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Crop Residue Burning: Issue and Management for Climate-Smart Agriculture in NCR Region, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Today India enjoys the second position worldwide in agricultural output and as well as plays a significant role in the overall socio-economic construction of India too. There is no doubt that intensive agriculture also plays a significant role in climate change over time. Today climate change becomes the major concern all over the globe. The main cause of climate change is the various anthropogenic activities, in these agricultural Crop Residue Burning (CRB) of rice and wheat crops has been identified as a major reason for climate change. This unwise practice as it leads to severe air pollution and emits traces of carbon dioxide, methane, carbon monoxide, nitrous oxide, and particulates which affect causing various respiratory and other health problems along with as a regional polluter as per various studies. In addition, it causes the loss of vital nutrients from the soil resulting in the loss of fertility and unviable for agriculture in the long run. Along with this CRB create visibility problems in vehicle driving which result in many road accidents every year. In a recent study it is estimated that India annually emissions of 824 Gg of Particulate Matter ($PM_{2.5}$), 58 Gg of Elemental Carbon (EC) and 239 Gg of Organic Carbon (OC). Additionally, 211 Tg of CO_2 equivalent greenhouse gases (CO_2, CH_4, N_2O) were also added to the atmosphere. In this regarding Punjab

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and Haryana are the major contributor to air pollution due to residue burning. These two states contribute to 48 percent of the total emission due to paddy and wheat straw burning across India. Now the time has occurred to tackle this noxious practice with best management practices and capacity building of the farmer community to conserve the climate for the sustainable development of agriculture and the human race in developing country like India. Hence, an attempt has been made in this paper is to describe the current status and available alternative management practices like *in situ* agronomic management, new machineries viz., zero drill, happy seeder, straw baler as well as capacity building of farmer community for crop residue to minimize the climate change and soil infertility for sustainable on long-run basis.

Keywords: Agriculture; climate change; crop residue; burning; mitigation; management.

1. INTRODUCTION

Agriculture is the most important sector in the Indian economy along with it also play a significant role to sustain the livelihood security for millions of farmers in the country. Along with this sector also contribute to climatic variability. Today climate changes are unique research challenges to present day agriculture and it is highly sensitive to climate variability and weather extremes. The impact of climate changes on agriculture is already seen. The factors which are responsible for climate degradation are mainly by natural and anthropogenic activities. Some natural causes of climate change are referred to as ‘climate forcing’ or ‘forcing mechanisms'. Changes in the state of this system can occur externally (from extraterrestrial systems) or internally (from the ocean, atmosphere and land systems), through any one of the described components. For example, an external change may involve a variation in the Sun's output which would externally vary the amount of solar radiation received by the Earth's atmosphere and surface. Internal variations in the Earth's climate system may be caused by changes in the concentrations of atmospheric gases, mountain building, volcanic activity, and changes in the surface or atmospheric albedo. However, some climatologists are of the opinion that only a limited number of factors are primarily responsible for most of the past episodes of climate change on the Earth it include variations in the Earth’s orbital characteristics, atmospheric carbon dioxide variations, volcanic eruptions, variation in solar output, plate Tectonics and thermohaline Circulation. Whereas in anthropogenic include the entire activities which created by human viz., greenhouse gas emission, fossil fuel burning, black carbon, industrial production, deforestation, urbanization, and agriculture with respect to the environment. It has also been observed those developing countries are more vulnerable to climate change, where agriculture typically plays a larger role in national economy [1]. Agricultural production is a major emitter of GHGs, currently accounting for 18% of total GHG emissions in India [2] along with this an unhealthy practice is done by the farmers in India is burning of crop residues which cause air pollution. In NCR region, intensified agricultural practices are adopted that include rice-wheat cropping system. Rice is generally sown in May-August and harvested during the period of September-November followed by Wheat is sown in October-November and harvested in April-May. On harvesting, along with the desired crop so produced, a lot of residues is also generated which may be termed as stubble. The scarcity of time for land preparation, for next season crop, forces farmers to adopt an easy way to get rid of the residue by burning the stubbles. Hence, this practice is termed stubble burning. Earlier when the harvesting was done manually, stubble so generated was less in amount and could be managed by the farmers. But now with the advent of mechanized harvesting, a large amount of stubble is generated which is become a major problem for climatic pollution. In a study by Gadde [3], explains that open burning of crop stubble results in the emissions of harmful chemicals like polychlorinated dibenzo-p-dioxins, polycyclic aromatic hydrocarbons (PAH’s) and polychlorinated dibenzofurans (PCDFs) referred to as dioxins. These air pollutants have toxicological properties and are potential carcinogens. Furthermore, the release of carbon dioxide in the atmosphere due to crop stubble burning results in the depletion of the oxygen layer in the natural environment causing a greenhouse effect. Another adverse effect also observed on the health of milk producing animals. The burning of crop stubble has severe adverse impacts especially for those people suffering from respiratory disease, cardiovascular disease. Pregnant women and small children are also likely to suffer from the smoke produced due to stubble burning. In recent years, the National Capital Delhi and adjoining areas have experienced alarmingly poor air quality starting winter. The farmers mainly from Northern India set their paddy fields on fire after harvesting. The resultant smoke, however, gets carried by winds all the way to Delhi and beyond, adding to the existing suspended particulate matter (SPM) and noxious substances that clogs lungs and leaves behind a near eclipsed sun (Economic Survey 2017-18). Air pollution contributed to a total of 80,665 premature deaths of adults over 30years in Mumbai and Delhi in 2015, a two folds jump from 1995. The study has said the impact on health and productivity as a result of exposure to pollution and the consequent burden of respiratory ailments rose with every passing decade. In fact, a number of reasons cause the massive spike in suspended particulate matter (PM 2.5, being the most dangerous) during winter in this part. In 2016, it surpassed 1,000µg/m3 making Delhi one of the unhealthiest cities in the world in terms of air pollution [4]. Generally, also, the annual average PM 2.5 levels remain about 3 times higher than the prescribed standards. A combination of reasons, among which crop burning in the adjoining states plays a major role, piling on top of one another, in a dense urban concentration of a massive and growing capital city renders this region in a serious hazardous state. So keeping all these facts of seriousness in view present study was carried out to explore the cause, current status and mitigation management of the crop residue burning problem.

2. MATERIALS AND METHODS

In this study conclusion was made with help of enough literature study from various sources viz; research article, books and information from internet. The area for this study was Indo-Gangetic plain of India, in which major crop residue burning states viz: Punjab, Haryana, and Uttar Pradesh were taken purposely because these states are the major producer of rice and wheat crops in the country. The secondary data is used in the present study.

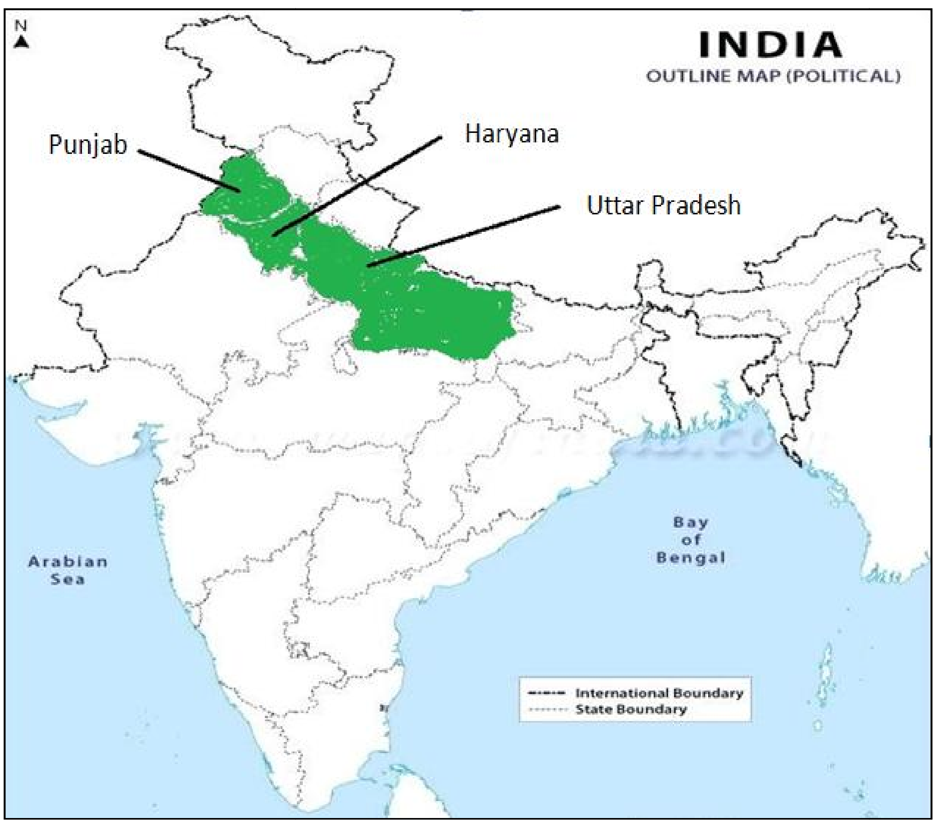

Fig. 1. Study area map of CRB

2.1 Production of Crop Residue and Its Burning Level

Many studies have been conducted to find out the quantity of crop stubble produced and burnt in India. As per various investigations, the residues of rice and wheat crops are major contributors to the total stubble loads in India. The residue to product ratio (RPR) indicates the amount of residue available for each tonne of crop production. Thus, an RPR of 2 would indicate that 2 tonnes of residue is produced for 1 tonne of crop production. In case rice is cut at about 2 inches above the ground, the RPR of rice straw equals 1.75 whereas it falls to 0.452 if only the top portion of the rice stem is cut [5]. Using these RPR values estimated that about 507,837 thousand tonnes of on field crop residue was generated in India during 1997 of which 43 percent was rice and 23 percent wheat. In a another study [6], find that total amount of crop residue generated in India is estimated at 350 × 10^6 kg per year of which wheat residue constitutes about 27% and rice residue about 51% whereas [7] confirmed that contribution of rice and wheat stubble loads in the total stubble as 36 and 41%, respectively in the year 2000, while the contribution of Punjab in the total burnt stubble of rice and wheat to be 11 and 36%, respectively during the same time period. According to Gupta et al. [8], the total crop residue produced in India during 2000 was 347 million tonnes, of which rice and wheat crop residues together constituted more than 200 million tonnes. An estimate from [9] implies that 16 percent of this crop residue was burnt. The results from [10] suggest that 116 million tonnes of crop residue were burnt in India in 2001, but with a strong regional variation. A majority of the fires occurred in the western Indo-Gangetic plain during the months of May and October corresponding to the two major harvesting seasons for rice and wheat. The authors' conclude that the harvesting of cereal wastes and their field burning in major agricultural states such as Punjab, Haryana and Western Uttar Pradesh is the largest potential contributor to these emissions. According to Sidhu and Beri [11] total production of paddy stubble in Punjab in 2004-2005 reached 18.8 million tonnes, of which 15 million tonnes were burnt in open fields. The study further quotes that 80% of the rice harvested using combined harvester is burnt in open fields. However, according to Singh et al. [12], around 17 million tonnes of paddy straw are produced every year in Punjab, of which 90% are burnt in open fields. Pathak et al. [13] found that residues from crops (rice, wheat, cotton, maize, millet, sugarcane, jute and rapeseed-mustard) are burnt in the field. Total crop residues generated by these nine major crops are about 566 Mt of which about 93 Mt are subjected to burning in the fields. An estimated 7-8 million tonnes of rice residue associated with post-monsoon agricultural burning are burned each year in Punjab, India [14]. An another study by Khaiwal et al. [15] estimated that in India 488 Mt of total crop residue was generated during 2017 and about 24% of it was burnt in agricultural fields. This resulted in emissions of 824 Gg of Particulate Matter (PM2.5), 58 Gg of Elemental Carbon (EC) and 239 Gg of Organic Carbon (OC). According to a report published in a leading newspaper in India, about 500 to 550 millions of tonnes total crops residue produced every year from which rice crop residue is 36 percent and 26 percent of wheat. In Punjab state, 50.99 million tonnes and Haryana 28 million tonnes crops residue is produced. These both states burnt 80 percent of the crop residues in the field [16].

Table 1. Total quantity of crop stubble generated in India as per different studies in India

Study and year	A total quantity of crop residue produced
Garg (2008)	133,138 Gg
Mandal el al. (2004)	350 × 106 kg year^{-1}
Gupta el al. (2004)	347 million tonnes
Agarwal el al. (2008)	184,902 Gg

Source: Kumar et al., (2015) [14]

2.2 Straw/Residue to Grain Ratio

To obtain the average amount of straw generated and burnt, the Residue to Product Ratio (RPR) must be known. Different studies on the subject of crop stubble in India have considered different residue/stubble to product ratio (RPR). As per these studies, the residue to product ratio (RPR) varies from 0.416 to 3.96. Table 2 provides the estimates of RPR obtained in various studies.

2.3 Level of Pollution Increase Due to Crop Residue Burning

Crops residues burning results in the emission of a lot of hazards gases in the environment, like Carbon Monoxide, NO_2, SO_2, CH_4, N_2O along with particulate matter and hydrocarbon. Agricultural residues burning may emit significant quantity of air pollutants like CO_2, N_2O, CH_4, emission of air pollutants such as CO, NH_3, NOx, SO_2, NMHC, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) and particulate matter like elemental carbon at a rate far different from that observed in savanna/forest fire due to different chemical composition of the crop residues and burning conditions [17,18]. The negative effect of these gases not only on the climatic chemistry but adversely affect the human as well as other living organism health level [20,21,22,23]. Pathak et al. [13] estimated that burning of crop residues in fields emitted 0.25 Mt of CH_4 and 0.007 Mt of N_2O in 2007. The burning of rice straw contributed the maximum (39%) to this GHGs emission. Large-scale burning of rice residues in Punjab, Haryana and western Uttar Pradesh is a matter

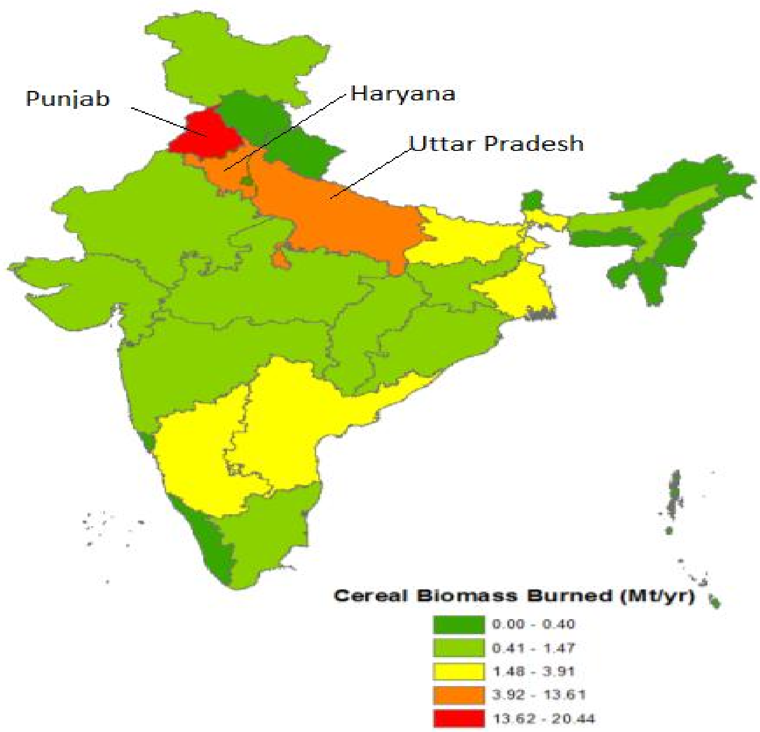

Fig. 2. Map of major crop residue burning states
Source: Jain et al. (2014)[19]

Table 2. Residue to product ratio according to various studies

References	RPR ratio/quantity	Reason
AIT-EEC (1983)	0.416	If only the top portion of the rice stem
Bhattacharya and Shrestha (1990)	0.452	along with 3-5 leaves is cut, leaving the remaining in the field
Bhattacharya et al. (1993)	1.757	When the rice is cut at about 2
Vimal (1979)	1.875	inches from the ground
Sidhu et al. (1998)	1.5:1	For both rice and wheat
Gupta et al. (2004)	1.5:1	Every 4 t of rice or wheat grain produces about 6 t of rice or wheat straw
Njie (2006)	1.25	For rice
Bhattacharya et al. (1993)	1.76	For rice
Singh and Rangnekar (1986)	1.5:1	For both rice and wheat
Koopman and Koppejan (1997)	1.757 and 0.267	For paddy straw and rice husk Respectively
Badarinath and Chand Kiran (2006)	(3.2–5.6 t/ha and 6.2–11.8 t /ha)	For wheat and rice respectively

Source: Kumar et al. (2015) [14]

of serious concern not only for GHGs emission but also for problems of pollution, health hazards and loss of nutrients. It has been estimated that for the year 2000, the emission of CH_4, CO, N_2O, and NO_2 was 110, 2306, 2 and 84 Gg respectively, from the field-burning of rice and wheat straw [6]. In a another study conducted by the National Remote Sensing Agency in Punjab reported that wheat crop residue burning contributed about 113 Gg (Giga gram = 10 billion gram) of CO, 8.6 Gg, of NO_2, 1.33 Gg of CH_4, 13 Gg of PM10 and 12 Gg of PM2.5 during May 2005 and paddy straw/stubble burning was estimated to contribute 261 Gg of CO, 19.8 Gg of NO_2, 3 Gg of CH_4, 30 Gg of PM10 and 28.3 Gg of PM2.5 during October 2005 [24].

2.4 Effect of the Crop Residue Burning on Climate and Human

Long et al. [25] studied the health consequences from burning of agricultural residue. The authors' found that people with underlying respiratory disorders were susceptible to the air pollution caused by burning of agricultural residue. Ramanathan and Carmichael [26] claimed that in the Himalayan region heating from black carbon at higher elevations has as large an effect on the melting of snow packs and glaciers as heating due to greenhouse gases. Furthermore, when black carbon is deposited over snow and sea ice, it darkens the snow thereby significantly enhancing solar absorption by snow and ice leading to a retreat of the Arctic sea ice. It is also well established that large concentration of aerosols leads to the creation of fog that reduces visibility. Low visibility causes multiple accidents and delays in the road, railway, and air transport. The off-field impacts are in form of black soot generated during burning also results in poor visibility which could lead to increased roadside incidences of accidents [27]. In another study of [12] more than 60% of the population in Punjab live in the rice growing areas and is exposed to air pollution due to the burning of rice stubbles. As per the same study, medical records of the civil hospital of Jira (Punjab), in the rice-wheat belt showed a 10% increase in the number of patients within 20-25 days of the burning period every season.

Burning of agricultural biomass residue, or Crop Residue Burning (CRB) has been identified as a major health hazard. In addition to causing exposure to extremely high levels of Particulate Matter concentration to people in the immediate vicinity, it is also a major regional source of pollution, contributing between 12 and 60 percent of PM concentrations as per various source apportionment studies. In addition, it causes loss of vital components such as nitrogen, phosphorus, sulphur, and potassium from the topsoil layer, making the land less fertile and unviable for agriculture in the long run. According to Sidhu et al. [28], crop residue is not a waste product but rather a useful natural resource. About 25% of nitrogen (N) and phosphorus (P), 50% of sulphur (S) and 75% of potassium (K) uptake by cereal crops are retained in crop residues, making them valuable nutrient sources estimated the quantity of nutrients available in rice. According to Gupta et al. [8], burning of crop stubble increases the temperature in the soil up to 33.8-42.2°C. Burning also results in the loss of 27-73% of nitrogen present in the soil and reduces the bacterial and fungal populations on the top 2.5 cm of the soil. Furthermore, repeated burning can diminish the bacterial population by more than 50%. Long-term burning also reduces total nitrogen and carbon and potentially mineralized nitrogen in the 0–15 cm soil layer along with a loss in the soil organic matter. Table 3 show the nutrients viz; nitrogen, phosphorus and potassium loss due to crop residue burning in rice and wheat crops.

This large-scale burning of rice residue is a major source of trace gases along with sub-micron sized aerosols, which are known to aggravate lung and respiratory diseases. Badarinath and Chand [24] suggested that emissions from wheat crop residues in Punjab are relatively low compared to those from paddy fields. It is inferred that incorporation of agricultural residues into the soil in rice-wheat systems is highly sustainable and eco-friendly, rather than burning the crop residues.

Table 3. Loss of nutrients due to the burning of crop residues Mt/Yr

Crop residues	N loss	P loss	K loss	Total
Rice	0.236	0.009	0.200	0.45
Wheat	0.079	0.004	0.061	0.14
Total	0.315	0.013	0.261	0.59

Source: Jain et al. (2014) [19]

2.5 Reasons for Crop Residue Burning in India

In North, India rice-wheat is major cropping system. Particularly in northern India, fires are mostly from residue burning, which peaks in April to May (pre-monsoon) and October to November (post-monsoon), corresponding to burning after the wheat and rice harvests, respectively [29, 10]. Crops residues' burning is the common practices done by farmers. The reason behind these unhealthy practices is the use of combine harvester, the short time span between crops harvesting and crop sowing and a shortage of labor and high cost for proper crop residue management. There is one more reason for CRB is nitrogen immobilization in soil due to residue incorporation in the soil, which results in the yellowing of the succeeding crop. Also if when crop residue is incorporated with soil then an extra dose of nitrogen is necessary.

2.6 The Short Span of Sowing Time

Multiple cropping and shortened intervals between crops give a very short window of about 10-15 days during which the field needs to be prepared for the next crop. This does not give enough time for farmers to allow the straw to be incorporated in the soil or use other methods of disposal. In a study [8] attribute the open field burning of crop residues to combine harvesters that leave a large amount of loose residue on the field. The authors' assert that a major constraint in a rice-wheat cropping system is the available short time between rice harvesting (late October and early November) and sowing of wheat (November). Given this short time, farmers find it difficult to utilize the residue and hence opt for burning.

2.7 Low Nutritional Value of Rice Crops Straw

Another main reason for this is the low quality of rice straw and high content of silica which has less use for animal feed. A study of Erenstein et al. [30] found that the practice of *in-situ* burning as a land preparation measure is present for both the rice and the wheat crops. However, rice residues are burnt on a much larger scale than wheat residues. Only rice residues from Basmati varieties are used as animal feed. Coarse rice residues are not fed to livestock due to the perceived high silica content and fear of reduced milk yields.

2.8 Shortage of Labour

In the region of Punjab, mechanized harvesting has reduced the need for manual labor in the past two to three decades. However, the scattered, root-bound crop residue left behind by combine harvesters is difficult to remove and burning is usually the fastest and cheapest method to clear fields for the next planting [3,14]. So the use of expensive labour for stubble extraction is not feasible. Costs are especially high in Punjab and Haryana, where farm sizes are large and use of mechanized harvesters is common. Burning of residues is a cheaper and easier option for the farmers.

2.9 Lack of Market for Crop Residue Sells

The low commercial and economic value of crop residue, coupled with the high costs of processing, reduces its value for farmers. Although the quantities of residue produced are equivalent to the total crop output, this entire volume of residue has little or no economic value although in the NCR region there is no such market for crop residue sell so in this situation farmer prefer to burn the crop residue to get rid of this problem.

2.10 Management of Crop Residue Burning

Management of crop residue burning is urgent need of time to minimize pollution due to it. Here are various alternatives to solve the issue.

Change in agronomic Practices: *In situ* incorporation being the best option may be further investigated for fast decomposition of residue. According to a study by [11], the best alternative available to the burning of rice residue is *in situ* incorporation. The results of a 6-year study period showed that if the rice residue is incorporated in the soil 10, 20 or 40 days before sowing the wheat crop, then the productivity of the subsequent wheat and rice crops is not adversely affected. Paddy straw incorporated in wheat did not show an adverse residual effect on the succeeding rice crop. Several reports show similar to rice and wheat yields under different residual management practices such as burning, removal, or incorporation [31,32,33]. Singh et al. [32] reported that the incorporation of paddy straw 3 weeks before sowing significantly increased wheat yield on clay loam soil but not on sandy loam soil. Studies conducted by [34,35] showed no adverse effect of straw incorporation on the grain yield of wheat and the following rice. This study further shows that incorporation of crop residues increased organic carbon by 14-29%. Tables 4 and 5 shows the impact of different residue management practices on the *in situ* management of rice and wheat crops by different scholars. Data revealed from the Tables 4-5 strongly support the incorporation of residue in the soil for better management of nutrient as well as physiological properties of soil in a sustainable and eco-friendly manner.

Improvement in technological Interventions: Technological improvements in the implements need of time, so that the option of planting into residue, drilling operation, *in situ* incorporation, etc. can be made feasible. In a study, Gupta [36] finds that the Happy Seeder technology is a viable alternative to the open-field burning of rice residue in Punjab. It also finds that operators of this technology can save about INR.1000-1060 per hectare (or USD 23) on average in field preparation costs compared to plots that were conventionally tilled. In addition, the mean output of wheat crops is similar from plots that have been conventionally tilled and from those that have been cultivated using Happy Seeder technology. Along with this stubble shaver, straw reaper, Hey rakes and rotavator technologies can also prove the best alternative for CRB. Farmers also enjoy substantial time savings because the Happy Seeder can be brought into the field immediately after the rice harvest.

Establishment of Custom Hiring Centers: Government, as well as the private agency, can establish this center because farmer burnt the crops residue due to lack proper tool and machinery as well as high cost of these so smallholder farmers can't purchases these. This can be a better way in this direction to lower the risk of burning residue.

Subsidy on Crop Residue Management Machinery: Government can play a big role through state agriculture department by providing subsidy on the implement which is used for crop residue management for full adoption of these because the implements have a high cost.

Diversified Uses of Crop Residue: Residue of rice and wheat crops can be used for various alternative uses if it is not burnt. These include the use of crop stubble as fodder for animals, use of crop stubble for the generation of electricity, use as input in the paper/pulp industry etc. The use of rice residue as fodder for animals is relatively low in Punjab as compared to the wheat stubble. This is because the rice residue is

Table 4. Impact of different residue management practices on soil properties in Ludhiana (Pb)

Soil properties	Crop management practices		
	Burned	Removed	Incorporated
Total P(mg kg^{-1})	390	420	612
Total K(g kg^{-1})	17.1	15.4	18.1
Olsen P (mg kg^{-1})	14.4	17.2	20.5
Available K (mg kg^{-1})	58	45	52
Available S (mg kg^{-1})	34	55	61

Source: Sidhu and Beri (2005)[11]

Table 5. Effect of different crop residue management practices on the soil physiological properties

Physiological properties of soil	Residue management		
	Incorporated	Removed	Burnt
pH	7.7	7.6	7.6
EC	0.18	0.13	0.13
Organic C(%)	0.75	0.59	0.69
Available N (kg ha^{-1})	154	139	143
Available P (kg ha^{-1})	45	38	32
Available K (kg ha^{-1})	85	56	77
Total N (kg ha^{-1})	2,501	2,002	1,725
Total P (kg ha^{-1})	1,346	924	858
Total K (kg ha^{-1})	40,480	34,540	38,280

Source: Mondat et al. (2004)[6]

high in silica content which in turn is not good for animal health. However, very often the crop stubble is treated with urea before it is fed to the animals. Rice straw also can be used by mixing it with other dry fodder, silage making, and dry fodder box. As per Badve [37] treating crop residues with 4% urea and 45–50% moisture improves the nutritive value by increasing digestibility, palatability, and crude protein content.

Capacity Building and Awareness Generation: Training of farmers for awareness generation through mass and print media can be done for crop residue management before the harvesting season to minimize the extent of the problem. This will help the farmer to understand the hazards of crops residue burning for climate as well as human health.

Demonstration of Crop Residue Management Technologies: Most of the farmer not aware about crops management technology so public and private can play a big role to become aware and to learn farmer by demonstrating the latest technologies. This will improve the management skill and knowledge of farmers to handle this issue.

Diversified Agriculture: It has been increasingly felt by the expert, to move the farmers away from the rice-wheat crop rotation into new areas like vegetables, fruits, oilseeds, pulses, etc. The importance of crop diversification to protect the natural resources and to stabilize farm income is increasingly felt. The government should launch integrated farming approaches so that farmers can full fill their farm input need within from their farm at some level, this will help in increasing the farmer's income along with reducing the unnecessary exploitation of natural resources. In this regard, organic farming can be a better alternative to balance the eco-system by using the bio-insecticide /pesticide instead of inorganic chemical for crop protection and production.

3. CONCLUSION

The problem of pollution caused by rice and wheat crop residue burning has not received much attention from the policymakers and the various pollution authorities. This could be partially due to the fact that the rice and wheat burning taken place only during selected months of October, November, and December. The pollution is restricted only during these months. However, even during these months, there is a considerable loss to human health and environment degradation. In the local dailies of NCR, you might come across articles requesting farmers to stop burning the stubble or creating awareness among them about its ill effects. But the problem still remains more or less unresolved. So, to tackle with the crop residue burning issue there is urgent need of improvement in the existing machinery used in crops harvesting like the combine harvester. Along with this government need to provide incentive on the latest machinery which is quite beneficial like Straw shaver, happy seeder[1], Zero-till seed-drill[2], straw baler, rotavator as well as efforts should do to change the cropping pattern with integrated and organic farming. Capacity building also important aspect because without change in farmer thought regarding residue burning, technology can't help much so, farmers should be aware through various training programme and other mass media aids about pollution and human health. The government should also provide a platform to sell the crops residues for the various sectors this will generate the extra income for farmers to help in doubling the farmers' income as declared a mission of Government of India.

1. Happy seeder which combines the stubble mulching and seed drilling functions in the one machine and used for sowing wheat without any burning of rice residue.
2. Zero-till seed-drill is a way of growing wheat crops without tillage or disturbing the soil in paddy-harvested fields.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Majumder D, Kingra PK and Singh SP. Climate variability impact on water requirement on spring maize in central and sub-mountainous Punjab. Annals of Agricultural Research. 2016;37(2):1-6.
2. INCCA. Indian Network for Climate Change Assessment, Ministry of Environment and Forests, Government of India. India: Greenhouse Gas Emissions; 2010.
3. Gadde B, Bonnet S, Menke C, Garivait S. Air pollutant emissions from rice straw open field burning in India, Thailand, and

the Philippines. Environmental Pollution. 2009;(157):1554-1558.

4. Binamrata Borwankar citing IIT Mumbai study, 2016: Air pollution killed 81,000 in Delhi & Mumbai, cost 70,000 crore in, Times of India; 2015.
5. Koopmans A, Koppejan J. Agricultural and Forest Residues - Generation, Utilization and Availability, Paper presented at the Regional Consultation on Modern Applications of Biomass Energy. 1997;6: 10.
6. Mandal KG, Misra AK, Hati KM, Bandyopadhyay KK, Ghosh PK, Mohanty M. Rice residue management options and effects on soil properties and crop productivity. Food, Agriculture and Environment. 2004;(2):224-231.
7. Garg SC. Traces gases emission from field burning of crop residues. Indian Journal of Air Pollution Control. 2008;8(1):76-86.
8. Gupta P, Sahai S, Singh N, Dixit C, Singh D, Sharma C, el al. Residue burning in rice-wheat cropping system: Causes and implications. Current Science. 2004;87 (12):1713-1717.
9. Streets D, Yarber K, Woo J, Carmichael G. Biomass burning in Asia: Annual and seasonal estimates and atmospheric emissions, Global Biogeochemical Cycles. 2003;17(4):1099.
10. Venkataraman C, Habib G, Kadamba D, Shrivastava M, Leon J, Crouzille B, el al. Emissions from open biomass burning in India: Integrating the inventory approach with high-resolution Moderate Resolution Imaging Spectroradiometer (MODIS) active fire and land cover data, Global Biogeochemical Cycles. 2006;20(2): GB2013.
DOI:10.1029/2005GB002547
11. Sidhu BS, Beri V. Experience with managing rice residues in intensive rice-wheat cropping system in Punjab. In Abrol IP, Gupta RK, Malik RK (Eds.), Conservation agriculture: Status and prospects. New Delhi: Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre. 2005; 55-63.
12. Singh RP, Dhaliwal HS, Sidhu HS, Manpreet-Singh YS, Blackwell J. Economic assessment of the Happy Seeder for rice-wheat systems in Punjab, India. Conference Paper, AARES 52nd Annual conference, Canberra. Australia: ACT; 2008.
13. Pathak H, Singh R, Bhatia A, Jain N. Recycling of rice straw to improve crop yield and soil fertility and reduce atmospheric pollution. Paddy Water Environ. 2006;4(2):111-117.
14. Kumar P, Kumar S, Joshi L. Socioeconomic and Environmental Implications of Agricultural Residue Burning: A Case Study of Punjab, India; 2015.
15. Khaiwal R, Singh T, Mor S. Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emissions. Journal of Cleaner Production. 2018;208(20):261-273.
16. Available:http://epaper.amarujala.com/rt/20171115/07.html?format=img
17. Zhang H, Hu D, Chen J, Ye X, Wang SX, Hao J, el al. Particle size distribution and polycyclic aromatic hydrocarbons emissions from agricultural crop residue burning. Environ. Sci. Technol. 2011;(45): 5477-5482.
18. Mittal SK, Susheel K, Singh N, Agarwal R, Awasthi A, Gupta PK. Ambient air quality during wheat and rice crop stubble Burning episodes in Patiala. Atmos. Environ. 2009; (43):238-244.
19. Jain N, Bhatia A, Pathak, H. Emission of air pollutants from crop residue burning in India. Aerosol and Air Quality Research. 2014;(14):422-430.
20. Gupta PK, Sahai S. Residues open burning in rice-wheat cropping system in India: Anagenda for conservation of environment and agricultural conservation. In Abrol IP, Gupta RK, Malik RK (Eds.), Conservation Agriculture-Status and Prospects New Delhi: Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre. 2005; 50-54.
21. Lal MM. An overview to agricultural burning. In proceeding of the workshop on air pollution problems due to burning of agricultural residues, held at PAU, Ludhiana organized by the Indian Association for Air Pollution Control in collaboration with the Punjab State Pollution Control Board, Patiala and the Central Pollution Control Board, New Delhi; 2006.
22. Agarwal S, Trivedi RC, Sengupta B. Air pollution due to burning of residues. In proceeding of the workshop on air pollution problems due to burning of agricultural

residues, held at PAU, Ludhiana Organized by the Indian Association for Air Pollution Control in collaboration with the Punjab State Pollution Control Board. New Delhi: Patiala and the Central Pollution Control; 2006.
23. Canadian Lung Association. Pollution and air quality; 2007.
(Accessed 20 June 2018)
Available:http://www.lung.ca/protect-protegez/pollution-pollution_e.php.
24. Badarinath KVS, Chand Kiran TR. Agriculture crop residue burning in the Indo-Gangetic Plains-A study using IRSP6 WiFS satellite data. Current Science. 2008; 91(8):1085-1089.
25. Long W, Tate R, Neuman M, Manfreda J, Becker A, Anthonisen N. Respiratory symptoms in a susceptible population due to burning of agricultural residue. Chest.1998;113(2):351.
26. Ramanathan V, Carmichael G. Global and regional climate changes due to black carbon. Nature Geoscience. 2008;1(4): 221-227.
27. Singh FP. Stubble Burning in India side effects and alternatives. International Journal of Research in Social Sciences & Humanities. 2018;6.
28. Sidhu HS, Singh M, Humphreys E, Singh Y, Singh B, Dhillon SS, el al. The happy seeder enables direct drilling of wheat into rice stubble. Australian Journal of Experimental Agriculture. 2007;(47):844-854.
29. Vadrevu KP, Ellicott E, Badarinath, K. MODIS derived fire characteristics and aerosol optical depth variations during the agricultural residue burning season, North India. Environ. Pollut. 2011;(159):1560-1569.
30. Erenstein O, Thorpe W, Singh J, Varma A. Crop-livestock inter-actions and livelihoods in the trans-Gangetic Plains, India, ILRI (aka ILCA and ILRAD); 2007b.
31. Walia SS, Brar SS, Kler DS. Effect of management of crop residues on soil properties in rice-wheat cropping system. Environmental Ecology. 1995;13: 503-507.
32. Singh Y, Singh D, Tripathi, RP. Crop residue management in rice-wheat cropping system. Abstracts of poster sessions. 2nd International Crop Science Congress New Delhi, India: National Academy of Agricultural Sciences. 1996; 43.
33. Singh Y, Singh B. Efficient management of primary nutrients in the rice-wheat system. In: Katoke PK (Ed.), Rice-wheat cropping system of South Asia: Efficient production management. Binghamton: Food Products Press; 2001.
34. Sharma HL, Modgal SC, Singh MP. Effect of applied organic manure, crop residues and nitrogen in rice-wheat cropping system in north-western Himalayas. Himachal Journal of Agriculture Research. 1985; (11):63-68.
35. Sharma HL, Singh CM, Modgal SC. Use of organics in rice-wheat crop sequence. Indian Journal of Agricultural Science. 1987;(57):163-168.
36. Gupta R. Causes of Emissions from Agricultural Residue Burning in North-West India: Evaluation of a Technology Policy Response. SANDEE Working Papers; 2012.
ISSN 1893-1891; WP 66-12.
37. Badve VC. Feeding systems and problems in the Indo-Ganges plain: The Case study. In Speedy A, Sansoucy R (Eds.), Feeding dairy cows in the tropics. Proceedings of the FAO Expert Consultation Held in Bangkok, Thailand; 1991.

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