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Preventing Agricultural Practice of Stubble Burning Through Applications of Artificial Intelligence

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Abstract
Stubble burning, a common agricultural practice, is widespread across most of Asia and contributes significantly to severe air pollution. Our analysis aims to inform policy decision-makers about the relevance of artificial intelligence in controlling stubble burning by providing a comprehensive and structured review of the related streams of literature. From our balanced review of the related empirical literature, we infer that AI can help manage the effects of climate change by utilizing limited resources with less human intervention. In this study, Structural Topic Modelling (STM) and Sentiment Analysis tools have been employed to demonstrate how artificial intelligence can help reduce stubble burning and contribute to environmental conservation.
Keywords- Artificial Intelligence, Agriculture, Structural Topic Modelling, Air Pollution, Sentiment Analysis.

1. Introduction

The New York Times article published on 3rd November 2023, "New Delhi Chokes as Annual Curse of Pollution Returns with a Vengeance,". It highlights that the schools were closed, and a lot of other steps were taken, but the people are still suffering from the pollution.

Figure 1 Source- https://www.nytimes.com/2023/11/03/world/asia/new-delhi-india-pollution.html

In 2021, an article in the New York Times, "What India Looks Like When the Air Turns to Poison". "This year, the pollution has become so dire that the Indian government declared a public health emergency on Friday, shutting all primary schools for days and halting construction projects. NASA satellite imagery showed large swathes of India's northern plains smothered by haze," it said.

The Straits Times article published on 18 September 2023, titled"Thailand urged to halt crop burning air pollution spike", argues that Thailand must ban stubble burning by farmers to improve air quality. Mrinal Singha et al. (2021) concluded, based on observations from multiple satellites from 2001 to 2018, that cultivation of paddy expansion (+22%) increased groundwater depletion (−1.50 cm/yr), residue burning (+500%), and air pollution (+29%, $PM_{2.5}$) in the breadbasket of India.

The Philippine Rice Research Institute (PhilRice) urged farmers in 2019 to refrain from burning rice straws and said this could reduce soil nutrients and make farmlands unproductive. Evelyn

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Javier, supervising science research specialist of PhilRice's Agronomy, Soil and Physiology division, said rice straw-burning, being practised during the harvest season, causes air pollution by producing carbon dioxide, carbon monoxide, nitrogen dioxide, and sulphur dioxide.
As the air pollution caused by Stubble burning worsens year after year, serious medical impairments in the form of breathing problems are anticipated to grow. The rising number of atmospheric pollutants has worsened air quality alarmingly in South Asian countries.
Artificial intelligence (AI) offers enormous promise to handle air pollution challenges efficiently. AI can help monitor farm fires and predict the amount of area burnt, the wastage done, and the emissions caused. Machine learning can effectively help with the identification of stubble-burnt fields. Many researchers have found various applications of AI in detecting, identifying, and preventing stubble burning. The foremost reason for Stubble Burning is the short time span between rice harvest and wheat sowing. In India, the Punjab Preservation of Subsoil Act (2009) mandates paddy transplanting on June 20. As a result, rice harvesting is pushed ahead, giving farmers a window of 20-25 days between crops. As a result, farmers are compelled to resort to stubble burning as the simplest and most practical method of dealing with the residue.

Research Objectives
The following aims of this study are given based on the research questions:
Q1. What were the issues, topics, and themes that past researchers explored in Stubble Burning?
Q2. What Strategies and initiatives can combat air pollution due to stubble burning?
Q3. Exploring how Artificial intelligence-based techniques can be used to combat stubble burning.
After discussing the conceptual basis of this study in the introduction section, other sections are depicted as follows: Section 2 depicts the Literature Review. Section 3 contains Research Methodology, Section 4 Analysis and Interpretations, Section 5 Sentiment Analysis Discussion, Section 6 Recommendations, and Section 7 contains conclusion of the paper.

2. Literature Review

Impact of Pollution on Health & Environment
The impact of rising pollution on health and the environment is illustrated in Figure 1. The global climate change caused by air and other pollutants and its influence on socioeconomic and natural resources has become a serious concern worldwide. There is enough scientific information to speculate on the triggering causes and the magnitude of the effects of climate change. Many Indian cities, including New Delhi, are on the world's most polluted list (Cheng et al., 2016). Approximately 80% of Indian cities breach the specified limits for ambient air quality, as shown in Figure 2 (CPCB 2014). Multiple factors contribute to the problem, necessitating sector-specific measures for air quality regulation.
Azid et al. (2014) focused on the pattern recognition of Malaysian air quality based on the data obtained from the Malaysian Department of Environment (DOE). Eight air quality parameters in ten monitoring stations in Malaysia for 7 years (2005–2011) were gathered. Principal component analysis (PCA) in the environmetric approach was used to identify the sources of pollution in the study locations.

Stubble Burning is a serious health hazard
India's Indo-Gangetic Plain (IGP) region has become the global hot spot of air pollution, and stubble burning in northern India has increased concern due to its impact on air quality and

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health. Kalbande et al. (2021) studied the emission of Benzene and Toluene from Stubble Burning and Their Implications for Ozone Chemistry and Human Health in the Indo-Gangetic Plain Region. Through their review, Lin and Beghot (2022) have identified that the reasons for burning crop residues are mainly the high cost of incorporating, collecting, transporting, and processing crop residues in South Asia. Along with it, shortages of labour, the marketability of the crop residue, and the short interval between harvest and the next cropping season are factors affecting farmers' decisions to burn crop residue.

Maithani S., Sharma S.K.(2022) done Trend Analysis of Nitrogen dioxide (NO2) in Northern Part of India During Paddy Residue Burning Using a Contextual Approach

Kumar A., Hakkim H., Sinha B., Sinha V. (2021) done a study on Gridded 1 km × 1 km emission inventory for paddy stubble burning emissions over north-west India constrained by measured emission factors of 77 VOCs and district-wise crop yield data.

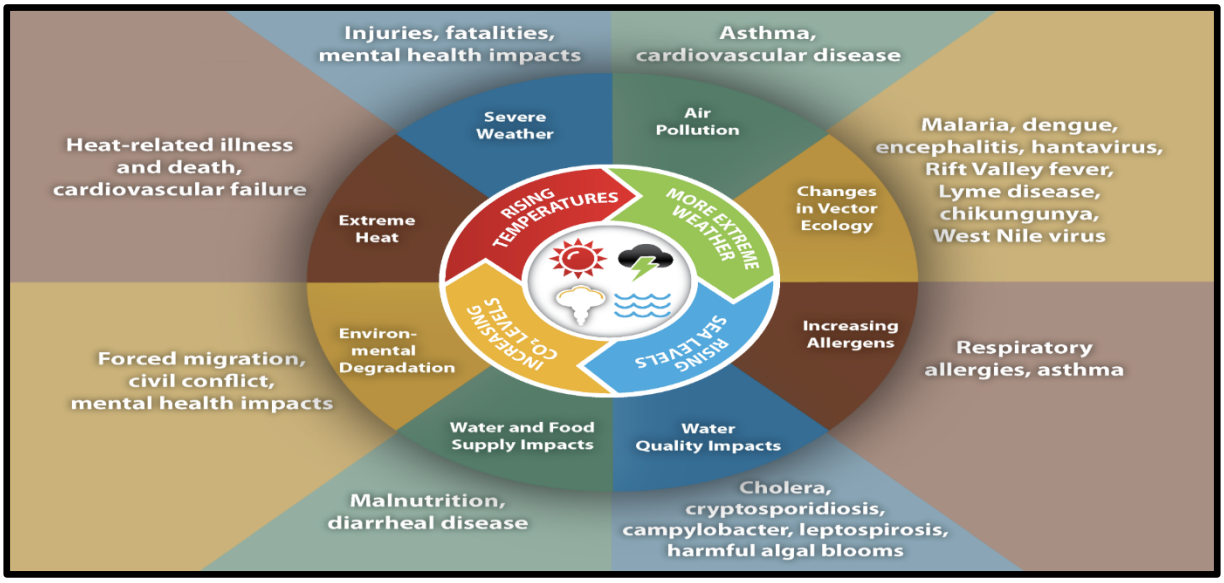

Figure 2. Pictorial representation depicting the impact of pollution on health and the environment (source: Center for Disease Control & Prevention)

According to Beig et al. (2020), burning agricultural residue during the post-monsoon season in nearby provinces causes regular bouts of high pollution, which are related to premature morbidity and death. Stubble burning has been identified as a significant source of particulate matter (PM10 and PM2.5), as well as gaseous pollutants such as carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur oxides (SO_x), all of which are harmful to the environment and human health (Abdurrahman and colleagues, 2020). This demands massive strides in the development of economically viable solutions using AI and awareness campaigns to educate farmers, policymakers, and consumers about the cumulative impacts of stubble burning. Figure 2 illustrates the air quality standards with reference to the air quality index.

It is critical to guarantee that the population is healthy and fit, enabling the economy to thrive. Artificial Intelligence is a game-changer in climate change mitigation. AI assists scientists in developing robust systems that learn from weather conditions, perceive all data, and analyze it to provide efficient solutions to farmers (Hartman et al., 2018). Data are processed using AI technologies, including robots, computer vision, machine learning, and deep learning algorithms to forecast environmental influences on agricultural productivity(Kowalska, and Ashraf, 2023)).

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It aids in the development of improved electric systems, the monitoring of farm emissions and deforestation, the development of novel low-carbon materials, the prediction of extreme weather events, and the management of stubble.

According to Irfan (2024), the common practice of stubble burning degrades air quality by significantly contributing to already prevalent air pollution in the South Asian region. It also impacts soil quality by diminishing the long-term productivity of the land. Hazardous oxides are released into the atmosphere when a third of the nitrogen and sulfur, 75% of the potash, and 25% of the phosphorus in paddy straw are exposed to heat and oxygen as a result of burning. On average, one acre of land provides 2.5-3 metric tonnes of paddy straw, which, when burnt, may remove 32 kg of urea, 5.5 kg of di-ammonium phosphate (DAP), and 51 kg of potash manure. These natural components play an important role in influencing the quality and fertility of the soil. Despite the government's desire to address the issue of stubble burning and the associated increase in air pollution, it has so far been unable to do so.

According to the Ministry of New and Renewable Energy (MNRE), India, an average of 500 million tons of crop leftovers is produced annually in India (Venkatramanan et al., 2021). It is the process of burning the straw stubble that remains after grains have been harvested that causes the massive air pollution. We have gathered information from different people and organisations, like elderly people, people advocating against stubble burning, policy advocates, and farmers, and found contrasting viewpoints on the process of stubble burning. Here are a few points:

- It is simple, inexpensive, and convenient to dispose of the residues after harvesting.
- It can successfully control pests and weeds.
- Will minimize nitrogen binders in the soil.
- Negative consequences:
- Soil nutrients are jeopardized.
- Greenhouse gases are emitted, depleting the ozone layer.
- Significantly lower the geography's Air Quality Index.
- The danger of a fire spreading.

Evaluating the positive and negative effects of this practice, it can be clearly understood that it has severe consequences and an enduring effect on our biosystem, leading to the rise of health impairments and has become an inevitable and permanent living situation of the ecosystem of the specific zone.

3. Research Methodology

3.1 Sentiment Analysis

Sentiment analysis is a natural language processing (NLP) technique that determines the emotional tone underlying a body of text (Kumar, 2024). This is a common method for businesses to determine and categorize customer views about a product, service, or idea. Sentiment analysis can extract the polarity (or the degree of positive and negative), subject, and opinion holder within the text, in addition to determining mood. Sentiment analysis stages are deeply embedded, encompassing a wide range of machine learning and natural language processing jobs and subtasks:

Step 1: Twitter data is obtained via Live API. For this, keywords/ hashtags like #AirPollution, #StubbleBurning #Delhi, etc., were used.

Step 2: Text cleaning was accomplished by deleting frequently used terms, often known as stop words. Non-English terms, special characters, equations, and numbers were also removed.

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Step 3: Data is visualized using a word cloud and trigrams for the frequently and most used words.

Step 4: A rule-based sentiment analysis is carried out. This research results in a collection of rules (also known as a lexicon or sentiment lexicon) that classify words as positive or negative, along with their associated intensity measure.

3.2 Emerging Research Topics of AI and Stubble Burning using STM

Using the STM technique, a total of 200 papers were evaluated. Topics were generated from the probabilistic distribution of the most frequently occurring terms, such as in Topic 1: A predictive model to study pollutant emissions from biomass, which was generated from words like 'Model,' 'use,' 'process,' 'predict', 'study,' 'air,' 'pollutant,' 'emission,' 'biomass.' Similarly, other topics are generated based on their most common terms. As shown in Table 1. **Topic 1**: A predictive model to study pollutant emissions from biomass; **Topic 2**: Propose a model to predict the impact of stubble burning on soil; **Topic 3**: Determining crop choices, hybrid seed selection to generate higher yields based on regions; **Topic 4**: A predictive model for locating straw burning; **Topic 5**: A machine learning model to analyze the pollution from stubble burning. The research papers were examined based on each topic after creating them using the STM technique, and an analysis for each topic was made. The dominant keywords for each of the topics can be seen in Figure 6-11.

S. No.	Topic Labels	Words with the highest probability
1.	A predictive model to study pollutant emissions from Stubble Burning	Model, use, process, predict, study, air, pollutant, emission, Stubble burning, $NO_{2,}$
2.	Propose a model to predict the impact of stubble burning on soil	Model, propose, result, use, prediction, air, fire, soil, study, method, straw, impact, crop yield
3.	Using artificial intelligence to determine crop choices and hybrid seed selection to generate higher yields based on regions.	Crop, rotation, selection, generate, yield, regions, artificial intelligence, machine, learning, AI, model, study
4.	A predictive model for locating straw burning	Model, fire, prediction, use, predict, carbon, study, emission, machine, base, locate
5.	A machine learning model to analyze the pollution from stubble burning	Study, learning, model, machine, base, prediction, analysis, use, pollutant, result, fire, straw, emission, level
6.	Strategies or policies to banish or reduce Stubble burning	Policy, Study, Reports, Initiatives, Artificial intelligence, Awareness, Government, NGO's, Agriculture, Technology

Table.1 List of Topics generated using the Structural Topic Modelling Method

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4. Analysis and Interpretations

4.1 A predictive model to study pollutant emissions from biomass

Several research studies investigated the predictive modelling of rice husk pyrolysis to establish the thermal degradation process of rice husk, which is the primary cause of stubble burning. The quick decomposition technique based on Artificial Intelligence might be employed to appropriately handle stubs. The Indian Agricultural Research Institute recently identified a microbial cocktail named 'Pusa Decomposer' that can swiftly decompose leftovers into compost using artificial intelligence(Verma et al 2024). It requires making a liquid formulation using decomposer capsules, fermenting it, and spraying stubble over the field to ensure quick decomposition.

Furthermore, bioenergy from biomass can be a significant alternative to fossil fuels, making the route to sustainable development simpler and decreasing reliance on traditional energy sources(Young, 2009,). Artificial intelligence approaches can be useful not only for predicting energy from biomass, but also for evaluating computing-reasoning strategies for managing bioenergy generation, biomass supply chain, and process parameter optimization for effective bioconversion technologies (Gujar and Kumar, 2025).

4.2 Propose a model to predict the impact of stubble burning on soil

Stubble burning degrades soil fertility, eliminates organic fertilizers, and lowers groundwater levels. Ground-based approaches for identifying deterioration are labor-intensive and time-consuming. Remote approaches based on vegetation indices analysis can greatly minimize the number of ground surveys(Igwenagu et al, 2025). A lot of research has been done. Machine learning models can help predict the impact on soil due to straw burning. Machines are becoming increasingly "intelligent." A huge dataset of soil-labeled pictures may be used to construct pattern recognition algorithms. Models may be developed and evaluated to assess changes in soil particles and forecast future changes. Deep learning methods that are based on multi-temporal remote sensing data can be built. Deep machine learning can be used to select suitable remote sensing data scenes. Over 35 years, areas of soil deterioration may be determined based on the frequency of occurrence of low NDVI values and humus content.

4.3 Determining crop choices, hybrid seed selection to generate higher yields based on regions using artificial intelligence.

With data points on temperature, soil, water usage, weather conditions, and so on, artificial intelligence and machine learning models can help obtain useful insights in real-time, such as determining the best time to sow seeds, determining crop choices, hybrid seed selection to generate higher yields, and so on (Kassem, 2025). Remote sensing provides a cost-effective and efficient method for agricultural land monitoring and mapping. Previously, traditional approaches were devised and utilised. These strategies are often based on machine learning algorithms, which are simple to build but need human interaction in decision-making. With the availability of a large amount of data and computational power, deep learning algorithms can be used in the monitoring and mapping process of land.

4.4 A predictive model for locating straw burning

In this study, the authors have found that a lot of research has been done on locating straw burning and analyzing the different aspects of crop waste. Fuzzy-based machine learning

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methods can be used to identify paddy stubble-burning fields (Palavesam Sarathamani, and Kumar, 2025). Various research projects may be conducted to assess the capabilities of machine learning approaches, such as the Bayes Network (BN), Multivariate Logistic Regression (MLP), Decision Tree (DT), and Naive Bayes (NB), for the prediction and mapping of fire susceptibility. Many studies have demonstrated that the Artificial Neural Network model is more accurate than other strategies for forecasting fires. Satellite imaging data may be used to investigate and evaluate biophysical and human-related factors.

4.5 A machine learning model to analyze the pollution from stubble burning

Researchers have focused on predictive modelling, aiming to properly forecast PM2.5 levels to develop a monitoring system that informs the public and enables preventative actions to avert harmful impacts on ambient air quality and public health (Patel et al., 2025). Numerical and analytical dispersion models are utilized for various air quality studies, including calculating concentrations and predicting air quality in metropolitan climates. A decent model for forecasting the concentration level of PM2.5 particles may assist in better equipping residents with improved preventative and safety tactics, saving them from numerous health-related ailments. Using time series analysis and regression, a regression model anticipating PM2.5 concentration levels in various areas of Delhi on an hourly basis may be created, depending on numerous atmospheric and surface parameters such as wind speed, atmospheric temperature, pressure, and so on. The data for the study may be acquired from the Indian Meteorological Department's many weather monitoring stations put up around the city (IMD).

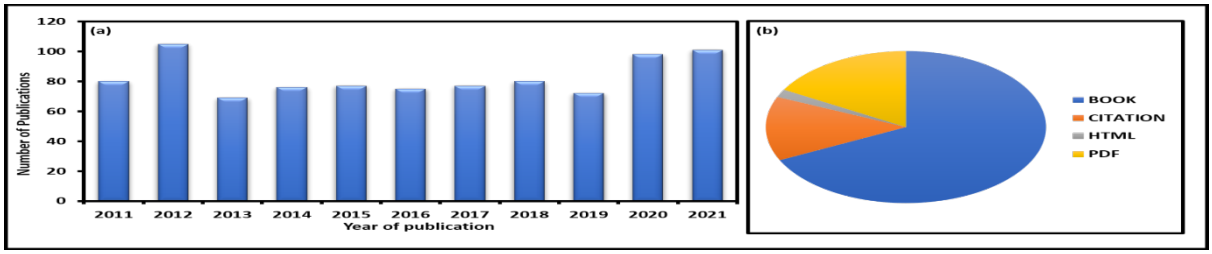

Figure 6 (a) Year-by-year publishing of works in the fields of AI in Stubble Burning and (b) bifurcation of articles

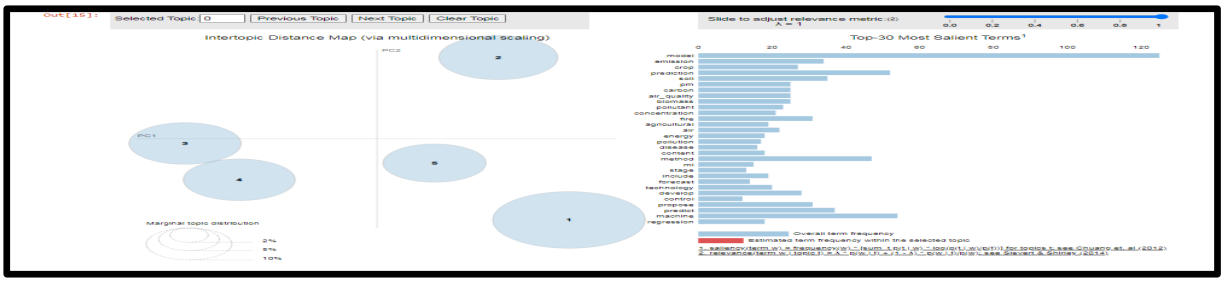

Figure 7: The dominant keywords for all the topics combined.

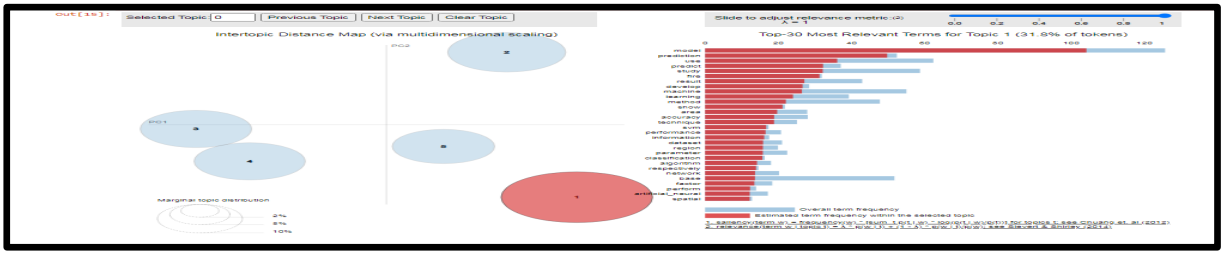

Figure 8: The dominant keywords for Topic 1

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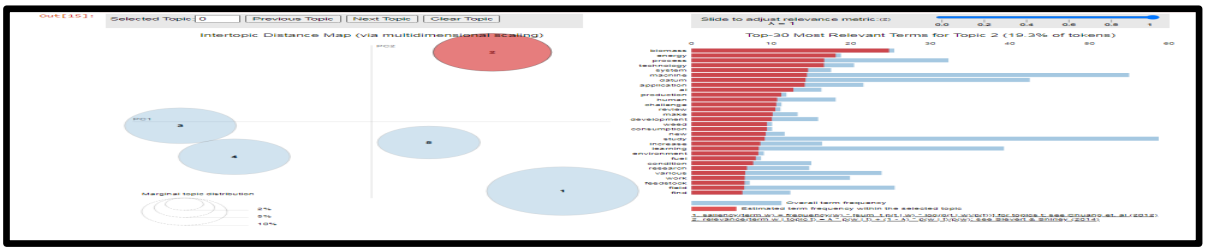

Figure 9: The dominant keywords for Topic 2

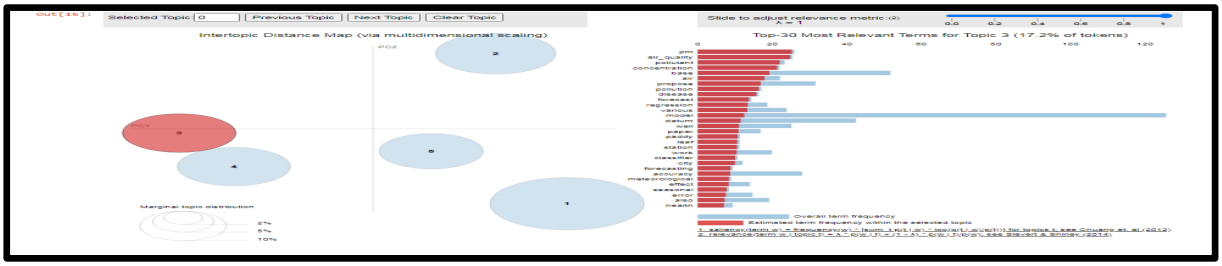

Figure10: The dominant keywords for Topic 3

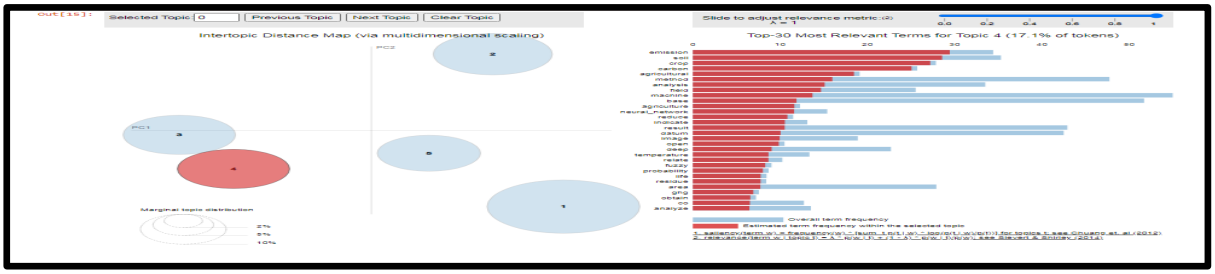

Figure 11: The dominant keywords for Topic 4

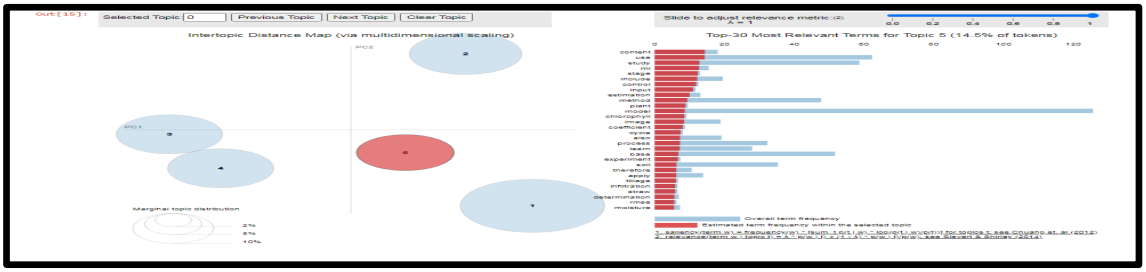

Figure 12: The dominant keywords for Topic 5

5. Sentiment Analysis Discussion

Sentiment analysis was done on the fetched tweets from Twitter. For fetching this data, keywords/ hashtags like #AirPollution, #StubbleBurning #Delhi, etc. were used. A word cloud of the most used words was created as depicted in Figure 13. Some of the important keywords which stood out were 'air quality', 'waste', 'segregate', 'aqi', 'stubble burning' etc. N-grams for the words were also generated as shown in Figure 14-16.

The issue of rising pollution is a great concern for the citizens of Delhi, and this can be interpreted from the data shown in Figure 17. In the analysis, it is found that 58% of negative sentiment, 24% of neutral sentiment, and 18% of people are tweeting in positivity. Upon analyzing the wordcloud for words, it was found that people are not just talking about the negative impacts of pollution from stubble burning, but also the steps to be taken to minimize the pollution from the environment.

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Figure 13 WordCloud of the most used words.

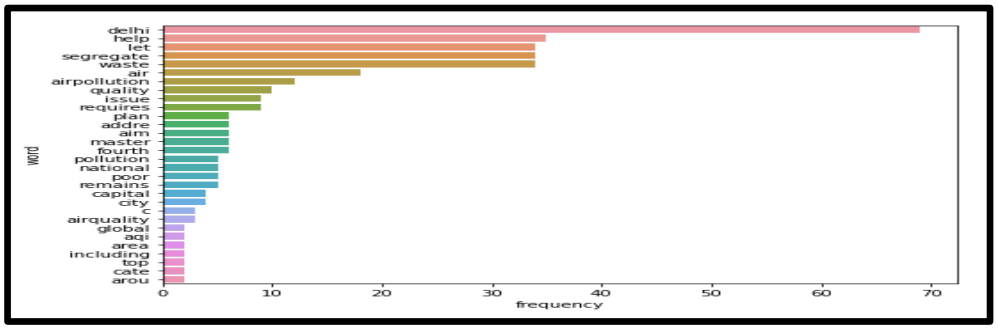

Figure 14 Unigram depicting words frquency.

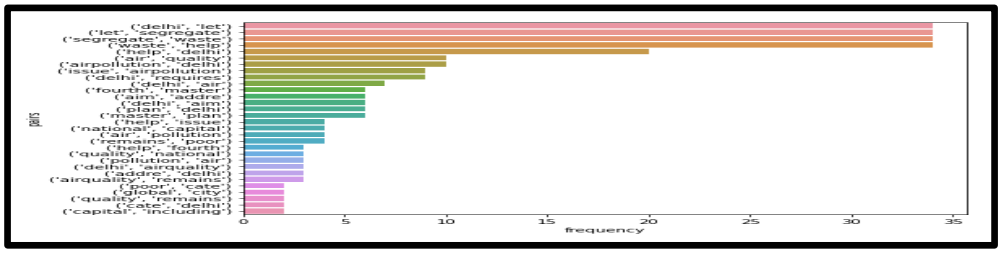

Figure 15 Bigram depicting words frquency.

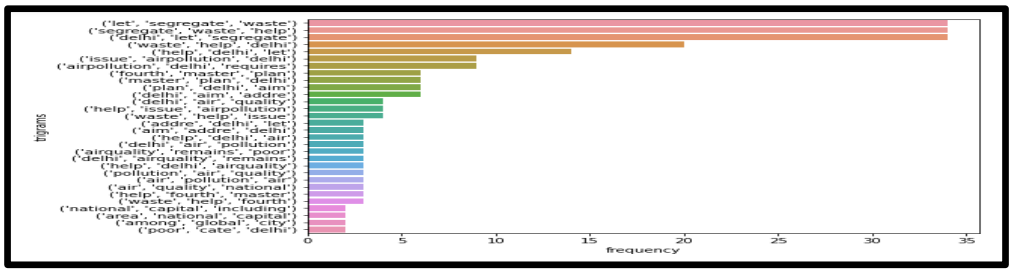

Figure 16 Trigram depicting words frquency.

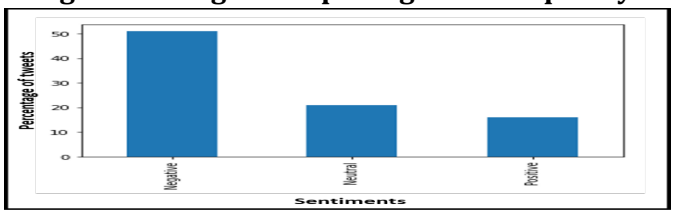

Figure 17 Sentiment Analysis

6. Recommendations

- AI can be utilized to locate straw burning and stop the pollution generated by straw burning. The detection of straw burning can be based on two factors: flame and smoke. Straw burning is frequently accompanied by a lot of smoke, and it is possible to tell if there is straw burning by looking at the smoke. The present smoke detection technologies all have flaws, such as not using the dynamic properties of smoke and inefficient and

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complicated processing. Improved detection methods and faster AI models can help increase the proficiency in detecting straw burning.

- A smart AI based platform can help monitor farm fires and the pollution caused by them. This can help government and NGOs identify such areas and reach out to the farmers taking necessary steps to create awareness and mitigate the cause of pollution.
- Another area, where AI can be helpful in preventing stubble burning is an AI-enabled marketplace for crop-waste transaction. This will include the involvement of alternative users like furniture manufactures, packaging producers, power plants, etc. Utilizing the calorific value of agricultural waste can assist enhance clean power generation. The supply chain modelling tools will allow and catalyze alternate agricultural residual uses in lucrative and sustainable industries such as engineered wood and sustainable packaging. This can act as a good start for a business model where different services can be provided to the different stakeholders and generate revenue.
- Analyzing the thermal composition of crop waste using artificial neural network models can help in predicting the devolatilisation behavior of biomass. This biomass can be used to generate bioenergy, thereby decreasing our reliability on fossil fuels. Based on this analysis, a service can be offered to farmers advising them which crops to go for and make profit.
- The government may tell farmers about the various new technologies that have been created to help with stubble removal and even provide incentives for them to use them. AI can be used in advertisement. Language processing techniques can be used to convert advertisement into native languages of farmers for easy understanding. This can act as a source of revenue by offering an advertisiting system to the industry & government for target messaging sending specific messages to the farmers for different type of plantation and region.
- AI can play a critical role in analyzing and forecasting groundwater levels, soil quality, and other variables. Crop diversity should be encouraged, especially given the alarming pace of groundwater depletion, low soil quality, and air pollution. Crop diversification, like crop rotation, polycultures, agroforestry, and other approaches, can help farmers cope with the consequences of climate change and severe events.

Based on the above recommendations, a business model can be proposed encompassing a smart platform with built-in technologies like Artificial Intelligence, IoT devices, and cloud that can help farmers with income problems by introducing a smart marketplace for crop waste transactions which has been proposed by AlZubi & Galyna, (2023). .

7. Conclusion

This study provides a more in-depth knowledge of the importance of AI in agriculture and can aid in reducing the impact of agricultural pollution on health and the environment. The current work uses bibliometric analysis and sentiment analysis to analyze the trends in research in the domain of AI in reducing stubble burning and also develops thematic issues for systematic literature analysis. AI has the potential to be extremely useful in assessing and forecasting groundwater levels, soil quality, and other variables. Deep learning-based algorithms can play a crucial role not only in detecting soil degradation but also in forecasting the emissions from biomass and predicting pollution levels. Smart platforms with built-in AI can help monitor agricultural fires, the pollution they cause, and the intelligent crop-waste transactions. The AI solutions can help

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farmers achieve sustainable and green agriculture, which must be provided to farmers' doorsteps in their native language, with sufficient training and input assistance, and in a collective/cooperative way. Artificial intelligence technology in agriculture has the potential to cut carbon emissions from farm operations while also rejuvenating the entire industry. Some of the latest tools available are BreeZo, an innovative application used to monitor air quality emissions, and Zuri, a platform that can monitor farm and forest fires. It provides data related to fire counts, intensity, emissions, predicted crop waste and calorific value, burning estimates, high-risk zones, and other data that can be utilised for monitoring and regulation.

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