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Area estimation of paddy stubble burning in ten major paddy growing districts of Haryana, India using geo-informatics

Manoj Yadav, R. Prawasi, Satyawan, Pooja Rana, Kiran Kumari, Shyam Lal, Karamdeep, Siddharth and R.S. Hooda
Haryana Space Applications Centre (HARSAC)
C.C.S.H.A.U. Campus, Hisar- 125004, India
Email: manojyadav60@rediffmail.com

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Abstract: The present paper describes the methodology and results of assessment of paddy stubble burnt areas for ten major paddy growing districts of Haryana. Mechanized combine harvesting technologies, which have become common in Haryana and Punjab states, leave behind large quantities of straw in the field. As the fields are immediately required to be vacated for the sowing of next crop, the farmers opt for easy way out of burning the stubbles in the field. Such burning results in release of polluting gases and aerosols. Besides, the heating of the soil kills the useful microflora of the soil causing soil degradation. Multi-date AWiFS data from Resourcesat 1 & 2 satellites between October 14, 2013 to November 26, 2013 were used for the study. In-season ground truth data collected using hand held GPS along with field photographs were used to identify paddy stubble burnt areas and other land features. Complete enumeration approach and Iterative Self-Organizing Data Analysis Technique (ISODATA) unsupervised classifier was used for digital analysis. Normalised Difference Vegetation Index (NDVI) of each date was also used with other spectral bands of temporal stacked images. To improve the classification accuracy the non-agricultural areas were masked out. The area was estimated by computing pixels under the classified image mask. The area estimates are based on the available satellite data and the burnt paddy stubble area identified on the multi-date images. Total paddy stubble burnt area in the ten project districts was observed to be 208.34 thousand hectares. Study indicates that concentration of burnt paddy stubble area is more in three northern districts i.e. Karnal, Kaithal, Kurukshetra and one western district i.e. Fatehabad as compared to other study districts. Concentration of burnt paddy stubble area is moderate in Sirsa and Ambala districts while in Jind, Yamunanagar, Sonipat and Panipat districts very less paddy stubble burning was observed. Due to non availability of multi-date cloud free LISS-III data, in-season multi-date AWiFS data was used. The data were found to be useful to some extent for the estimation paddy burnt stubble areas at district level.

Keywords: Paddy, Stubble, Ground control points, Crop residue, NDVI

1. Introduction

Almost 90-95% of Paddy area in Punjab, Haryana and Western UP in India is under intensive Rice-Wheat-System (RWS) (Ladha et al., 2000). RWS in Haryana is mostly concentrated in the north-eastern and north-western part of Yamuna and Ghaggar flood plains occupying 9.16 lac hectares, which is 24.75% of the total agricultural area of the state (Panigrahy et al., 2008). Now it has become approximately 12 lac hectares, which is about 33% of total agricultural area. Mechanized combine harvesting technologies, which have become common in RWS in India, leave behind large quantities of straw in the field for open burning of residue. The burning of rice residue emits green house gas emissions as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), pollutants as carbon monoxide (CO), particulate matter (PM) and toxic as polycyclic aromatic hydrocarbons (PAHs) due to the incomplete combustion process (Lemieux et al., 2004 and Duan et al., 2004). The emissions of CH_4, CO, N_2O and NO_x have been estimated to be about 110, 2306, 2 and 84 Gg respectively, from rice and wheat straw burning in India in the year 2000 (Gupta et al., 2004). Residue burning causes nutrient and resource loss and adversely affects soil properties, thus calling for improvement in harvesting technologies and sustainable management of RWS. As per one study nearly 5504 km^2 of wheat crop area and 12685 km^2 of rice crop area was burnt during 2005 in Punjab state (Badarinath et al., 2006).

Burning of crop residue leaves black coloration of the field which can be picked up and assessed by remote sensing. Such attempt has been made for Punjab using course resolution AWiFS satellite data for the year 2005 (Badrinath et al., 2006). However, they have used a single date satellite data for both the seasons. Techniques of remote sensing (RS) based crop discrimination and area estimation including single date approach based on maximum likelihood classification as well as hierarchical classification has been developed in India (Dadhwal et al., 2002). As residue burning and ploughing the fields is a gradual process, all burning areas may not be picked up in the single date imagery**.** Singh et al. (2009) investigated the use of multi-sensor characteristics for the accurate assessment of crop residue burnt areas at regular interval for two districts of Punjab. They used temporal LISS-III, LISS-IV, MODIS and AVHRR data of pre-burning and post burning for quantitative estimation of burnt areas. The multi-temporal image difference technique using three different indices, NDVI (Normalized Difference Vegetation Index), NBR (Normalized Burn Ratio) and GEMI3 (Global Environmental Monitoring Index) were used to

identify crop stubble burnt areas (Singh et al., 2009). Moderate resolution LISS-III data was found to be useful for accurate estimation of burned surface. Area estimation of burnt paddy stubbles for major paddy growing districts of Haryana was attempted by Yadav et al. (2014a & b) using multi-date AWiFS sensor data of Indian satellites. Crop residue discrimination over agricultural fields of Moga and Naraingarh areas of Punjab state of India was attempted by Singh et al. (2013) using hyper spectral data.

In view of the adverse impacts of crop residue burning, environment agencies and courts have taken a serious note of it and asked the government to map and monitor such areas. However, no ground based Girdawari data is available with the Government for the same. In a meeting held under the chairmanship of Principal Secretary, Environment-cum-Chairman, Haryana State Pollution Control Board (HSPCB), the need for getting a detailed remote sensing based survey done was emphasized as the same has been desired by Environment Pollution (Prevention & Control) Authority of National Capital Region (EPCA). In view of the above, the present study was undertaken with following objectives:

- To develop and demonstrate methodology for assessment of crop residue burning using satellite data.
- To estimate district wise area of paddy stubble burning in 10 major districts of Haryana.
- To prepare district wise maps of paddy stubble burning area in the project districts to study regional variability in crop residue burning.

2. Materials and methods

2.1 Study area

Ten project districts namely Ambala, Fatehabad, Jind, Kaithal, Karnal, Kurukshetra, Panipat, Sirsa, Sonipat, and Yamunanagar situated between $28^0$45' to $30^0$35' N latitudes and $74^0$25' to $77^0$40'E longitudes, were selected for the study as these districts contribute more then 84% of the paddy area of the state (Figure 1). The geographical area of these ten districts is 1574, 2538, 2702, 2317, 2520, 1530,1268, 4277, 2122 and 1768km^2, respectively. The project districts have a sub-tropical continental monsoon climate with hot summer and cool winter. The average annual rainfall of districts for the four years 2007-2010 varied between 267mm in Western district Sirsa to 964mm in most northern district Yamunanagar (State Statistical Abstract of Haryana, 2013). For all these districts, wheat is the dominating/major crop during rabi season and paddy is the dominating/major crop during kharif season.

2.2 Data used

2.2.1 Satellite data: Satellite, sensor and acquisition dates for the data used during analysis are given in Table 1.

Figure 1: Location map of study districts

Table 1: IRS Satellite data used in digital analysis

Crop of study	Satellite and sensor	Date of acquisition
Paddy	Resourcesat- 1/2 AWiFS	14/10/2013, 16/10/2013, 23/10/2013, 28/10/2013, 01/11/2013, 02/11/2013, 11/11/2013, 16/11/2013, 21/11/2013, 26/11/2013

2.2.2 Collatoral data: In-season ground truth was collected using the handheld GPS along with the field photographs, twice during second fortnight of October and first fortnight of November, 2013. This ground truth information was used for the identification of the stubble burnt areas of rice, associated crops and land features during digital classification of satellite data.

2.3 Digital data analysis

Digital image analysis was carried out using Geomatica, ERDAS Imagine and ArcGIS software packages using complete enumeration approach. Details of the steps involved in digital analysis are described elsewhere (Anonymous, 1990; Patel et al., 1993; Yadav et al., 2008; Hooda et al., 2008; Yadav et al., 2014). The Geo-tiff image data was imported to image format using ERDAS Imagine software package and later on exported to pix format using Geomatica software package. Stack of all the temporal images

prepared was used for digital analysis using complete enumeration approach. In complete enumeration approach the administrative boundary of the project districts were superimposed on the geo-referenced image and all the data elements (pixels) within this were extracted for further classification etc. Figure 2 showing the approach adopted . Such a procedure has been successfully used for wheat (Dadhwal and Parihar, 1985; Kalubarme et al., 2004), rice (Kalubarme and Vyas, 1990), Oilseeds (Sharma et al., 1991), Sugarcane (Saroha et al., 1999), Saanthi Paddy (Hooda et al., 2008) and for burnt wheat/paddy stubble (Yadav et al., 2013 & 2014) in the past. Normalized Difference Vegetation Index (NDVI) was computed for each date of satellite data and used during analysis along with spectral bands. NDVI was scaled up by multiplying with 100 and adding 100 to obtain range from 0 to 200 (Panigrahy et al., 2004). To round off the NDVI values 0.50 was added. The NDVI was computed as follows:

$$NDVI = 100 * [DN(NIR) - DN(R)]/[DN(NIR) + DN(R)] + 100.5$$

Unsupervised classification based Iterative Self-organizing Data Analysis Technique (ISODATA) clustering approach was used and classes of interest were identified using ground truth information and field photographs (Figure 3 to 5). To improve the accuracy, mask of non-agricultural classes and NDVI was generated and used during classification. Different land use classes such as water bodies, settlements, forests & plantations, waste lands and water logged area etc. were clipped from landuse/landcover map and a mask was created (Figure 2). The burnt stubbles, associated crops and other land features were identified using ground truth data. The mask of mixed classes (classes of burnt area with other land features) was prepared and image under the mask was reclassified to segregate the burnt stubble area from associated land features. A combined mask was prepared from multi phased temporal classified images. Percent rice burnt stubbles area was computed using combined mask of rice stubble burning area. The district level acreage was computed using per cent rice stubbles burnt area of the district images and district geographical area.

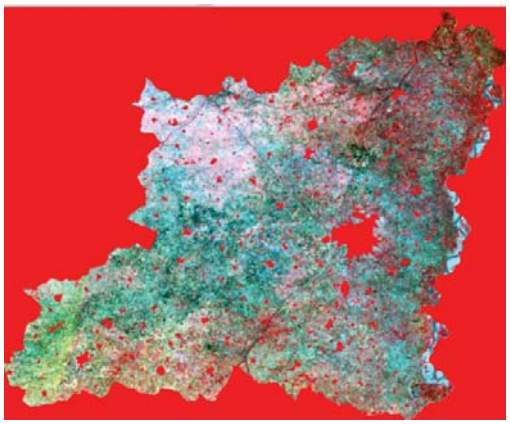

Figure 2: Mask of non-agricultural classes

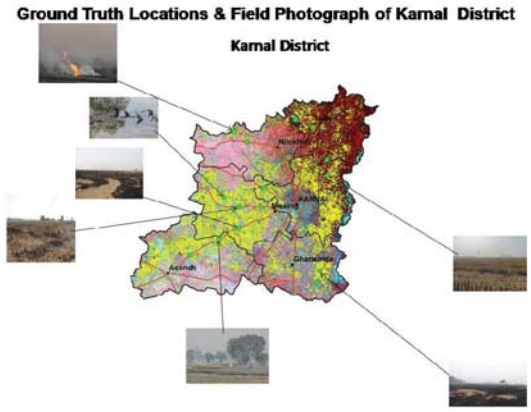

Figure 3: Ground truth locations and field photographs

Figure 4: Fields showing paddy stubble burning

Figure 5: Fields showing paddy stubble burning

3. Results and discussions

Sowing/planting of paddy in Haryana takes place during June to July and harvested during first fortnight of October to first fortnight of November. As the fields are immediately required for the sowing of next crop, the farmers adopt easy way out to go for burning of stubble in the field. District wise paddy stubble

burning area along with their percent contribution in the total paddy cropped area of the district for the year 2013 are given in Table 2. Figure 6 indicate the classified image with satellite images in the background for project districts. The yellow color indicates the identified crop residue burning areas.

Table 2: Paddy stubble burning area in districts of Haryana (2013)

Sr. no.	District /Parameter	Paddy area ('000 ha.)*	Stubble burnt area ('000 ha.)	% of paddy area
1	Ambala	79	12.27	15.54
2	Fatehabad	93	32.68	35.14
3	Jind	118	4.17	3.54
4	Kaithal	158	41.42	26.21
5	Karnal	162	54.33	33.54
6	Kurukshetra	118	39.82	33.75
7	Panipat	62	0.81	1.31
8	Sirsa	68	19.61	28.84
9	Sonipat	100	1.23	1.23
10	Yamunanagar	69	1.98	2.87
	Total	1027	208.34	20.29

*Source: Department of Agriculture, Haryana

Total paddy stubble burning area in the ten project districts was observed to be 208.34 thousand hectares which is 20.29% of the total paddy cropped area in these districts. Study indicates that concentration of burnt paddy stubble area is more in three northern districts i.e. Karnal (54.33 th. ha.), Kaithal (41.42 th. ha.), Kurukshetra (39.82 th. ha.) and one western district of Fatehabad (32.68 th. ha.) as compared to other study districts (Table 2 and Figure 6). Concentration of burnt paddy stubble area is moderate in Sirsa (19.61 th. ha.) and Ambala (12.27 th. ha.) districts while in Jind (4.17 th. ha.), Yamunanagar (1.98 th. ha.), Sonipat (1.23 th. ha.) and Panipat (0.81 th. ha.) districts very less paddy stubble burning area was observed (Table 2 and Figure 6).

Total paddy stubbles burning area recorded in Ambala district was 12.27 thousand hectares which is 15.54 % of total paddy area (Table 2). Major paddy stubble burning area was observed in central, southern and northern part of the district (Figure 6). Total paddy stubble burning area recorded in Fatehabad district was 32.68 thousand hectares which is 35.14 % of total paddy area (Table 2). Paddy stubble burning area concentrated in northern, central and eastern part of the district (Figure 6). Total paddy stubble burning area observed in Jind district was 4.17 thousand hectares which is 3.54 % of total paddy area observed in the northern part of the district (Table 2 and Figure 6). Total paddy stubbles burning area recorded in Kaithal district was 41.42 thousand hectares which is 26.21 % of total paddy area (Table 2), majority of which was confined to northern part of the district (Figure 6). Karnal district was observed to have 54.33 thousand hectares of burnt area, which is 33.54 % of total paddy area (Table 2), majority of which concentration of paddy stubble burning area was observed in western and south western and moderate in eastern part of the district (Figure 6). Total paddy stubbles burning area recorded in Kurukshetra district was 39.82 thousand hectares which is 33.75 % of total paddy area (Table 2). Major concentration of paddy stubbles burning area was observed in western and central part of the district. In rest of the district very less paddy stubble burning area recorded in the form of scattered patches (Figure 6). Total paddy stubbles burning area recorded in Panipat district was only 0.81 thousand hectares which is 1.31 % of total paddy area (Table 2). As compared to other districts the paddy stubble burning area is very less in the district. Major paddy stubble burning area recorded in northern part of the district while in rest of the district area is very less/negligible (Figure 6). Total paddy stubble burning area recorded in Sirsa district was 19.61 thousand hectares which is 28.84 % of total paddy area (Table 2). Major paddy stubble burning area was confined in central, central western, central eastern part of the district which is lying under Ghaggar flood plain (Figure 6). In rest of the district scattered patches of paddy stubble burning area were observed. Total paddy stubble burning area recorded in Sonipat district was 1.23 thousand hectares which is 1.23 % of total paddy area (Table 2). As compared to other districts the paddy stubble burning area is very less in the district (Figure 6). Total paddy stubble burning area recorded in Yamunanagar district was 1.98 thousand hectares only which is 2.87 % of total paddy area (Table 2). As compared to other districts the paddy stubble burning area is very less in the district. Major paddy stubble burning area recorded in southern and south-eastern part of the while in rest of the district area is very less/negligible (Figure 6).

The area estimates are based on the available satellite data and the burnt rice stubble area available on the image between October 14 to November 26, 2013. As the satellite data of paddy harvesting season were not available between October 01 to 14 and November 02 to 11, 2013 due to cloudy conditions, it may be possible that the paddy stubble burning area of the period may have been re-sown for rabi crops and not picked on the satellite images. Therefore, we apprehend slight underestimation of the paddy stubble burning area in the study. October 01 to 14 is just the beginning of the paddy harvesting and we do not expect missing much of paddy burnt areas. However during November 02 to 11, the basmati rice harvesting is at its peak and 2 to 5% of burnt area may not be picked up on satellite images. This assumption is based on the similar study conducted for the year 2014 for which the results are yet to be published.

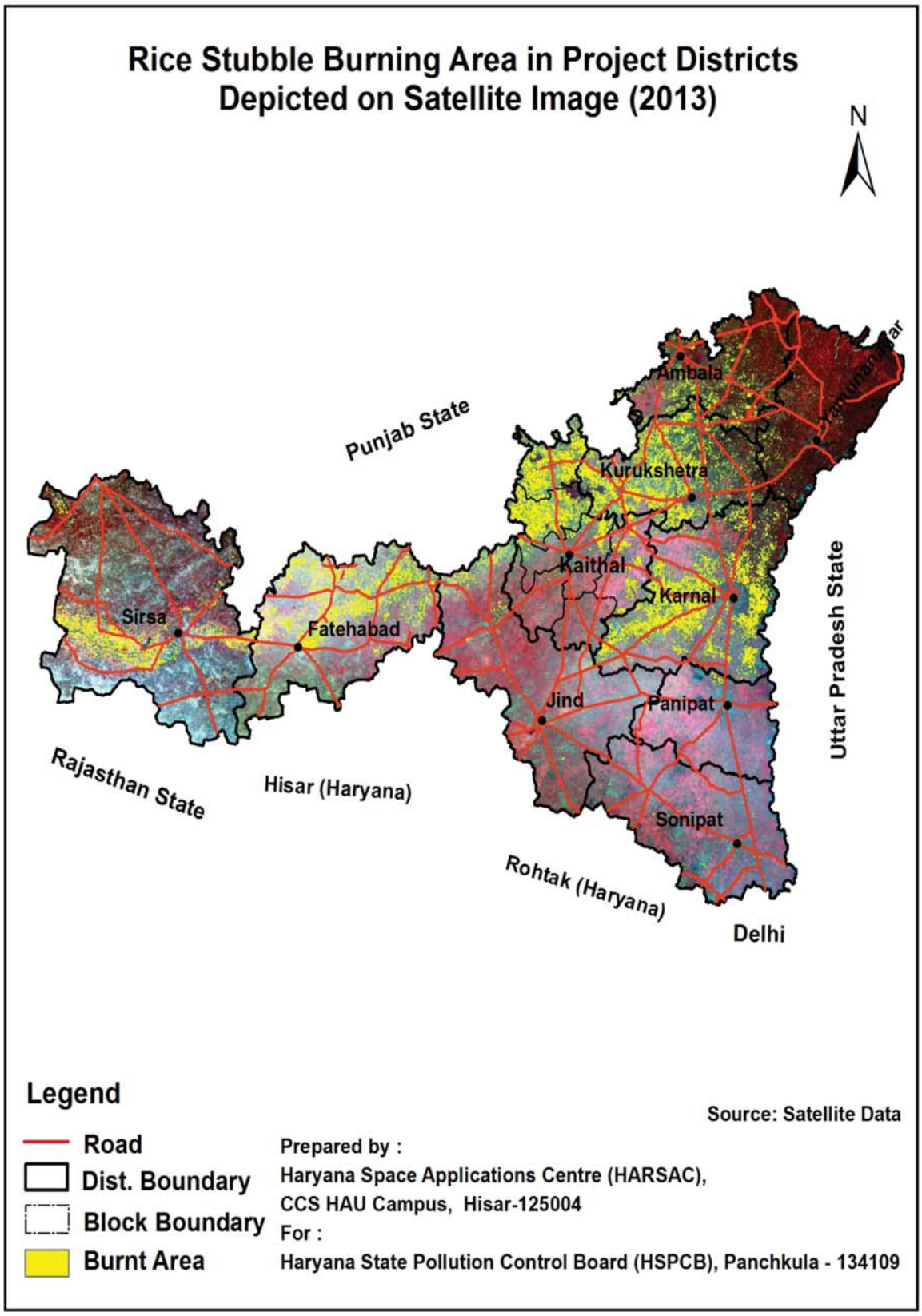

Figure 6: Rice stubble burning area in project districts depicted on satellite image (2013)

It was observed that in-season multi-date LISS-3 data is useful for the acreage estimation of burnt paddy stubble at district level. In the present study due to non availability of multi-date cloud free LISS-III digital data, in-season multi-date AWiFS data were used. The AWiFS data were found to be adequate, probably due to its better temporal resolution and favorable ground condition of having large synthetic field sizes. For a small state like Haryana complete enumeration approach, along with masks of non agricultural classes, is useful to provide desired accuracy. It avoids spectral confusion with some of the classes having similar spectral responses. In-season multi-date AWiFS data for an appropriate time duration are required.

Total paddy stubble burnt area in the ten project districts was observed to be 208.34 thousand hectares. Study indicates that extent of burnt paddy stubble area is more in three northern districts of Karnal, Kaithal, Kurukshetra, and one western district i.e. Fatehabad, moderate in Sirsa and Ambala districts while in Jind, Yamunanagar, Sonipat and Panipat districts very less paddy stubbles burning was observed. Low paddy stubble burning in Jind, Yamunanagar, Sonipat and Panipat districts may be due to manual harvesting and low land holding. It was observed that early paddy stubble burning takes place during first fortnight of October in Karnal, Kaithal, Kurukshetra and Panipat districts while late burning takes place during first fortnight of November in rest of the districts. As the satellite data of paddy harvesting season are not available between October 01 to 14 and November 02 to 11, 2013 due to cloudy conditions, it may be possible that the burnt area of the period may be resown for rabi crops and not picked on the satellite images of the later date. Consequently there could be little under estimation in paddy stubbles burnt area. More frequent satellite data availability is required to improve the accuracy of estimates for such type studies especially for the gap periods observed during the present study for which the data was not available. Regular monitoring of paddy stubble burning area using satellite data is required for controlling the menace of crop stubble burning in open fields and to monitor the effect of campaign against the dangerous practice.

4. Conclusions

Information about paddy stubble burning area is required for monitoring the menace of crop stubble burning in open fields due to its adverse environmental effects. A methodology was developed for area estimation under paddy stubble burning in the state of Haryana. Spatial information about some land cover classes were used to mask out non agricultural classes. The methodology is based on unsupervised classification and complete enumeration approach of Resourcesat 1 & 2 multi-date AWiFS data, along with ground truth. Total paddy stubble burnt area in the ten project districts was observed to be 208.34 thousand hectares.

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