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Estimating *area* under *In situ* Crop Residue Burning in District Bathinda, Punjab, India using Satellite Imaginaries

Roopjit Kaur[1,2*], Manjeet Bansal[2], Seema Sharma[3]
[1]Junior Research Fellow, Biotechnology, I. K. Gujral Punjab Technical University, Jalandhar- 144603, Punjab, India
[2]Department of Civil Engineering, Giani Zail Singh Campus College of Engineering & Technology, Bathinda-151001, Punjab
[3]Department of Applied Chemistry, Giani Zail Singh Campus College of Engineering & Technology, Bathinda-151001, Punjab
*Email: roop.cevs@gmail.com

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Abstract

Satellite imaginaries and remote sensing is a very useful technology for the monitoring of *in situ* crop residue burning at regional and global level. It is very important to monitor and estimate the area under *in situ* crop residue burning to further estimate its impact on air quality and in turn health of localities. The current study was an attempt to monitor area under *in situ* crop residue burning by satellite imaginaries of LANDSAT, MODIS (Moderate Resolution Imaging Spectroradiometer), (Tera & Aqua images) in District Bathinda, Punjab, India. *In situ* crop residue burning for the year 2014 and 2015 was monitored for both Rabi and kharif sessions. The analysis of satellite imaginaries using QGIS software indicate that during Rabi season the area under *in situ* crop residue burning was 48.63% and 34.76% of total area under agriculture in Bathinda district for the year 2014 and 2015, respectively. However, the area burnt during the kharif was accounted 5.59% and 8.33%, respectively, for 2014 and 2015 for the same.

Introduction

In situ agriculture residue burning is defined as burning of crop residues (stem and roots) still anchored to soil through roots in agricultural fields left after harvesting of crop. *In situ* agriculture residue burning is a worldwide problem of agricultural nations and especially developing countries. With the advent of new technologies and crop varieties, the farmers have been able to utilize their agricultural fields several times for crop production. Earlier, only 2 crops, one during Rabi and other during kharif season were grown but now crops are grown even for 3 or more seasons. This leaves very less time between harvest of one crop and sowing of next crop. Hence, the farmers find it easy to get rid of crop residues by burning them in the fields. The agriculture mechanization especially harvesting by combines has also added to this problem. These combines harvest the only top layer having grains and leave the stem and roots intact in fields. Removing of these residues manually is costly and time consuming affair. Hence, the farmers find it easy to burn these residues after drying in the agricultural field by spraying petrol/diesel. Further, some farmers burn the crop residues *in situ* with the belief that in this way the farm will get rid of the diseases of previous crops and crop production will be higher in next season.

Though it saves time and may be economical for farmers, it has become a great nuisance for the people not only of the area but to even faraway places wherever the pollution of biomass burning travels. During burning period, a large number of harmful gases are released, which influence climate, environment, health, agricultural fields and land cover. It was estimated that at global level 90% of crop residue burning is caused by anthropogenic activities and only 10% by natural activities like atmospheric lightning (Sahu *et al.,* 2015). Degradation of air quality impairs visibility, produces smog, global warming and leads to imbalance of the global climate system at regional or global scales.

The actual status of affected area under crop residue biomass burning gives an idea of the total residue burnt, its quantitative effect on air, soil pollution etc. This in-turn helps to form policies and apply preventive measures. Manually, it is very difficult to monitor and calculate the area under burning as the crop residue burning is not a continuous and in a single stretch process. The crop residue burning takes place randomly in patches and continues approximately for 30 to 45 days. In this regard, the use of remote sensing is very effective tool for monitoring of biomass or stubble burning. Satellite Remote Sensing is the only measure, which can produce quantitative information of fire events on global scale along with geo-coordinates of burning places. Currently, satellite based fire images are used frequently for the prediction of biomass burning affected areas. Satellite-based fire observations can offer a reliable source of fire occurrence data on regional and global scales (Junpen *et al*., 2018; Zhuang *et al.,* 2018; Lasko *et al*., 2017).

In one of the previous studies, Badarinath *et al*., (2006) used the data from Indian Remote Sensing satellites (IRS-P6) and Advanced Wide Field sensor (AWiFS) for estimating the extent of crop residue burning in Punjab during wheat and rice crop growing periods. Punia *et al*. (2008) studied the feasibility of using MODIS and AWiFS satellite data for burned area patches in Punjab and Haryana. Singh *et al*. (2009) used LISS-III, LISS-IV, MODIS and AVHRR satellite data for quantitative estimation of burnt areas in 2 districts of Punjab. Yadav *et al*. (2014) used multidate AWiFS data from Resourcesat 1 and 2 satellites data for monitoring seasonal progress of rice stubble burning in some districts of Haryana (Thumaty *et al*., 2015).

Biomass-burning is widespread problem of Punjab. Punjab produces around 23 million tons of rice straw and 17 million tons of wheat straw annually. More than 80% of paddy straw (18.4 million tons) and almost 50% wheat straw (8.5 million tons) produced in the state is being burnt in fields every year (SOE Punjab, 2007). Farmers of this state burn around 80-85% crop residue in fields. Rabi and Kharif are the two main seasons of biomass burning. Straw burning practices are very common in all areas of Punjab. The highly agricultural intensive region Bathinda district of Punjab is selected for target study. High level of biomass burning practices in Bathinda district of Punjab is the reason to choose study area. In this article, the burning area of Bathinda district of state Punjab has been estimated for the years 2014 and 2015, where a significant amount of biomass burning occurred. So, as the incidents of biomass burning events are prevalent, this study is attempted to monitor the affected areas of biomass burning in district Bathinda from 2014 to 2015 in both Rabi and Kharif seasons. In this regard, the prediction or monitoring of biomass burning areas will be very helpful for the policy maker, government and people, which are living in this agri-intensive area.

Description of Study Area

District Bathinda is located on the northwestern region of India and is a part of the Indo Gangetic alluvial plains (Figure 1). It lies on co-ordinates 30.20°N and 74.95°E and has elevation of 201metre (660ft) from sea level. It is the seventh biggest urban district by area in the state Punjab and has an area of 3,344 km^2; out of this nearly 2840 km^2 is under agriculture. Wheat (Rabi), rice & cotton (Kharif season) are the major crops of this area (Table 1). Average rainfall is in a range of 20 mm to 40 mm with semi-arid and having high variation between summer and winter temperatures.

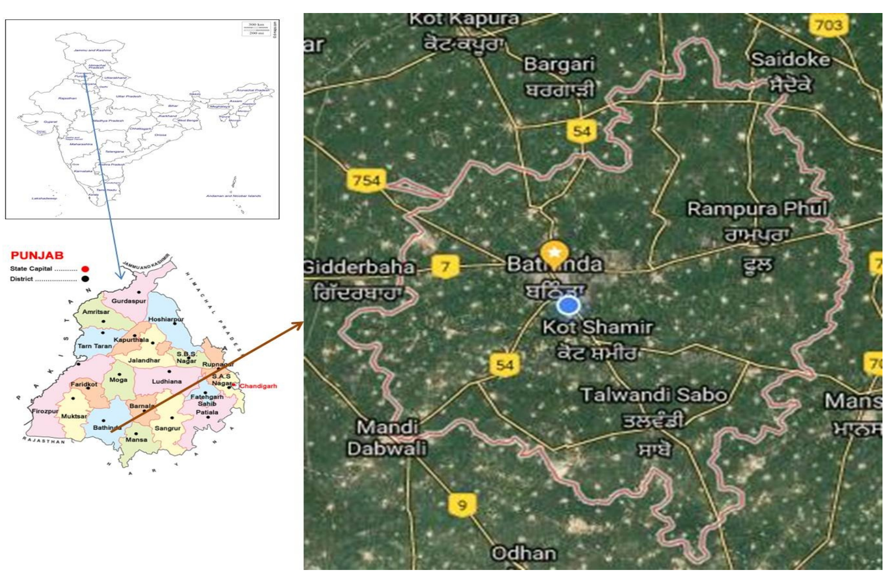

Figure 1. District map of Bathinda (study area)

Table 1: Total area and production of rice, cotton and wheat during year 2014 and 2015

YEAR	Total area under agriculture (Km^2)	Rice		Cotton		Wheat	
		Area (Km^2)	Production (Kg/Hectare)	Area (Km^2)	Production (Kg/Hectare)	Area (Km^2)	Production (Kg/Hectare)
2014	2840	1190	4444	1370	613	2540	4797
2015	2840	1370	4530	1120	179	2530	4679

Source: Statistical abstract of Punjab 2014 & 2015

Material and Methods

Collection of active fire points: The collection of active fire locations was done using remote sensing satellite datasets captured by MODIS instrument on boarded at Tera & Aqua satellite launched by National Aeronautics and Space Administration (NASA) (http://earthdata.nasa.gov/labs/worldview).

Rice straw burning period was observed between 1 October and 30 November (Rabi Season) whereas time period 15 April to 30 May (Kharif Season) was considered in case of wheat straw burning. However, it was observed that 99% of the burning took place between 25 April to 22 May and 12 October to 22 November. So, MODIS Terra/Aqua images of Rabi and kharif seasons are reported here for 12 October to 22 November and 25 April to 22 May, respectively. In this study, fire and thermal anomalies captured by TERA, AQUA and combined TERA / AQUA has been used. The time of Terra passes is at 10.30 am whereas time of Aqua pass is 1.30 pm. The entire methodology has been categorized into two segments (Giglio *et al*., 2003; Justice *et al*., 2002a; Justice *et al*., 2002b; Loboda *et al.,* 2007; PRSC, 2015) and is further depicted in figure 2.

- Classification of total cropped area seasonally
- Classification of total active fire locations seasonally

Cropped area classification: The cropped area classification helps to identity the total land covered by the types of crop sown in an area. In this study, the classification of land use has been done using ERDAS Imagine software applying supervised classification technique on satellite images acquired by landsat 7 & 8.

Separation of points according to date and seasons: The data provided by the MODIS data portal was in the form of images. The snap short of the image has been taken and the image was exported to QGIS Software for the geo-referencing, pixel extraction and other analysis.

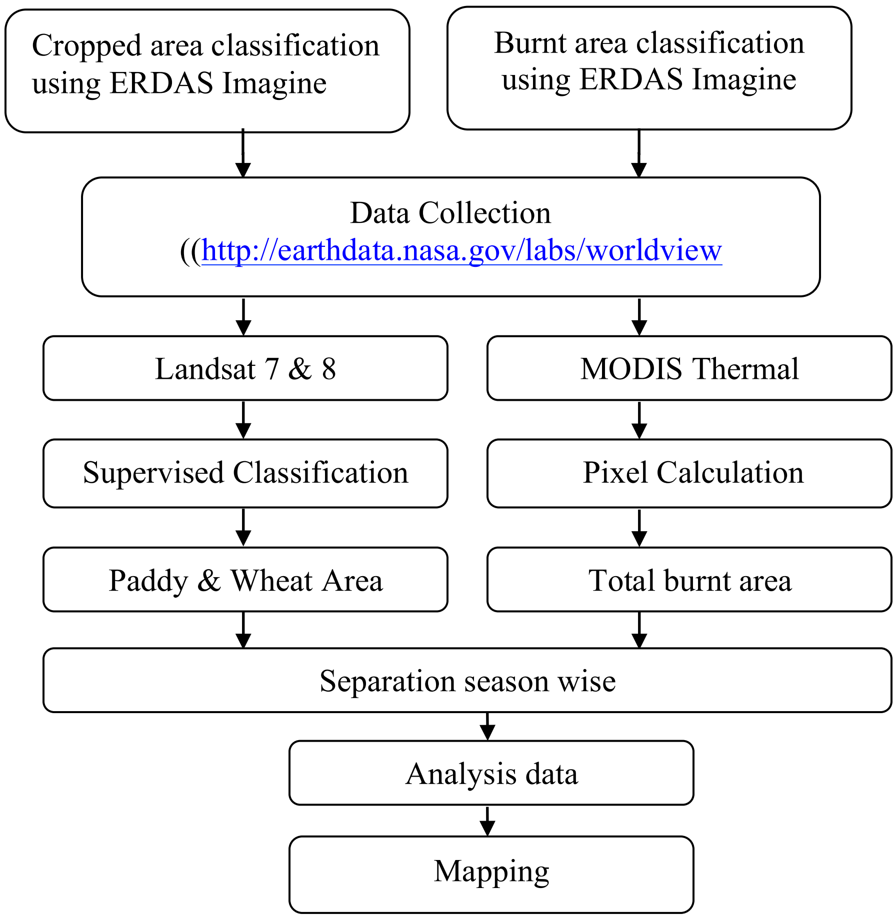

Figure 2. Flow chart showing methodology used for experimental work

Analysis of data sets and area Calculation

Extracted data sets have been further used for analysis. In this step location of the active fire points and number of pixels have been counted. The area calculation was done by counting number of pixels (date wise) extracted by different sensors. The extracted data set has been classified according to cropping season (Rabi & Kharif).

However, some limitations of this study are problems of data recording in cloudy & rainy days, differentiation of straw burning & other types of fire, type of crop burnt, chances of false fire points etc.

Results

During Kharif season (wheat as major crop), *in situ* crop residue burning was observed between 25 April to 22 May during the year 2014 and 2015. Figure three shows that the burning was on its peak during 2 May to 8 May with 78 and 102 fire counts during the year 2014 and 2015, respectively. Further, during the next 2 weeks the number of fire counts decreased sharply. The total number of fire events during the year 2014 and 2015 were 1235 and 950, respectively. Here, we can draw the conclusion that the number of fire events was higher during 2014 as compared to 2015. On the basis of fire events and pixels of each fire point, area under burning was calculated. It was calculated that the *in situ* crop residue burning area during kharif season 2014 and 2015 was 142.04 and 210.614 km^2, respectively (Table 2). This accounts for the 5.59% and 8.33% of total area under agriculture and 5.22% and 7.74% of total district area (Table 2). The area under crop residue burning during 2014 was higher than 2015.

Table 2: Total area, percent area of total agriculture and particular crop under burning during Rabi & kharif season during the years 2014 and 2015

	Kharif Season		Rabi Season	
Year	2014	2015	2014	2015
Area Burnt (Km^2)	142.04	210.614	1244.83	865.48
% area under burning of total area agriculture land (Km^2)	5.22	7.74	45.43	31.59
% area under burning of total area of crops (Km^2)	5.59	8.33	48.63	34.76

Similar to Kharif season, the number of fire events for the Rabi season (Rice and cotton as major crops) for the years 2014 and 2015 were counted. The results of the MODIS data show that the burning starts from 2nd week of October and continues till end of November. The highest number of fire events witnessed in last week of October (26 October – 1 November) and first 2 weeks of November (2 – 15 November) in both the years i.e. 2014 and 2015 (Figure 4). The total number of fire events during the Rabi season in the year 2014 and 2015 were 116 and 172, respectively. The area calculated under *in situ* crop residue burning during Rabi season in the year 2014 and 2015 was 1244.83 km^2 and 865.48 km^2, respectively. This accounted for the 48.63 and 34.76% of total area under agriculture and 45.43% and 31.59% of total district area. Further, the supervised crop classification maps show that the majority of *in situ* residue burning occurred in rice agricultural fields (Table 2). Further, the number of fire events and area under burning was less in 2015 as compared to 2014. Additionally, the comparison between kharif and Rabi season shows that the percentage of burning during Rabi season was much higher compared to kharif season (Figure 5).

The images of fire events are mapped in map of district Bathinda separately in burning period of rice and wheat straw. The fire events of whole Rabi & kharif seasons in two separate files were provided by NASA Earth data FIRMS (Fire Information for Resource Management System). Further, fire events of both Rabi and kharif straw burning period of 2014 and 2015 are depicted on map of Bathinda district in Figure 6 (a-

d) with the help of QGIS version 2.8. Some individual images of straw burning and their locations on Map are depicted as in figure 7.

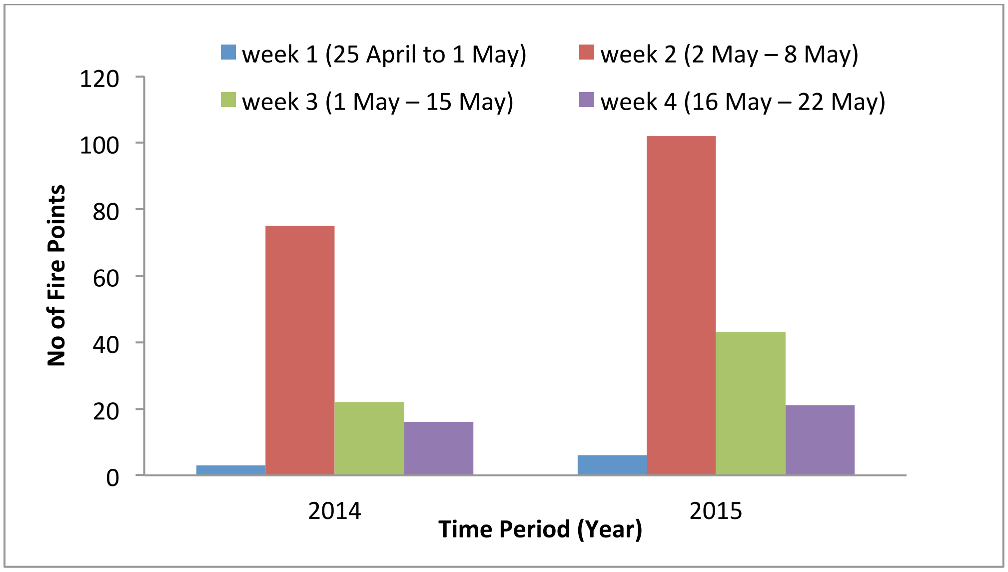

Figure 3. Fire events during kharif season

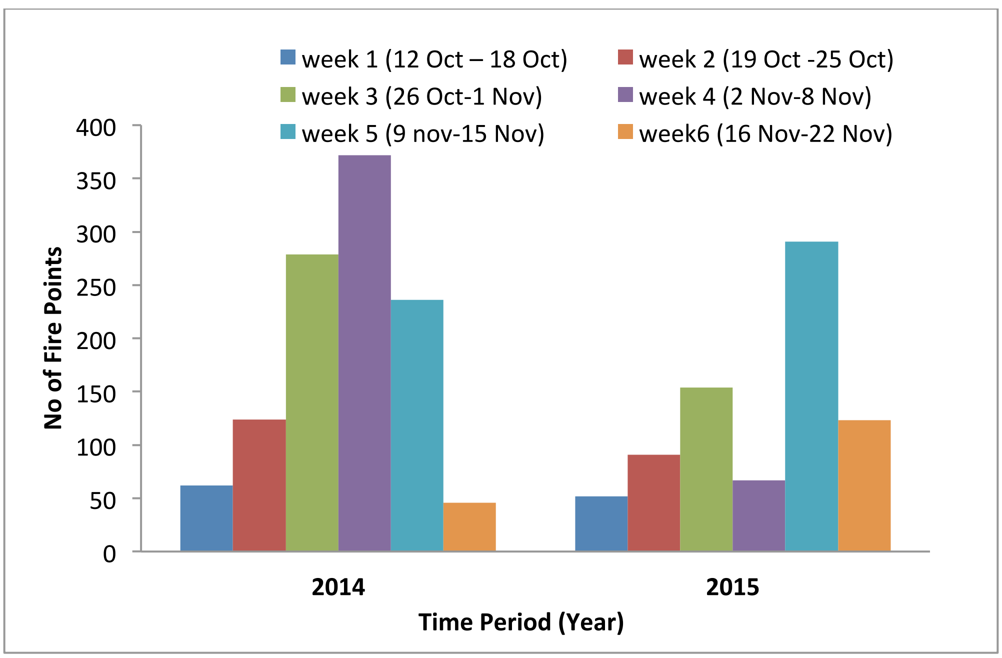

Figure 4. Fire events during Rabi season

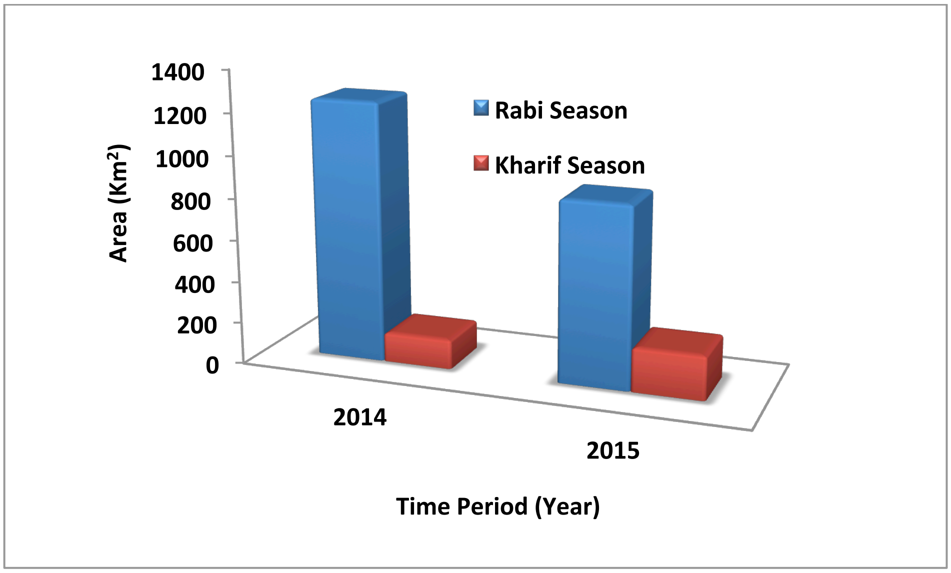

Figure 5. Biomass residue burning during the year 2014 and 2015

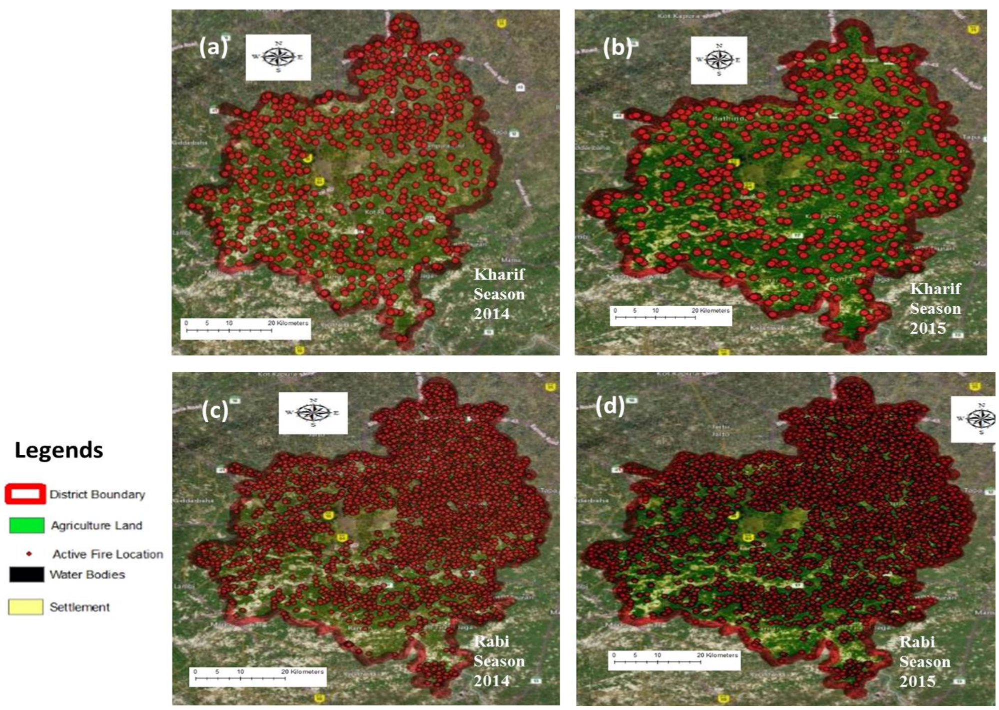

Figure 6 (a-d). Burning fire events in Kharif & Rabi Season during year 2014 and 2015

Figure 7. Location of active fire points in district Bathinda

Discussion

The study revealed that the *in situ* crop burning during Rabi season is much higher than kharif season. This is because wheat straw (stem) is used as cattle feed by the farmers. Hence, after straw harvesting, very less amount of biomass is left for burning. Secondly, wheat is harvested in the month of April and there is enough time for the sowing of next crop as next crop is usually sown in the month of June or July. But in case of Rabi season, rice crop residues have no significant use for farmers and the sowing period for next crop is very less. Hence, farmers find it easy to burn the residues directly without applying any other alternative method. The results have shown reducing trend of burning affected area in straw of Rabi season (Fig 4) in year 2015 as compared to 2014. This may be due to awareness among the local people and strict rule and regulations of government. Punjab Remote Sensing Centre has also reported similar trends in study report of 2015 (PRSC, 2015). The report stated that the rice biomass burning area decreased from 98,310 to 77,490 hectares from 2014 to 2015 during Rabi season. The another report of Badarinath *et al.* (2008) used Indian Remote Sensing Satellite (IRS-P6) Advanced Wide Field Sensor (AWFS) data during May and October 2005 for estimating the extent of burnt areas and the resulting Green House Emissions (GHG) from crop residue burning. The authors concluded that the emissions from wheat residue in Punjab were relatively low as compared to the paddy residue. However, due to the lack of alternatives, it is very difficult to stop it completely. The burning of paddy and wheat straw in the fields has been banned in the state. Recommendations of the Task Force set up by the government for suggesting alternative uses of straw need to be implemented. These include using straw (especially paddy straw) for power generation, as feed and bedding of animals, as mulch, etc. In this concern, Punjab government has already layed 1st bio-ethanol plant foundation stone at district Bathinda. Environmentalists say that there is no solution as crop residue burning itself is at peak in Punjab as farmers have to sow the next crop in less than 20 days and burning is the only solution to remove the residues.

Conclusion

This study provides an account of the agriculture crop residue burning in Punjab during Rabi and kharif crops growing periods. MODIS data during Rabi and kharif session for 2014 and 2015 have been analyzed for estimating the extent of burnt areas and from crop residue burning. The burning affected area of rice during Kharif season is more than wheat straw burning during Rabi season. Results indicated that the crop residues burning in Punjab decreased in 2015 compared to 2014.

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Author's Contribution: Ms. Roopjit Kaur (Research Scholar) performed the research experiments, interpreted the data and wrote the manuscript. Dr. Manjeet Bansal and Seema Sharma (Supervisor and Co-supervisor) designed the work, supported in writing the article and corrected it.

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