphur (1.2 kg) in the soil. Moreover, the heat from burning crop residue kills critical bacterial and fungal populations in the soil, apart from organic carbon (Hesammi and Talebi, 2014). Stubble burning emits PM2.5, which is the most adverse for human health, since the particles can get trapped inside the lungs and increase the risk of lung cancer by 36% . According to (Kumar et al, 2015) people in rural Punjab spend more than Rs 7.6 crore every year on treatment for ailments caused by stubble burning. Cost of air pollution due to stubble burning in India is estimated to be USD 30 billion annually (International Food Policy Research Institute, 2019). Further, stubble burning reduces the availability of straw to livestock, which is already in short supply by more than 40 % (Kumar et al 2015).

4. Recent Policy Interventions and other measures taken

The problem of crop stubble burning in Punjab has been addressed by various policy and other interventions by the Central government, as well as the government of Punjab. Key interventions are (Figure 1):

Figure 1: Key Policy Interventions and other measures



i. **The National Policy for Management of Crop Residues (implemented in 2014):**

The Policy focuses on promotion of technology for in-situ management of crop residue as well as diversified uses of crop residue. Besides, there are provisions for promotion of adaptive research and capacity building of stakeholders.

ii. **Crop Diversification Programme (CDP) under Rashtriya Krishi Vikas Yojana (RKVY):**

The objectives are to demonstrate and promote the improved production technologies of alternate crops for diversion of; paddy cultivation; and second, to restore the soil fertility through cultivation of leguminous crops that generates heavy biomass and consume less nutrient intake crops (MOA 2013). These policy

initiatives by the Centre are definitely off-track as the latest agricultural statistics by the ministry of agriculture and Farmers Welfare for 2016 show an increase in area under paddy cultivation over the previous year for the states of Punjab and Haryana. Despite this clearly dismal performance, the fund allocation under the crop diversification programme for the component on "alternative crops demonstration" was reduced from 60 per cent in 2013-14 to 40 per cent in 2015-16 (Kedia 2017). The awareness among farmers about the policies on crop diversification is very low (TERI-GGGI 2015). Surprisingly, the national programme on crop diversification is vague about provisions related to awareness and outreach activities to sensitise the farmers.

iii. NGT's Ban on Stubble Burning:

On November 04, 2015, the National Green Tribunal (NGT) ordered banning of agriculture stubble burning in the states of Rajasthan, Uttar Pradesh, Haryana and Punjab under Section 188 of the IPC and under the Air and Pollution Control Act of 1981[3]. NGT has also ordered fine of INR 2,500 to INR 15,000 on farmers indulged in straw burning. Even though violators can be booked for disobedience of the ban, farmers continued to burn paddy stubble due to lack of viable alternatives. Hence, following a ground level study, a government panel recommended to the NITI Aayog that a machinery- based solution would be ideal (Vishnoi 2017).

iv. CSS: Promotion of Agricultural Mechanization for In-Situ CRM

A Central Sector Scheme, 'Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue in the State of Punjab, Haryana, Uttar Pradesh & NCT of Delhi' was launched in 2018. Under this scheme, financial assistance at the rate of 50% is provided to farmers for purchase of in-situ residue management machines such as Gyrorake, Baler, Chopper Shredder, Rotavator, Happy Seeder, and Zero Till Drill. The scheme covers three components-

[3] The Punjab government took action against 2,923 farmers after receiving complaints against 20,729 cases of stubble burning in 2019. The enforcement teams had imposed environment compensation of Rs 41,62,000 in 1,585 cases, a red entry made in Khasra Girdawaris in 1,136 cases, and prosecution/FIR filed in 202 cases against the defaulting farmers (Sandhu, 2019). The State Government of Punjab during 2019-20 imposed Environmental Compensation in 23,200 incidents of paddy straw burning as per the directions of NGT (MOAFW 2019).

Establishing Farm Machinery Banks for Custom Hiring of the CRM machinery (financial assistance provided to cooperatives, SHGs etc to further rent out machines to farmers), financial assistance to individual farmers, and IEC for awareness on CRM.

CPCB and SPCBs have to conduct regular co-ordination meetings at official and ministerial level with Government of NCT of Delhi, Punjab, Haryana, Uttar Pradesh and Rajasthan.

v. The Agriculture Policy for Punjab (2013)

The policy advocates that the strategy for agriculture development has to address the sustainability concerns while achieving the overall growth objectives. The policy aims to make concerted efforts to reduce the area under paddy cultivation by 40 per cent from current levels in a span of 5–7 years. As per the policy, area under paddy should be restricted to 16 lakh hectares for maintaining the ground water balance. The Policy for Management and Utilization of Paddy Straw in Punjab 2013 provides information on alternative options for utilizing paddy straw and challenges witnessed in collection & storage of the straw.

Other measures

i. In 2019, the NITI Aayog also asked the Indian Agriculture Research Institute to expeditiously conduct field trials of technologies that allows paddy straw to decompose in fields (Sharma 2019)

ii. MoU between Punjab Government and CSIR-NEERI

In 2019, the Punjab government signed an MoU with Council of Scientific and Industrial Research (CSIR) - National Environment Engineering and Research Institution (NEERI) to extend technical support to the state for abatement of pollution, besides waste management (UNS, 2019).

iii. Compensation to farmers for not burning paddy stubble

In 2019-20, the Punjab Government disbursed INR 19 Crore among 29,343 non-basmati cultivating small and marginal farmers, as compensation for not burning stubble @ INR 2500/acre (NewIndianExpress, 2019). However, after some panchayats reported that farmers received compensation despite burning paddy stubble, reverification of claims was started in Punjab. The procedure has been made more stringent and a farmer has to meet three conditions to receive

compensation now: the total landholding should not exceed five acres; the farmer has not burnt paddy residue and the farmer must be a non-basmati crop grower (Vasdev 2019).

iv. Adoption of over 100 villages in Punjab and Haryana by Confederation of Indian Industry (CII) to curb pollution

In 2019, the CII adopted over 100 villages and 100,000 acres of farm area in Punjab and Haryana to guide zero crop residue burning by providing technical support through machineries and training, and a comprehensive awareness campaign (PTI, 2019).

v. Paddy Straw Challenge Fund (PSCF)

Punjab's State Farmers and Farm Workers Commission have set up a fund of one million dollars to find an appropriate technology to address the issue. The challenge is open worldwide to find a technology that ensures in-situ decomposition/degradation of surface-retained paddy straw within 20 days of harvesting by combine harvester under ambient Punjab conditions (Sethi, 2018).

5. Remaining Issues

i. Timely availability of CRM machines to farmers: Unavailability of CRM machines has been a key issue in mitigating crop residue burning. In 2019/20, the number of machines delivered fell to 14,625 from 28,609 in 2018-19. Table below illustrates the machines delivered under the subsidy scheme in Punjab in 2019-20, against the number of machines sanctioned.

Machines given under the subsidy scheme in Punjab (2019-20)	Machines Sanctioned	Machines Delivered
Zero Till Drill	6,079	4,321
Paddy-straw chopper	4,951	2,910
Happy Seeder	4,812	2,936

RMB Plough	3,178	2,012
Mulcher	2,110	1,277
Super SMS	990	528
Cutter-cum-spreader	435	356
Rotary Slasher	275	157
Super Seeder	NA	112
Shrub Master	24	16
Total Machines in 2019-20	22,854	14,625
Total Machines delivered in 2018-19	28,609	

Source: Nirmal, 2019

Further, it is important to note that the total area that could be sown using the 12,694 Happy Seeder machines in the last two years would be maximum 25 lakh hectares (given that one Happy Seeder sows 6-8 acres a day). Given that Punjab has about 75 lakh acres under paddy, Happy Seeder have been used in only one third of the area (Nirmal 2019). Thus, relief from crop burning cannot be expected with the current number of machines given out.

ii. Farmers claim that the machines to dispose paddy stubble are unaffordable, despite the subsidy provided by the government. Happy Seeder costs INR 1.50 lakh and requires a 65-horsepower tractor. It is not affordable for small farmers to buy the machinery, even with the subsidy at current rates of 50 per cent (PTI, 2019). Further, even though the CSS scheme provides 80% subsidy to cooperative societies to further rent out to farmers, most of the cooperative societies did not have funds to buy such machinery on even 80 per cent subsidy (Tribune 2018).

iii. Facilities to dispose of the paddy residue are non-existent. Even though wheat stubble can be used as fodder after converting it into chaff, such uses do not exist for paddy stubble (Khanna 2019).

iv. Lack of awareness, uncertainty about new technologies and misconceptions that Happy Seeder machines reduces yield, constraints in the supply-chain and rental markets are other issues impacting adoption of Happy Seeder.

According to a field study by TERI-GGGI (2015), farmers were uncertain of the impact of machines on crop productivity.

v. Farmers claim that the machines to dispose paddy stubble are unaffordable, despite the subsidy provided by the government. Happy Seeder costs INR 1.50 lakh and requires a 65-horsepower tractor. It is not affordable for small farmers even with the subsidy at current rates (PTI, 2019)

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6. Key Proposals on the table for consideration of governments

The Punjab government has shown commitment to identify a workable, long-term solution for the problem of stubble burning. In this context the following is important:

i. The Punjab State Farmers and Farm Workers Commission held workshops with various stakeholders in November 2019. The following are the key suggestions made by farm activists to the Punjab government (TOI, 2019).

a) Provide compensation for crop residue management (CRM) to all farmers having less than ten acres of land, as compared to the current condition of landholding less than five acres.

b) Build a cooperative relationship with farmers, and not fine them for burning residue

c) Create strong marketing network for crops other than paddy

d) The government should not make red entries into the land records of farmers for burning stubble

ii. Key Recommendations of the committee set up to review the scheme "Promotion of Agricultural Mechanization for In-Situ Management of Crop Residue" (Farmech, 2019)

a) The key issue identified by the committee is delay in supply of machinery to farmers in Punjab, where the final date for supply of machinery was 15th November in 2018. Addressing these delays is critical and hence the committee recommended that the CRM machines by 30th September each year, and it should be available with the farmers for the entire sowing period.

b) Awareness campaign through media and extension agencies. The latter need to hand hold farmers in addressing specific issues.

c) Rather than ex-situ utilisation of paddy straw, focus on incorporating it in the soil by providing support to farmers for adoption of CRM solutions. This will also look after soil health.

7. International Experience

For years, crop burning was perceived as normal by several countries and open burning of crop residue was often overlooked to meet the growing demand for food as well as to maximize profits from cultivation. However, the problem was recognised as severe when the scale at which it is carried out became significant. In absolute terms, India, China are the biggest burners of crop residue in the world in term of the kilos of biomass burned annually (Cassou 2018) . Steps taken by China, Australia and UK are as below:

a. China banned burning crop residue in 1999 and imposed heavy fines on violators. CRM in China has "in-situ" focus which helps balance composition of nitrogen, phosphorous and potassium in the soil (Sun et al, 2016).

b. In Australia, comprehensive guidelines exist to deter for crop residue burning. There are certain exceptions where burning is allowed, such as clearing agriculture or regeneration of pastures.

c. United Kingdom banned crop residue burning in 1993 due to environmental concerns. Farmers are pressing for return to licensed (limited and controlled) stubble burning which may be necessary in some cases to control Blackgrass (a weed) which is resistant to pesticides and herbicides.

Burning of blackgrass is seen as the only solution to get rid of it (Tasker 2012).

8. The Way Forward

A holistic approach is required to address crop residue burning. The challenge cannot be mitigated alone by agricultural agencies, as it requires a multi-disciplinary approach involving technical agencies, market based economic tools, supporting policies and awareness and capacity building of farmers.

8.1 Addressing the practical Issues of affordability and availability of Happy Seeder Machines

a. Farmers' misconceptions regarding reduction of yield due to use of Happy Seeder must be addressed using awareness campaigns and on field training.
b. Current subsidies for CRM need to be reviewed. A subsidy at Rs. 3000 per acre as compared to the current rate of subsidy of Rs. 2500 per acre may be more acceptable to farmers and might encourage removal of straw manually in cases where buying happy seeders is unaffordable and the rental market for happy seeders is unable to meet the demand for machines in time.
c. Even though the CSS scheme provides for establishing Farm Machinery Bank to provide hiring services to farmers, the rental market remains weak. For instance, in 2018, Muktsar district which has 144 cooperative societies, sent a demand for 96 Happy Seeder to the authorities, out of which only 41 were delivered (Tribune 2018). Thus, building an efficient rental market should be a priority.

8.2 Crop Diversification/Rotation

While technological interventions may be useful in the short term, crop diversification as a medium to long term policy intervention needs to be emphasised by both the central and the government. Crop diversification can improve resilience from the effects of greater climate variability and extreme events. It can be implemented in various ways such as crop rotation, poly-cultures, increased structural diversity or agroforestry. A flexible policy environment will allow

farmers to choose a strategy that increases resilience as well as provides economic benefits (Lin, 2011).

a. Focus on crop diversification needs to be increased and the crop composition in the IGP region needs to be re-evaluated. In 2016, the allocation of money in the "alternative crops demonstration" component in the Crop Diversification Program of GOI, were reduced by 20% as compared to 2015. Awareness of farmers about the scheme needs to be improved

b. Crop diversification efforts should be a mix of policy measures, encouragement of agro-business enterprises, possibly under "Aatmanirbhar Bharat Abhiyan" scheme, increased awareness of farmers about the importance of the scheme for them and what it offers, economic incentives such as minimum support prices, along with infrastructure support like agricultural inputs for identified alternative crops. A detailed study involving all stakeholders will be required to understand slow progress towards crop diversification in spite of regulatory policy nudges and fiscal policy incentives announced by both the central and state governments.

8.3 Other measures

More research is needed to understand the full implications of the ***Punjab Preservation of Subsoil Act, 2009*** on crop stubble burning and the trade-offs therein. Also, a deeper understanding of the issue of availability of labour[4] due to cultural practices of celebrating the season of major festivals in north India (October-November) with families in native villages/ districts and its impact on stubble burning and what could be the potential solutions to address it.

[4] Due to mandatory late sowing of rice, harvesting of rice and sowing of the next crop-wheat gets pushed closer to the season of major festivals in north India

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