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Stubble Burning: Health and Environmental Effects and Management Techniques

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Abstract

Stubble burning has been identified as a major source of air pollution, particularly in South Asia. It is a major producer of gaseous pollutants like as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), and methane (CH_4), as well as particulate matter (PM 10 and PM 2.5), which cause considerable harm to human health and the environment. According to reports, burning 63 Mt of agricultural stubble emits 3.4 Mt of CO, 0.1 Mt of NO_x, 91 Mt of CO_2, 0.6 Mt of CH_4, and 1.2 Mt of PM into the atmosphere. Due to the extensive rice-wheat rotation system, which creates a considerable quantity of stubble, the situation in India is more austere. It is estimated that around 352 Mt of stubble is created in India each year, with wheat and rice stubble contributing 22% and 34%, respectively. Every year, approximately 84 Mt (23.86%) of the stubble is burned on the field shortly after harvest. Because it corresponds with the burning times, the terrible haze visible over India during the winter season has been related to stubble burning (October-November). Air pollution's health impacts vary from skin and eye irritation to serious neurological, cardiovascular, and respiratory disorders, including asthma, chronic obstructive pulmonary disease (COPD), bronchitis, lung capacity loss, emphysema, and cancer. It also increases death rates owing to extended exposure to high pollution levels. In addition to affecting air quality, stubble burning has an impact on soil fertility through nutrient degradation, economic growth, and climate.

Keywords- Stubble Burning, Health, Environmental Effects, Management Techniques.

Introduction

Crop stubbles, if handled properly, may bring enormous economic advantages to farmers while also protecting the environment from severe pollution. Alternative management strategies include incorporating stubble into the soil, using stubble as fuel in power plants, using stubble as raw material for the pulp and paper industries, or using stubble as biomass for biofuel production. It may be used to make compost and charcoal, as well as a blend for cement and bricks. Most farmers in North India are unaware of the several possibilities for controlling stubble and, as a result, believe that burning is the best option. This demands massive awareness campaigns to educate farmers about the availability of economically viable solutions and the cumulative impacts of stubble burning.

Stubble or residual is the stuff that remains after crop harvesting. In other terms, residue refers to all plant portions other than commercially relevant material. Across the globe, grains and legumes account up the majority of residue. When we compare rice and wheat in India to other grains and pulses, rice and wheat come out on top. Rice and wheat combined supply around 30% of global food needs, making it a key source of sustenance for billions of people worldwide. After China, India is second in rice and wheat production, producing 175.58 Mt of rice and 101.29 Mt of wheat every year. Furthermore, rice occupies around 44 million hectares and wheat covers 29.5 million ha, indicating the importance of both commodities in Indian agriculture. Cereal crops create the greatest leftovers, with

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352 Mt, according to the Indian Agricultural Research Institute (IARI) in New Delhi. Paddy and wheat account for 34% and 22% of total output, respectively. The simplest approach to clear an agricultural field and begin land preparation for the next crop is to burn crop leftovers in place. Stubble burning is the purposeful act of burning crop remnants in the field in order to begin land preparation for the next crop's planting. Rice-wheat cropping pattern is prevalent in India; specifically, it is generally followed in the Indo-Gangetic plains of Haryana and Punjab, which account for the majority of stubble burning in India (Sain, 2020). Rice is often harvested by a combine harvester, which leaves a significant amount of residue on the agricultural field. Due to a lack of time to gather and use the leftover material, farmers burn the leftovers so that field preparation may begin quickly to sow wheat harvest in the month of November Furthermore, due to high quantities of silica, animals do not appreciate rice straw. Farmers are unable to feed it to their animals, forcing them to burn the remnants on the field. Rice straw includes carcinogenic chemicals such as methane. A significant amount of the stubble generated is burnt on the field. According to the Indian Agricultural Research Institute (IARI), around 63.6 percent, or 14 million tonnes, of the 22 million tonnes of rice stubble created each year is slated to be burned. Punjab and Haryana, two of India's most important rice-producing states, account for roughly half of the total stubble burnt (Gadde et al., 2009).

CROP STUBBLE PRODUCTION AND COMBUSTION- Rice (*Oryza sativa*), wheat (*Triticum aestivum*), sugarcane (*Saccharum officinarum*), cotton (*Gossypium hirsutum*), jute (*Corchorus olitorius*), and mesta (*Hibiscus cannabinus*) are the most common crops grown in India (*Arachis hypogaea*), castor seed (*Ricinus communis*), and sesame (*Sesamum indicum*)) (Jain et al., 2014). The highest stubble is generated from rice production as illustrated in Table 1.

Table 1. Types and quantities of crops commonly generated in India (Jain et al., 2014)

Type of Crop	Quantity of Crop Produced (Mt/year)	Quantity of Stubble generated (Mt/year)	Ratio of Stubble to Crop
Rice	153.35	188.98	1.23
Wheat	80.68	120.07	1.49
Jute	18.32	31.51	1.72
Sugarcane	285.03	107.50	0.38
Maize	19.73	26.75	1.36
Cotton	37.86	90.86	2.40
Millets	17.62	21.57	1.22
Rapeseed	7.20	17.28	2.40
Groundnut	7.17	11.40	1.59
Total	627.96	620.43	-

There are several ideas about the overall proportion of agricultural stubbles burnt in the field, ranging from 6.6% to 43%. Table 2 shows the amount of stubble burned in India based on several research. According to the Intergovernmental Panel on Climate Change (IPCC), farmers burn 25% of field stubbles, while Jain et al. (2014) indicated 23% for wheat and rice, and 10% for other crops. According to Cao et al. (2008), approximately 6.6% of crop stubble created on the farm is burned in-situ soon after harvest. According to another survey, almost 43% of all agricultural stubble created in India is burned on the field (Singh and Kaskaoutis, 2014).

Table 2. Loss of nutrients due to rice stubble burning in Punjab, India (Kumar et al., 2015)

Nutrient	N	P	K	C
Nutreint Content in Stubble (g/kg)	6.5	2.1	17.5	400
Percentage Lost due to burning (%)	90	25	20	100
Amount lost per hectare (kg/ha)	35	3.2	21	2400

The rice-wheat rotation system is the most frequent agricultural strategy in the Indo-Gangetic Plain (IGP). The IGP is a significant region in South Asia that is endowed with fertile agricultural farmlands and a diversified ecology. Geographically, it accounts for around 20% of India, Pakistan, Bangladesh, and Nepal's total land area. In India, it accounts for around 40% of the entire population while occupies approximately 20% of the total geographical area. This region produces 41% of India's yearly food production, the majority of which being grains. A total of about 66 million hectares (total area of the IGP) are used for the wheat-rice (crop rotation) farming method (Sharma et al., 2010). In India, an estimated 9.6 million hectares of land are used annually for rice-wheat farming (Sharma et al., 2010). The majority of farmers in this region utilise combine harvesters to plant and harvest their crops, resulting in a substantial amount of stubble. The usage of combine harvesters for grain harvesting is prevalent among Indian farmers, particularly in the country's north. This machine is capable of combining three distinct jobs, namely reaping, threshing, and winnowing, into a single operation.

A large portion of the stubble created is programmed to burn on the field. According to the Indian Agricultural Research Institute (IARI), around 14 million tonnes (Mt) of the 22 Mt of rice stubble created (approximately 63.6%) Every year, India is on fire. Haryana and Punjab, two of India's most important agricultural states, provide 48% of this total (Gadde et al., 2009). Rice and wheat account for approximately 85.91% of overall agriculture in the Punjab region, with other crops grown in very modest quantities. Rice is typically planted in the summer, around May/June, and harvested in the fall, around October/November. Wheat, on the other hand, is often sown throughout the winter, typically in December, and harvested during the summer immediately after harvest in each season. However, at this moment, different in other places of the world (Kapil, 2019). Farmers like to burn agricultural residue after harvest in order to swiftly prepare the ground for the following sowing (of rice or wheat as the case may be). In order to swiftly prepare the farmland for the following crop, farmers simply burn the stubble on the field, producing a high quantity of dangerous pollutants (Krishna et al., 2011). Another reason for burning the stubble is a lack of time between harvesting and planting the following crop (Ravindra et al., 2018). The typical time interval between rice harvest and wheat planting was found to be 15 days, with rice sowing following wheat harvest being substantially longer, up to roughly 46-48 days. As a result, farmers do not have enough time to properly manage crop residue, particularly following rice harvest (Krishna et al., 2011). Stubble burning has a greater impact during the rice stubble burning season because the lower winter temperature leads to a more stable environment (inversion circumstances) (Ghei and Sane, 2018). The fact that pollutants remain in the atmosphere for longer at this period, and that the volume of rice stubble burnt is much more than that of wheat, results in a severe degree of pollution. Pollution frequently obstructs vision. According to reports, the amount of air pollution in Delhi in October 2017 was six times higher than in July of the same year. The atmospheric inversion allows pollutants to spend more time in the atmosphere, resulting in poorer dispersion and a slower rate of smoke diffusion.

Air pollution is a serious hazard to human health and well-being, causing death and morbidity rates to grow in many regions of the world. According to WHO, hazardous air caused by pollution kills around 7 million people worldwide each year (WHO, 2008). According to the Energy and Resources Institute (TERI), air pollution caused around 5 million fatalities in South Asia in 2012, accounting for approximately 22% of all deaths in the area. According to the survey, more than 51% of the entire population in South Asia has been continuously exposed to PM 2.5 levels exceeding WHO guidelines (Ghosh et al., 2019).

EFFECTS OF STUBBLE BURNING- In addition to air pollution, stubble burning may contribute to climate change, global warming, and soil nutrient depletion. As a result, it is critical to create comprehensive strategies to address this threat at its root. Given that stubble burning has been a hotly discussed subject in recent years due to the dangers it poses to the environment and human life. Farmers, experts, and government officials have all cited different causes for residue burning. Ironically, a few farmer arguments were absurd, such as avoiding labour in collecting straw and instead starting a fire, which is purely due to a lack of responsibility. One of the major causes of stable burning in India is a lack of time between the harvesting of the rice crop and the planting of the subsequent wheat crop, which is why the government and agriculture universities consistently advise farmers to sow rice crop in nurseries 10 days earlier than the previously followed date of sowing. Furthermore, those stubble burning operations are exceedingly harmful to the environment, human health, and soil health. The deliberate act of shooting stubbles not only harms the environment, but it also harms humans, wildlife, and soil.

- **Environmental Impact**

Crop residue burning can emit greenhouse gases as well as other chemically and radioactively relevant trace gases and aerosols such as methane, carbon monoxide, nitrous oxide, and other hydrocarbons. Carbon (C) is predicted to be released as CO_2 (70%), CO (7%) and 0.66% CH_4 as a result of burning rice straw, while Nitrogen (N) in straw is emitted as N2O at a rate of 2.09%. Furthermore, burning agricultural waste generates a considerable amount of particulate matter, which contains a diverse range of biological and inorganic species. The bulk of the pollutants found in substantial quantities in biomass smoke are known or probable carcinogens that, when breathed, can induce a range of lung ailments. Despite major air quality improvements in 2019 and 2020, India's air pollution remains alarmingly high. Unfortunately, India's yearly PM2.5 rankings by city remain unchanged. 22 of the top 30 most polluted cities in the world are situated in India. Residue burning adds only around 20% of organic and elemental carbon to the entire national budget of pollution from agricultural waste burning in northwest India. Gupta et al. determined that CO_2, CO, N_2O, and NO_X emissions from rice and wheat straw burning were approximately 2.306, 0.11, 0.002, and 0.084 million tonnes, respectively (2016). Crop residue burning emits 4.1, 91, 0.6, 0.1, and 1.2 tera grammes of CO, CO_2, CH_4, NO_x, and total PM per year, respectively (Yevich and Logan) (2003). 100% of the carbon, 80-90% of the nitrogen, 25% of the phosphorus, 20% of the potassium, and 50% of the sulphur present in agricultural residues are released as toxic gases and particles (PM) that pollute the air. According to government regulations, burning rice straw and stubble leads in large soil nutrient losses, including organic carbon of 3.85 MMT, nitrogen of 59,000 t, phosphorus of 20,000 t, and potassium of 34,000 t, as well as a considerable drop in ambient air quality. According to a research done by the National Remote Sensing Agency in Punjab (May 2005), burning wheat crop waste produced approximately 113 Gg of CO, 1.33 Gg of CH_4, 8.6 Gg of NO_2, 12 Gg of $PM_{2.5}$. Paddy straw burning was estimated to emit 261 Gg of CO, 3 Gg of CH_4, 19.8 Gg of NO_2, 28.3 Gg of $PM_{2.5}$, and 30 Gg of PM_{10}. On a scale of 0-500, the air quality index, or AQI, is a range of category pollution levels that assist describe the quality of air in a specific place. The majority of Northern India's areas have above the AQI threshold, which is detrimental to the environment, particularly during peak burning months.

- **Impact on soil fertility and characteristics**

Stubble burning on the farm causes severe harm to soil qualities. Gupta (2008) claims that agricultural stubble flaming raises soil temperatures by up to 33.8-42.2 °C. In-situ crop waste burning also depletes 27-73% of nitrogen in the soil and degrades the microbial community, i.e., bacteria and fungus, on the upper layer of soil, i.e., 2.5 cm, which is the most productive layer. Furthermore, recurrent burning can lower the number of beneficial soil microorganisms by up to 50%. It also reduces total nitrogen, carbon, and accessible nitrogen. Nitrogen loss in the top 0-15 cm soil layer, as well as soil organic matter reduction According to Mandal et al. (2004), burning of wheat and rice stubble resulted in significant soil loss of most key minerals (Table 2). It also results in the loss of important nutrients contained in agricultural stubble. Plant residues include around 25% of the nitrogen and phosphorus intake, 75% of the potassium uptake, and 50% of the sulphur uptake by cereal crops, making them acceptable nutrient sources for subsequent crops (Gadde et al., 2009). According to Singh et al. (2008), nutrient depletion from rice residue burning in Punjab was 35 kg nitrogen, 3.2 kg phosphorus, 21 kg potassium, 2.7 kg sulphur, and 2400 kg carbon per acre in 2001-2002. Carbon and nitrogen losses were practically full, but losses of phosphorus, potassium, and sulphur were minor (around 20–60%). The agriculture sector is affected by crop stubble burning. There is strong empirical evidence that air pollution has an impact on food output. Pollutants can have a direct or indirect impact on agricultural output. Direct effects include damage to leaves, grains, and heavy metal assimilation. Nitrogen oxide, for example, can harm plant tissue and create discoloration. SO_2 may cause acid rain, which has severe effects on plants and soil and may result in plant death (Augustaitis et al., 2010). Plants exposed to particle pollution for an extended period of time may develop chlorosis or bifacial necrosis (Ghosh et al., 2019). The providing of suitable conditions for the establishment of pests or illnesses is one example of an indirect effect. High SO_2 and NO_2 concentrations, for example, promote the proliferation of aphid pests (Ghosh et al., 2019). VOCs and NO_x are released during stubble burning, which combine to generate ground-level ozone. In the presence of solar light, nitrogen oxide and volatile organic molecules react to generate ozone in the near environment. Ground-level ozone disrupts plant metabolism, penetrates, and kills leaves, wreaking havoc on agriculture in northern India. Ozone has been shown to have a significant impact on the performance of some crops, such as wheat and soy, while others, such as barley, have shown some resilience to it. Rice and maize were said to be mildly impacted (Sharma et al., 2019). As a result, stubble burning has a detrimental influence on agricultural productivity and must be addressed correctly in order to boost agricultural production and fulfil rising food demand.

- **Crop residue management**

Crop residue may be used in a variety of ways, which necessitates some fundamental knowledge and general awareness. Crop waste as animal fodder: When it comes to animal feed in India, crop leftovers come in top. In Northern India, wheat and maize straw are the principal sources of animal feed. On the contrary, despite its high silica concentration, rice straw takes first position in the southern portion of the nation, maybe due to a lack of other feed sources. In southern India, rice husk is ground into a fine powder and given to animals, notably cattle. Statistics on crop residue need and availability for livestock in India reveal that there is a requirement of 415.83 million tonnes, but only 253.26 million tonnes are available. As a result, there is a 40% shortfall in animal feed in the form of crop waste. However, over the same time period, green fodder demand is 221.63 MT, while availability is 142.82 MT, representing a roughly 36% shortage.

- **Crop waste used as cattle bedding**

Paddy straw is frequently utilised as bedding material in livestock sheds in southern Indian regions. However, on government suggestion, this is now being implemented in northern sections, mostly during cold seasons. The results of a research done at PAU's College of Agriculture revealed a considerable improvement in milk quality and quantity due to the comfort, leg and udder health given by crop waste bedding over the winter months. Winter bedding assists cattle in staying warm and controls the body's heat loss. Furthermore, it produces a stable, dry, and gripping environment, lowering the risk of injury. The possibility of lameness and injury Healthy legs and hooves help cows produce more milk and reproduce more successfully (Mandeep et al., 2012). Used paddy straw may be repurposed in biogas facilities.

- **Biogas plants using crop residue**

As an alternative to fossil fuels, biogas, which is created from agricultural waste, can be used. Rice straw, in particular, is a key source of lignocellulose, which is necessary in the manufacture of biogas. Agriculture wastes may also be used to make biogas and biochar. Grinders are used in biogas generation to slice stubbles into small bits before inserting them in digesters with other materials. This is an entirely anaerobic process that generates not just biogas but also solid and liquid organic fertilisers as by-products (Ravindra et al., 2018; Singh et al., 2016).

- **Bio thermal plants using crop residue**

Paddy residues play an important part in the generation of electricity in bio thermal plants. Many organisations and power facilities are now pushing the use of rice leftover to create electricity, allowing farmers to avoid stubble burning while also profiting from their residue. Agricultural residue can also be converted into energy by extraction, methanation, or gasification. Crop residue can be sold to power plant manufacturers for 350 rupees per tonne (Kumar et al., 2015). In India, the energy potential of agricultural stubble is roughly 1570 petajoules each year. Furthermore, the Ministry of New and Renewable Energy (MNRE) and the Central Government have constructed almost 500 power plants throughout the country. the country that are powered in part or fully by biomass with a combined installed capacity of 8,700.8 MW, these power plants account for about 11.5 percent of the total renewable energy produced in the country.

- **Mushroom production and crop residue**

Rice, wheat, and sugarcane bagasse residues are effective sources of substrate in mushroom development. Paddy straw is a less expensive feedstock with a high lignocellulosic content that is widely desired for mushroom production. As a result, it may be used profitably in mushroom cultivation to offset the rising cost of mushroom production. Most plants in the mushroom kingdom are *Agaricus bisporus* (button mushroom), *Calocybe indica* (milky mushroom), *Volvariella spp*. (paddy straw mushroom), and oyster mushroom (*Pleurotus ostreatus*). In India, edible species are widely accessible. The type of compost used for nourishment has a big impact on the growth of these mushrooms. However, the efficiency of mushroom spawn in using various components of compost is dependent on the substrate used in bagging, which in turn is dependent on several physiochemical parameters involved in the composting process and mushroom development. Despite the vast potential for crop residue utilisation, just 0.03% of field agricultural leftovers are employed in mushroom growing in India (Gupta et al., 2016).

- **Composting of crop residue**

The typical method of preparing enhanced organic material is composting. Composting is a natural process that includes the decomposition of organic waste and certain municipal garbage with the help of microorganisms. Following the breakdown process, it is utilised as natural organic fertiliser. This organic fertiliser enhances the physical, chemical, and biological qualities of the soil. Harvest rejects include stubble, straw, stover, and different crop haulms. Composting also uses crop residues from thrashing sheds and stuff left over after crop processing. These wastes have enormous potential for use as organic fertiliser after composting them into manure. In addition, one kilogramme of straw absorbs around 2-3 kilogrammes of urine from an animal shed. As FYM, one hectare of paddy straw generates over 3.2 tonnes of nutrient-rich manure. Farmers may prepare this waste in their shed and reuse it as organic fertiliser, which has the potential to boost crop output by 4-9 percent. Crop waste in the paper industry: Paper is made by combining paddy straw and wheat straw in a 40:60 ratio. The sludge left over from paper production might be utilised to generate electricity via bio-methanization. This technique is already in use in some paper mills, where it produces around 60% of the required energy. Paddy straw is also a common raw material used in the manufacture of paper and pulp board (Sain, 2020). This management method might serve as an alternative to deforestation.

IN SITU CROP RESIDUE MANAGEMENT

Managing stubble on the farm is one of the greatest management methods used by farmers since it provides benefits at a low cost. There are two strategies for effectively using crop residue in-situ: stubble integration and stubble mulching.

- **Incorporation of Stubble**

Straw is absorbed into the soil after being harvested manually or by heavy machinery such as rotavators, choppers, and so on, which cut the straw and incorporate it into the soil. Rice straw may be properly handled on agricultural land by allowing 20-25 days between the integration of straw and the sowing of the wheat crop. Nitrogen scarcity as a result of N immobilisation Nitrogen and straw applications, either alone or in combination, increased biomass carbon, respiration activity, and phosphate levels in the soil. 30 days following straw breakdown, the greatest quantities of microbial biomass carbon and phosphate were discovered. Field trials revealed that integrating paddy straw 21 days before to wheat sowing resulted in a considerable increase in wheat production in clay loam soil in Sonepat district, but not in sandy loam soil in Hissar district.

- **Mulching of Stubble**

Stubble/straw mulching is the technique of equally spreading leftovers on the land surface to minimise soil erosion from wind and precipitation, retain soil moisture, and control weed development. Few studies have shown that mulch conserves soil moisture in the deeper layers, resulting in around 40% greater root length as compared to no mulch. In comparison to non-mulched crops, the use of rice straw as mulch reduced crop water demand by 3-11%, improved wheat yield, and increased water use efficiency by 25%.

- **Happy seeder**

It is a zero-till tractor-mounted mechanical device that cuts the upright rice straw on the soil, sows wheat seeds, and then mulches the residue. This mulch aids in the conservation of soil moisture, the prevention of soil erosion, and the suppression of weed development. Furthermore, using the happy seeder decreases labour requirements for residue removal and sowing by 80%, herbicide use by up to 50%, and irrigation requirements by 20-25%. Happy seeder, when combined with the basic straw spreading mechanism, produces an effective 'Super straw management system.
This is linked to a combine harvester, distributing residue equally over the harvest width, and this super straw management technology increases work quality and yield stability (Lohan et al., 2018; NAAS, 2017). In July 2001, a group of engineers and researchers from CSIRO Griffith and Punjab Agricultural University (PAU) created the Happy seeder (Humphreys et al., 2006). Currently, over 11,000 happy seeders are in use in northern India, with approximately 80% of them functioning in the state of Punjab (personal communication with machine manufacturers).

CONCLUSION- \The large-scale rice-wheat crop rotation strategy used in India has resulted in a substantial amount of crop stubble, 10 times the amount of grains harvested. A significant amount of these stubbles are often burned on the farm to clear the property for the next planting, releasing hazardous chemicals into the environment and deteriorating air quality. Based on the available research, it is possible to conclude that the combined impacts of stubble burning emissions and climatic circumstances are the source of the severity of air quality, particularly during rice stubble burning events in north Indian towns. The toxins emitted by stubble burning constitute a serious threat to the health of the exposed people, since they have been related to a variety of health problems, including death in severe cases. Crop residue burning harms environmental health through air pollution, human health through numerous respiratory, ocular, and pulmonary ailments, and soil health by eliminating important soil microorganisms. However, lawmakers intervened after substantial harm had been done; attempts are being made to curb indiscriminate straw burning by implementing a few new solid restrictions. Straw management alternatives for farmers include bovine feed, mushroom production, bio-thermal plants, paper companies, bio-char preparation, mulching, soil inclusion, and so on. Happy seeder is one of the most brilliant ideas, providing a viable alternative to stubble burning. It is now up to farmers to manage agricultural leftovers in any of the above-mentioned methods other than burning in order to protect the world from pollution.

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