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Crop Residue Burning : Impacts, Management Techniques and Policies

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ABSTRACT

In latest studies, it is revealed that crop residue burning in India has huge impacts on environment, climate, health of all living beings, soil and agricultural productivity. The stubble burning is more extensive in the states of north India and air quality of the region gets deteriorated especially in the post-monsoon season. In this paper, emphasis has been made on understanding the concentration of pollutants released during crop residue burning and its impact on air quality of the region. The impact of stubble burning on human health, harmful diseases caused due to stubble burning and number of deaths caused due to air pollution as per World Health Organization (WHO) report and Global Burden of Disease study has been discussed. The types of crops cultivated in Haryana and their quantity of production in the state along with nutrients present in Haryana's soil and their loss during stubble burning have also been discussed. The various *ex-situ* and *in-situ* crop residue management practices that can be followed to minimize stubble burning have been mentioned. The national schemes/policies launched in different years from 2014-19 and Haryana government's various schemes and initiatives taken to manage stubble burning have been discussed in detail in this paper.

Key words : Crop residue burning, impacts, management techniques, policies

INTRODUCTION

Stubble or crop residues are agricultural by-products left after harvesting on the agricultural field. There is very short window between the harvesting of rice and preparing field to sow wheat and thereafter management of loose crop residue is very laborious and not cost-effective due to shortage of labour after implementation of schemes like MGNREGA. Therefore, farmers prefer the option of stubble burning to avoid yield loss. There are some farmers that prefer to cultivate same three crops that lead to difficulty in managing the crop residue left behind. The technology such as combine harvesters helps in harvesting crops but 14-15 inch lengthy stubbles are left behind and to remove them it costs Rs. 3500/ha which is very high for farmers (MoAFW, 2019). In a study by Kumar *et al.* (2015), it was reported that 48% farmers prefer stubble burning because it is much cheaper and faster than other means to manage. In north India, crop residue burning is more rampant in states of Punjab, Haryana and Uttar Pradesh (Bhuvaneshwari *et al.*, 2019). The most contribution to crop residue is from sugarcane (43%), wheat (21%), sugarcane (19%) and oilseeds (5%). Crop residue burning is significant source of open-air emissions that degrade the quality of air in north India. The increase in $PM_{2.5}$ concentrations in the states of Punjab and Haryana is found to be linked with crop residue burning (Kaskaoutis *et al.*, 2014). Stubble burning episodes started to increase in 1980s with the introduction of technologies such as combine harvesters as it leads to generation of crop residues that are difficult to handle. The practice of stubble burning especially in developing countries is not just associated with decreased crop productivity but is also associated with regional air pollution issues. From the last decade, the deteriorating air quality and air pollution episodes in India during the onset of winters are found to be linked with crop residue burning. In India, the agrarian emissions released from the burning of crop residues have become a cause of concern due to its adverse impact on human health and the environment. A huge amount of pollutants is released at the ground level including oxides of nitrogen (NO_x), oxides of sulfur (SO_x), carbon monoxide (CO), particulate matter (PM), soot and carcinogenic polycyclic aromatic hydrocarbons (PAHs). These pollutants further cause harmful effects once they are inhaled, absorbed or ingested in the body. Despite numerous evidences on the harmful effects of these pollutants, very few studies exist from India that provide the impact

of stubble burning on ambient air and human health. Moreover, crop residue burning affects the energy budget of the planet and contributes to global climatic changes. Thus, the rampant burning of crop residues in open fields may also result in global warming.

Crops Cultivated in Haryana

The crops cultivated in Haryana are rice (paddy), wheat, cotton, jute, jowar, bajra, maize, barley, gram, mustard (including rapeseed), cotton and sugarcane. Rice (*Oryza sativa* L.) is a **kharif** crop sown in June-July and harvested in November-December. It is a cereal crop which feeds half of the world. The alkaline soils with pH 8 in Haryana are suitable for cultivation of rice in Haryana. The production of rice in agricultural year 2019-20 in Haryana was 5198 kilotonne (Kt). The highest production of rice in Haryana is in Karnal district (585 Kt) followed by Kaithal (504 Kt) and Fatehabad (493 Kt). Wheat (*Triticum aestivum*) is a **rabi** crop which is sown in October- December and harvested in the months of spring. India stands at 2nd position in world in terms of wheat production (11877.4 Kt). It is highest among other crops cultivated in Haryana. The Sirsa district (1484 Kt) had maximum wheat production followed by Jind (1,126 Kt) and Hisar (1,096 Kt). Maize is a **kharif** crop and is grown in the months of June-September (rainy season) and is harvested in December. Jowar and bajra are **kharif** crops and barley is a **rabi** crop. The highest production of Jowar was in Rohtak (6 Kt), bajra in Mahendergarh (203 Kt), maize in Panchkula (12 Kt) and barley in Sirsa (10 Kt) in 2018-19. As per Statistical Abstract of Haryana (2019), the maximum cultivable area in Haryana is in Sirsa 400,000 ha followed by Hisar 397000 ha and Bhiwani 316000 ha. The rice production is found highest in Karnal (12.95%) followed by Kaithal (11.16%) and Fatehabad (10.91%), whereas the wheat production is found highest in Sirsa (11.80%) followed by Jind (8.96%) and Hisar (8.72%). The detailed district-wise statistics about rice, wheat, barley and bajra are given in Table 1.

Table 1. District-wise cultivable area ('000 ha) and production (%) of principal crops in Haryana

District	Total cultivable area ('000 ha)	Production (%)			
		Rice	Wheat	Barley	Bajra
Ambala	148	6.15	3.31	0.00	0.00
Bhiwani	316	1.02	3.98	15.52	9.45
Charkhi Dadri	149	0.55	2.17	10.34	7.74
Faridabad	33	0.80	1.21	1.72	1.14
Fatehabad	223	10.91	8.02	3.45	0.46
Gurugram	83	0.31	1.70	5.17	8.43
Hisar	397	4.16	8.72	12.07	6.15
Jhajjar	182	2.59	3.98	10.34	10.59
Jind	244	8.57	8.96	1.72	2.28
Kaithal	209	11.16	8.41	0.00	0.23
Karnal	197	12.95	8.01	0.00	0.11
Kurukshetra	145	9.21	4.45	0.00	0.00
Mahendragarh	158	0.00	1.68	3.45	23.12
Nuh	123	0.69	2.76	3.45	7.74
Palwal	114	2.17	3.20	5.17	2.16
Panchkula	45	0.97	0.56	0.00	0.46
Panipat	107	4.72	3.46	0.00	0.11
Rewari	128	0.13	1.61	3.45	15.38
Rohtak	158	2.90	3.79	6.90	2.05
Sirsa	400	7.02	11.80	17.24	1.25
Sonipat	156	6.95	5.14	0.00	1.14
Yamunanagar	125	6.07	3.10	0.00	0.00

Crop Residue Burning and Emission of Air Pollutants

The combustion activities such as stubble burning for the preparation of agricultural field for next crop are a considerable source of atmospheric pollutants. Now-a-days this has drawn global concern due to the impact on visibility, air, human health and the release of trace gases. The release of pollutants can alter the biogeochemical processes of earth's atmosphere. The principal emitted pollutants from crop residue burning release toxic gases such as carbon monoxide, volatile organic compounds, carcinogenic polycyclic aromatic hydrocarbons and particulate matter (PM_{10} and $PM_{2.5}$) in the lower troposphere (Jain *et al.*, 2014) resulting in hazardous air quality and poor visibility. As air pollution does not have definite boundary, hence, these harmful gases can travel thousands of kilometers in the atmosphere, increasing the level of air pollution on global level. The stubble burning practices in north resulted in 80% increase in methane concentration in central and southern part of India due to long range transportation (Sarkar *et al.*, 2018).

In north India, during stubble burning period Air Quality Index (AQI) exceeds the safe limit set by the national government in most of the regions. The air quality of an area can be characterized by the Air Quality Index (AQI), which helps in understanding the quality of air in an area and helps in communicating air quality status to people on the daily basis. It includes eight parameters ($PM_{10,}$ $PM_{2.5}$, SO_2,

NO_2, O_3, CO, NH_3 and Pb). The AQI ranges from 0 to 500. The higher AQI value represents the higher concentration of air pollution and more health concern. The AQI is divided into six categories as depicted in Table 2. Each category has a specific colour which represents different levels of health concerns.

The $PM_{2.5}$ concentration increased by 3.5 times during crop residue burning period in Haryana (Grover and Chaudhry, 2019) and crop burning activities in northern part of India showed enhancement in $PM_{2.5}$ concentrations in Delhi region. The concentration of pollutants varied according to the season and a study by Rana *et al.*, (2019) showed in Patiala region that during winter and post monsoon season, the $PM_{2.5}$ concentrations were found 42-270 and 39-320 μgm^{-3}, respectively. During post-monsoon season, stubble burning contributed to 7-78% of the total $PM_{2.5}$ concentration increase in Delhi (Cusworth *et al.*, 2018). The emissions of VOCs during crop residue burning and its transportation can contribute to toxic photochemical smog and poor air quality in the downwind populated areas of IGP (Kulkarni *et al.*, 2020). VOCs like furan, 2-furaldehyde and methyl furans that resulted from biomass burning have been identified recently in studies and have significant atmospheric chemistry impacts (Coggon *et al.*, 2019) and have high OH reactivity. The smoke emitted during stubble burning under stagnant weather conditions gets mixed with the urban fumes resulting into secondary fine particulates.

Impact of Stubble Burning on Soil and Agricultural Productivity

Haryana's soil is abundant in micro-nutrients such as iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) but is deficient in macro-nutrients (N, P, K and S). Crop residue burning destroys the important nutrients of the soil such as nitrogen, phosphorus and potassium (NPK). The use of fertilizer or compost to regain the soil fertility leads to the economic losses. The stubble burning increases the subsoil temperatures at 10 mm depth to about 33.8-42.2°C and because of long term effects it can reach up to 15 cm of the top soil. The particle size of the soil is reduced to stubble burning affecting the properties of soil such as permeability and porosity. The heat due to burning of stubble leads to increase in porosity of soil and decrease in compressibility. Lohani *et al.* (2020) reported that liquid limit and plastic limit properties of soil samples changed due to crop residue burning. The pollutant released from stubble burning has impacts on agricultural productivity also. Acid rain caused by SO_2 emission during stubble burning leads to mortality of plant. The productivity of crops like wheat and soy is reduced to the harmful effects of Ozone.

Effects of Stubble Burning on Human Health

Crop residue burning is the simplest and easy way to manage the crop residue. It is a general practice followed almost everywhere due to lack of awareness and suitable management practices, which ultimately leads to release of various toxic gases in the environment. It contributes towards the emission of various greenhouse gases and air pollutants that pose threat to environment and human life. Smoke produced from burning causes irritation in eyes and thus creating eye-problems. The pollutants emitted from stubble burning have very ill impacts on human health and lead to

Table 2. Description of AQI categories

AQI (Air Quality Index)	Concern level	Code of colour	Impacts on health
0-50	Good	Green	Impact is minimum
51-100	Satisfactory	Light green	Little breathing problem to sensitive population
101-200	Moderate	Yello	Breathing problem to the population with diseases of lungs, asthma and heart
201-300	Poor	Orange	Breathing discomfort to larger population on exposure for longer period
301-400	Very Poor	Red	Healthy population will also face health problem. Sensitive population will be seriously affected and outdoor activities to be reduced.
401-500	Severe	Maroon	Affects healthy people with strong symptoms and seriously impacts those with existing diseases. Outdoor activities should be avoided by entire population.

various harmful diseases such as bronchitis, asthma, chronic-obstructive pulmonary disease (COPD), eye irritation, pneumoconiosis, skin diseases, corneal opacity, blindness, cataract and pose great risk factors mainly among infants and the elderly population. Very fine particles have the ability to penetrate alveolar region of lungs and get absorbed into the bloodstream of human body. The ultrafine particle has the efficiency to get deposit in upper as well as lower airways when inhaled and leads to various respiratory diseases and cancer evidences (Chen *et al.*, 2017).

WHO report 2012 stated that 1.59 million people died of lung cancer and 4.3 million people died prematurely due to household air pollution. Air pollution is linked with several impacts on health which led to worldwide 7 million deaths in 2016 (WHO 2021). Rajput *et al.* (2017) found that 84.5% of the population had a health condition due to an elevated occurrence of smog. It was found that 76.8% of people experienced irritation in the eyes, 44.8% mentioned irritation in the nose and 45.5% mentioned irritation in the throat. 41.6% of people mentioned cough or rise in cough and 18.0% mentioned wheezing. It was estimated that rural population in Punjab spent Rs. 7.6 crore per year on health problems caused due to stubble burning. In India, according to Global Burden of Disease Study (2017), the deaths due to air pollution were found highest in Uttar Pradesh (2,60,028) followed by Maharashtra (1,08,038) and in Haryana which were reported to be 28,965.

Crop Residue Management Practices

For the adoption of cleaner production alternatives, various crop residue management practices have been proposed in agricultural sector in India. As India produces huge volumes of crops such as rice, wheat, pulses and a lot of agricultural waste is generated after the harvesting of these crops. Traditionally, rice straw has been widely used in roof making of the rural houses but due to advancement in technologies and increasing income, this utilization of rice straw reduced in the past years. The decreasing demand of straw for feeding purposes also resulted in management difficulties of crop residue for Haryana's farmers (Bhattacharyya *et al.*, 2021). Thus, new techniques are required to manage crop residue. The proper utilization of crop residues can reduce 25% coal consumption which will help in declining emissions of pollutants released from coal based power plants. Agribiopanels were recently utilized in Bihar and Jalandhar which were made from crop stubble to construct solar powered COVID care units (Sharma *et al.*, 2021).

To ensure the environment-friendly, economically viable and sustainable use of crop residues, the Ministry of Agriculture & Farmers Welfare in 2018 has proposed numerous alternative techniques. These crop residue management techniques can be divided into two categories : *Ex-situ* and *In-situ* management of crop residues.

The most common followed *ex-situ* management techniques include composting, bio-char production, biofuel production, energy generation, use as animal feed and other uses. These details and advantages of each *ex-situ* techniques are given in Fig. 1.

There are many machines and equipments available for on-site management of crop residue which include :

Super straw management system (SMS) : This machine can be fixed with the combine harvester machine to shred the standing rice straw into smaller fragments which are then evenly leftover in the fields. It helps in cultivating the next crop without setting the field on fire. This machine was developed by Punjab Agricultural University (PAU), Ludhiana and it costs around Rs 1.2 lakh.

Chopper and spreader : The chopper and spreader machine after the use of combine harvesters helps in cutting, chopping and spreading of leftover straw which can be further utilized into the soil and various sowing methods can be utilized for farming.

Rotavator, plougher and zero till : Rotavator is also used in cutting the paddy straw into tiny pieces and further plougher helps in sowing paddy into the soil. Zero till machine includes seed box, fertilizer box, furrow openers and it does not require any seed bed before sowing of wheat crop.

Turbo happy seeder : This machine can help in performing the three tasks which are

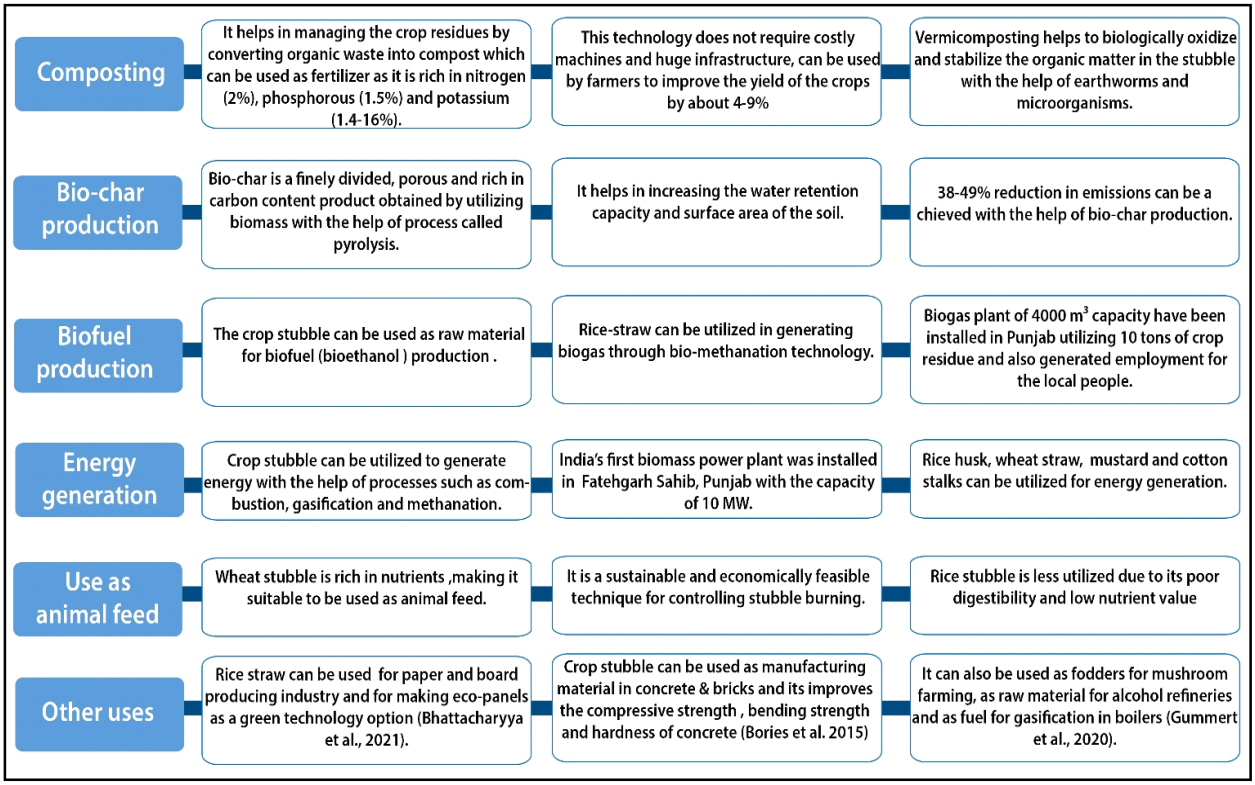

Fig. 1. *Ex-situ* crop residue management techniques.

harvesting the crop, cutter blades of harvester help in cutting the standing leftover straw making it suitable to be used in soil as organic mass and also help in sowing the wheat seeds. It prevents stubble burning thus improving environment by reduction in CO_2, particulate matter and black carbon emissions. The use of this machine also helps in improving soil health and cost of one Turbo Happy Seeder is around Rs 1.3 lakh.

National Schemes and Policies for Management of Crop Residue Burning

The central government for promotion of agricultural mechanization for *in-situ* management of crop residue sanctioned an amount of Rs. 331.94 crore to Punjab, Rs.193.35 crore to Haryana and Rs.159.59 crore to Uttar Pradesh during the year 2021-22. The central government also released Rs. 523.04 crores to the State Governments for providing 75223 numbers of various machines and equipment to the farmers on subsidy, 1540 custom hiring centers, 53 Hi-tech hubs and 2629 Farm Machinery Banks. The various national schemes and policies for management of crop residue burning have been mentioned in Table 3.

Schemes and Initiatives by Haryana Government

- Haryana Krishi Yantra Anudan Yojana has been launched by Government of Haryana for providing 50-80% subsidy on agricultural equipments to farmers of the state.
- Haryana government launched the scheme "Mera Pani Meri Virasat" for divergence from farming of rice crop to alternate crops. Under this scheme, Rs. 7000 per acre incentive to be provided to the farmers.
- In order to keep the track of fire incidents and manage crop residue burning efficiently the state have been divided into three zones–red, yellow and green zones on the basis of data provided by the Haryana Space Applications Centre (HARSAC). According to the number of fire counts detected, Sirsa, Fatehabad, Kaithal, Jind, Karnal and Kurukshetra districts have been categorized in red zone.

Table 3. The national schemes/policies launched in different years

S. No.	National schemes/policies	Launched in year	Key points of the policies
1.	National policy for management of crop residues	2014	It was the first national policy introduced to control burning of crop residue and to reduce harmful effects caused due to it. The farming machines and equipments such as Turbo Happy Seeder was promoted in this scheme.The remote sensing techniques with participation of national agencies to identify the burning locations was also promoted.
2.	Biomass utilization for power generation through co-firing in pulverized coal-fired boilers	2017	In order to encourage the use of biomass pellets, Central Electrical Authority (CEA) drafted policy where all coal-based thermal power plants were advised along with use of coal to blend 5-10% of biomass pellets, crop residues. It will help to utilize about 30% of the annual crop residue produced in the country (CEA, 2019).
3.	National Biofuel Policy	2018	It aims to increase the production of biofuels which will utilize crop residues which will help to meet the national demand of energy and prevent change in climate. The policy will contribute to production of ethanol from utilization of grains such as wheat, rice etc. which are now unhealthy to be consumed. It was identified that Panchayats of village and local groups will play important role in amplifying the supply of grains for biofuel production.
4.	Promotion of Agricultural Mechanization for *In-Situ* Management of Crop Residue in the States of Punjab, Haryana, Uttar Pradesh & NCT of Delhi	2018	It promotes the machineries for crop residue management that will reduce the burning of crop residue and also the concentrations of harmful pollutants will be controlled. It is assessed that 0.13 Mt of carbon (C) per year can be improved by incorporating of 1 Mt of crop residues into soil. The Centre has allocated huge amount of Rs. 1151.80 crore for this programme.
5.	National Clean Air Programme	2019	The goal of the NCAP is to keep the level of pollutants within the prescribed ambient air quality standards in the country. This programme also mentions the stubble burning as an important issue to be responsible for poor air quality. The Centre has allocated more than Rs. 1,600 crore to stop stubble burning and for improving air quality in Delhi and the NCR. It also aims for 20-30% reduction of PM2.5 and PM10 concentration by 2024 in the country. NCAP was proposed to be launched in the 43 smart cities of the country.

- Haryana government in 2021 has planned to provide Rs. 1000 per acre on rice straw for the crop residue management.
- There are six Bio Mass Power Projects of 60.35 MW capacity under installation to utilize 6.4 lakh MT of paddy straw.
- The production of ethanol by utilizing 2 lakh MT of rice straw has been also planned by government of Haryana.
- It has been observed that the machine operators prefer to function first in the districts on GT road and later they move towards the Sirsa-Fatehabad belt for harvesting of crop. This leads to disrupted pattern in harvesting of crops in the state. Thus, the nodal officers at the village level have been asked by the government to advise the farmers to stagger their harvesting schedule.

CONCLUSION

The Indian government has made numerous schemes and policies to manage crop residue burning and latest of it is National Clean Air Programme (2019) which emphasises on stubble burning as major source of air pollution in the country. The government spends crores of rupees in these policies to stop the practices

of stubble burning but along with *in-situ* management practices need to be encouraged more such as Turbo Happy Seeder and Super Straw Management System (SMS) which help in cutting the standing rice crop in the field without delaying the sowing time period of the next crop wheat and also help in utilizing the leftover straw in the field which increases the soil health. National Biofuel Policy (2018) encourages crop residue in generating bio fuels which is environment-friendly technique and setting up such plants can generate more employments for local population. Thus, there is need to setup more plants for bio fuel production, energy generation and encourage farmers to use techniques such as composting which can help in increasing the yield of the crops along with using crop residue as animal feed that can result in preventing the crop residue burning and improving the air quality of the region.

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