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THE STUBBLE BURNING IN THE STATES OF PUNJAB & HARYANA: A GIS BASED SPATIO-TEMPORAL ANALYSIS (from 2012 to 2017)

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Abstract

Spatiotemporal patterns are difficult to portray through traditional methods, but the space-time cube allows time to be analyzed as a third dimension. The spatio-temporal GIS analysis of the MODIS data enables us to know about the varying degree of stubble burning in the regions of Punjab and Haryana. The said activity is one of the crucial reasons for the smog problem that is faced by the NCR (National Capital Region) every winter for last decade. With the help of spatio-temporal tools in GIS, the intensity and trends of the study area, that burns agricultural waste, can be assessed and analyzed.

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INTRODUCTION

North India is known for its notorious drop in temperature during the winter months; which leads to the formation of fog. The urban pockets of the northern front, mainly the NCR or National Capital Region and the capital city of New Delhi suffer a lot during this time.

Being one of the highly populated areas of India, the number of vehicles and the smoke emitted by them had always been the obvious choice to blame for the smog, which is the mixing of the particulate matter of dust and smoke with the already prevailing fog resulting in a thick white veil which makes visibility to the minimum causing several health concerns.

Recent studies however showed that the anthropogenic factor that should also held responsible for the smog situation is the burning of stubble in the adjoining states of Punjab and Haryana, which are majorly agricultural states.

Scientists agree that events like Diwali (a festival celebrated by burning fire crackers) and stubble burning may be pushing pollution to "emergency" levels briefly.

The burning of crop residues in fields is one of the most significant activities of global biomass burning (excluding biofuels; Streets et. al., 2003) that is causing air pollution.

Stubble is the cut stalks of cereal plants left out of the ground after the grain is harvested, in layman's word they are the agricultural waste.

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The Indian state surrounding the NCR has two growing seasons: one from May to September and another from November to April. Many farmers rotate between crops like rice and wheat. In order to quickly prepare their fields for the next crop, they simply burn leftover plant debris since they act as a soil fertilizer.

The burning of stubble, has certain positive attributes for the farmers, which includes that it:

~ Quickly clears the field and is cheap.

~ Kills weeds, including those resistant to herbicide.

~ Kills slugs and other pests.

~ Can reduce nitrogen tie-up However, it has a number of harmful effects on the environment:

~ Loss of nutrients.

~ Pollution from smoke.

~ Damage to electrical and electronic equipment from floating threads of conducting waste.

~ Risk of fires spreading out of control.

After harvesting, the waste rice straw is frequently burned in the open in regions with insufficient time before planting the next crop to remove and dispose of it in a more controlled manner, such as in a furnace or by using another closed burning technique (Calvo et. al., 2011). Almost 90-95% of Paddy area in Punjab, Haryana is under intensive Rice-Wheat-System (Ladha, et. al., 2000). Unlike wheat stalks that are used as animal fodder, the paddy straw has high silica content that animals can't digest. Since farmers need to sow wheat within a fortnight of harvesting paddy, they burn the straw, to save time and money.

Meteorologically speaking, the said time of the year is known for the westerly winds that flow across the tropics and mid-latitudes. The wind flows from west to east and while on its path, it takes the entire smoke of stubble burning from Punjab and Haryana towards NCR and Delhi. The situation of Delhi already remains iffy during this time as the festival of Diwali ends which is celebrated by burning fire crackers that emits additional smoke which just gets worse after mixing with the prevailing influx.

Here, with a spatio-temporal hot spot analysis, we showed the area of Punjab and Haryana that comes under the intense influence of the stubble burning activity and the trend over the period of six years.

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The analysis uses long term retrospective data to study changes in the stubble burning activity over time.

STUDY AREA

The study area covers two of the north Indian state, Punjab and Haryana, which is situated western and north-western side of the capital, New Delhi. They are landlocked states situated at the foothills of the mighty Himalayas. Some of the major rivers flow through these states making them fit for cultivation. Owing to the fertility of the soil present there, both are agricultural states which means major income of both the states come from their agricultural productivity.

Fig:01 Map of study area (source: Google imageries)

METHODOLOGY

Satellite data captured by the MODIS was used for analysis. The data is collected from the website of NASA and analyzed in the Arc GIS software to produce maps showing specific trends.

The MODIS active fire and burned area software contain information unique to understanding the timing and spatial distribution of fires and their characteristics. The MODIS active fire software detects fires in 1km pixels that are burning at the time of overpass.

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They are spatio-temporal data which we took to show the trend of stubble burning across the study area along a period of six years. The maps show the most generally marked hot spots and their patterns over the years.

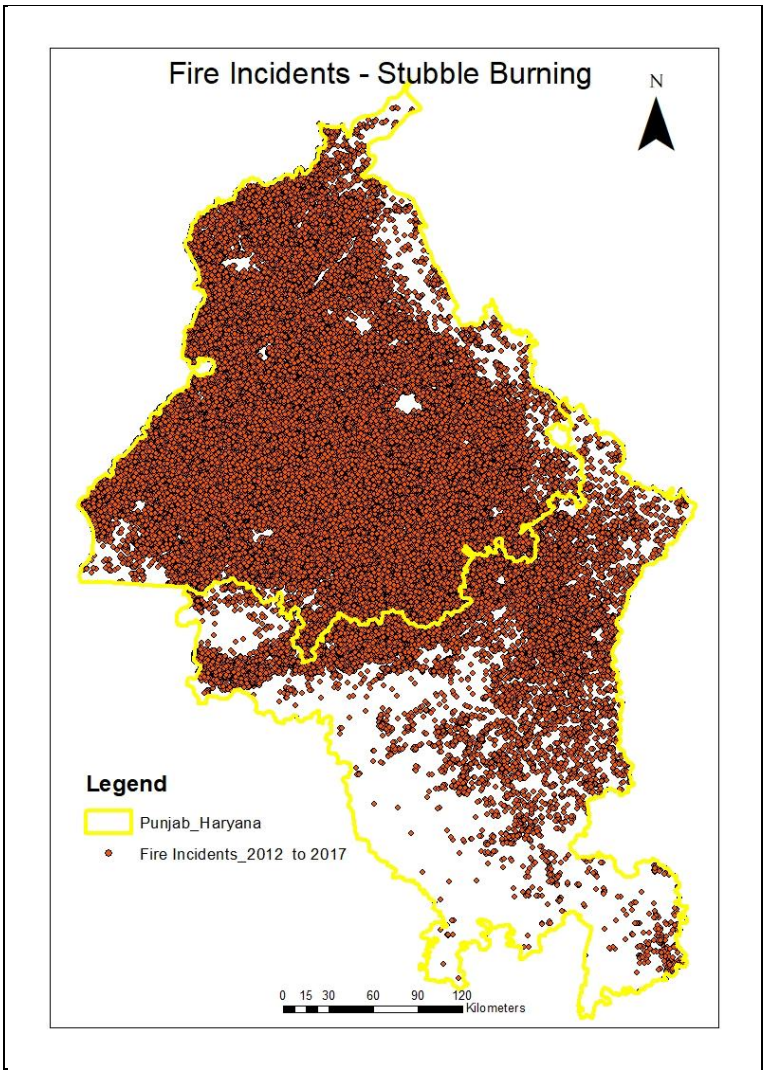

Fig: 02 Fire incidents from 2012 to 2017 in Punjab and Haryana (source MODIS data)

THE SPATIO-TEMPORAL ANALYSIS

1. **Space Time Cube** - The focus of this project required exploring the stubble burning data in both space and time. Spatiotemporal patterns are difficult to portray through traditional methods, but the space-time cube allows time to be viewed and analyzed as a third dimension, with the spatial locations represented by x and y and time represented by the z-axis. Each month of stubble burning data is considered as one time slice of the space-time cube for six years. The default Distance Interval is 5929 meters. The space time cube has aggregated 129808 points into 8080 hexagon grid locations over 71 time step intervals. Each location has a height of 5929 meters, a width of 6846.22

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meters, sides of 3423.11 meters, and an area of 30443426.53 square meters. The entire space time cube spans an area 412484.72 meters west to east and 598829 meters north to south. Each of the time step intervals is 1 month in duration so the entire time period covered by the space time cube is 71 months. Of the 8080 total locations, 3545 (43.87%) contain at least one point for at least one time step interval. These 3545 locations comprise 251695 space time bins of which 27186 (10.80%) have point counts greater than zero.

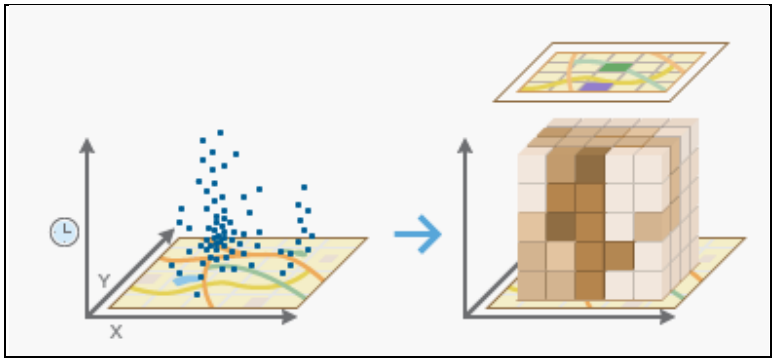

Fig:03 The space time cube

The results of the space-time cubes are analyzed using the space time pattern mining tool suite, which includes the

~Mann-Kendall Trend Test

~Emerging hot spot analysis tool

~ 2D and 3D visualization tools.

2. **Mann-Kendall Trend Test** – The space-time cube tool packaged the bin dataset into a Net CDF file with trend data created from the Mann-Kendall trend test. The Mann-Kendall test compares each bin value with the value from the previous year. If the value is greater than the previous year, the bin is given a1 value. If the value is less than the previous year, the bin is given a -1 value. If there is no change, the bin is given a 0 value. The resulting values for each bin are added together to determine the overall trend. No trend results in a 0 value. Positive or negative scores indicate an overall trend in the data (Esri 2017b). The Mann-Kendall trend analysis is a valuable tool for determining overall trends in data without making too many assumptions about the data itself. It is a non-parametric rating system that is sensitive to slight overall trends rather than assessing the data based on fluctuations from a median value (Cotter 2009). Overall trend values can show many changes in the stubble burning around six years of collected data.

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3. **Emerging Hotspot Analysis** - The emerging hot spot analysis technique improves upon traditional hot spot methods by including time. Rather than running a hot spot analysis for each year independently, in emerging hot spot analysis neighbors in both time and space contribute to the determination of a hot or cold spot. The hot spot analysis was completed using the Getis Ord Gi* statistic.

   This tool compares data in each cell with the surrounding cells within the parameters and identifies trends in the clustering of point densities (counts) or summary fields in a space time cube created using Create Space Time Cube. Categories include new, consecutive, intensifying, persistent, diminishing, sporadic, oscillating and historical hot and cold spots.

The default neighborhood distance here is taken as 26467.341919 meters while the distance interval is 5929 meters.

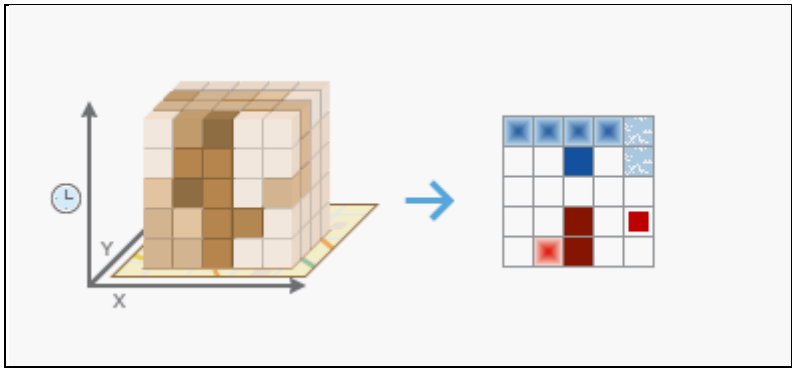

Fig:04 Determining the emerging hotspots from the space-time cube

4. **Space-Time 3D Visualizations** - Visual identification of spatial patterns is often the first step to discovery and explanations for the underlying processes. The space-time cube allows for much different visualization that uncovers different parts of the same story. The Create Space Time Cube tool summarizes point datasets into a net CDF data structure by aggregating the points into space-time bins that form a cube. Each bin within the cube contains a count of the number of points that occurred at the bin location for the time-step interval specified.

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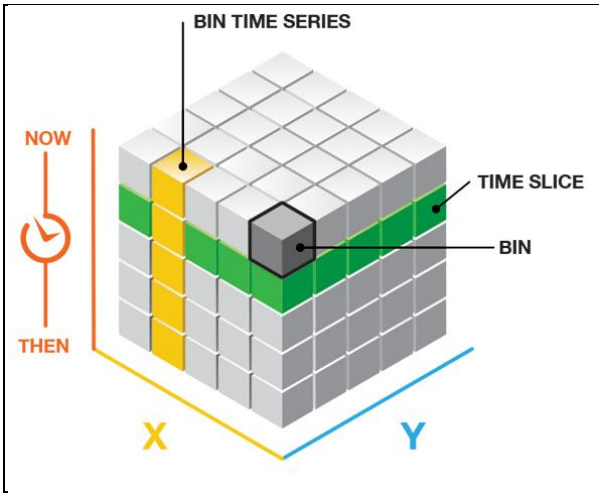

Fig:05 3D visualization of space time cube

RESULTS AND ANALYSIS

The spatial "footprint" of the stubble burning is shown using several exploratory tools in Arc GIS Pro 2.1.

The resulting analyses show which areas were mostly influenced by the burning and how it changed over time.

Space Time Cube is the aggregation of the original point datasets that was completed by the ArcGIS Pro 2.0. The result shows the number of cases of fire due to stubble burning that has been reported in the last six years

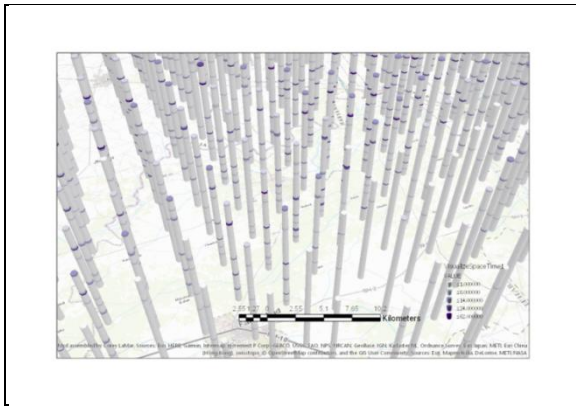

Fig: 06 Number of fire cases reported due to stubble burning (2012-2017) (source author)

The Mann-Kendall trend test results show the overall increase or decrease of the values in each bin. Districts such as Rohtak, Karnal, Hisar, Muktsar, Fatehgarh Sahib, Gurdaspur showed downward trend while districts such as Fatehabad, Bhatinda, Firozpur, Mansa, Patiala showed upward trend. Some districts such as Kaithal, Kurukshetra, Ambala, Amritsar, Hoshiarpur, Rupnagar showed both upward and downward trend.

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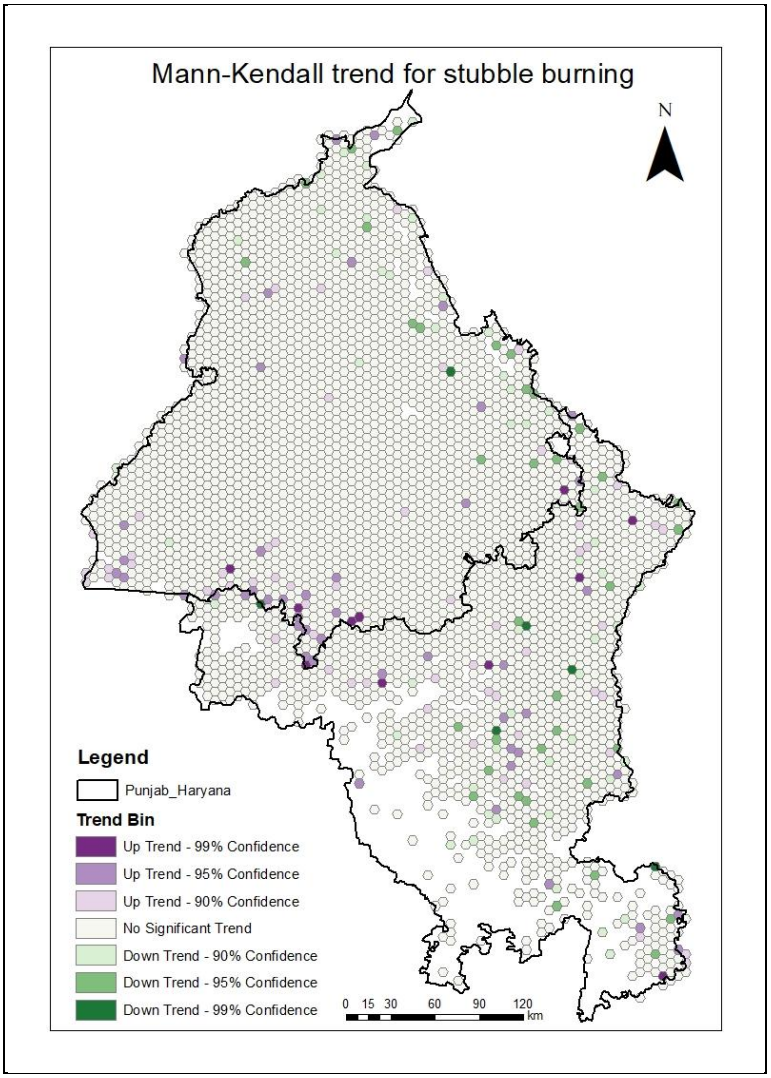

Fig:07 Trend of the number of fire cases due to stubble burning (2012-2017) (source author)

The emerging hot spot analysis takes into account both consistency and intensity for each time step to determine a classification of the hot or cold spot. Time is a more important factor in this analysis than the simple cumulative z-score because each time step is assessed in relation to the others. Results of the emerging hot spot analysis classify Punjab and Haryana as Oscillating Hot Spot. Although this area is consistently identified as a hot spot, its intensity has diminished over time.

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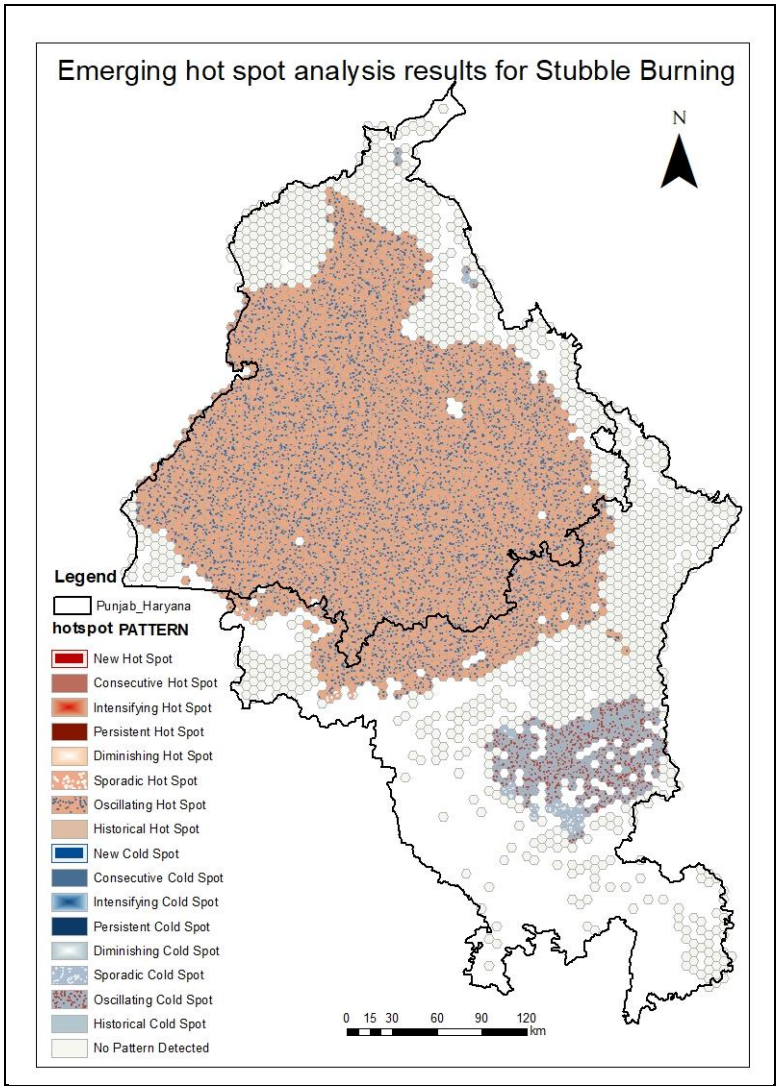

Fig: 08 Pattern of hotspots (source author)

The three-dimensional hot spot analysis allows the entire stack of the space-time cube to be viewed. Areas that were marked Oscillating Hot Spot in the emerging hot spot analysis can be examined through the complete annual range using this method. Most locations are hot spot.

The top layer shows data from the last time step, 2017.

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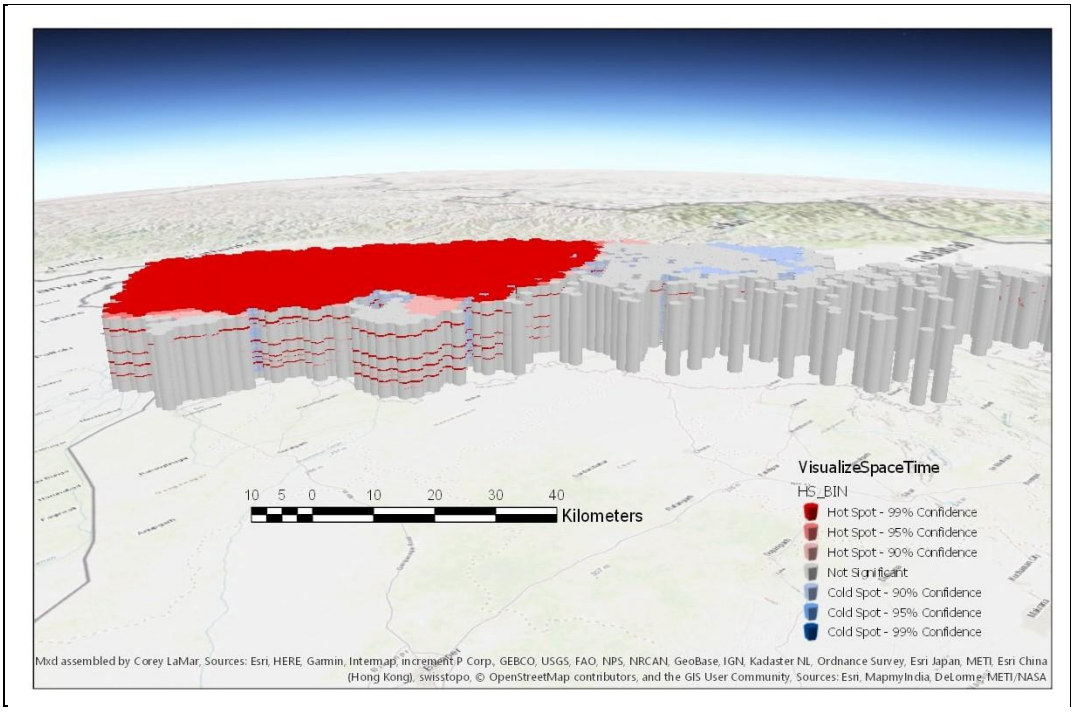

Fig:09(a) The result of 3D hotspot analysis by cumulating the incidents and yearly data (source author)

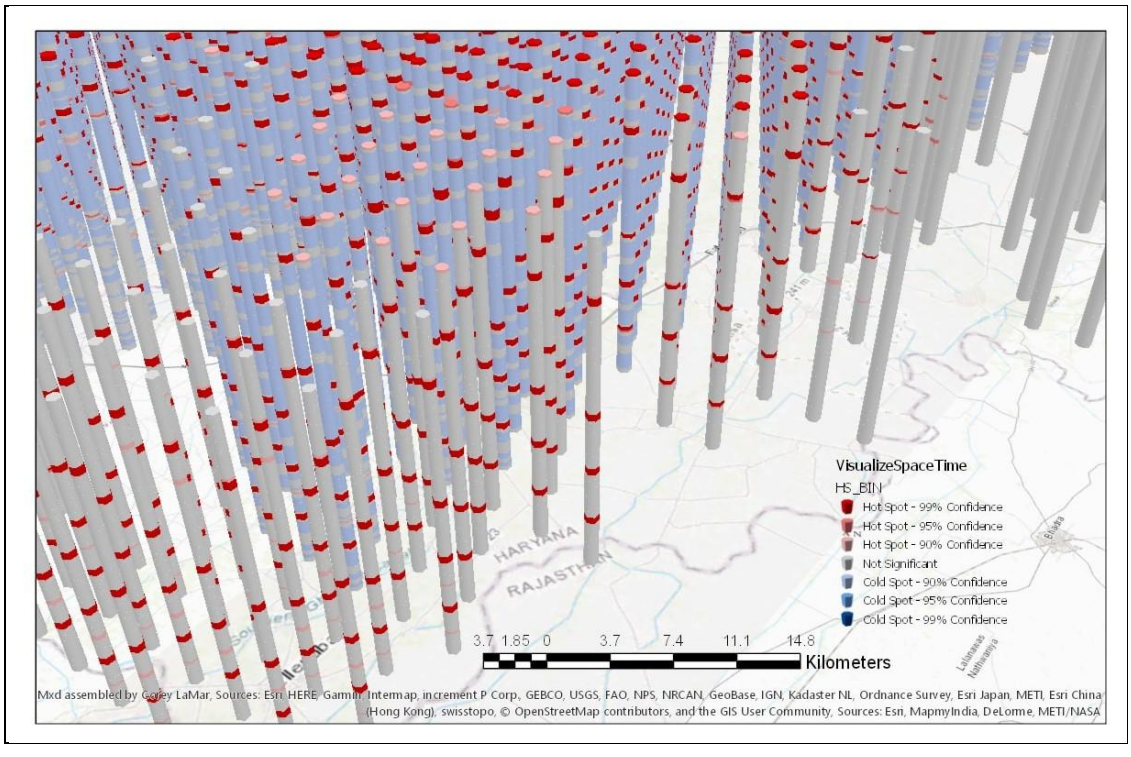

Fig: 09(b) The result of 3D hotspot analysis by studying each incident separately with yearly data (source author)

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DISCUSSION

MODIS fire data of six years, was acquired from the website of NASA, and analyzed with the help of ArcGIS. Spatiotemporal patterns are difficult to portray through traditional methods, but the space-time cube allows time to be viewed and analyzed as a third dimension making it easier to pin point the areas.

By using tool-suits like:

~Mann-Kendall Trend Test

~Emerging hot spot analysis tool

~ 2D and 3D visualization tools,

The hotspots and pattern of stubble burning over the years are shown.

CONCLUSION

The study shows the pattern of the fire due to stubble burning. Districts such as Rohtak, Karnal, Hisar, Muktsar, Fatehgarh Sahib, Gurdaspur showed downward trend while districts such as Fatehabad, Bhatinda, Firozpur, Mansa, Patiala showed upward trend. Trend in the oscillating hotspot should also be taken under consideration while making policies for future, and also to evaluate the effect of existing policies that are implemented.

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