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Stubble Burning: Impacts On Air Quality Index(AQI),Environment and Public Health and Sustainable Management Techniques.

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Abstract
Stubble Burning is a common agricultural practice that presents serious health, environmental, and social problems, especially in relation to soil erosion and air pollution in Punjab and Haryana. This study examines the scope of stubble burning, its effects on soil fertility, air quality, and human health, as well as alternative management techniques like mushroom farming and conservation tillage and zero tillage. It also highlights the opportunities and difficulties in stubble-burning research and policymaking. Fire events arising in Punjab have become a frequent environmental and public health hazard, particularly during the post-harvest season. The province's highest fire event record for 2024 was recorded in Amritsar and Tarn Taran, according to a comparison of fire incidences in Punjab's several districts. In 2023, Moga and Gurdaspur became the leaders during the Rabi season. In certain areas, this high quantity could be the reason for many diseases and deaths. For most individuals, burning stubble is the easiest and least expensive alternative. While keeping the nutrients in the agricultural residue in the soil, composting and the manufacture of biochar are two efficient sustainable methods that can help to reduce the problem. In an effort to address this issue, the Indian government has launched a number of initiatives and policies that support sustainable management practices including turning agricultural waste into electricity.

Keywords: Stubble, Pollutants, Particulate matter (PM2.5, PM10), Air pollution, Fire events, crop residue management.

I. INTRODUCTION

Stubble, also known as residue, is the debris that remains after a crop is harvested. To put it another way, residues are any plant parts that are not commercially significant [1].After sugarcane stems or cereal plant grains are harvested, the cut stalks that remain on the field are known as stubbles. One of the main causes of air pollution worldwide is stubble burning, which releases gaseous and particle pollutants that have detrimental impacts on the environment and human health. The emissions are also caused by other biomass burning practices like wildfire, open-field incineration of municipal garbage, and wood burning for home cooking [2].Stubble burning alone is responsible for around one-fourth of biomass burning events that occur globally. India ranks second in terms of its contribution to stubble burning (33%), after China (44%) [3]. About 90% of biomass burning is caused by humans, according to a study, with natural fires accounting for a very small portion of the overall amount of plants burned. The overuse of combine harvesters, which produce stalks that are around a foot tall and cannot be tilled back into the soil, has caused it to rise within the last ten years. On the field, a sizable portion of the stubble produced is set to fire. About 14 million tons (Mt) of the 22 Mt of rice stubble (about 63.6%) produced annually in India are put to fire, according to the Indian Agricultural Research Institute (IARI) (IARI, 2012). Just two of India's major agricultural states, Haryana and Punjab, account for 48% of this total [2]. The main production activity that serves as an auxiliary activity for secondary and tertiary activities is agriculture. Rice and wheat are the main crops farmed in Punjab, Haryana, while many other crops are also grown there each year. Since burning straw and other residues is the simplest and most cost-effective way to get rid of them in the brief time between rice and wheat crops, it is a part of the intensive farming techniques of the Indo Gangetic Plains in Punjab and Haryana [4].In India, agriculture is the main industry, and it is still difficult to use crop leftovers (such as rice and wheat) sustainably. In the Indo-Gangetic plain (IGP), significant air pollution episodes are caused by CRB emissions combined with other air pollution sources (such as firecracker emissions) and stagnant weather. In 2020, the Research Institute of Humanity and Nature (RIHN) in Kyoto, Japan, initiated the Aakash Project, which is titled "An Interdisciplinary Study towards Clean Air, Public Health and Sustainable Agriculture: The Case of CRB in North India." The Aakash project's rigorous measurement campaign, which ran from late

September to mid-November 2022, verified that CRB was the primary factor contributing to the elevated PM2.5 load in the Northwestern (NW) IGP's rural, semi-rural, and urban areas [5].

In order to swiftly prepare the soil for the subsequent sowing (of rice or wheat, as the case may be), farmers find it easier to burn the crop stubble after harvest. Due to their haste to get the farmland ready for the following planting, the farmers just burn the stubble on the field, which releases a lot of dangerous pollutants [2].Crop residue burning times vary by area and are contingent on the harvesting season. Numerous studies have demonstrated that burning rice stubble causes a rapid environmental impact by producing a high number of pollutants (RSPM, NOx, and SO2) in a brief burning period [6]. Due to poor or diminished visibility, dense smoke from burning stubble also contributes to an increase in car accidents [3]. According to a study, Delhi's air quality index (AQI) is directly impacted by 149 million tonnes (Mt) of carbon dioxide (CO2), 9.0 Mt of carbon monoxide (CO), 0.25 Mt of sulfur oxide (SOX), 1.28 Mt of particulate matter (PM), and 0.07 Mt of black carbon (BC) produced by burning crop residue in northwest India. Byproducts of combustion include benzene, aldehydes and alkenes, soot, aromatic amines, heterocyclic aromatic compounds, formaldehyde, carbon (C), nitrogen (N), and sulfur (S) oxides, as well as polycyclic aromatic hydrocarbons (PAHs). By entering the ecosystem as extra constituents, the pollutants may upset the equilibrium of stable greenhouse gases (GHGs), such as CO2 and methane (CH4), which prevent heat energy from escaping into space and cause global warming [7].The National Green Tribunal in India has banned the custom of burning stubble and straw in the heavily polluted city of New Delhi, as well as in the nearby NCRs of Punjab and Haryana. Numerous initiatives have been proposed for the proper management of crop stubble burning in these states due to the growing issues surrounding it.Alternative uses of straw and stubble are being promoted by government agencies and research facilities as alternatives to blazing. These include using farm residue for in situ incorporation into the soil, mushroom farming, thermal power plant fuel, paper and pulp production, bio-lubrication, biogas generation, and animal feed and bedding in cattle sheds [8].This paper aims to describe the effects of stubble burning on AQI and its impacts on health of people ,soil fertility, agricultural productivity followed by worsened air quality in north and east region of India (pollution hotspots),fire events in districts of Punjab and various alternatives for stubble burning.

II. METHODS

We searched Google Scholar, scihub for articles published in English relating to stubble burning in Punjab and other states of India and its affect on health and impact on AQI in Punjab and Delhi areas. we also searched Down to Earth and Crop residue burning information and Management system website to compare the District wise data of fire events happened in October month in year 2023 and 2024 in various districts of Punjab and investigated the problems, various policies and management Techniques related to stubble burning.

[A] AIR QUALITY INDEX (AQI)

A daily fundamental predicted indicator of environmental air pollution levels is the Air Quality Index (AQI). It provides information on the possible short-term health impacts on wellbeing. Everyone can be protected from the negative impacts of poor air quality by being aware of AQI. The health of vulnerable persons, such as patients, elderly people, and children, can be impacted by even low AQI values. The Indian government (CPCB) states that the AQI is a number between 0 and 500, where 0 is good and 500 is severe (Table I). When calculating the AQI, eight primary pollutants must be taken into account: PM 2.5 and PM 10, CO, O3, NO2, SO2, NH3, and Pb. Data for at least three pollutants are needed to calculate AQI, and one of those pollutants must be PM2.5 or PM10[9].

According to [10], PM can be divided into three groups: PM 2.5 (diameter < 2.5 μm), PM 2.5–10 (coarse particles), and PM 10 (diameter < 10 μm). The carbon released by autos, trucks, stone crushers, and burning garbage makes up the majority of PM particles. The ground, seas, and volcanoes are among the natural sources of PM particles. Vehicle exhausts from gasoline, diesel, compressed natural gas (CNG), and liquefied petroleum gas (LPG) are the main sources of NOx. Airborne particulate matter, or PM, is a mixture of solids, liquid particles of different sizes, and chemical compositions [11].

Due to the agricultural practice of burning residue, which negatively affects the ambient air quality, Kaithal, Karnal, and Kurukshetra—the three main rice-wheat agricultural districts of Haryana—suffer from extreme air pollution. The parameters SOx, NOx, and PM2.5 were examined at three separate study sites within each district throughout the rice and wheat harvesting season in order to measure the effect of burning agricultural residue on the ambient air quality.For both burning and non-burning periods during the rice and wheat crop seasons, the concentrations of the principal pollutants (SOx, NOx, and PM2.5) and the Air Quality Index (AQI) were measured. Concentrations of SOx, NOx, and PM2.5 were 78%, 71%, and 53% higher than the NAAQS values during crop residue burning periods, respectively. All of the study sites' AQIs fell into the fairly clean (AQI 25–50) category during the rice and wheat seasons, while during the burning periods they ranged from moderately (AQI 50–75) to severely polluted (above 125) categories. This was the case for Anjanthali village in Karnal, Mirzapur village in Kurukshetra, and Kangthali village in Kaithal [12].

Table I. Air Quality Index

AQI Values	Category	Colour
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for sensitive Group	Orange
151-200	Unhealthy	Red
201-300	Very Unhealthy	Purple
301-500	Hazardous	Maroon

SOURCE: HTTP://AIRNOW.GOV/INDEX.CFM?ACTION= AQIBASICS.AQI [13]

[B] IMPACTS OF STUBBLE BURNING

Effects on Health

One of the main causes of health risks, including bronchial asthma, asthma, acute respiratory infections (ARI), and eye irritation, is residue burning. India has more blind individuals than any other country in the world, and it accounts for one out of every three cataract cases worldwide. Conjunctival hyperemia, eye watering, and eye discomfort are signs of smoke exposure [14].In addition, breathing in tiny particles can exacerbate long-term heart and lung conditions and is linked to early mortality in those who already have these conditions. Worldwide, air pollution causes 3.3 million premature deaths each year. By 2050, if emissions keep increasing, this figure will quadruple [8].Dioxins such as polychlorinated dibenzo-p-dioxins, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated dibenzofurans (PCDFs) are released when paddy stubble is burned. Additionally, burning rice stubble releases CO2 into the atmosphere, which causes the oxygen layer to thin and contributes to the greenhouse effect. Burning crop stubble causes air pollution, which kills animals because high blood CO2 and CO levels can change healthy hemoglobin into fatal hemoglobin and have serious negative effects, particularly for those with respiratory and cardiovascular conditions. Smoke from burning stubble is also likely to harm expectant mothers and young children [15]. According to a study in India, children were the most vulnerable group and the risk of acute respiratory infections increased by more than three times in a district with high agricultural crop residue burning, even after controlling for socioeconomic and family factors [16].

Effects on soil fertility

Because stubble burning destroys the vital nutrients in the soil, it also has an impact on soil productivity. Burning stubble depletes the soil of vital minerals, such as nitrogen, phosphorus, and potassium (NPK), along with additional micronutrients [2]. Burning farm leftovers raised the temperature of the soil to 33.8–42.2◦C, down to 1 cm, which has an impact on soil ecology. Thus, roughly 23–73% of the nitrogen in different forms is eliminated from the soil due to the elevated soil temperature, and the beneficial microbial population also decreases down to a depth of 2.5 cm in the soil. Burning the waste raises the soil's temperature considerably, which causes the carbon-nitrogen (C-N) equilibrium in the top three inches of soil to alter quickly. Nitrogen is transformed into nitrate, while carbon is released into the environment as CO2.About 824 thousand metric tonnes of nitrogen, potassium, and phosphorous (NPK) nutrients are lost from the soil as a result of this process [8]. Stubble burning eliminates Trissolcus species, which naturally compete with sunn pests by laying their eggs in their eggs, so lowering the quality of the wheat crop. It is well known that stubble fires kill the bugs that are helpful in many biological fights and that live on field borders, road edges, river edges, and shrubs [17].

Effects on air quality

The air quality is being threatened by stubble burning. Aerosols are also released as stubble burns. Because of their effects on cloud microphysical processes and light scattering, the aerosols have an impact on regional and potentially global radiation budgets [18]. Because carbon monoxide, NO2, PM10, and PM2.5 emissions exceed the allowable limits set by the CPCB's NAAQS (National Ambient Air Quality standards), the quality of the air deteriorates [19]. The Particulate Matter (PM) released from the burning of crop residues is 17 times higher than that of the emissions from various other sources like motor vehicles, waste incineration, and industrial waste [20].According to India's Central Pollution Control Board (CPCB), the air quality index consistently stays at 500 in the National Capital Region (NCR) of Delhi, Haryana, and Punjab, indicating dangerous circumstances. Paddy burning in Punjab alone released 261 Gg of CO, 19.8 Gg of NOx, and other pollutants into the atmosphere, according to the National Remote Sensing Agency. In India, the in situ burning of rice stubble results in the emission of 144,719 Mg of total suspended PM [8]. According to recent estimates, agricultural practices such crop straw removal, pest control, and short-lived ash fertilizing appear to have accelerated the rate of Open Crop Stubble Burning (OCSB). The harvesting of crops including rice, wheat, and maize, followed by the burning of agricultural residues, causes significant OBB (Open Biomass Burning), particularly from OCSB (Open agricultural Stubble Burning), to occur in May to June and October to November [21]. Burning crop leftovers in Delhi releases 17 times as much PM as all other sources combined, including industry, car emissions, and waste burning. As a result, burning residues in northwest India accounts for almost 20% of the country's total emissions from burning agricultural waste, both organic and elemental [22].

Effects on agricultural productivity

Burning crop stubble has an impact on the agriculture industry. There is solid scientific evidence that the production of food is impacted by air pollution. Agricultural productivity may be directly or indirectly impacted by the contaminants. Damage to leaves, grains, or heavy metal absorption are examples of direct consequences. Nitrogen oxide, for instance, has the ability to discolor and harm plant tissue. Acid rain, which has detrimental effects on plants and soil and can result in plant mortality, can be caused by SO2.Plants exposed to particle pollution for an extended period of time may develop Bifacial Necrosis or Chlorosis [2].

Effect on climate

The environment is negatively impacted by stubble fire emissions because they produce greenhouse gases including CO2 and CH4, which contribute to global warming. Black carbon, a climate pollutant that contributes to air pollution, climate change, and increased melting of snow and ice, is still thought to come from open burning [19].

The productivity of rice is also predicted to decline due to the gradually rising temperatures. Increased respiration losses and sterile blooms are just two of the several problems associated with higher temperatures that ultimately result in poorer yields. According to a recent study done in Punjab, Pakistan, the crop is negatively impacted by both warmth and premature rainfall [23].

[C] FIRE EVENTS IN PUNJAB

With 84 teragram per year(Tg/year), India is the world's second-largest contributor to crop residue burning (CRB). India produces a far higher overall volume of agricultural waste each year than other nations. During the rabi harvesting season, between 85 and 90 percent of paddy straw is burned in the fields, and to a lesser extent, wheat straw as well. An estimated 97 Tg of paddy residue are produced annually in India, with about 24 percent of that amount being burned as surplus in fields. About half of the annual paddy straw excess is produced in Punjab and Haryana alone. An estimated 35 million tons of paddy straw are burned in the state during two to three weeks each year in October and November [24]).In 2024,Amritsar and Tarn Taran is recorded as highest record of fire events in Punjab and in 2023, Moga and Gurdaspur took the lead during the Rabi season as shown in Fig.1 and Fig.2. [25].

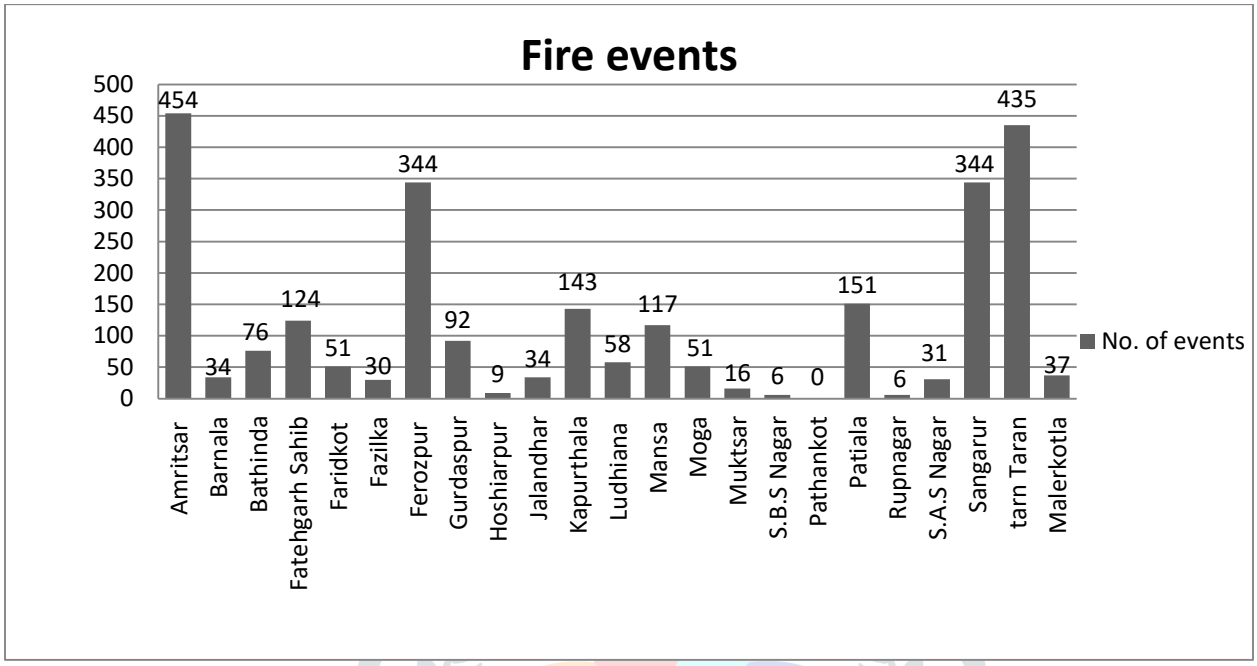

Fig.1. District wise fire incidents of October 2024 captured by satellite in Punjab

Source: Crop Residue Burning (CRB) Information and Management System

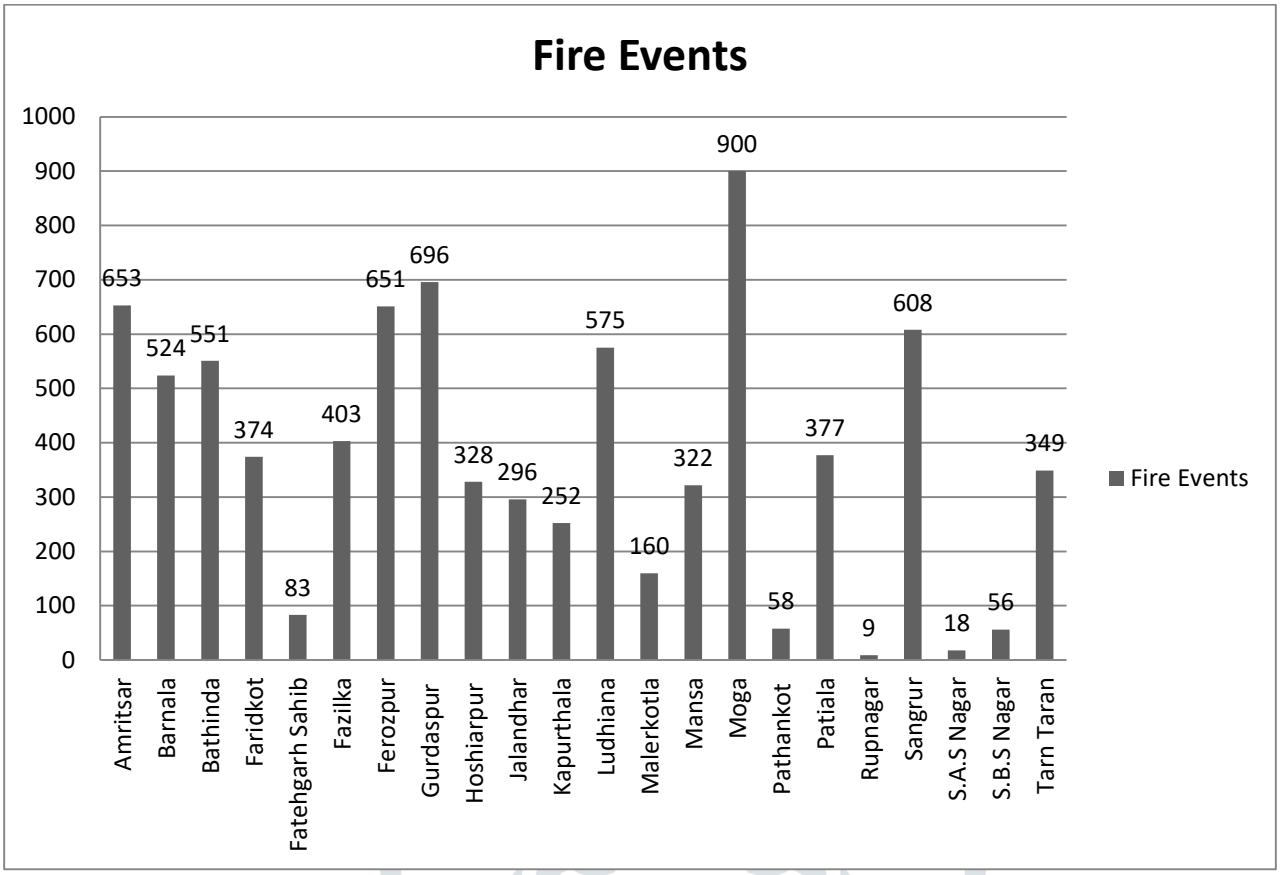

Fig.2. District wise fire incidents of October 2023 captured by satellite in Punjab

Source: Crop Residue Burning (CRB) Information and Management System

[D] The North and East are the most polluted during the winter of 2023–2024; the North's air quality considerably deteriorated.

As winter arrived, the public's health was once again threatened by the return of harmful air pollution, which began much earlier than usual and was made worse by weather conditions like slow breezes throughout the season and little rainfall in September and October. A thorough analysis of winter air quality by the Delhi-based think group Centre for Science and Environment has revealed concerning patterns. The most polluted Union territories/states in the nation were Chandigarh and Delhi, with PM2.5 concentrations of 100.9 µg/m³ and 188 micrograms per cubic meter, respectively. On the other hand, with a winter average of 32 µg/m³, Karnataka stood out as a shining example of cleaner air.

North and East India continued to be the most polluted regions, with North India's air quality significantly worsening from the previous winter while East India's showed indications of improvement, according to the final report for the 2023–24 winter season. With the lowest PM2.5 values, South India continued to hold the top spot.

A closer look at city-level statistics revealed that smaller cities like Rajasthan and Bihar were just as polluted as major ones like Delhi. With average winter PM2.5 levels of 213.5 µg/m³ in Bihar and 171.6 µg/m³ in Rajasthan, cities like Hanumangarh and Begusarai are comparable to the national capital in terms of pollution levels. Additionally, it was discovered that industrial areas in the Himalayan region and South India were also struggling with high pollution levels.

On the other hand, cities with average PM2.5 levels of 9.8 µg/m³ and 14.9 µg/m³, respectively, such as Gangtok in Sikkim and Silchar in Assam, glowed with cleaner air quality.

With North and East India suffering the most from pollution, the average PM2.5 readings in the nation's main regions confirmed how serious the issue is. The average PM2.5 concentration in the North was 89.9µg/m³, and the East came in second with 85.9 µg/m³. The National Capital Region (NCR) significantly exceeded these thresholds, with an average of 113.6 µg/m³.

During and following Diwali, the country's air quality was very bad, with daily average PM2.5 levels reaching a peak of 120 µg/m³. Due to reasons including crop stubble burning and prohibitions on firecrackers during the holiday, the NCR diverged from this tendency and reached its peak ten days prior to Diwali.

The severity of the problem is highlighted by the regional peaks in pollution levels, which on November 3, 2023, exceeded the peak of 202 µg/m³ on Diwali day, with North India achieving a 24-hour average of 156.7 µg/m³ and the NCR reaching 218.4 µg/m³ [26].

The Centre for Science and Environment (CSE) has published an evaluation of the annual trends in Delhi's particulate matter 2.5 (PM2.5) air levels in 2024 as the new year gets underway, and the results are not encouraging. "Persistent and consistent rise for a second consecutive year since 2022," according to the report. In 2024, the yearly PM2.5 concentration rose to 104.7 micrograms per cubic meter (µg/m³), a 3.4% increase over 2023 values. Additionally, this is more than double the 40 µg/m³ national ambient air quality threshold.
Between October and December 2024, the average PM2.5 levels were 4.6% higher than the three-year winter average (2021–2023). The winter peak for the entire city was 26% greater than it was the previous year [27].

[E] Policy and Technological Solutions

Government Intervention: Through government-initiated projects, the Indian government made a number of attempts to inform and educate the farming community on the best procedures for managing agricultural waste. Environmentalists and government representatives also developed a number of forums and recommendations to stop burning crop residue and encourage the use of alternative sustainable management techniques [22].
In India, the Ministry of Environment, Forests, and Climate Change (MoEF&CC), the Central Pollution Control Board (CPCB), and its state-level subsidiaries are the main administrative entities in charge of controlling emissions and enhancing air quality. The board collaborates with the MoEF&CC and other organizations to effectively monitor and manage issues connected to air pollution [2].

Biogas Plants: The Indian government has implemented biogas plants as a progressive measure to reduce crop burning and prevent pollution. Since the 1970s, biogas technologies have gained popularity. The National Biogas and Manure Management Program runs a number of programs, including an off-grid biogas power production program, to supply sustainable energy for lighting, cooking, and electricity generation. The government carried out these initiatives as part of its "waste to energy mission." This is included in India's climate change action plan as well. There are 56 biogas-based power plants in operation in India at the moment, with the bulk of them located in the states of Kerala, Karnataka, and Maharashtra [22].
The government updates the guidelines for crop residue management, allowing for the effective ex-situ handling of paddy straw produced in the states of Delhi, Punjab, Haryana, and Uttar Pradesh.

According to the updated guidelines, industries that use paddy straw and the Beneficiary/Aggregator (farmers, rural entrepreneurs, Cooperative Societies of Farmers, Farmers Producer Organizations (FPOs), and Panchayats) will enter into a bilateral agreement to establish techno-commercial pilot projects for the Paddy Straw Supply Chain. Financial aid for the capital cost of machinery and equipment will be provided by the government. The industry and the beneficiary may jointly finance the necessary working capital, or the beneficiary may use the Agriculture Infrastructure Fund (AIF), NABARD Financial, or financing from financial institutions. As directed by the end-use industry, the recipient shall prepare and arrange the land for storing the gathered paddy straw.
The results of the aforementioned interventions are

- Through in-situ choices, the initiative will support paddy straw management activities.
- The states of Madhya Pradesh, Uttar Pradesh, Haryana, and Punjab will see the construction of roughly 333 biomass collection depots with a 4500 MT capacity.
- Burning stubble will significantly lessen air pollution.
- It would create over 9,000 man-days of employment possibilities [28].

[E] Stubble burning management techniques

Composting: The natural breakdown of organic matter by microorganisms in a regulated setting is known as composting. Examples of raw organic materials that, after composting, increase their suitability for use as soil fertilizer include crop residues, animal and food waste, some municipal garbage, and suitable industrial waste [22].When crop leftovers are combined with other organic materials like manure, kitchen scraps, or green waste, they can be composted to produce cheap, nutrient-rich organic manure for crops [29].Rice straw is positioned at threshing regions as an illustration of in situ composting. The compost can be put out into the soil as fertilizer at the beginning of the next season when the straw breaks down gradually, mostly aerobically. In rural India, the composting process usually uses a passive aeration system with aeration holes, and the treatment period lasts two to three months. Composting technique may be particularly attractive to small farms with sufficient labor resources because it doesn't require expensive equipment, complicated infrastructure, or financial commitment, but it does require manpower [20]. By preserving the nutrient pool and providing nitrogen, phosphorus, potassium, and sulfur, compost enhances soil fertility by meeting the needs of numerous critical micronutrients, including zinc and iron [30].

Crop residue as cattle bedding: According to official recommendations, paddy straw is utilized as cattle bedding in northern regions mostly during the winter months. According to the results of a study done at the College of Agriculture at PAU, the comfort, leg, and udder health that crop residue bedding provides throughout the winter months significantly improves the quality and quantity of milk produced. Cattle used bedding to stay warm during the winter and control heat loss from their bodies [1].
Biochar: Biochar is a carbon-rich, dependable, and durable material that farmers use to improve the quality and health of their soil. Biochar is created by thermally treating crop waste. Biochar is made by Pyrolysis, Gasification, Torrefaction, Carbonization, and Combustion, among other thermal processes. Pyrolysis is the most widely used technique for creating biochar due to its speed and effectiveness. Additionally, biochar adds macronutrients (P, K, N, Ca, and Mg) and micronutrients (Cu, Zn, Fe, and Mn) that are necessary for effective agriculture [31].Because of its exceptional surface area and adsorption capacity, biochar is more able to retain inorganic contaminants. Biochars have also reduced the mobility and bioavailability of heavy metals in soils. Additionally, biochar alters some chemical soil characteristics, such as pH and cation exchange capacity, and creates a condition that is conducive to the

immobilization of heavy metals. A number of procedures, including as complexation, precipitation, electrostatic interaction (also known as chemisorption), ion exchange, and physical sorption, may aid in managing the removal of heavy metals from aqueous solutions using biochar [32].

Conservational tillage and zero tillage: Low tillage combined with minimal soil inversion is known as conservation tillage, and it encourages the plant residues that remain to cover at least 30% of the soil surface. This technique, which combines little tillage with crop residues to cover the soil surface, reduces soil evaporation, prevents soil erosion by shielding soil particles from the effects of water and air, and inhibits weed growth [33].

Biogas Production: The Food and Agriculture Organization (FAO) of the United Nations calculated that the emissions of greenhouse gases (GHGs) from agricultural wastes amounted to 750 billion US dollars, or 3 gigatonnes (Gt) CO2 equivalents. Consequently, one of the best chances to create renewable fuels is through garbage. The predominant method in the European agricultural industry is continuous wet anaerobic digestion in continuous stirred tank reactors (CSTRs), which release animal manure and agro-industrial wastes primarily in liquid form.

Anaerobic digestion is a natural process that speeds up the biological processing of organic substrates by enabling the growth of microbial communities without oxygen. It also treats organic wastes in an efficient and eco-friendly manner. Dry anaerobic digestion is regarded as a novel technology and a viable strategy for producing biogas on a modest scale from solid waste in the agricultural industry [34].The percentages of the three main components of rice straw—cellulose (9–80%), lignin (5–35%), and hemicellulose (10–50%)—may have an impact on how quickly the substrate degrades. The main characteristics of rice straw are its high water absorbability, low density, and poor fluidity. In contrast to other lignocellulosic wastes like corn stover or wheat residue, the bioconversion of organic matter is made possible by the low lignin level. Throughout the world, rice straw is the most used lignocellulosic substrate for producing bioenergy. Using crop straw and manure, anaerobic digestion is a suitable technique for generating renewable energy since it can turn waste into a resource [35].

Mushroom Cultivation: Commonly referred to as straw mushroom or Chinese mushroom, paddy straw mushroom (Volvariella spp.) is a member of the Phyllum-Basidiomycota, Class-Basidiomycetes, Order-Agaricales, Family-Pluteaceae, and Genus *Volvariella.* Known for its delicious flavor and taste, paddy straw mushrooms (Volvariella spp.) are the third most important cultivated fungus in the world.Growing paddy straw mushrooms just requires a modest space, or more, depending on the grower's availability, rather than agricultural land or capital expenditure. It may be grown effectively both indoors and outdoors on a variety of agricultural leftovers, such as cotton waste and paddy straw, and has a shorter growing period. Along with having a great composition of different elements and vital amino acids, paddy straw mushrooms are a nutritious food since they include a good amount of protein, crude fibers, and ash [36].

Paper production: In place of hardwood, rice straw is a good raw material for the paper and pulp industries due to its high cellulose and low lignin concentration. The pretreatment procedures needed for the pulping process take less time and effort, which ultimately lowers production costs.

Silica extraction: Research has previously demonstrated that rice straw has a high silica content (70–80% of the total mass), suggesting that silica particles could be synthesized from this agricultural waste. In a number of experimental investigations, researchers have discovered that silica particles with a diameter of approximately 200 nm can be extracted by first letting the samples cook at 450°C in a basic solution, and then adding them to an acidic solution where heating is applied to eliminate excess solvents.

Feed for ruminants: Paddy straw has a relatively high silica concentration, which reduces its digestion, hence farmers typically express a lower preference for utilizing it as fodder. However, a new option for using rice straw as a source of feedstock for milch animals like cows, goats, and buffaloes has emerged due to its abundance and affordability [37].

III. CONCLUSION

Because of its detrimental impact on the environment and human life, stubble burning has become one of the most contentious topics in recent years. Farmers, researchers, and government officials have discovered a number of causes for residue burning. Furthermore, those stubble burning practices seriously harm human, environmental, and soil health. Comparing the fire incidents in Punjab's several districts revealed that Amritsar and Tarn Taran had the province's greatest fire event record in 2024. During the Rabi season in 2023, Moga and Gurdaspur emerged as the leaders. This elevated amount may be the cause of numerous illnesses and fatalities in some regions. Most people consider burning stubble to be the simplest and most economical option. As a result, the states of Haryana, Punjab, Uttar Pradesh, and Uttrakhand ought to implement or start using new technology. Crop wastes have significant economic value as industrial raw materials, fuel, and animal feed. Crop residue problems, however, differ by area and are associated with socioeconomic needs. Enhancing soil quality and agricultural productivity requires crop leftovers. Returning plant wastes to the soil can save a substantial quantity of fertilizer because they are rich in nutrients. Composting, cow bedding, biochar production, conversion tillage and zero tillage, bioenergy, biogas generation, mushroom culture, paper manufacture, silica extraction, and ruminant feed are just a few of the many alternatives available to farmers for managing straw. It is also evident that they have no other choice but to use this one because they lack access to other, more expensive technology. Given farmers' financial circumstances, the government ought to give them the greatest chances possible, opening the door to sustainable farming. Future studies aim to develop more efficient technologies and practices that can make the practice of straw disposal more sustainable.

IV CONFLICT OF INTEREST

There was no conflict of Interest.

V AUTHOR'S CONTRIBUTION

Literature survey was done by Neelam Kumari and Gurinder Singh. Manuscript preparation was done by neelam and Ayushi. Proof reading and guidance was done by Dr. Puneet and Harpreet Kaur.

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