

# Spatial Patterns of Stubble Burning during Kharif Season: A Geographical Analysis of Punjab

Rohit Kumar\*, Navneet Kaur\*\*

## Abstract

The Agricultural state of Punjab is dominated by paddy and wheat cropping patterns because of extensive agricultural land and fertile plains of rivers - Ravi, Sutlej and Beas. During the kharif season, paddy is the most sown crop by farmers of Punjab, which leads to stubble burning after crop harvesting. Existing literature shows that there has been a dearth of studies on patterns of stubble burning in Punjab during the kharif season. Therefore, the major objective of the present study is to analyse the pattern of stubble burning in Punjab during the kharif season and to highlight the factors responsible for stubble burning. The present investigation is mainly based on secondary data taken from the website of the Punjab Remote Sensing Center, Ludhiana, for the years 2016-2022, and the district has been taken as a unit of the study. Data has been analysed using an Excel sheet. The findings of the study show that, overall, there has been a declining trend in the patterns of stubble burning in the state of Punjab.

**Keywords:** Spatial Patterns, Paddy, Kharif Season, Stubble Burning, Declining Trend

## INTRODUCTION

Stubble burning is a typical agricultural practice that is carried out all throughout the world, including Punjab, India. Burning crop residue after the harvest, sometimes referred to as stubble burning, is typically done to clear the field rapidly for the following crop since it is seen to be an affordable and effective practice. It is a serious environmental concern in India, especially in the northern areas where agriculture is the primary economic activity. Kumar et al. (2015) studied the socioeconomic and environmental repercussions of agricultural residue burning in Punjab, India, and discovered that the practice had negative effects on human health, soil quality, and

climate change. It contributes heavily to the haze in the northern regions of India during the winter, though, making it one of the main sources of air pollution, posing serious health risks and degrading the ecosystem. Sarkar et al. (2018) examined the rising danger of agricultural residue burning in northern India using satellite data and discovered that crop residue burning in this region has become more frequent and severe, resulting in major repercussions on air quality, human health, and the ecosystem. The authors emphasized the critical importance of governmental actions to promote alternative crop management practices and reduce the negative consequences of agricultural residue burning.

The issue of stubble burning has received substantial attention at the national scale in the past few years due to its negative impact on air quality and human health. Punjab, which is renowned for its excellent agricultural output and is also one of the top states for stubble burning. Sharma et al. (2019) used satellite data to identify hotspots of stubble burning in agricultural areas of northwest India. The study found that stubble burning was most prevalent in the central and western regions of Punjab, particularly in the districts of Ludhiana, Sangrur, and Firozpur. They attributed this pattern to the high frequency of paddy-wheat cropping systems in these areas, leading to substantial crop residue being generated and burned. The Kharif season, which lasts from June to October, is when farmers in Punjab engage in large-scale stubble burning. Punjab, regarded as India's breadbasket, is a key contributor to the country's agricultural output and one of the states with the highest stubble-burning rates resulting in significant environmental and health consequences. Jethva et al. (2019) explored the relationship between agricultural production, residue fires, and air quality in northern India and discovered that crop residue fires in Punjab and Haryana had a major influence on air quality in the region,

\* Research Scholar, Department of Geography, Panjab University, Chandigarh, India. Email: rohitkumar80822@gmail.com

\*\* Associate Professor, Department of Geography, Panjab University, Chandigarh, India.

especially during the post-monsoon season. According to the authors, lowering the incidence of stubble burning by encouraging alternative crop management practices might enhance air quality and lower the health risks associated with air pollution exposure in northern India. Kumar et al. (2020) examined the spatial distribution of stubble burning in Punjab during the 2019 season using data from the Indian Space Research Organization's (ISRO) OceanSat-2 satellite and discovered that the districts of Sangrur, Barnala, and Mansa in the state's central region had the greatest density of stubble burning. According to the authors, this trend may be owing to the significant proportion of small and marginal farmers in these regions, who may be more prone to engage in stubble burning due to economic limitations.

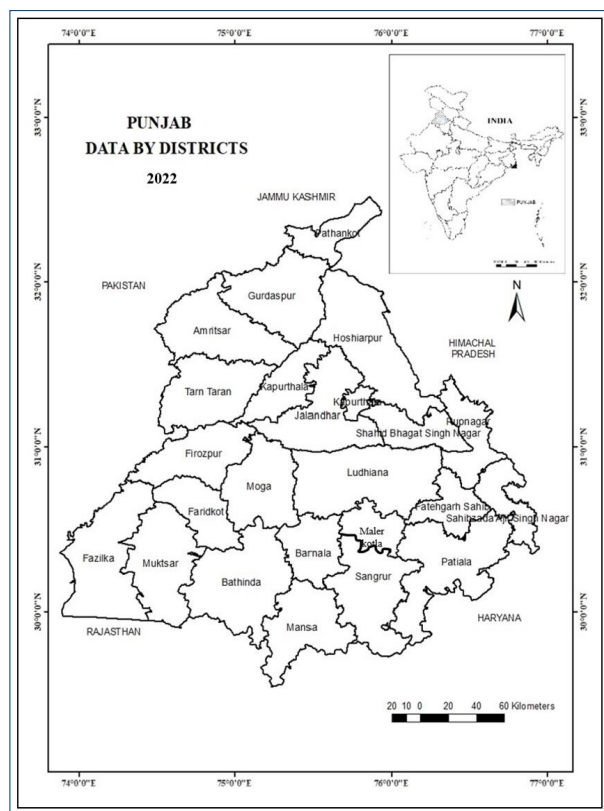
In India, stubble burning is practised mostly in Punjab, Haryana and UP, which contributes solely to the grave winter pollution in the National Capital, Delhi. The state of Punjab is known for being India's BREADBASKET. Though relatively small, Punjab grows about 30.2% of the rice (Statistical Abstract of Punjab, 2022), and 90-95% area is under intensive paddy farming. In November, farmers typically harvest rice and sow wheat. After harvest, they set fire to leftover plant debris to clear the fields for the next plantings. Stubble burning became a rampant practice during the green revolution period when mass production of paddy was enabled in the plains of Punjab and Haryana. Historically, farmers harvested and ploughed fields manually, tilling plant debris back into the soil. But after the introduction of COMBINES in the year 1980s, burning of stubble became common because the machines leave stalks that are about one foot tall. Burning the stalks was the quickest and cheapest way to clear them. Earlier, due to a lack of adequate knowledge and correct information about how effectively utilise the stubble, they have no choice but to burn the stubble to clear the field for the next crop. Das et al. (2021) investigated the geographical patterns of stubble burning in Punjab during the 2020 crop season. They discovered that agricultural waste burning was predominant in Punjab's central and western regions. According to the study, the overall number of burning events in 2020 will be fewer than in past years, potentially as a result of increasing knowledge and adoption of alternative crop management practices. Gulati et al. (2023) discovered significant year-to-year fluctuations in stubble-burning areas and pollution

concentrations in Punjab between 2019-2022 and found that November consistently had more burned areas and higher pollutant levels than October, highlighting the need for focused actions to offset the negative effects of stubble burning on air quality. The government has also established a network of biomass power plants to convert crop leftovers into electricity and has provided farmers with incentives to encourage them to use alternative agricultural waste management practices. Despite these measures, stubble burning remains a major environmental and health concern in Punjab during the Kharif season. This study report aims to make a contribution to a better understanding of the regional patterns of stubble burning and to suggest viable strategies to mitigate the practice's negative repercussions.

## STUDY AREA

Punjab is an agricultural state that is known for its rice-wheat cropping system. Punjab is a landlocked state in northern India that shares borders with Pakistan, Jammu and Kashmir, Himachal Pradesh, Rajasthan, Haryana, and other states. The three principal geographical areas of Punjab are Majha, Doaba, and Malwa, each with its distinct topography, climatic conditions, and agricultural practices. The region is located between 29 degrees 30 minutes north and 32 degrees 32 minutes north latitude and 73 degrees 55 minutes east and 76 degrees 50 minutes east longitude, with a population density of 550 persons per square kilometre. It has a land size of 50,362 square kilometres (1.53 per cent of India's total geographical area) and a population of 2,77,04,236 people (2.29 per cent of the total population) (Census of India, 2011). Until 2021, Punjab had 22 districts. Nonetheless, on June 2, 2021, the Punjab government formally recognized Malerkotla as the province's 23<sup>rd</sup> district. As a result, the total number of districts will increase to 23 by 2023.

Punjab is known for its vibrant culture and has a long history that covers many different eras. Punjab, sometimes known as the "Granary of India," is a state with a mainly agricultural economy. Many industries, including those manufacturing textiles, sporting goods, and pharmaceuticals, are also located there. Despite recent significant economic growth, the state is still dealing with difficulties such as unemployment, poverty, and income inequality.



Source: Census of India (2011) and Statistical Abstract of Punjab, 2022.

**Map 1**

## RESEARCH OBJECTIVES

- To analyse the Spatial Pattern of Stubble Burning in Punjab during the kharif Season.
- To highlight the factors responsible for Stubble Burning.
- To suggest alternatives to avoid Stubble Burning.

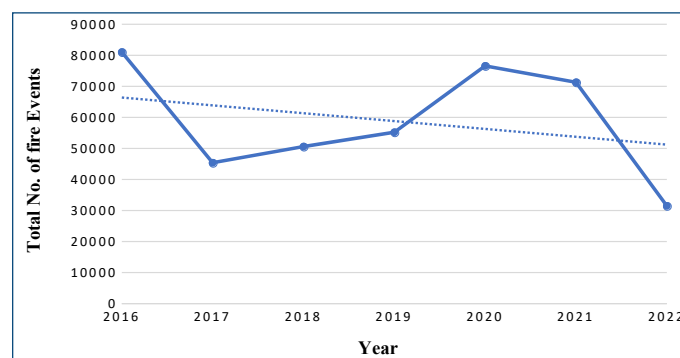
## RESEARCH METHODOLOGY

The present investigation is mainly based on secondary data taken from the website of Punjab Remote Sensing

Center, Ludhiana, for the time period of 2016-2022 for the kharif season and to analyse the spatial patterns of stubble burning and the district is taken as a unit of the study. To process the data, at first, data was entered into micro soft Excel sheet, and then Microsoft Excel was used for analysing the data along with descriptive analyses. Bar graphs and Arc-Gis maps have been used to interpret and represent the data.

## RESULTS AND DISCUSSION

After the analysis of the data, it has been found that overall, there has been a declining trend in the patterns of stubble burning from 2016-2022. Fig. 1 shows the trends of stubble burning.



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

**Fig. 1:** Trends of Stubble Burning during Kharif Season: 2016-2022

Farmers are becoming more sensitive towards the issue of stubble burning, especially paddy–straw burning, and government interventions, incentives, and policies are the major factors that are responsible for the decline in the spatial patterns of stubble burning. So, on the basis of the total number of fire events that occurred each year, we can divide each year into three categories low, medium and high and a detailed description of the same is given below.

**Table 1: Punjab: District Wise Total Number of Fire Events from 2016-2022**

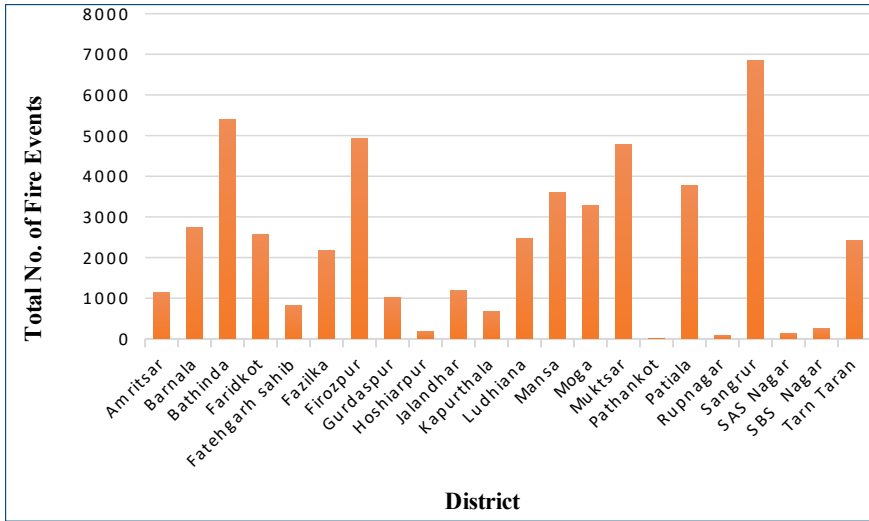
District	2016	2017	2018	2019	2020	2021	2022
Amritsar	1788	999	1151	1510	2413	2175	1542
Barnala	4585	2481	2735	3257	4519	4326	2910
Bathinda	7047	3693	5402	6036	7806	4481	4592
Faridkot	3550	2277	2570	2545	3845	3953	2693
Fatehgarh sahib	1862	1229	828	896	1362	1724	1149
Fazilka	3063	1359	2181	1886	3125	2388	2856
Firozpur	6036	3496	4924	5313	6947	6288	4295
Gurdaspur	1769	1185	1036	1497	1938	1396	854
Hoshiarpur	709	378	175	316	407	331	259
Jalandhar	3679	1543	1198	1627	1794	2548	1388
Kapurthala	2369	1155	684	1422	1631	1797	1279
Ludhiana	7697	3239	2481	2532	4330	5817	2682
Mansa	4405	3293	3596	3924	4961	3217	2815
Moga	7150	2200	3280	3267	5843	6515	3609
Muktsar	5250	3003	4792	3961	5458	4600	3884
Pathankot	28	13	9	4	11	6	1
Patiala	4986	3829	3784	4212	5304	5368	3336
Rupnagar	554	244	82	131	209	307	246
Sangrur	9556	6968	6862	7021	9705	8006	5239
SAS Nagar	240	168	144	201	262	206	162
SBS Nagar	1100	547	256	279	192	355	270
Tarn Taran	3619	2085	2420	3373	4528	4117	3184
Malerkotla	-	-	-	-	-	1383	677
Total	81042	45384	50590	55210	76590	71304	49922

Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

### Spatial Pattern of Stubble Burning during Kharif Season - 2016

In 2016, there were 81,042 fire incidents recorded in Punjab. This demonstrates the state's huge extent of stubble burning as a concern, which contributes to air pollution and environmental deterioration. Certain districts had a much higher number of fires than others,

like Ludhiana (7697), Sangrur (9556), and Bathinda (7047). Due to extensive paddy agricultural practices, crop trends, and a lack of knowledge, some districts saw lesser incidents of fire as compared to others like Pathankot (28), Rupnagar (554), SAS Nagar (240), and Hoshiarpur (709). This shows that due to terrain, stubble burning may be less frequent or less common in some regions. Fig. 2 is the graphical representation of the patterns of stubble burning.

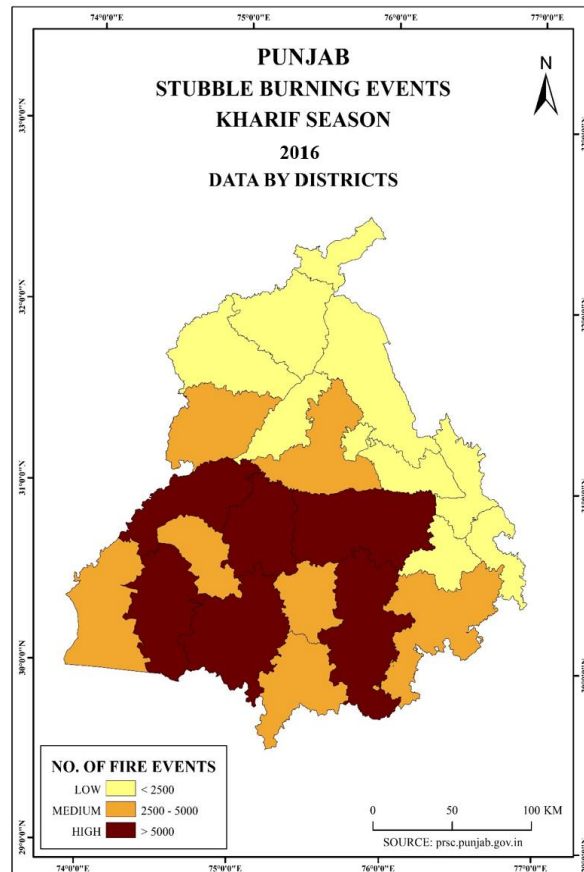


Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

**Fig. 2: Total Number of Fire Events in the Year 2016**

The distribution of fire occurrences among districts suggests that stubble-burning practices vary across Punjab. Districts in the Malwa area, such as Bathinda, Ludhiana, and Sangrur, reported a larger number of fire occurrences than districts in other regions, such as Majha

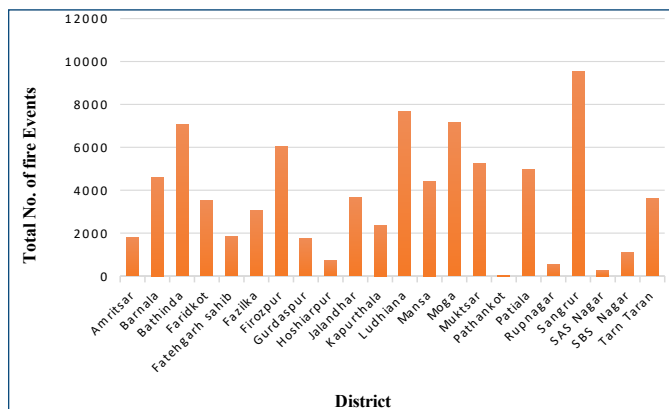
and Doaba. Crop types, farming practices, economic conditions, awareness level, etc., may all have an impact on regional variation. The map 2 shows the spatial patterns of stubble burning during the kharif season for the year 2016.



**Map 2**

### Spatial Pattern of Stubble Burning during Kharif Season - 2017

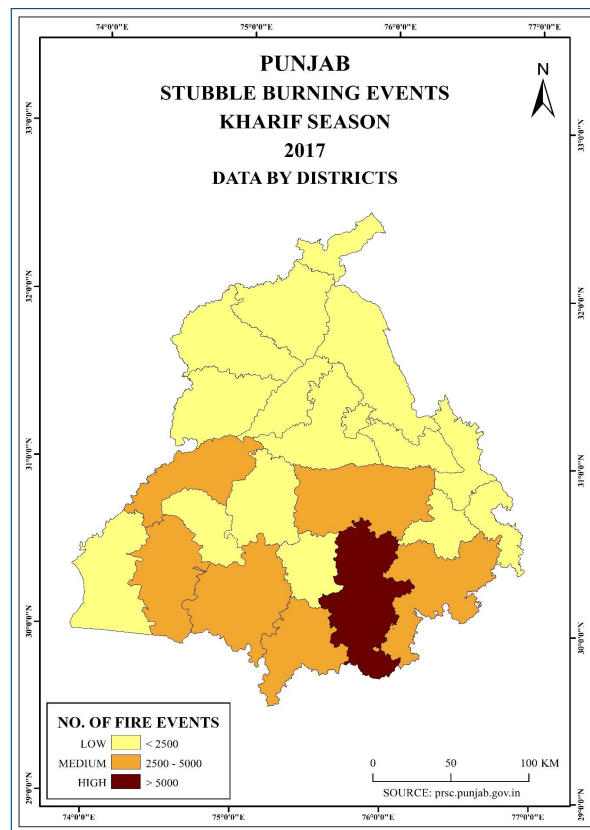
Fig. 3 reflects the number of fires caused by stubble burning in different districts of Punjab in 2017. In 2017, 45,384 fires were caused by stubble burning in Punjab. There are considerable differences in the number of fire occurrences across various districts when we analyse the data. Sangrur had the most number of fires, with 6,968 incidents, followed by Bathinda (3,693), Mansa (3,293), Ludhiana (3,239), Firozpur (3,496), and Muktsar (3,003). Due to a larger agricultural area or a higher concentration of farms, these areas suffered a significant quantity of stubble burning. Pathankot, on the other hand, had the fewest fires, with only 13, indicating that stubble burning was less common in that area.



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

**Fig. 3: Total Number of Fire Events in the Year 2017**

The figure also shows that several districts, such as Amritsar (999), Barnala (2,481), Faridkot (2,277), and Tarn Taran (2,085), saw a moderate number of fires. These figures imply that there is a considerable presence of stubble burning in these locations. It is crucial to highlight that stubble burning adds to air pollution, particularly during the post-monsoon season, exacerbating northern India’s already severe air quality problems.

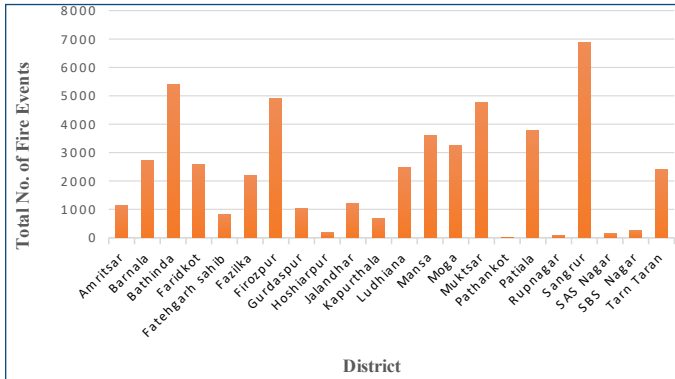


**Map 3**

### Spatial Pattern of Stubble Burning during Kharif Season-2018

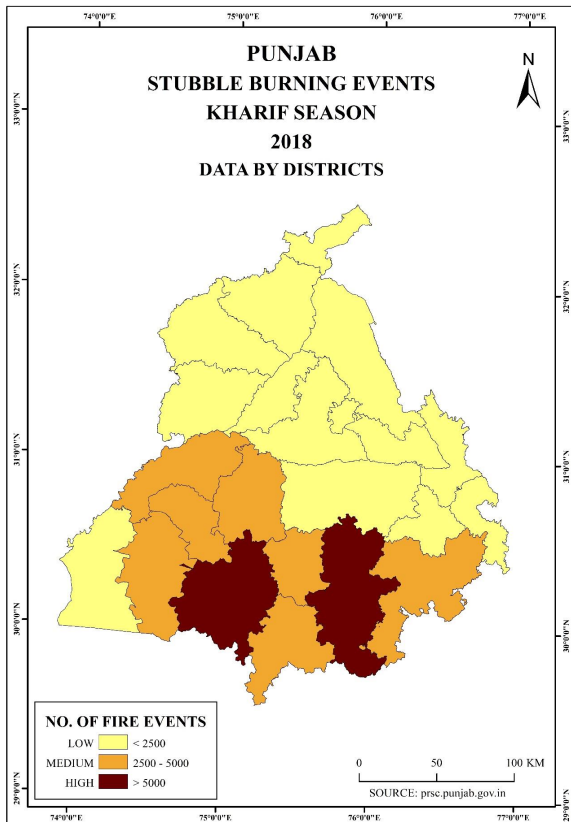
In 2018, there were 50,590 fires in Punjab as a result of stubble burning. Sangrur had the greatest number of fire occurrences in 2018, with a total of 6,862 incidents. Bathinda (5,402), Firozpur (4,924), Muktsar (4,792), and Mansa (3,596) are other districts with a high number of fires. This suggests that stubble burning was more common in these regions. These districts may have had a greater number of agricultural fields, and the farmers in these areas may have been more likely to engage in stubble burning. Districts with a moderate number of fires were Barnala (2,735), Fazilka (2,181), Ludhiana (2,481), and Moga (3,280). Some districts suffered fewer fires than others, including Rupnagar (82), Pathankot (9),

SAS Nagar (144), and SBS Nagar (256). According to the findings, stubble burning was not uniformly dispersed throughout all districts in Punjab. In 2018, Sangrur appeared as a possible hotspot for stubble burning, with the most fire occurrences. Districts such as Rupnagar, Pathankot, SAS Nagar, and SBS Nagar experienced fewer fires, implying that stubble burning was not as popular or prevalent in those regions. Fig. 4 shows the total fire events in the year 2018.



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

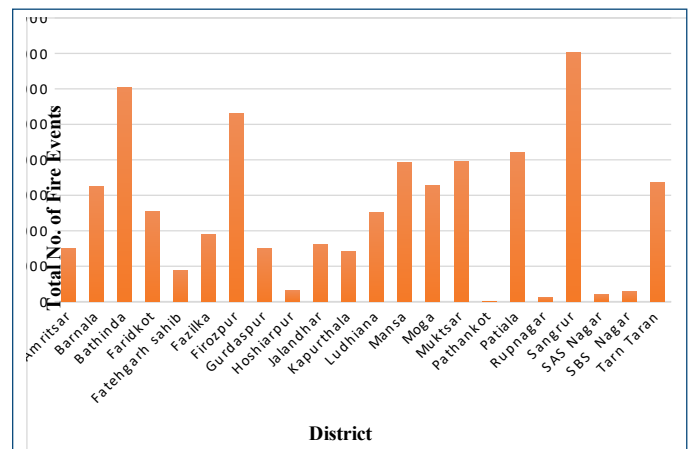
**Fig. 4:** Total Number of Fire Events in the Year 2018



**Map 4**

### Spatial Pattern of Stubble Burning during Kharif Season-2019

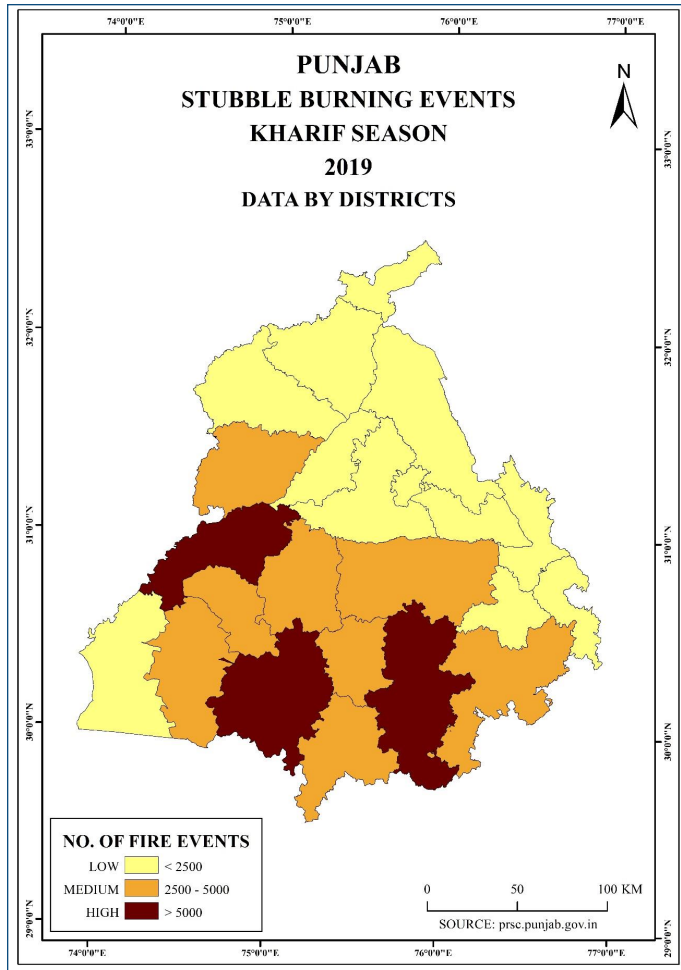
From the Fig. 5, it is clear that in 2019, a total of 55,210 fires caused by stubble burning were reported in Punjab. After the analysis of the given data, the results show that stubble burning was frequent in all districts of Punjab, albeit to various degrees of intensity. Sangrur, Bathinda, and Ferozpur had the largest number of fire occurrences, with 7,021, 6,036, and 5,313 fires, respectively. These districts feature a large concentration of agricultural activities, including crop production such as rice and wheat, as well as a lack of awareness that contributes to stubble burning. Mansa (3,924), Muktsar (3,961), and Moga (3,267) are three more districts with a high number of fires. These areas were likewise heavily agriculturally based.



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

**Fig. 5:** Total Number of Fire Events in the Year 2019

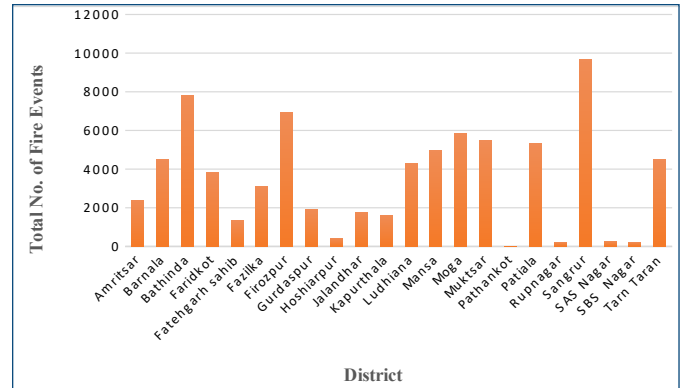
However, areas such as Pathankot (4), Rupnagar (131), SAS Nagar (201), and Hoshiarpur (316) recorded fewer fires. These districts may have fewer agricultural lands, or farmers may have chosen alternate crop residue management practices. Therefore, it emphasises the importance of effective legislation and public awareness initiatives to encourage farmers to use alternative and sustainable crop residue management strategies.



Map 5

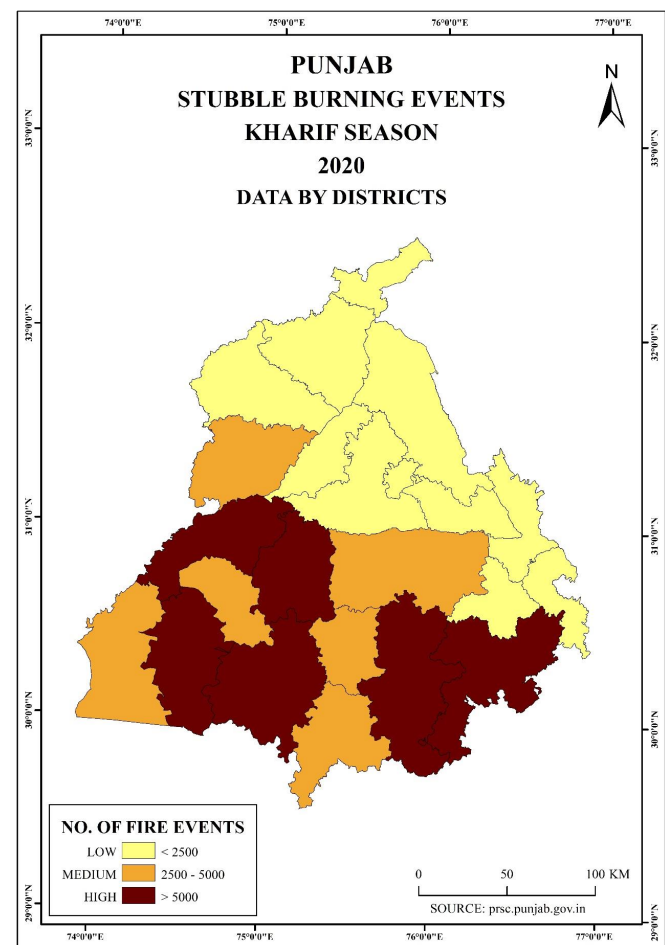
### Spatial Pattern of Stubble Burning during Kharif Season-2020

In 2020, 76,590 fires caused by stubble burning were reported in Punjab (Fig. 6). Sangrur had the largest number of fires among the districts, with a staggering 9,705 instances due to the district’s high agricultural activity and intensive farming practices. The districts of Firozpur and Moga also saw a high number of fires, with 6,947 and 5,843 instances, respectively. Due to the great concentration of agricultural land in these regions, large-scale stubble burning occurs.



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

Fig. 6: Total Number of Fire Events in the Year 2020



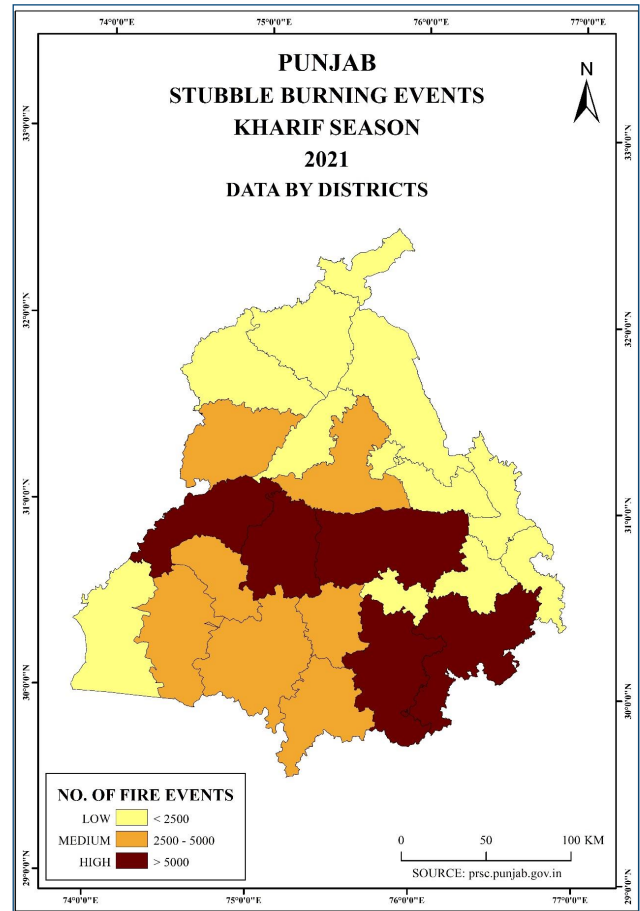
Map 6

Bathinda, another important district, had 7,806 fires because of its vast agricultural practices, especially paddy agriculture, which produces a significant amount of crop waste. Mansa (4,961), Muktsar (5,458), and Tarn Taran (4,528) are three more districts with a high number of fires. It is disturbing that even regions with lesser populations, such as Barnala (4,519) and Fazilka (3,125), saw a significant number of fires. This suggests that stubble burning is a common practice throughout Punjab’s agricultural regions. However, it is important to note that certain districts saw fewer fires than others, such as Rupnagar (209) and SAS Nagar (262). This shows that these areas may have put in place effective measures to avoid stubble burning or adopted alternate agricultural residue management strategies.

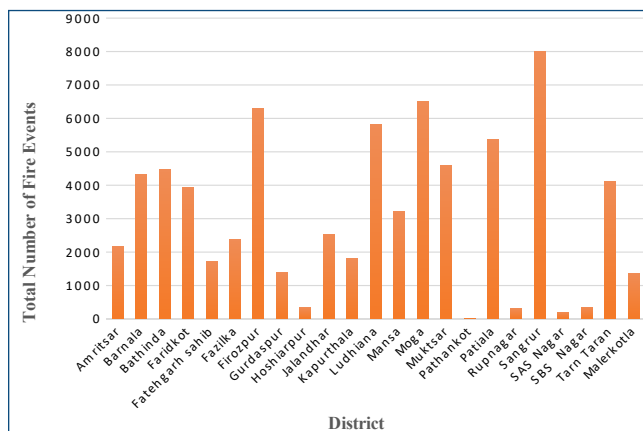
considerable number of fires. These districts are recognised for their agricultural operations and vast farming, which explains why stubble burning is more common. Some districts, on the other hand, experienced fewer fires, such as Pathankot (6), Rupnagar (307), and SAS Nagar (206). These districts have less land for farming due to rugged topography.

### Spatial Pattern of Stubble Burning during Kharif Season-2021

The data given in Fig. 7 shows the number of fires caused by stubble burning in various districts of Punjab in 2021. In 2021, 71,304 fires were reported in Punjab as a result of stubble burning. Sangrur had the maximum number of incidences among the districts, with 8,006 fires, followed by Moga with 6,515 fires and Firozpur with 6,288 fires. These regions saw a significant quantity of burnt stubble, showing that this is a common agricultural practice that adds to the problem.



Map 7



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

Fig. 7: Total Number of Fire Events in the Year 2021

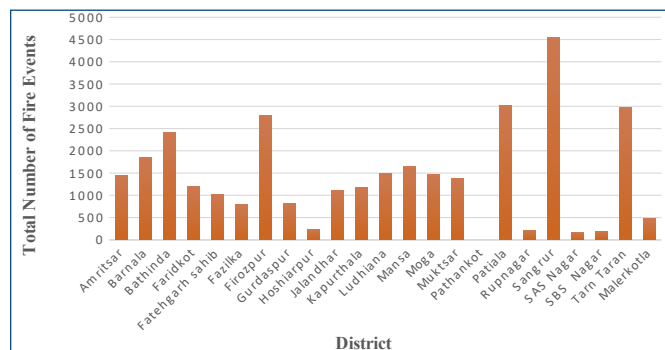
Several additional districts, including Bathinda (4,481), Muktsar (4,600), and Ludhiana (5,817), reported a

### Spatial Pattern of Stubble Burning during Kharif Season-2022

In the year 2022, the total number of fire events that occurred was 49922, as shown in Fig. 8. After analysing the data, It has been found that Sangrur had the highest number of fire occurrences in 2022, with an astounding total of 5,239. This suggests that stubble burning was common in that area, which might be due to a variety of variables such as crop type, agricultural practices, or a lack of information about other options.

Other districts with a high number of fires were Bathinda (4,592), Firozpur (4,295), Moga (3,609), and Muktsar (3,884). In these districts, there were also a high number of stubble burning occurrences, showing a repeating tendency.

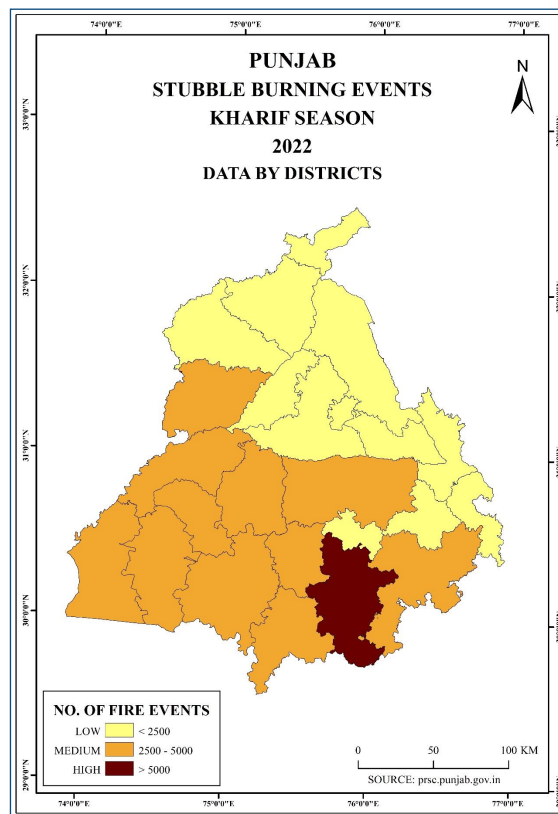
farmers about the possible risks of stubble burning and equip them with suitable alternatives.



Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

**Fig. 8: Total Number of Fire Events in the Year 2022**

Some districts, on the other hand, saw fewer fires, such as Pathankot (1), Rupnagar (246), and SAS Nagar (162). These districts may have enacted stronger laws or promoted alternate agricultural residue management strategies, resulting in fewer incidences of stubble burning. Therefore, it is crucial to mitigate the issue of stubble burning. To address this issue, it is critical to educate



**Map 8**

**Table 2: Punjab: Total Percentage Change in Fire Events from 2016-2022 during Kharif Season**

District	2022	2016	Total Change (2016-2022)	Total % Change (2016 -2022)
Pathankot	1	28	-27	-96.43 %
SBS Nagar	270	1100	-830	-75.45 %
Ludhiana	2682	7697	-5015	-65.16 %
Hoshiarpur	259	709	-450	-63.47 %
Jalandhar	1388	3679	-2291	-62.27 %
Rupnagar	246	554	-308	-55.60 %
Gurdaspur	854	1769	-915	-51.72 %
Moga	3609	7150	-3541	-49.52 %
Kapurthala	1279	2369	-1090	-46.01 %
Fatehgarh Sahib	1149	1862	-713	-38.29 %
Sangrur	5916	9556	-3640	-38.09 %
Barnala	2910	4585	-1675	-36.53 %
Mansa	2815	4405	-1590	-36.10 %
Bathinda	4592	7047	-2455	-34.84 %
Patiala	3336	4986	-1650	-33.09 %

District	2022	2016	Total Change (2016-2022)	Total % Change (2016-2022)
SAS Nagar	162	240	-78	-32.50 %
Ferozpur	4295	6036	-1741	-28.84 %
Muktsar	3884	5250	-1366	-26.02 %
Faridkot	2693	3550	-857	-24.14 %
Amritsar	1542	1788	-246	-13.76 %
Tarn Taran	3184	3619	-435	-12.02 %
Fazilka	2856	3063	-207	-6.76 %
Total	49922	81042	-31120	-38.39 %

Source: Punjab Remote Sensing Center, Ludhiana, Punjab.

### Total Percentage Change in Fire Events from 2016-2022 during Kharif Season

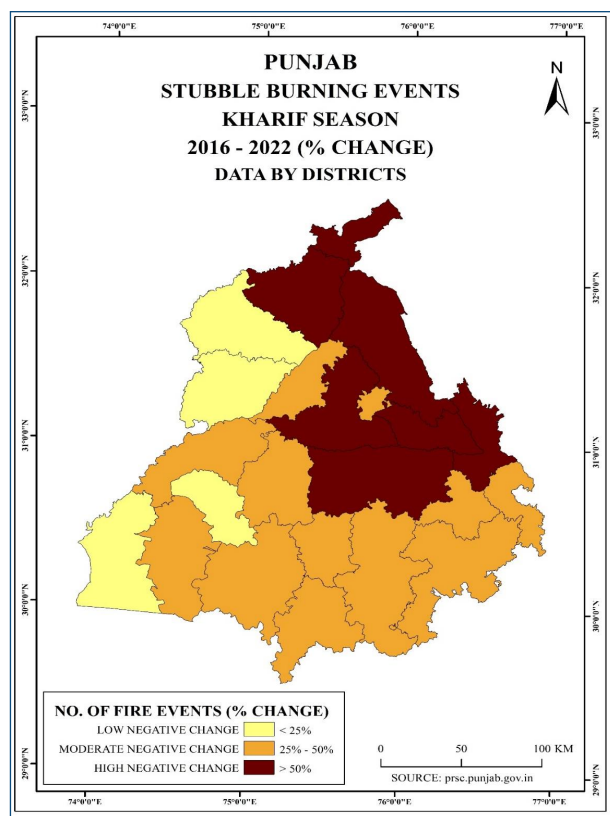
From Table 2, it is very clear that the district of Pathankot had the most substantial drop, with a 96.4286% decrease in fire occurrences throughout the Kharif season. This demonstrates a significant decrease in the number of fires in this district throughout the investigated period. Fire incidents decreased significantly in Ludhiana, Hoshiarpur, Jalandhar, and SBS Nagar, with percentage decreases of -65.1553%, -63.4697%, -62.2724%, and -75.4545%, respectively.

Several additional districts, including Gurdaspur, Rupnagar, and Kapurthala, had considerable reductions in fire occurrences, with reductions ranging from -51.7241% to -55.5957%. However, a few districts saw considerably modest decreases in fire incidents. Fazilka (-6.75808%), Tarn Taran (-12.0199%), and Amritsar (-13.7584%) are among them. In all, there were 38.3998% fewer fire occurrences during the Kharif season from 2016 to 2022, when all the Punjabi districts were taken into account. These figures point to a general pattern of declining fire incidents in Punjab over the study period.

### Factors Responsible for Stubble Burning

The practice of stubble burning has been pointed out on a variety of grounds, including a lack of other options, economic restrictions, and a lack of awareness of its negative environmental consequences. Some of the key factors for stubble burning in Punjab are as follows:

- *Time Constraints:* Farmers in Punjab have a narrow window of time between the harvesting of paddy (rice) and the sowing of the next crop. Stubble burning is often resorted to as a quick and inexpensive method to clear the fields and prepare them for the subsequent crop.
- *Lack of Alternatives:* Farmers face challenges in managing crop residue due to the limited availability of economically viable alternatives. The use of mechanized equipment for residue management can be expensive, and there is a lack of infrastructure for handling large quantities of crop residue effectively.
- *Financial Burden:* Disposing of crop residue through alternative means such as mechanical or manual removal, mulching, or incorporating it back into the



Map 9

soil requires additional labour, time, and resources. The financial burden associated with these alternatives often leads farmers to choose stubble burning as a cost-saving measure.

- Area under paddy continues to dominate the Kharif crop mix, leading to enormous paddy residue generation.
- *Subsidies and Incentives:* Some argue that the provision of subsidies for farm equipment like happy seeders (machines that sow wheat without the need for prior clearing of residue) and financial incentives for adopting alternative residue management practices have not been adequate or accessible to all farmers, which discourages them from adopting non-burning methods.
- *Limited Awareness and Education:* Many farmers may not be aware of the detrimental effects of stubble burning on air quality, human health, and the environment. Lack of knowledge about alternative techniques for managing crop residue contributes to the continued practice of burning.
- *Socio-Economic Factors:* The socio-economic conditions of farmers, including small landholdings, lack of credit, and economic pressure, can influence their decision-making process. Immediate financial gains from stubble burning may outweigh the long-term benefits of adopting sustainable practices.

Punjab's Malwa region accounts for a higher number of fires because farmers favour the long-lasting PUSA 44 paddy type. PUSA 44 is a high-yielding rice variety with a short CRM period of roughly 160 days after sowing and a high straw load that enhances crop residue. Despite efforts by the Punjab Agricultural University and the state government to discourage its adoption due to its lengthy and input-intensive cultivation, farmers continue to favour this rice variety due to its better yield when compared to shorter-duration alternatives. Over 27% of the Malwa districts' land was governed by PUSA 44 in Kharif 2020.

Addressing stubble burning requires a multi-faceted approach that involves providing accessible and affordable alternatives for crop residue management, raising awareness among farmers about the environmental and health impacts of burning, improving infrastructure for residue handling, and implementing effective policies and incentives to encourage the adoption of sustainable

agricultural practices. Collaborative efforts involving the government, agricultural experts, researchers, and farmers' organisations are crucial for finding viable solutions and mitigating the issue of stubble burning in Punjab.

## Alternative to Avoid Stubble Burning

To avoid stubble burning in Punjab, several alternate solutions have been proposed and implemented. These solutions aim to provide farmers with economically viable and environmentally friendly alternatives for managing crop residue. Crop residue can be managed in two ways. The residue left after the crop harvest can either be incorporated back into the soil or collected and supplied for other applications as boiler fuel in industries and power plants and in packaging materials, among others. These management practices are referred to respectively as in-situ and ex-situ. Over the last few years, both the central and the state governments have been recommending the in-situ method as the ideal solution for residue management. Here are some of the alternate solutions:

- *Promoting Farm Machinery:* Encouraging the use of specialised farm machinery like happy seeders, mulchers, and zero tillage machines can help manage crop residue effectively. Happy seeders, in particular, allow farmers to sow wheat without clearing the previous crop residue, reducing the need for burning.
- *Crop Diversification:* Promoting crop diversification by encouraging farmers to cultivate crops with shorter harvest residues, such as maize, pulses, or vegetables, can reduce the problem of stubble burning. These crops have lower residue volume and can be managed more easily.
- *In-Situ Crop Residue Management:* Adopting in-situ crop residue management techniques involves incorporating crop residue back into the soil through ploughing, mulching, or using specific machinery. This practice helps improve soil health, retains moisture, and reduces the need for burning.
- *Bioenergy Production:* Encouraging the use of crop residues for bioenergy production, such as biomass power plants or biogas generation, provides farmers with an additional income source while reducing the

need for burning. This approach promotes the sustainable utilization of crop residue.

- *Financial Incentives and Subsidies:* Providing financial incentives and subsidies to farmers for adopting non-burning practices and investing in machinery for residue management can alleviate the financial burden associated with alternative methods.
- *Awareness and Education:* Conducting awareness campaigns and educational programs to highlight the environmental and health hazards of stubble burning can help change farmers' perceptions and promote the adoption of sustainable practices. Sharing success stories and best practices from farmers who have successfully shifted away from burning can also inspire others to follow suit.
- *Research and Development:* Continued research and development efforts can focus on developing cost-effective and efficient technologies for residue management. This includes exploring innovative techniques, improving existing machinery, and finding new uses for crop residues.
- *Collaborative Approach:* Encouraging collaboration between government agencies, agricultural institutions, research organisations, and farmers' associations is essential for effective planning, implementation, and monitoring of stubble-burning alternatives. This collaboration ensures that solutions are practical, tailored to local needs, and supported by relevant stakeholders.

Therefore, it's important to note that the successful implementation of these alternate solutions requires sustained support from the government, adequate infrastructure, financial resources, and the active participation of farmers. A comprehensive approach that addresses technical, economic, and social aspects is crucial for long-term solutions to stubble burning in Punjab.

## CONCLUSION

So, in conclusion, it can be said that overall, there has been a declining trend in the patterns of stubble burning, but paddy straw waste or Paraali has been identified as a major Environmental and Health Hazard. Therefore, it is extremely important to understand the underlying

cause and existing situation as to why the farmers burn stubble and then deal with the basic problem. The effects of stubble burning have expanded beyond the borders of Punjab, affecting other states as well. Within Punjab, certain hotspots and clusters have arisen, and government measures have attempted to address the issue. Alternative efforts were made through Kisan camps, training and workshops, apart from campaigns through various print media, televised shows and radio jingles, informing farmers about the alternative usage of crop residue. Stronger monitoring and enforcement mechanism through the use of remote sensing technology - use of real-time satellite imagery, along with the village-level enforcement teams with the aim of zero incidence rate of crop residue burning through prevention and penalization. To establish long-term solutions and alleviate the environmental and health dangers connected with stubble burning, however, continued efforts and a multi-faceted approach combining farmers, legislators, and technical improvements are required.

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