Paddy and Wheat Stubble Blazing in Haryana and Punjab States of India: A Menace for Environmental Health.

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Abstract: The paddy and wheat cropping is one of the widespread farming practice in north western parts of India mainly the riverine plains of Haryana and Punjab. These fertile lands are well-known for extensive agricultural fields but equally defamed for burning of paddy and wheat straw and stubbles by peasants after the harvesting season. In India, it is reckoned that 22289 Gg of paddy stubble biomass is generated annually out of this 13915 Gg is set ablazed in the agricultural fields. Haryana and Punjab alone produce 48 percent of the whole straw production which is openly burnt in situ. The blazing of paddy and wheat stubbles causes soil nutrient loss of Organic Carbon: 3.85 million tonnes; Nitrogen: 59,000 tonnes, Phosphorus: 20,000 tonnes and Pottassium: 34,000 tonnes, besides deteriorating the ambient air quality. Burning of farm residue discharges various trace gases like CO_X, CH_4, NO_X, SO_X and huge quantity of particulates matters (PM_{10} and $PM_{2.5}$) into the atmosphere which causes ill impacts on human health. The major problems faced by the local people are eye irritation, dryness of eyes and chest congestion. The National Capital Region (NCR) faced a disastrous impact during October, 2016. It also led to chronic obstructive pulmonary disease (COPD), pneumoconiosis, pulmonary tuberculosis, bronchitis, cataract, corneal opacity and blindness. Due to severe air pollution, Delhi-NCR alone faces approximately 20,000 premature deaths annually. The cases of road accidents also enhance during the period of stubble burning due to poor visibility. It also contributes to haze, global warming and climate change. In India, National Green Tribunal (NGT) prohibited this antediluvian farm practice of straw burning in pollution-wrecked city New Delhi and the adjacent states of Punjab and Haryana. One of the methods to reduce this menace is incorporation of straw into soil which eventually enhances soil fertility. The crop residue material can also be used for compost formation as a traditional approach. Alternate energy resources can also be generated from this agro biomass. Further, in past decades many conversion processes have been developed to produce alternate biofuels under different forms (pellets, briquettes) from crop residues. An integrated crop residue management approach is need of the hour to control this human induced catastrophe.

[Jabrinder Singh. **Paddy and Wheat Stubble Blazing in Haryana and Punjab States of India: A Menace for Environmental Health..** *J Am Sci* 2018;14(4):36-42]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 5. doi:10.7537/marsjas140418.05.

Key Words: Blazing, Energy, Health, Paddy, Pollutant, Residue, Stubble, Wheat.

1. Introduction

India is an agrarian state with diverse farming practices according to agro-climatic zones. The paddy and wheat system (PWS) is an extensively practiced farming system in north western states of India and generates a huge amount of agricultural wastes in the form of straw and stubbles. The practice is widespread throughout the riverine plains of Haryana and Punjab. Farming system residues or the stubbles are the biomass of crop remains in the farm after reaping of the profitable constituents i.e., seed. The farming dregs generated include mainly the cereal straws, stubbles, woody stems, cotton stalks and leaves etc. A large amount of husk and other biomass is also generated after farm yield processing in the agro industries. The agricultural residue mainly leaves and stubbles are utilized as animal fodder, roofing and shedding of homes, cattle shed, domestic usage fuel and small scale industries raw material and fuel. Still, a bulky part of the stubbles and straw is not employed and remains in the agricultural farms. The dumping of huge quantity of farm yield residue is a far reaching problem for the farmers.

The IARI (Indian Agricultural Research Institute), New Delhi estimates that maximum residue is generated by cereal crops i.e. 352 Mt, out of this, 34% and 22% are contributed by paddy and wheat respectively (IARI, 2012). In situ burning of crop residue is adopted to clear the agricultural field promptly and allocate tillage practices for sowing of next crop (Jain et al, 2014). The north-western Indo-Gangetic Plains are a critical demographic region of the world that serves as the agricultural “bread basket” of South Asia. Due to increasing human induced activities, there is concern that air pollution in the form of increased surface ozone is adversely affecting crop yields. These river plains are famous for its extensive agriculture are equally defamed for burning of rice and wheat straw and stubbles by peasants after the reaping season. Stubble burning is the deliberate setting fire of the straw stubble that remains after wheat, paddy, cotton and other grains have been harvested. This incident is spread universal and also a significant cause of poor air quality throughout the globe (Yang et al, 2008). Globally, forest fires are the biggest cause of the fire discharges due to its high carbon content and agricultural residue burning is the second biggest one, contributing approximately 2020 Tg ($1/4^{th}$ part of total biomass burned) (Chang & Song, 2010).

Farm residues blazing emit a high magnitude of air pollutants like N_2O, CO_2, CH_4, CO, NH_3, SO_2, Hydrocarbons, VOCs and suspended particulate matter at a diverse pace which is observed in any grassland or forest fire because of separate composition of the farm residues and burning forms (Zhang et al, 2011), (Mittal et al, 2009). These air pollutants cause adverse impacts on human health. They can cause chronic obstructive pulmonary diseases (COPD), pneumoconiosis, pulmonary tuberculosis, bronchitis, skin diseases, eye irritation, cataract, corneal opacity and blindness. In October, 2016 straw burning cause disastrous smog in National Capital Region. The cases of road accidents also enhance during the period of stubble burning.

In India, National Green Tribunal (NGT) forbids the tradition of straw and stubble flaming in highly polluted city New Delhi as well as its adjacent states of Haryana and Punjab. Due to the increasing problems combined with crop stubble burning in these states, numerous initiatives for its appropriate management have been approached. Government organisations and research centre's are encouraging alternate utilization of straw and stubbles in lieu of blazing such as: use of farm residue as animal fodder; utilization of stubbles in thermal power plants; its use for mushroom farming, for bedding material in cattle shed; utilization as bio-lubricant; paper and pulp production; bio-gas generation and in situ amalgamation in soil (Kumar et al, 2015).

Further, In last two three decades many conversion processes were developed to produce alternate bio fuels under different forms (pellets, logs, briquettes) from crop residues in order to be used in household boilers, stoves and even in some plants for producing heat and electricity at a wide scale. In this paper an attempt has been made to discuss the implications of stubble burning in Haryana and Punjab states of India and their mitigation methods.

2. The generation and burning of crop stubble: After harvesting of grain i.e. economic part of agricultural practice, the biomass left in the field is the residual biomass in the form of straw and stubbles. Every year, a huge amount of farm residues are produced, in the form of leaves/tops, straws, stubbles, stem etc. (Jain et al, 2014). Table 1 depicts the amount of crop residue generated as studied by different authors. Cereal crop dregs production is maximum in the Uttar Pradesh (72 Mt) chased by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7 Mt). Cereal crop residues are generated maximum by paddy (53%) followed by wheat (33%) (Gadde et al, 2009). According to Sahai et al, 2011, agricultural remains production was 253 Mt in 2010.

Table 1: The status of crop stubble produced in India as stated by various authors.

Sr. No	Author and Publication year	The amount of crop residue generated in India per year
1	Garg (2008)	133,138 Gg
2	Mandal et al. (2004)	350 million tonnes
3	Gupta et al. (2004)	347 million tonnes
4	Agarwal et al. (2008)	184,902 Gg

Table 2: Rice straw disposal pattern adopted by cultivators

S. No.	Author and Year	Usage pattern of farm yield residue of rice
1	Sarkar et. al. (1999)	75 % Mechanized harvested and 100 % burnt
2	Sidhu and Beri (2005)	In situ burning (Paddy - 81% and Wheat - 48%), Animal fodder (Paddy- 7% and Wheat – 45%), Rope making (Paddy- 4% and Wheat – 0%), Soil incorporation (Paddy- 1% and Wheat – 1%), Miscellaneous (Paddy- 7% and Wheat – 7%)
3	Badarinath et al (2006)	75 % of straw and stubbles are burnt in situ
4	Venkataraman et al. (2006)	30–40 % straw is burnt (IGP)
Average		**75 % of paddy is burnt**

According to a study conducted by IARI, paddy straw production was 22289 Gg in excess in India annually out of which 13915 Gg is burnt in situ. Haryana and Punjab, the two states alone share 48 % of the entire amount and burn the same in farms. Further, it was studied that about 40 million tonnes of farm yield waste every year is produced in Punjab alone. In India, the excess amount of residues (balance residue after domestic utilization) of cereal crops amounts to 82 Mt are usually fired in the agricultural farm, in which rice and wheat contribute 44 Mt and 24.5 Mt respectively (IARI, 2012). We can see plumes of smoke are rising from the fields which by the end of October or sooner, becomes a thick blanket in the air over Haryana and Punjab extending up to the National Capital Region (Sandhu, 2016). It's the season for paddy stubble burning in this region. According to another study, In India 84 Tg of crop remains are burnt annually (Streets et al, 2003).

Various methods have been preferred for disposal of paddy stubbles and straw as mentioned in different studies (Table 2 and 3). Figures 1, 2 and 3 illustrate the burning of straw in agricultural fields by farmers.

Table 3: Utilization of straw and stubbles by the farmers of Punjab (Source: Govt. of Punjab 2007)

Sr. No	Pattern of End Usage	Percentage of total paddy stubble generated	Percentage of total wheat stubble generated
1	Animal feed	7	45
2	Soil amalgamation	1	1
3	Burning	81	47
4	Rope production	4	0
5	Miscellaneous	7	7

Figure.1: In situ stubble burning after harvesting of crop.

Figure 2: Farmer keeps on straw burning despite of ban by authorities.

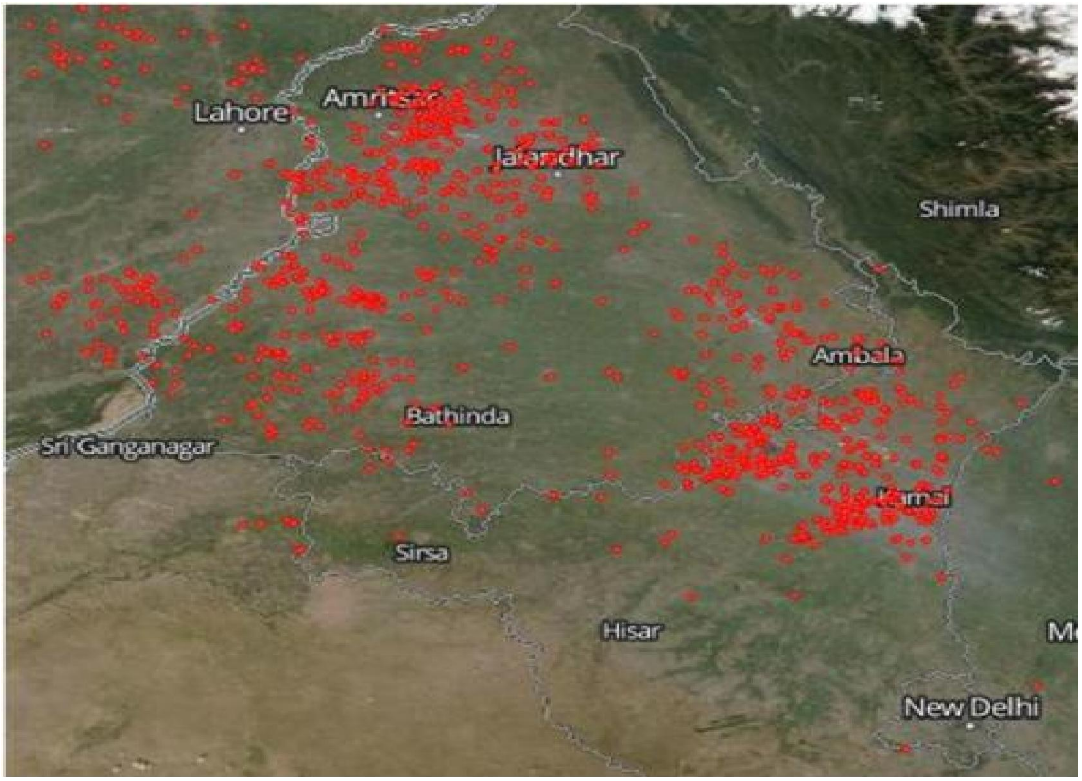

Figure 3: An Imaginary showing stubble burning during October, 2016 in Haryana and Punjab (Source: NASA)

3. Effects of stubble burning on Environment

According to Yevich and Logan (2003) crop residue burning discharges 91, 4.1, 0.6, 0.1 and 1.2 Tg/yr of CO_2, CO, CH_4, NOx and total particulate matter respectively in India. Central pollution control board, India states that in national capital region (Delhi, Haryana & UP) air quality index always remains as high as 500 which is hazardous. It also created huge smog like conditions during October, 2016 in this region. Some scientists have calculated that there is an emission of 4.86 Mt of carbon dioxide equivalents of green house gases, 3.4 Mt of carbon monoxide and 0.14 Mt of nitrogen oxides by burning of 63 Mt of crop residue (Sahai et al, 2011). Another study concluded that one tonne of straw on burning releases 3 kg of particulate matter, 60 kg of CO, 1,460 kg of CO_2, 199 kg of ash and 2 kg of SO_2 (Gupta et al, 2004). According to National Remote Sensing Agency, paddy burning in Punjab alone released 261 Gg of CO, 19.8 Gg of NOx, and other gases to the atmosphere. In India, there is an emission of 144719 Mg of total suspended particulate matter by virtue of in situ burning of paddy stubbles.

The above emissions have several atmospheric, biospheric and ecological implications. Since the paddy - wheat cropping system is cultivated on a large scale (about 9.6 million ha in India), pollutants from agricultural residue burning are very significant. These high amounts of residues from the paddy-wheat agro ecosystems when burnt form an important source of GHGs, in the Indian region. Considering these implications, agriculture residue burning is one of the major areas, where GHG mitigation options can be focused upon (Badarinath et al, 2006).

Lefroy et al, 1994 concluded that stubble and straw blazing also burn the nutrients present in the farm residues besides causing a huge pollution. The total quantity of Carbon, 80–90% Nitrogen, 25% of Phosphorus, 20% of Pottassium and 50% of Sulphur present in various crop remains are vanished in the harmful gaseous forms and particulate matter, causing the air pollution. The blazing of rice straw and stubbles cause huge soil nutrient loss (Organic Carbon: 3.85 million tonnes; Nitrogen: 59,000 tonnes, Phosphorus: 20,000 tonnes and Pottassium: 34,000 tonnes) besides severely affecting the ambient air quality as stated officially. As a result various hazardous gases are also added to the atmosphere. These gaseous discharges can create human health risks, especially asthma, persistent bronchitis and dwindling pulmonary function. Burning of farm yield residue also increases ozone concentration in lower atmosphere (Kumar et al, 2015). As stated by another experiments, farm residue burning elevated the soil temperature up to 33.8–42.2 °C (up to one cm depth) which affects soil ecology. Due to the same, about 23–

73 % of nitrogen in various forms is vanished and the beneficial microbial population also declined (2.5 cm depth of soil). The residue burning increases the temperature of the soil to a high extent which results in changes in the C-N equilibrium hastily in the upper 3 inches soil. The carbon is vanished to atmosphere in the form of CO_2 and nitrogen is translated to nitrate. Due to this process, approximately 824 thousand tones of NPK are lost from the soil (Gupta et al, 2004).

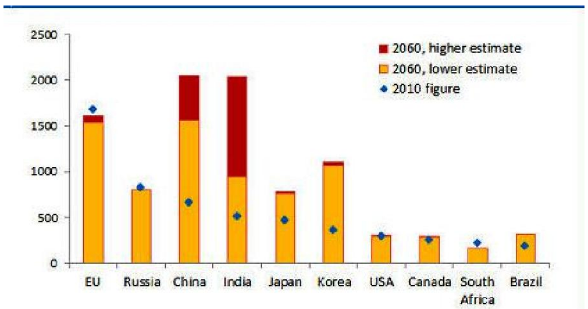

Figure 4: Projected premature deaths (per year per million) due to outdoor air pollution exposure (Source: OECD, 2016).

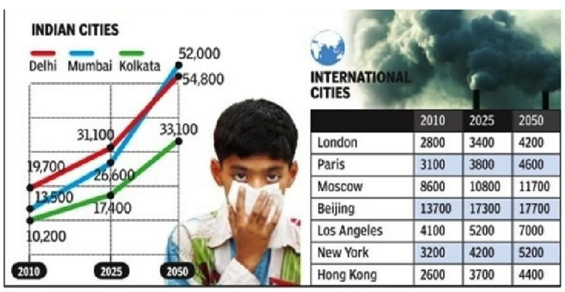

Figure 5: Premature mortality (deaths per year) in the most polluted mega cities.

The studies discussed above indicate that burning of the farm residues (in situ) at enormous level is critically detrimental to the environment. Furthermore, in situ crop residual flaming also declines population of soil micro organisms and burns the multipurpose tree species in agricultural fields. It also causes off-site health hazard impacts such as cough, emphysema, asthma, bronchitis, eye irritation, corneal opacity and skin diseases. Small respiratory particles can also intensify persistent cardiac and pulmonary ailments and furthermore related with untimely deaths in people previously suffering from these illnesses. The black dust produced during residue flaming also results in poor visibility which hampers traffic movements and raised road side accidents (Kumar et al, 2015). Annually 3.3 million people die prematurely due to air pollution worldwide. If emissions continue to rise, this number will double by 2050. According to OECD, 2016 annually, it is estimated that in Delhi-NCR alone, approximately 20,000 premature deaths occur due to air pollution which may rise up to 32,000 by 2025 and 52,000 by 2050. It is further calculated that India and China will top the world in premature deaths due to air pollution by 2060 (Figure 4 and 5).

According to Gadde et al, 2009, detrimental compounds like polyhalogenated organic compounds (PCDDs), peroxy acyl nitrate (PAN) polyaromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans (PCDFs) referred commonly as dioxins are emitted by open burning of farm residue. These atmospheric pollutants may have noxious properties and are carcinogenic in nature. Burning of crop straw and stubble has severe negative impacts on health. Pregnant women and infants are more prone to dangerous consequences due to stubble burning pollutants. Respiratory suspended particulate matter of very small size ($PM_{2.5}$) inhalation prompts asthma and can even worsen symptoms of bronchial attack. Table 4 describes the catastrophic level of pollutants in Delhi NCR region during harvesting season in Haryana and Punjab in October, 2016. Figure 4 and 5 depicts the premature deaths occur due to various air pollutants released by straw burning and other causes in India's capital region encircled by Haryana and Punjab.

Table 4: Level of air pollutants in Delhi-NCR during harvesting season in Haryana and Punjab (Source: DPCC report, 2016).

Pollutant	Area in Delhi NCR	Level	Permissible limit
PM_{10}	Punjabi Bagh	1000 µg/m³	60-80 µg/m³
$PM_{2.5}$	Punjabi Bagh	650 µg/m³	60-80 µg/m³
Nitrogen dioxide	Anand Vihar	167 µg/m³	60-80 µg/m³
Carbon monoxide	IGI Airport	6.3 µg/m³	2-4 µg/m³
Sulphur dioxide	IGI Airport	29.8 µg/m³	60-80 µg/m³

4. Management of crop stubble

Due to ever growing predicaments linked with crop residue flaming in the north western states of India, several proposals and techniques have been developed for its appropriate handling in the past years by different agencies.

Soil incorporation is a broadly documented strategy for enhancing organic carbon (OC) sequestration and enhancing soil health and crop yield. In a study conducted on Maize-Wheat cropping system, the best remedy is high straw return for domestic animal fodder, but more suitable practices, such as wheat and maize straw mulching in soil, increase crop yield and soil carbon sequestration, eventually led to establishment of a sustainable cropping system (Li et al, 2016).

Flawed use of residue and in situ burning of straws not only generates threat to environment by producing large quantity of greenhouse gas (GHG) emission, but also led to lose of a vital by product from farming practices. Straw and stubbles can be employed in bio-fuel generation and can be a source of additional monetary benefit and justified utilization of waste. It will also meet the demand of clean and green energy to ever increasing power demand in India (Singh et al, 2016).

4.1 In situ soil mulching and composting

The farm residue has a range of optional values however cultivators prefer burning of stubbles as an easy mode for disposal of residue. After mechanized harvesting, farmers can opt for in-situ incorporation of the crop residue in soil. According to a study, the best substitute for flaming of paddy residue is amalgamation of stubbles in soil on the field site (Sidhu and Beri, 2005). Some scientists reported that the paddy residue incorporation in soil three weeks before sowing considerably increase wheat yield on clay loam soils. It will also increase organic carbon in soil by 14–29 % (Singh et al 1996). In contrary, if the paddy residue is amalgamated instantaneously before sowing the wheat in rabi, then the crop production is reduced due to arrest of inorganic nitrogen which adversely cause nitrogen deficit (Singh et al, 1996). As per some studies, amongst the various alternatives to burning of stubbles, incorporation of farm yield residues into the soil in R–W systems seems to be the best strategy, instead of residue burning (Sood, 2013). Different studies indicated that one of the best methods to reduce this menace is incorporation of straw into soil which eventually enhances soil fertility.

4.2 Some alternate approaches for crop residue management

Some traditional utilization of crop stubbles is animal fodder, fuel materials, cattle shed preparation and mulching in soil. A few other options such as fuel in heat generated power plants; utilization in mushroom farming, for extraction of bio-lubes; paper and pulp manufacturing and bio-gas generation can be incorporated to avoid drawbacks of stubble and straw burning. Some alternate utilization includes amalgamation of wheat and paddy straw in soil to produce organic mulch, various energy technologies and thermal power generation (Jain et al, 2014). Power and paper industries are now approaching to farmers for rice, mustard, cotton and wheat straw and stubbles. Further, the stubble compost contains 1.7 to 2.1 per cent of nitrogen, 1.5 per cent phosphorous and 1.4 to 1.6 per cent potassium which improve crop yield by 4 to 9 per cent (Sood, 2013).

The crop residue material can also be used for bio-compost formation. These methods are adopted traditionally also in various farming practices. Several researchers suggested alternate energy resources can be generated from this biomass of agricultural sector. The milestone step to prevent this threat is to set up alcohol refineries to take out sustainable bio-energy from this farm yield residue by employing various models. As a sustainable approach in situ bio-gas plants can also be employed for disposal of crop residue such as straw and stubble which can also meet energy and fuel demands of cultivators.

5. Conclusion

Burning of farm residues i.e. straw and stubbles from paddy-wheat farming systems of Haryana and Punjab, at a large scale is an issue of grave concern which results in green house gases emission besides causing problems of atmospheric pollution, health risks and thrashing nutrients from soil. It becomes need of the hour to authenticate the emission calculations experimentally and the allied ambiguity. The farm yield residues can be exploited to various prolific methods such as compost formation, in situ assimilation in soil, bio-energy generation etc. and this is possible only if straw and stubbles are gathered and handled properly.

Regardless various austere legislations and compliance steps implemented by the Government of India and different state authorities, this malignant practice of in situ stubble burning continuously add woes to the ambient air quality and health problems of the area, and becomes a matter of critical concern even for various transportation modes. Effective execution of statutory policy verdicts to curb this threat is required with periodic to continuous monitoring and improvement. According to India's Ministry of Environment and Forestry, prohibition of stubble burning by states of Haryana, Punjab, Uttar Pradesh and Rajasthan has outcome with 38.93 per cent and 20.3 per cent reduction in stubble burning in Punjab and Haryana respectively.

Programs related to awareness and incentives must be launched for the farming communities. They must be well conscious regarding the harmful consequences of crop straw and stubble flaming and significance of alternate uses such as crop residues incorporation in soil, for maintaining agricultural efficiency sustainably.

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4/25/2018