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THE USE OF REMOTE SENSING AND GIS APPLICATIONS TO STUDY THE ENVIRONMENTAL IMPACTS OF STUBBLE BURNING IN HARYANA AND PUNJAB STATES

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ABSTRACT

This research explores the application of remote sensing and GIS techniques to study the environmental impacts of paddy straw burning by farmers in Haryana and Punjab, the major northern rice producing states of India. In both these states, stubble burning is a common agricultural practice in the months of October and November, which significantly contributes to air pollution, soil erosion and climate change in this region. Remote sensing techniques, mainly through data from satellites such as Sentinel, MODIS and LANDSAT, provide an efficient way to monitor fire hotspots, smoke dispersion and post-harvest land use changes. Complementarily, GIS Applications facilitates spatial climate change analysis, enabling the integration of multi-source datasets to identify affected areas, assess air quality degradation and map the proximity of vulnerable populations and ecosystems. This study highlights the features of these techniques, such as real-time monitoring, comprehensive spatial coverage and multi-spectral analysis to detect emissions and heat signatures. However, the study also discusses the pros and cons of these techniques, including challenges such as low-resolution data cost, weather-dependent imagery, and data processing complexities. Integration of remote sensing and GIS provides valuable information about spatial and temporal patterns of stubble burning, which provides a basis for effective policy-making and sustainable agricultural practices.

Keywords: *Remote Sensing, GIS, Stubble Burning, Air Pollution, Climate Change.*

Introduction

Stubble burning in Haryana and Punjab is a serious environmental problem that affects not only these states but the entire North India. This problem occurs especially after the harvesting of paddy when farmers burn the stubble left in the fields. Paddy crop is grown in both these states in the Kharif season (June-July to September-October). When farmers harvest paddy in October-November, immediately after that they have to prepare the field to grow Rabi crop, due to which they dispose paddy straw by burning it directly in the fields. Often many farmers are not aware of alternative methods of disposal of paddy waste. Along with this, the lack of effective government policies to prevent stubble burning is also a prominent reason of burning incidents. It is noteworthy that the stubble burnt in Haryana and Punjab has been considered the main culprit for air pollution in Delhi-NCR. The monitoring report that has come from the Center in the context of the year **2024** is quite shocking. In this, the incidents of stubble burning in some districts of Punjab and Haryana have been the highest till October **4.** According to the report, till November **2024**, there are **188** cases of stubble burning in Punjab, **119** in Haryana, **22** in Uttar Pradesh, **13** in Madhya Pradesh, zero in Delhi and **09** in Rajasthan. If seen, Punjab is at number one in stubble burning, Haryana is at second and UP is at third place. The districts of Punjab which burn the most stubble include Amritsar (**94)**, Ferozepur (**11)**, Gurdaspur (**11)**, Kapurthala (**16)**, Jalandhar (**9)** and Sangrur (**6).** Similarly, the districts which burn the most stubble in Haryana include Karnal (**36)**, Kurukshetra (**25)**, Faridabad (**9)**, Kaithal (**8)**, Sonipat (**8)**, Yamuna Nagar (**8)** and Fatehabad (**5).**

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But, meanwhile, the Ministry of Environment has presented a big figure. The Environment Ministry said on 7 October, 2024 that incidents of paddy residue burning in Punjab and Haryana have seen a significant decline since the year **2022.** According to the ministry's data, **48**,**489** incidents of stubble burning were reported in Punjab in **2022**, which has now come down to **9**,**655** in **2024.** At the same time, a significant reduction was also registered in Haryana, during the same period the cases fell from **3**,**380** to **1**,**118.** Responding to a question in the Lok Sabha, Minister of State for Environment, Forest and Climate Change Kirti Vardhan Singh said that the Indian Space Research Organization (ISRO) has developed standardized protocols in collaboration with key stakeholders including the Indian Council of Agricultural Research (ICAR). Due to which efforts can be made to prevent stubble burning in this area by marking them in time. The objective of this research work is to discuss the availability of remote sensing and GIS applications for characterizing stubble burning incidents and studying the environmental impacts of stubble burning with special reference to Punjab and Haryana.

Research Methodology

This research paper is based on descriptive research method, under which the researcher has compiled the data and information obtained from various sources and discussed it in the research paper. Secondary data has been used in this research paper, which has been obtained from various research papers, magazines and websites. The major websites under the website are https://modis.gsfc.nasa.gov/, https://LANDSAT.gsfc.nasa.gov/ and https://up42.com/marketplace/data/ archive/sentinel-2 in this research paper, the required information has been obtained and its analysis has been presented.

Finding and Discussion

There has been a steady increase in the area under paddy cultivation in Haryana and Punjab from **2015** to **2023.** In Haryana, the area increased from **12.5** lakh hectares to **15.2** lakh hectares, while in Punjab it increased from **28.0** lakh hectares to **32.0** lakh hectares. This increase has also been accompanied by an increase in stubble production, from **30.0** million tonnes in **2015** to **37.5** million tonnes in **2023.**

Table 1: Area Under Paddy Cultivation in Haryana and Punjab from 2015 To 2023

Year	Area of Paddy in Haryana (Lakh Hectares)	Area of Paddy in Punjab (Lakh Hectares)	Straw Production (Million Tonnes)
2015	12.5	28	30
2016	12.7	28.5	31
2017	13	29	32
2018	13.2	29.5	33
2019	13.5	30	34
2020	14	31	35.5
2021	14.5	31.5	36
2022	15	32	37
2023	15.2	32	37.5

Source: Agricultural Statistics at a Glance Year **201**5-11 to 2023

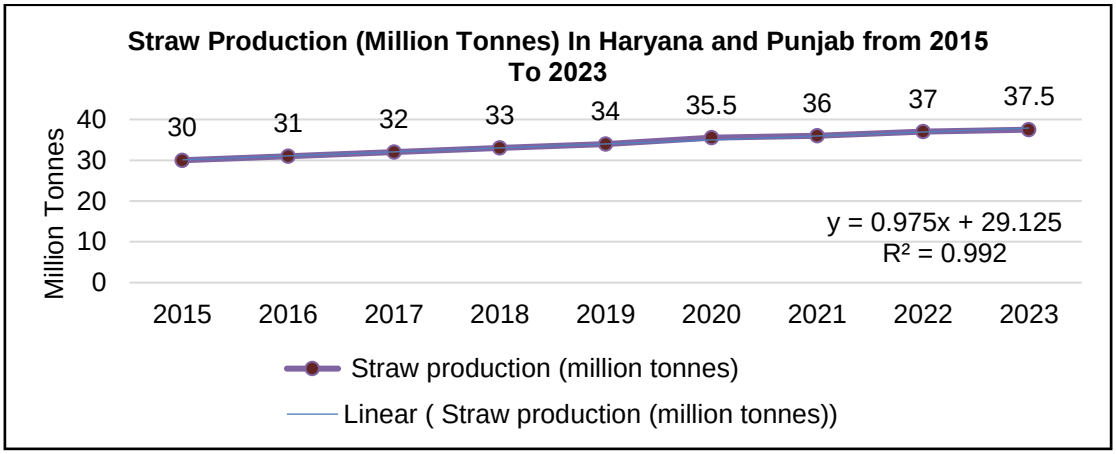

Fig. 1

Burning of paddy straw in Haryana and Punjab has a serious impact on the environment and human health. It results in many problems. Burning of straw emits harmful gases (such as carbon dioxide, methane, and nitrous oxide) and fine particles (PM2.5, PM10) into the air, which deteriorates the air quality. Burning straw destroys organic matter and microorganisms in the soil, reducing soil fertility. Harmful particles present in the smoke cause problems like respiratory problems, asthma, and heart diseases. Emission of greenhouse gases increases the problem of global warming and climate change.

Table 2: Effect of Paddy Straw Burning on Air Pollution

Contaminant	Affected Levels	Influence
PM**2.5** and PM**10**	Extremely High	Respiratory problems, heart disease, eye irritation
Carbon dioxide (CO**2**)	Enhancement of atmosphere	The greenhouse effect and global warming
Methane (CH**4**)	Increased emissions	Global warming potential **25** times greater than CO**2**
Nitrous oxide (N**2**O)	Increased emissions	Damage to the ozone layer and climate change
Carbon monoxide (CO)	Increased emissions	Difficulty breathing, especially in children and the elderly

Source: Nair, M., Bherwani, H., Kumar, S., Gulia, S., Goyal, S., & Kumar, R. (2020)

This is the reason why the government is constantly trying to stop the burning of paddy straw in Haryana and Punjab states. Remote Sensing and GIS technology has proved to be very important in this direction. Remote Sensing and GIS technology has not only helped in monitoring the burning of paddy straw, but it has also helped scientists significantly in determining the environmental pollution caused by the burning of paddy straw in Study area. The researcher has presented a discussion of some important Remote Sensing and GIS Techniques for monitoring the burning of paddy straw and assessing the environmental pollution caused by the burning of paddy straw under Haryana and Punjab, such as-

LANDSAT Satellites

LANDSAT satellites are used effectively to estimate the area of stubble burning. The satellite records electromagnetic radiation reflected from the Earth's surface, allowing sources of fire, smoke and heat to be identified. LANDSAT's thermal and multispectral imagery is helpful in accurately estimating the area of stubble burning. LANDSAT satellites are equipped with thermal infrared and optical sensors that record data at a spatial resolution of up to **30** metres. These sensors detect the distinctive signatures of heat and smoke generated by stubble burning. The heat generated by stubble burning and its thermal signature are recorded by the satellite. Along with this, the area of stubble burning and green areas are differentiated using multispectral bands (particularly red and near-infrared). Data obtained from LANDSAT satellite is used in GIS software to prepare maps of affected areas and through these maps, the trend of stubble burning is studied by comparing it with the data of previous years.

There are many advantages of using LANDSAT satellite. It provides information at high spatial resolution. It provides data at a resolution of **30** meters, which makes it possible to accurately identify the stubble burning area. Along with this, LANDSAT data is available free of cost, making it affordable for researchers and government agencies. LANDSAT satellite provides data from **1972** to the present period, which is helpful in historical analysis. Its multispectral imaging technology is suitable for monitoring stubble burning, crop harvesting and other agricultural activities.

However, there are some drawbacks of using LANDSAT satellite. The revisit period of LANDSAT satellite over an area is **16** days, due to which it is not possible to record data repeatedly. The quality of data is affected in cloudy or haze conditions. Similarly, the resolution of thermal data from the LANDSAT satellite is limited to **100** metres, which hinders the identification of small areas, and analysing the satellite data can be complex and time-consuming.

MODIS (Moderate Resolution Imaging Spectroradiometer) Satellite

The use of MODIS (Moderate Resolution Imaging Spectroradiometer) satellite is an effective method to assess stubble burning under paddy cultivation in Haryana and Punjab. MODIS satellite sensors are installed on NASA's Terra and Aqua satellites and observe the earth's surface twice a day. This sensor provides data in **36** spectral bands, with the thermal infrared band being used to detect areas of stubble burning.

The identification of stubble burning area by MODIS satellite is through thermal hotspots, which detect heat and smoke emanating from the burning areas. Thermal and red bands are mainly used for this. This sensor works at a spatial resolution of up to **1** km, which allows rapid assessment of large areas. During data processing, a map of stubble burning areas is prepared using GIS software.

The main advantage of MODIS is its high temporal resolution, which provides data twice a day. This feature is helpful in continuous monitoring of stubble burning. Additionally, the satellite covers a large area, making state-level assessments easier. However, MODIS has a relatively low spatial resolution, making it difficult to accurately identify small burning areas. Moreover, cloudy or hazy conditions can affect the data quality.

MODIS is particularly well suited to understand temporal and spatial trends. It is helpful in repeatedly monitoring stubble burning and assessing its air pollution impact. However, it is necessary to combine it with high-resolution satellite data such as LANDSAT or Sentinel-**2** for more accurate results.

Sentinel-2 Satellites

The use of Sentinel-**2** satellites in assessing stubble burning under paddy cultivation in Haryana and Punjab is a highly effective and modern technique. Sentinel-**2** is a satellite of the European Space Agency (ESA), which provides multispectral imagery at high spatial and temporal resolution. Its data is useful in analyzing the area, cropping pattern and environmental impacts of stubble burning. Sentinel-**2** has **13** spectral bands, out of which red, near-infrared (NIR), and shortwave-infrared (SWIR) bands are important for identifying stubble burning.

The methodology of this satellite is based on the identification of spectral signatures associated with stubble burning. Smoke and ash from stubble burning in burning areas show high reflectance in red and SWIR bands and low reflectance in NIR. Sentinel-**2** satellite provides data at high spatial resolution of **10** to **20** meters, allowing accurate assessment of stubble burning even in small areas. Moreover, its five-day recurrence period ensures rapid data updates.

The strengths of the Sentinel-**2** satellite include its high resolution, free data availability, and multispectral capabilities. It is helpful in large-scale field assessment and crop health monitoring. The satellite helps in detecting the exact area of stubble burning, effective spatial distribution, and temporal trends.

However, Sentinel-**2** has some drawbacks as well. Its five-day recurrence period may not always be sufficient for real-time monitoring, especially if the weather is bad. Clouds and haze affect its data quality. Moreover, data processing and analysis over large areas require more computing resources.

Conclusion

LANDSAT, MODIS and Sentinel-**2** satellites are critical technologies for delineating areas of stubble burning under paddy agriculture in the study area and assessing its impacts on the environment. LANDSAT provides high spatial resolution (**30** m) and historical data, but is limited by a **16-**day revisit period and sensitivity to cloud cover. MODIS provides better temporal resolution with twice-daily data collection and wider coverage, making it suitable for large-scale monitoring. However, its low spatial resolution (**1** km) limits its ability to accurately detect small burning areas. Sentinel-**2** combines high spatial resolution (**10-20** m) with multispectral capabilities, allowing accurate identification of stubble burning and its environmental consequences. Its five-day revisit cycle ensures more frequent updates, although cloud interference remains a challenge.

If these satellites are used collectively, this technology provides the ability to more accurately delineate areas of stubble burning under paddy cultivation and assess its impacts on the environment. While LANDSAT and Sentinel-**2** excel in spatial accuracy, MODIS ensures temporal continuity. Together, they enable comprehensive monitoring and analysis of stubble burning trends and their impacts on air quality and climate change. Integrating their data with GIS tools leads to the development of actionable maps and policies to mitigate the adverse effects of stubble burning in the region, promote sustainable agricultural practices and protect the environment.

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