The Scientific Temper
Vol. 13, No. 2, July-December, 2022:pp 146-152
ISSN 0976-8653, E-ISSN 2231-6396
A Web of Science Journal
DOI: https://doi.org/10.58414/SCIENTIFICTEMPER.13.2.2022.146-152
Doc ID: https://connectjournals.com/03960.2022.13.2.146

Management of Crop-Residue to Control Environmental Hazards

Archana Bansal
Department of Zoology, Sri Tikaram Kanya Mahavidyalaya, Aligarh, Uttar Pradesh, 202001
Corresponding author: bansalarchana26@gmail.com

ABSTRACT

India is one of the leading countries in production of crops such as wheat, rice, sugarcane and many more. It also generates a large amount of agricultural waste [including crop residue]. Waste materials derived from various agricultural activities are defined as agricultural wastes including crop residues. Due to high amount of crop residues, it becomes difficult for the farmers to dump that waste. Farmers generally gather crop residues and burn them in the fields. Crop residues burning is a common post-harvest practice in many parts of the world mainly developing countries to eliminate waste after harvesting. This practice mostly carried out in Punjab, Haryana, and Uttar Pradesh responsible solely to the worst winter pollution in the city of Delhi.

Crop burning contributes to atmospheric pollution leading to the environment degradation phenomena such as air pollution, global warming, smog, and climate change. Large amounts of toxic pollutants like methane, carbon dioxide, carbon monoxide, nitrous oxide, sulphur dioxide and submicron aerosols released in the atmosphere. After their release in the atmosphere, these pollutants disperse in the surrounding, form a thick blanket of smog causing adverse effect on human health. Crop residue burning destroys the nutrients in the soil, making it less fertile, leading to loss of moisture and useful microbes present in the upper layer of the soil. Due to the loss of friendly pests, there is a tremendous increase in enemy pests making crops more prone to diseases. The government of India has attempted to curtail this problem by enforcing various laws and imposing penalty on any offending farmer. However, governments implementation lacks strength. Now the time has come that integral approach should be started to spread awareness on scientific crop residue management.

Keywords: Crop residue, Agricultural waste, Air pollution, Smog, Stubble burning

INTRODUCTION

India is an agricultural country. Around 70% of Indian population depend on agricultural activities for their source of income [Mathur and Srivastava, 2018]. India with about 1.3 billion population requires a vast supply of food to cater their nutritional requirements [Mathur and Srivastava, 2018]. India ranks 2nd largest producer of crops such as wheat, rice, sugarcane and many more. According to the Union Ministry of Agriculture & Farmers welfare, India produces a record of 314.51 million tons [Mt] of foodgrains in 2021-22, which is 23.80 Mt more than average food production of last 5 years with a record production of 129.66 Mt of rice ,106.41 Mt of wheat and 430.50 Mt of sugarcane. So due to this huge production, a large amount of agricultural waste including crop residues is also generated. A total of 516 Mt of crop residue was generated during the year 2017-2018. Other studies have estimated the total amount of crop residues generated between 500 Mt and 620 Mt [Jain et al.,2014; Ravindra et al., 2019] The largest producers of crop residues are

Uttar Pradesh [60 Mt], Punjab [51 Mt] and Maharashtra [46Mt]. This huge amount of crop residue is generated because farmers are using machines to harvest the crops and it leaves about 6-10 cm. of paddy straw on the field [Mittal et al., 2009, Pratika and Sandhu, 2020]. Removal of this paddy stalk from the field is an intensive and a costly process. “The mechanization of Indian agriculture has resulted in development and adoption of combine harvester, which leaves residue of harvested crop in the field” [Peerzada, 2021], making residue recovery difficult [Gupta, 2010]. The practice of crop residue burning in the open field is commonly accepted by the farmers to get rid of this huge amount of waste. Removal of paddy stalk in the field is a labor- intensive process. Due to rise in labor cost and high cost of mechanical implements in Punjab and Haryana, 80-90% of paddy straw is burnt in the field [Kumar & Singh, 2021]. In India, rice, wheat and sugarcane are the major crop residues burnt [Jain et al., 2014]. Bhuvaneshwari et al. [2019] reported that about 0.092 Gigagrams [Gg] of crop residue is burned in India every year. Rice straw, wheat straw and sugarcane residue constitute about 40%, 22% and 20% of the total residue burnt, respectively. Ahmed et al. [2015] estimated that crop residue removal cost got up to 35% higher than burning. According to the Indian Agricultural Research Institute [IARI,2012] approximately 14 Mt out of 22 Mt of rice stubble [about 63.6%] generated every year in India is set to fire. The amount of crop residue burned increased from 18 Mt to 116 Mt between 1950 and 2017-18 [Venkatramanan et al., 2021]

IMPACTS OF STUBBLE BURNING

The stubble burning has devastating impacts on the environment. This practice is not environmentally sustainable. It is a common post- harvest practice in many parts of the world mainly developing countries to eliminate waste after harvesting [Mohammadi, 2015]. This practice mostly carried out in Punjab, Haryana and Uttar Pradesh responsible solely to the worst winter pollution in the city of Delhi and other National Capital Region [NCR] cities. Stubble burning is one of the major contributors to atmospheric pollution in the world releasing gaseous pollutants and particulate matter, which affect the human health as well as the environment [Sharma et al., 2010].

The air quality of urban areas is more affected by stubble burning emissions because of the presence of the accumulated pollutants from vehicular and industrial emissions leading to a severe air quality.

It has been demonstrated that wind direction and wind speed [Cao et al., 2008] and temperature [Liu et al., 2018] influence the transport and dispersion of air pollutants.

The Indian agriculture sector is responsible for about 12.2% of the total global Greenhouse gas [GHG] emissions [CO_2, N_2O, CH_4] from agriculture [Maraseni et al., 2018]. The two groups of pollutants from crop residue burning are gaseous [SO_2, NOx, CO_2, CO, CH_4, N_2O etc] and particulate matter [PM 2.5 and PM 10, VOC]. PM 2.5 and PM 10 are reported to have the highest effect on the health of the exposed population. Awasthi et al. [2011] reported 78% and 43% increase in the $PM_{2.5}$ concentration during the rice and wheat stubble burning periods respectively. In 2015 rice and wheat burning periods in Punjab were responsible for 86.7% of PM_{10} and 53.2% for $PM_{2.5}$ [Singh, 2015]. In North India, air quality gets worsened during winter mostly in November and December [Mishra, 2019]. The air pollutants emission from crop residue burning showed non-uniform pattern across different states in India which depends on the type of crop residue burnt. However, Punjab, Haryana, Uttar Pradesh, and Maharashtra were placed on top in the list of residues burning affected regions [Jain et al., 2014; Shyamsundar et al., 2019; Kaushal and Prashar,2021]. The division of Environmental Sciences of IARI, New Delhi reported that wheat contributed the highest in greenhouse gas emission of 24% of methane and nitrous oxide emissions in 2007. The GHG emission due to crop residue burning was around 5 Mt CO2 in 1995-1996 and it increased to 7 Mt CO2 in 2005-2006 [Peerzada, 2021].

Some of the soil properties like temperature, pH, moisture, available phosphorus, and soil organic matter are also get affected due to crop residue burning. Soil temperature increases to about 42°C, thus resulting in decline of microorganisms’ population in the soil up to a depth of about 2.5 cm. [Jain et al., 2014]. Soil also gets deprived of some essential nutrients like nitrogen, phosphorus, and potassium [NPK] including other micronutrients due to crop residue burning. Degradation of soil structure increases the risk of erosion [Sarkar et al., 2020]. Ground level ozone is created by Volatile organic compounds [VOC] and nitrogen oxides produced from crop residue burning, which in turn affects the metabolism of crops and destroys leaves cause crop losses [Augustaitis et al., 2010; Abdurrahman et al., 2020]. The scientists from ICAR-CSSRI based on soil diagnosis reported that after crop residue burning soils became deficient in Nitrogen [100%], Boron [86.7%], Zinc [66.7%], Iron [33.3%], Manganese [93.3%] and organic Carbon [73.33%]. Singh et al. [2020] stated that burning of crop residue resulted in a loss of almost all C, which leads to a drop in C sequestration. A loss of 90% of N, 60% of S and 20-25% of P & K as well as other micronutrients have been reported by Doberman and Fairhurst, 2002.

It is also responsible for alteration in the ecosystem by providing suitable conditions for the growth of pests or diseases. High concentrations of SO_2 and NO_2 due to residue burning provide suitable conditions for aphid pests [Ghosh et al., 2019].

Residue burning is also one of the causes for rapid loss of moisture content of soils resulting in death of some microbes due to tissue dehydration. Optimum soil moisture is required for better microbial population and low moisture content results in decrease of seed germination and growth of plants [Peerzada,2021]. Microbial activities also get affected due to rise in pH, caused by ash production after residue burning, which is rich in Ca, Mg and K ions. When burning is practiced for several years, these effects become more prominent [Peerzada, 2021].

HEALTH EFFECTS OF CROP RESIDUE BURNING:

Atmospheric pollution due to stubble burning has severe effects on human health [Sharma et al., 2010]. The second most important factor responsible for ill health in South Asia is exposure to air pollution [Krishna et al., 2017]. Harmful effects due to exposure to air pollution includes respiratory, neurological, cardiovascular disorders, skin and eye irritation. High levels of air pollutants may cause permanent health illnesses like asthma, bronchitis, Chronic Obstructive Pulmonary Disease [COPD], loss in lung capacity, emphysema, cancer etc. [Ghosh et al., 2019]. Kumar et al. [2015] reported that farmers complaint about eye and lung irritation. People with lung ailments such as asthma and COPD affected more quickly by tiny particles which enter in the lungs and then to the blood stream [Ghosh et al.,2019; Peerzada, 2021]. People suffering from allergies due to smoke in the air showed symptoms like sore throat, sore eyes, coughing, nasal and sinus congestion. A decline in lung capacity of children is also reported [Awasthi et al.,2010; Saggu et al., 2018; Chakrabarti et al. 2019 and Gupta ,2019]. A gradual increase in the rate of deaths due to pollution has been reported over the past few years. Respiratory system is the primary target of toxic substances responsible for respiratory disorders, cancer or even death in extreme cases. Increased rate of cardiovascular mortality has been observed due to prolonged exposure to particulate matter [PM] [Saggu et al., 2018]. More than 6,00,000 people die each year due to polluted air exposure [Lelieveld et al., 2015; Ghude et al., 2016]. Delhi inhabitants showed a decrease of about 6.4 years in their life expectancy due to exposure to a high level of pollution [Ghude et al., 2016]. In India, air pollution had claimed the lives of about 1.24 million people in 2017 [Balakrishnan et al., 2011].

REASONS BEHIND CROP RESIDUE BURNING:

Farmers do not have alternatives for effective utilization of crop stubble. There is paucity of time to clear fields for Rabi wheat cultivation [Wijaya, 2017]. The cost involved in collection and transportation and recycling is a concern for many farmers. Large volumes of residue post-harvest, off site residue management is currently not economically viable [Lohan et al., 2018]. Ahmed et al. [2015] estimated crop residue removal cost to be up to 35% higher than burning. Scarcity of laborers [due to lower migration owing to MNREGS, lack of crop residue management [awareness, machines] are some of the reasons responsible for crop residue burning. Farmers cannot afford the new technology that is available to handle the waste material.

USES OF CROP RESIDUE:

The wheat residue is mostly used for animal feed therefore it could be a sustainable and economically viable technique. However, rice straw due to low nutritional value and high silica content is not used as animal feed [Bisen & Rahangdale, 2017; Kaushal, 2020]. Excess crop would be used by farmers for cooking as to keep their animals warm or even as extra insulation for homes, but this is outdated now. Farmers derive specific benefits by that such as cost and time saving, controlling weeds, diseases, and pests.

The incorporation of crop residues into the field has been promoted to preserve organic matter and increases the soil fertility [Ravindra et al., 2018]. Nutrient levels have also been improved by the inclusion of straw into the soil [Liu et al.,2016]. Incorporation of crop stubble into the soil continuously for 3 weeks helps in a significant increase in productivity of crops like wheat. Singh et al. [1996] reported an increase in the carbon content of soil by about 14-29 %. In Punjab, about 14 % of rice and 9% of wheat stubbles are incorporated into the soil each year [Kumar et al., 2015]. The vital nutrients [Nitrogen, Phosphorus and Potassium] essential for plant growth are also present in stubble straws. Kumar et al. [2015] reported that in Punjab, rice straw contains an average of 0.61% Nitrogen, 0.18% Phosphorus and 1.38% Potassium. Wheat stubble proved to be better than rice stubble due to more nutrients present in it. Nutrient rich stubble can be improved by composting, which in turn improves the productivity of soil [Romasanta et al., 2017]. Sood [2013] reported 4-9% improvement in the crop yield. Vermicomposting is one of the popular composting methods by using earthworms. The compost produced by this method significantly improves the productivity of soil [Singh et al., 1996].

Another viable option is the utilization of crop stubble to produce biofuel for its management which also promotes cleaner air and greener environment [Singh et al., 2018] by preventing the release of toxic chemicals and by reducing the use of fossil fuels- based energy. Biogas can also be generated through anaerobic digestion of crop stubble [Sun et al.,2016]. This biogas can be used as fuel for domestic heating purpose and in turn reduce the indoor pollution. Efficient utilization of crop stubble can fulfill about 17% of the total energy demand in India [Hiloidhari et al., 2014]. Rice straw can be converted by eco-friendly and economically viable methods into pulp which can be used in producing paper [Rodriguez et al.,2010; Kaur et al., 2017] and packaging materials [Sain, 2020].

Apart from these, other options for the replacement of stubble burning are through its decomposition by using microorganisms which degrade the cellulose and lignin present in it. It helps to restore the fertility of the soil by recovering its nutrients and return to the soil [Zhao et al., 2019]. White rot fungus [*Pleurotus djamer* or *P. sajorcaju*] can be used for the decaying of agricultural wastes [Su et al.,2020]. One example of crop residue bio-decomposer containing microorganisms available in the market to the farmers in India at approximately Rs. 20 in solution, it can decompose about 10,000 metric tons of crop residue within 30 days after spraying [Wangchuk, 2019]. Other alternatives to tackle residue burning are to convert the burnable biomass into a feedstock for energy or valuable chemicals in other industry. For example, rice straw can be used for mushroom cultivation and electricity generation through gasification process [Wijaya, 2017].

Government of India has made several attempts to introduce and educate the farmers about the best practices of crop residue management through Government initiated projects. They promote the usage of alternative sustainable management practices. Some laws related to control the crop residue burning which are in operation are – "The section 144 of Civil Procedure Code [CPC] to put ban for paddy residue burning, The Air Prevention and Control of Pollution Act [1981], The Environment protection Act [1986], The National Tribunal Act [1995] and The National Environment Appellate Authority Act [1997]." [Kumar et al., 2015, Lohan et al., 2018].

The Union Government in 2014 released the National Policy for Management of crop residue. The National Green Tribunal [NGT] on 10th December,2015 had banned crop residue burning in the states of Rajasthan, Uttar Pradesh, Haryana, and Punjab. In Uttar Pradesh, a decrease of 51.71 % has been observed in the incidences of crop residue burning during the period of 2017 to 2021 after the release of crop management policy. National Capital Region [NCR] has also experienced a decrease of 48.78% incidences [Dixit ,2022]. Burning crop residue is a crime under Section 188 of the IPC and under the Air and Pollution Control Act of 1981 [Yadav, 2014]. Recently The Government of India has directed the National Thermal Power Corporation [NTPC] to use crop residue pellets [Approx. 10%] with coal for power generation. Farmers can get an economic benefit of about Rs. 5500 per ton of crop residue. Indian Government also run few schemes associated with bio-composting. These are "The Rashtriya Krishi Vikas Yojana [RKVY], State Plan Scheme of Additional Central Assistance launched in 2007 is a government initiative as a part of the 11th Five Year Plan by the Government of India "[Singh et al.,2017].

The central Government has adopted a number of measures to curtail the practice of residue burning in various states. The farmers of Punjab, Haryana and Uttar Pradesh have been provided Rs. 757.18 crores by the centre to encourage the purchase of Agri machineries. The present Government has approved a sum of Rs. 1151 crores of central funds in four major Indian states for control of crop residue burning for two fiscal years [Indian Council of Food and Agriculture, reports].

Management of crop residues can be done effectively by using various agricultural machines like Happy Seeder, Rotavator, Zero till seed drill, Baler, Paddy Straw chopper/ Cutter and Reaper Binder. However, these machines are very costly and farmers do not use them to manage the huge amount of crop residue generated. Government come forward to solve this problem by providing subsidy at 50-80 % for 14 types of crop residue management machinery.

CONCLUSIONS:

The generation of a significant quantity of crop stubble in India is related with a rice-wheat crop rotation system which is usually more than the quantity of harvested crop. This is usually burnt by the farmers to get rid of this unwanted crop residue by a quick and inexpensive method to clear the farm for next sowing. So, crop residues are the main source of biomass burning which is responsible for the release of toxic pollutants in the atmosphere which leads to climate change, global warming, destruction of soils natural properties and health. In North India climatic conditions further deteriorates the air quality in addition to stubble burning emission. The pollutants also affect human health by causing respiratory and cardiovascular diseases There is a need to discourage burning and implement policies to curtail this menace at the base level.

Crop stubble can be used in several ways to yield economically valuable and environment friendly products like compost. They can be used as biomass for biofuel production, as fuel in power plants or in paper and pulp manufacturing units. The farmers in North India are usually not aware of the alternatives for crop stubble. However, some farmers are aware of the negative consequences of crop burning [Kumar et al.,2015], despite that they opt for quick and inexpensive way to get rid of this unwanted crop residue due to a narrow gap between harvesting and sowing of next crop. Farmers should provide information through awareness programs about the environmental impacts and economic benefits of using crop stubble through alternative approaches. Various industries should be directed to use the crop stubble as raw materials. Governments have started to put ban and imposing penalties to farmers in several states to discourage them about burning. However, recently government has taken initiative and start to compel the power industry to use crop stubble as raw material.

ACKNOWLEDGEMENTS:

Thanks are due to the Principal, Sri Tikaram Kanya Mahavidyalaya, Aligarh, Uttar Pradesh, 202001 for providing laboratory facilities for the present work. I also declare that all ethical guidelines were followed during the course of the present study.

Declaration: *We also declare that all ethical guidelines have been followed during this work and there is no conflict of interest among authors.*

REFERENCES

Abdurrahman, M.I., Chaki, S., Saini, G., 2020. Stubble burning: effects on health & environment, regulations and management practices. Environ. Adv., 2, p. 100011.

Ahmed, T., Ahmad, B., Ahmad, W., 2015. Why do farmers burn rice residue? Examining farmers' choices in Punjab, Pakistan. Land Use Pol. 47, 448–458.

Augustaitis, A., Đopauskienë, D., Bauþienë, I., 2010. Direct and indirect effects of regional air pollution on tree crown defoliation. Baltic For. 16 (1), 13. https://www.balticforestry.mi.lt/bf.

Awasthi, A., Singh, N., Mittal, S., Gupta, P.K., Agarwal, R., 2010. Effects of agriculture crop residue burning on children and young on PFTs in North West India. Sci. Total Environ. 408 (20), 4440–4445

Awasthi, A, Agarwal, R, Mittal, SK, Singh, N, Singh, K, Gupta, P.K., 2011. Study of size and mass distribution of particulate matter due to crop residue burning with seasonal variation in rural area of Punjab, India. J. Environ. Monit. 13, 1073–1081. https://doi.org/10.1039/c1em10019j.

Balakrishnan, K., Ramaswamy, P., Sambandam, S., Thangavel, G., Ghosh, S., Johnson, P., Mukhopadhyay, K., Venugopal, V., Thanasekaraan, V., 2011. Air pollution from household solid fuel combustion in India: an overview of exposure and health related information to inform health research priorities. Glob. Health Act. 4, 5638. https://doi.org/10.3402/gha.v4i0.5638

Bhuvaneshwari, S., Hettiarachchi, H., Meegoda, J.N., 2019. Crop residue burning in India: policy challenges and potential solutions. Int. J. Environ. Res. Publ. Health 16(5), 832.

Bisen, N., Rahangdale, C.P., [2017]. Crop residues management option for sustainable soil health in rice-wheat system: a review. Int. J. Chem. Stud., 5 (4), pp. 1038-1042

Cao, G., Zhang, X., Wang, Y., Zheng, F., 2008. Estimation of emissions from field burning of crop straw in China. Chin. Sci. Bull. 53 (5), 784–790. https://doi.org/10.1007/s11434-008-0145-4

Chakrabarti, S., Khan, M.T., Kishore, A., Roy, D., Scott, S.P., 2019. Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons. Int. J. Epidemiol. 48 (4), 1113–1124

Deshwal, k., Kumar, S., Mishra, S., Singh, A. K. 2019. Crop residue burning: Cause, Effect and Management. https://krishijagran.com/featured/crop-residue-burning-effect-and-mamagement/Dixit, R. ,2022. Crop residue management scheme: stubble burning halved incidents in four years in UP. https://www.jagran.com/uttar-pradesh/lucknow.

Dobermann, A., Fairhurst, T.H., 2002. Rice straw management. Better Crop. Int. 16 (1), 7–11.

Ghosh, P., Sharma, S., Khanna, I., Datta, A., Suresh, R., Kundu, S., Goel, A., Datt, D., 2019. Scoping study for South Asia air pollution. Energy Resour. Inst. 153. https://www.gov.uk/dfid-research-outputs/scoping-study-for-south-asia-air-pollution.

Ghude, S.D., Chate, D.M., Jena, C., Beig, G., Kumar, R., Barth, M.C., Pfister, G.G., Fadnavis, S., Rao, P., 2016. Premature mortality in India due to PM2.5 and ozone exposure. Geophys. Res. Lett. 43, 4650–4658. http://dx.doi.org/10.1016/j.envdev.2015.07.009.

Gupta, R., 2010. The economic causes of crop residue burning in Western Indo-Gangetic plains. In: Conference Held at. Indian Statistical Institute, Delhi centre, pp. 1–26.

Gupta, S., 2019. Agriculture crop residue burning and its consequences on respiration health of school-going children. Glob. Pediatr. Health 6, 2333794X19874679.

Hiloidhari, M., Das, D., Baruah, D.C., 2014. Bioenergy potential from crop residue biomass in India.

Renew. Sust. Energ. Rev. 32, 504–512. https://doi.org/10.1016/j.rser.2014.01.025.

Jain, N., Bhatia, A., Pathak, H., 2014. Emission of air pollutants from crop residue burning in India. Aerosol Air Qual. Res. 14 (1), 422–430. https://doi.org/10.4209/aaqr.2013.01.0031.

Kaskaoutis, D.G., Kumar, S., Sharma, D., Singh, R.P., Kharol, S.K., Sharma, M., Singh, A.K.,

Singh, S., Singh, Atinderpal, Singh, D., 2014. Effects of crop residue burning on aerosol properties, plume characteristics, and long-range transport over Northern

India: effects of crop residue burning. J. Geophy. Res-Atmos. 119 (9), 5424–5444. https://doi.org/10.1002/2013JD021357.

Kaur, D., Bhardwaj, N.K., Lohchab, R.K., 2017. Prospects of rice straw as a raw material for paper making. Waste Manag. 60, 127–139.

Kaushal, L.A. ,2020. Examining the policy-practice gap-The issue of crop burning induced Particulate Matter pollution in Northwest India. Ecosys. Health Sustain., 6 (1), p. 1846460

Kaushal, L.A., Prashar, A., 2021. Agricultural crop residue burning and its environmental impacts and potential causes–case of northwest India. J. Environ. Plann. Manag. 64(3), 464–484.

Krishna, B., Balakrishnan, K., Siddiqui, A.R., Begum, B.A., Bachani, D., Brauer, M., 2017.

Tackling the health burden of air pollution in South Asia. bmj 359.

Kumar, P., Kumar, S., Joshi, L., 2015. The Extent and Management of Crop Stubble. In: Socioeconomic and Environmental Implications of Agricultural Residue Burning. Springer Briefs Env. Sci. Springer, India, New Delhi, pp. 13–34. https://doi.org/10.1007/978-81-322-2014-5_2

Kumar, P., Singh, R.K., 2021. Selection of sustainable solutions for crop residue burning: an environmental issue in northwestern states of India. Environ. Dev. Sustain. 23 (3),3696–3730

Lelieveld, J., Evans, J.S., Fnais, M., Giannadaki, D., Pozzer, A., 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature 525,367–371. http://dx.doi.org/10.1038/nature15371.

Li, S, Li, Y, Li, X, Tian, X, Zhao, A, Wang, S, Shi, J., 2016. Effect of straw management on carbon sequestration and grain production in a maize–wheat cropping system in anthrosol of the Guanzhong plain. Soil Till Res. 157, 43–51. https://doi.org/10.1016/j.still.2015.11.002.

Liu, T., Miriam, E.M., Ruth, S.D., Westervelt, D.M., Xia, K.R., Fiore, A.M., Mickley, L.J.,Cusworth, D.H., Milly, G., 2018. Seasonal impact of regional outdoor biomass burning on air pollution in three Indian cities: Delhi, Bengaluru, and Pune. Atmos. Environ. 172, 83–92. https://doi.org/10.1016/j.atmosenv.2017.10.024.

Lohan, S.K., Jat, H.S., Yadav, A.K., Sidhu, H.S., Jat, M.L., Choudhary, M., Jyotsna, K.P., Sharma, P.C., 2018. Burning issues of paddy residue management in north-west states of India. Renew. Sustain. Energy Rev. 81 (2), 693–706. 10.1016/j.rser.2017.08.057

Maraseni, T.N., Deo, R.C., Qu, J., Gentle, P., Neupane, P.R., 2018. An international comparison of rice consumption behaviours and greenhouse gas emissions from rice production. J. Clean. Prod. 172, 2288–2300. https://doi.org/10.1016/j.jclepro.2016.07.035

Mathur, R.; Srivastava, V.K., 2019. Crop residues burning: Effects on environment: Challenges, Technologies and Solutions, published in Greenhouse Gas Emissions, Energy, Environment and sustainability, Springer, Singapore, pp 127-140.

Mishra, M., 2019. Poison in the air: Declining air quality in India. Lung India 36 (2), 160. 10.4103/lungindia.lungindia_17_18

Mittal, S.K., Singh, N., Agarwal, R., Awasthi, A., Gupta, P.K., 2009. Ambient air quality during wheat and rice crop stubble burning episodes in Patiala. Atmos. Environ. 43 238–244. https://doi.org/10.1016/j.atmosenv.2008.09.068.

Mohammadi, A., 2015. Open crop residues burning and Environmental impacts: how it is dealt with? www.researchgate.net.

Peerzada, I., 2021. Impact of crop residue burning. In Greater Kashmir Paper https://www.greaterkashmir.com/todays-paper

Pratika, C., Sandhu, H.A.S., 2020. Stubble burns area estimation and its impact on ambient air quality of Patiala & Ludhiana District, Punjab, India. Heliyon 6 (1), e03095. https://doi.org/10.1016/j.heliyon.2019.

Ravindra, K., Singh, T., Mor, S., 2018. Emissions of air pollutants from primary crop residue burning in India and their mitigation strategies for cleaner emissions. J. Clean.

Prod. 208, 261–273. https://doi.org/10.1016/j.jclepro.2018.10.031.

Rodríguez, A., Sanchez, R., Requejo, A., Ferrer, A., 2010. Feasibility of rice straw as a raw material for the production of soda cellulose pulp. J. Clean. Prod. 18 (10–11), 1084–1091.

Romasanta, R.R., Sander, B.O., Gaihre, Y.K., Alberto, M.C., Gummert, M., Quilty, J., Nguyen, V.H., Castalone.A.G., Balingbing, C., Sandro, J., Correa, T., Wassmann, R. How does burning of rice straw affect CH_4 and N_2O emissions? A comparative experiment of different on-field straw management practices Agric. Ecosyst. Environ., 239 (2017), pp. 143-153 https://doi.org/10.1016/j.agee.2016.12.042

Saggu, G.S., Mittal, S.K., Agarwal, R., Beig, G., 2018. Epidemiological study on respiratory health of school children of rural sites of Malwa region (India during post-harvest stubble burning events. M.A.P.A.N. 33 (3), 281–295. https://doi.org/10.1007/s12647-018-0259-3

Sain, M., 2020. Production of bioplastics and sustainable packaging materials from rice straw to eradicate stubble burning: a Mini-Review. Environ. Conserv. J. 21 (3), 1–5.

Sarkar, S., Skalicky, M., Hossain, A., Brestic, M., Saha, S., Garai, S., Brahmachari, K., 2020. Management of crop residues for improving input use efficiency and agricultural sustainability. Sustainability 12 (23), 9808

Sharma, A.R., Kharol, S.K., Badarinath, K.V.S., Singh, D., 2010. Impact of agriculture crop residue burning on atmospheric aerosol loading–a study over Punjab State, 661 India. Ann. Geophys. 28 (2). (09927689) https://doi.org/10.5194/angeo-28-367-2010

Shyamsundar, P., Springer, N.P., Tallis, H., Polasky, S., Jat, M.L., Sidhu, H.S., et al., 2019. Fields on fire: alternatives to crop residue burning in India. Science 365 (6453), 536–538.

Singh R.P., 2015. Impacts of stubble burning on ambient air quality of a critically polluted area–Mandi-Gobindgarh 3(2), pp. 6. https://doi.org/10.4172/2375-4397.1000135.

Singh, Y, Singh, D, Tripathi, RP., 1996. Crop residue management in rice-wheat crop-ping system. International Crop Science Congress. National Academy of Agricultural Sciences New Delhi https://doi.org/10.1007/978-1-4020-9875-8_10.

Singh, P.D., Prabha R., 2017. Bioconversion of Agricultural wastes into High value bio-compost: A route to livelihood generation for farmers. Adv. Recycl. Waste Manag., 137

Singh, J., Singhal, N., Singhal, S., Sharma, M., Agarwal, S., Arora, S., 2018. Environmental implications of rice and wheat stubble burning in north-western states of India. In:

Siddiqui, N.A., Tauseef, S.M., Bansal, Kamal (Eds.), Advances in Health and Environment Safety. Springer, Singapore, pp. 47–55 edited by Springer Transactions in Civil and Environmental Engineering. Singapore2018. https://doi.org/10.1007/978-981-10-7122-5_6

Singh, P., Singh, G., Sodhi, G.P.S., 2020. Energy and carbon footprints of wheat establishment following different rice residue management strategies vis-`a-vis conventional tillage coupled with rice residue burning in north-western India. Energy 200, 117554.

Sood, J., 2013. Not a waste until wasted. Down to Earth. Available http://www.downtoearth.org.in/content/not-waste-until-wasted (Accessed 15 June 2020).

The Indian Express, 2017. "Can't have another "gas chamber", says Delhi HC on stubble burning. The Indian Express, 23 September, 2017. http://indianexpress.com/article/india/can't-have-another-gas-chamber-says-delhi-hc-on-stubble-burning-4856428/

Su, Y., Lv, J. L. Yu, M. Ma, Z.H., Xi, H., Kou, C.L., He, Z.C. Shen, A. L. 2020 Long-term decomposed straw return positively affects the soil microbial community J. Appl. Microbiol., 128 (1) (2020), pp. 138-150 https://doi.org/10.1111/jam.14435

Sun, J., Peng, H., Chen, J., Wang, X., Wei, M., Li, W., Yang, L., Zhang, Q., Wang, W., Mellouki, A., 2016. An estimation of CO2 emission via agricultural crop residue open field burning in China from 1996 to 2013. J. Clean. Prod. 112, 2625–2631. doi:10.1016/j.jclepro.2015.09.112.

Venkatramnan, V., Shah, S., Rai, A.K., and Prasad, R. [2021]. Nexus between crop residue burning, Bioeconomy and Sustainable development Goals over Northwestern India. Front. Energy Res. 26 January,2021 https://doi.org/10.3389/fenrg.2020.614212

Wangchuk, N.N., 2019. How Do You Tackle Crop Burning? Here Are 5 Solutions that Can Work! https://www.thebetterindia.com/202399/how-do-you-tackle-crop-burning-here-are-5-solutions-that-can-work/.

Wijaya, A.S., 2017. Open crop residue/Stubble burning. www.researhgate.net

Yadav, R.S., 2019. Stubble burning: A problem for the environment, agriculture, and humans. www.downtoearth.org.in. Zhao, S., Qiu, S., Xu, X., Ciampitti, I.A., Zhang, S., He, P., 2019. Change in straw decomposition rate and soil microbial community composition after straw addition in different long-term fertilization soils. Appl. Soil Ecol., 138 (2019), pp. 123-133 https://doi.org/10.1016/j.apsoil.2019.02.018