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STUBBLE BURNING: AN OVERVIEW OF ITS CAUSES, IMPACT, AND ALTERNATIVES IN INDIA

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Abstract- **The global human population is increasing, leading to an increased demand for food and putting additional pressure on the agriculture sector. Alongside producing food, and fiber, agriculture generates by-products or leftovers, known as crop residue. This residue is often treated as waste and large quantity makes it very difficult to be managed. As a result, many farmers resort to in-situ burning, known as stubble burning. This practice adversely affects air quality, soil quality, and human well-being. This paper examines alternatives to stubble burning and explores scientific advancements to manage residue generation and use it effectively.**

Keywords- **Stubble burning, AQI Index, Emissions, Alternatives**

I. INTRODUCTION

India is considered an agricultural country with massive annual production of approx. 620 MT (Million Tonnes) crops of different varieties. With an annual output of 117.47 MT rice varieties, India has secured the position of second largest rice producer across the globe. The Paddy sector has significant input in the country's economy, besides that it also contributes to waste generation by producing crop residues. This large amount of crop residue leads to its burning, which further pollutes soil, water, and soil (Sain, 2020; Satpathy and Pradhan, 2020). According to the Organisation of Economic Co-Operation and Development (OCED), crop residue refers to the remaining plant material left after harvesting. It includes bran, straw, stover, husk, shells, and roots (Satpathy and Pradhan, 2020). Top crop residue-generating states include Uttar Pradesh with 60 MT of crop residue, followed by Punjab with 51 MT, and Maharashtra with 46MT of crop residue (Swamy, et. al., 2021)). If the ratio of crop generation and residue generation is concerned, rice and wheat came out to be major crop residue producers. In increasing order, most residue-producing crops are oil seeds (groundnut, grapeseed, sunflower), followed by cereal crops (wheat and paddy and millets), and least by fiber crops (jute and cotton) (Satpathy and Pradhan, 2020).

According to the Ministry of New and Renewable Energy, India generates around 600 MT of crop residue every year and for the past 6 decades, it is increasing at a rate of 2.3 percent every year (Swamy, et. al., 2021 Singh, et.al., 2021). Modernization of infield equipment could be the valid and most appropriate reason for this increase. The usage of combine harvesters has increased in folds so have their after-harvesting leftovers. They leave a one-foot-tall stack after harvesting which cannot be for tilling in the soil (Chawala and Sandhu, 2020). There are numerous environmentally friendly options available to discard the crop residues like using it as a raw material for making compost, in the paper industry, and using it as fodder for cattle. It could also be used to make several items like mats, beddings in poultry farms, or mushroom culture, but the farmer-friendly and feasible option is in situ burning which is known as stubble burning.

Stubble burning is the incineration of crop residue or stubble by farmers on purpose or with some intention (Abdurrahman, et. al., 2020). Some direct impacts of stubble burning include the emission of greenhouse gasses, loss of biodiversity, soil fertility, and plant nutrients (Singh, et.al., 2021). Stubble burning is the major contributor to air pollution, a good quality of air pollutants like SOX, NOX, CO2, CH4, Volatile Organic Compounds (VOC), and particulate matter (PM2.5 and PM 10) are released into the atmosphere during the process. These pollutants not only degrade the air quality of a region but also have a great impact on soil, water, micro-organisms, and macro-organisms. In the long run, it also adversely impacts climate (Swamy, et. al., 2021). China being the top producer of food grains, is also the top crop residue producer with annual stubble production of more than 700 MT.

II. CAUSES OF STUBBLE BURNING

The crop leftovers can be reused in several ways which are mentioned in the further sections, still, farmers choose to burn them. There could be plenty of reasons why they opt to burn their crop residues over many other eco-friendly ways to manage stubble. Some of the possible reasons for the same short window or time gap between harvesting paddy and sowing the wheat (Saini, et. al., 2019). Rice harvesting and rabi sowing have already been pushed back to October and November following the passage of the Punjab Preservation of Subsoil Act, 2009. Harvesting the paddy crops, managing its stubble, and simultaneously preparing the field for sowing the wheat crop is an intense job. Cultural aspects and the festive season (Dusshera, Deepawali, and Chatth) in North India reduce the availability of labor. It also contributes to rice straw burning (Pandey, et. al., 2020). The penalty for burning crop residues decided by the government is far less as compared to the investments for managing it with eco-friendly methods. There are several myths and beliefs about stubble burning as it helps in controlling pests and weeds (Reddy, et. al., 2019).

III. EMISSIONS AND LEFTOVERS AFTER BURNING THE CROP

Emissions are anything that is released after a process is performed, it can be in the form of solid, liquid, or gas. Emissions from the stubble burning could be classified into two categories: particulate matter, and gases (CO, CH4, NOX, Polycyclic Aromatic Hydrocarbons (PAH).

Table 1: Emissions during stubble burning and their sources (Porichha, et. al., 2021)

Emissions	**Sources**
Particulate Matter	
PM2.5, PM10	Released when the material is released after complete combustion of gases and incomplete combustion of inorganic matter is condensed.
PM100	When organic material present in the field is completely combusted, PM100 is released into the atmosphere. These particles are generally burnt soil particles.
Gases	
CO	Released from incomplete combustion of organic matter in the field
CH4	Released from incomplete combustion of organic matter.
NO, NO2, N20	Released when the fertilizers that contain.
PAH	Released from incompletely combusted organic material.

IV. ADVERSE IMPACTS OF STUBBLE BURNING

A. Impact on air quality

Rice stubble burning is a serious problem since it occurs during the winter month when the inversion condition is most prevalent. The smoke created by burning does not disperse in the atmosphere due to a state of inversion and results in limited dilution. The generated smoke then mixes with for and creates smog, which is hazardous to human health. During October and November each year, the burning of stubble produces a massive cloud of smog which includes pollutants like RSPM, NOX, and SOX. These pollutants stay imprisoned in the troposphere and engulf the entire region. During these months the level of these pollutants exceeds the permissible limits of national ambient air quality standards. The peaks recorded in October and November are found higher than those in April and May. The rice stubble also contains a higher concentration of ash as compared to wheat (Chawala, et. al., 2020).

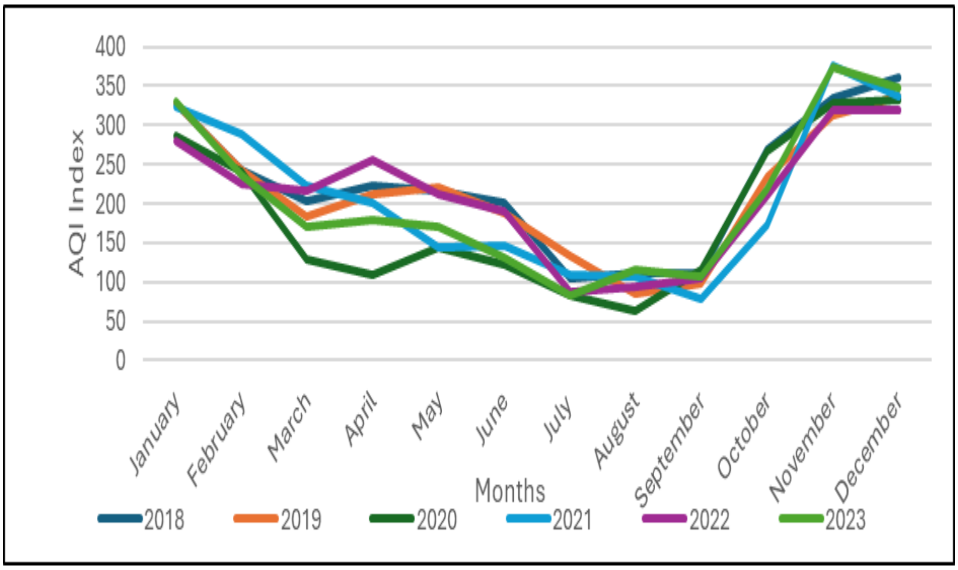

Figure 1: Monthly AQI Index of Delhi from the year 2018- 2023 (Source: MoHFW, 2023)

Delhi ranks as one of the states most significantly impacted by the practice of stubble burning, which has emerged as a pressing environmental concern. This agricultural practice, prevalent in the surrounding regions, leads to the burning of crop residue, particularly rice and wheat, in the lead-up to the winter months.

According to detailed data released by the Ministry of Health and Family Welfare, there is a marked and rapid increase in the Air Quality Index (AQI) during the months of October and November. This spike in air pollution levels directly correlates with the timing of crop residue burning, as farmers attempt to clear their fields for the upcoming planting season. The consequences of this burning are profound, contributing to hazardous air quality that affects the health and well-being of millions of residents in Delhi and its neighboring areas.

Figure 1 provides a visual representation of the AQI trends in Delhi over the past six years. The graph clearly depicts a consistent pattern; each year during October and November, there is a noticeable surge in AQI levels, reflecting the harmful effects of stubble burning on air quality. This trend underscores the urgent need to address the issue of crop residue management and implement sustainable agricultural practices to mitigate the adverse impacts on air quality and public health.

B. Impact on soil

Burning farm crop residue raises the ozone levels in the lower atmosphere. It also increases the soil temperature to 33.8- 42.2 degrees Celsius up to a depth of one centimeter, affecting the soil ecology. As a result of this increased soil temperature, approximately 23-73 percent of the nitrogen in various forms is taken from the soil. The beneficial microbial population drops up to a depth of 2.5 centimeters (Singh, 2018).

The increased temperature also increases the rate of change in Carbon- Nitrogen (C-N) equilibrium in the top three inches of the soil. Carbon is released into the atmosphere in the form of CO_2, while nitrogen is transformed into nitrates. Approximately 824 thousand metric tons of nitrogen, potassium, and phosphorous (NPK) nutrients are lost from soil because of this process (Singh, 2018).

C. Impact on human health

Air pollution and human health are very closely related. The increased pollutants (emissions from stubble burning) raise the risk of a variety of health problems, particularly in children, pregnant women, elder people, and people with existing health conditions. It has a wide range of negative effects on human health, from irritation of skin and eyes to serious neurological, cardiovascular, and respiratory disorders. It can potentially have lethal consequences in some situations, especially if the sufferer has preexisting respiratory difficulties. Chronic exposure to high levels of high levels of air pollution can result in long-term health effects such as asthma, chronic obstructive pulmonary disease (COPD), bronchitis, lung capacity loss,emphysema, cancer, and other lung illnesses. Most farmers who have been exposed to stubble smoke have complained of eye and lung irritation and must spend significant time in the hospital and money on medical bills (Abdurrahman, et. al., 2020).

V. ALTERNATIVES OF STUBBLE BURNING

Burning crops can have negative effects on the environment and human well-being. It is important to consider alternatives to crop residue burning that are both eco-friendly and cost-effective for farmers. Here are some viable options for reducing or eliminating burning practices.

A. Bio-oil production

Rice straw has drawn the researcher's interest in the last decade. Since it has the potential to be a source of energy in the form of bio-oil. Many organizations have used thermos-chemical ways to extract oil from straw, with pyrolysis emerging as a promising option. In a fluidized bed using a char separation mechanism, rice straw is pyrolyzed. The bed temperature for extracting bio-oil is between 440 to 500 degrees Celsius. Phenolics, furfural, acetic acid, levoglucosan, guaiacol, and alkyl guaiacol were the primary components of this oil. Using rapid pyrolysis, bio-oil can be extracted from straw at 550 degrees Celsius (Singh, et. al., 2020).

B. Mulching in soil

Rice straw mulching is a method of retaining moisture in the soil. It is used to grow crops such as maize, sugarcane, sunflower, soybean, potato, and chillis that require wetland. It also helps in maintaining optimum soil temperature during summers and winters. This method is extensively used for paddy straw in Haryana. Under the Rashtriya Krishi Vikas Yojana (RKVY) the governments of Punjab and Haryana have proposed seeking central assistance for providing farmers with types of machinery that will help them to manage crop residues in situ and retain straw as surface mulching (Kumar, et. al., 2015).

C. Pallet's production

In pellet form, crop residue can be utilized as a fuel. The crop residue (straw, peanut shells, cobs, cotton bars, soybean rods, weeds branches, leaves, sawdust, bark, and other solid waste) is crushed, pressed, compressed, and further shaped. It is both efficient and convenient to store. It can be utilized as the primary fuel in a commercial boiler (Kumar, et. al., 2015).

D. Contamination with plastic

Paddy straw can also be utilized as a material reinforcement in polymers. Paddy straw is blended with polypropylene and shredded into pieces of 1.5-2 mm. A twin screw extruder is then used to extrude the mixture into granules which is suitable to be used in ceramic and plastic industries (Kumar, et. al., 2015).

E. Paper industry

Crop residues can be used as raw material in the paper and pulp industry. It will not only help us combat the problem of stubble burning, but it will also help us overcome several other problems such as it will decrease the dependence on wood which will further reduce the rate of deforestation. Demand for paper in the paper industry is never going to end, for which the use of stubble appears a sustainable and comparatively easier approach (Singh, et. al., 2020).

F. Fuel for power plants

In Punjab, a few power plants have been built that use rice straw as the source of energy. By-products from the fuel combustion in power plants such as fly ash and bottom ash, can be used in cement and brick production industries. Paddy straw can either be directly used in the furnace as bales or as shredded straw with pluralized coal. Straw bales are preferred because they can be easily handled and stored (Kumar, et. al., 2015).

G. Scientific improvements

Indian Agricultural Research Institute (IARI) has created Pusa Decomposer. It is a mixture created with microbes (microbial cocktail), which will accelerate the process of decomposition. It is in the form of a capsule that contains seven strains of fungi that are identified by IARI for rapid decomposition of stubbles. The process includes liquid formation, followed by fermentation then spread in the field over the crop residues. It ensures the conversion of stubble into compost in twenty-five days, and it is also friendly to farmers pocket. It costs rupees one thousand only per acer (Mukhopadhyay, 2020).

Punjab Agriculture University has introduced a few genetically modified non-basmati paddy varieties like PR126, PR125, PR124, PR123, PR122, and PR121 which attain maturity 5 to 35 days prior to the traditional variety like PR118, and PUSA 44 which require 150 to 160 days (Mukhopadhyay, 2020).

Residue can be converted into biochar when it is burned in a fourteen-foot-high and ten-foot-wide structure called klin. The structure can hold up to twelve quintals of paddy straw and reduce it to almost half producing biochar which can further be used in the field. It will boost both organic and inorganic content and the water-holding capacity of the soil for a longer period, resulting in improved crop output (Choudhary, et. al., 2021; Barman and Mukhopadhyay, 2020).

VI. CONCLUSION

There is a notable lack of awareness among farming communities regarding the potential benefits of crop residue management. To address this, regular workshops should be conducted to educate farmers about scientific advancements, as well as to provide them with high-yield seeds and Pusa decomposers at affordable prices. Proper management of stubble can improve air quality and human health while enhancing soil quality. Additionally, effective stubble management might help mitigate the energy crisis and reduce our reliance on trees for paper production. Thus, stubble represents a sustainable alternative for various industries.

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