Assessment of Rice Straw Burning and its Power Generation Potential in major Rice Growing Districts of Haryana, India

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Abstract— **Due to urgent requirement of vacating the fields for sowing of next crop and non-availability of labour rice straw open-field burning is practiced in many countries, including India. It has proved a significant source of emissions of poisonous gases and creation of smog during the harvest season. This rice biomass which just burnt in the fields can be a potential source for power generation using biomass based power generation plants. Besides, the heating of the soil kills the useful microflora of the soil causing soil degradation. The present paper describes the methodology and results of inventory for rice straw burning and its potential for power generation in major rice growing districts of Haryana, India using remote sensing data. Multi-date AWiFS data from Resourcesat 1 & 2 satellites data between October 14, 2013 to November 26, 2013 were used for estimating acreage of rice straw burning areas for the year 2013. In season collected ground truth data using hand held GPS along with field photographs were used to identify rice straw burning 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 straw burnt area was estimated by computing pixels under the classified image mask. Total rice straw burnt area in the ten project districts was observed to be 208.34 thousand hectares. Harvest Indices (HI) values of rice and average yield data were used to assess total rice biomass, total non-grain /non-economic (NG/NE) agricultural biomass. Rice biomass requirement for generation of 1 MW electric power was used as available in literature. District-level power generation potential was computed using the availability of surplus rice biomass. Surplus biomass in the state was computed to be 1028.5 thousand tones per year. The total power generation potential from this biomass is 102.9 MW per year.**

Keywords: **Rice Straw Burning, Ground Control Points, Remote Sensing, NDVI, AWiFS, Harvest Index, Yield, Biomass**

1 Introduction

The burning of crop residues in fields is one of the most significant activities of global biomass burning and contributes substantially to air pollution (Streets et. al., 2003). Asian countries, where more than 1.2 million km^2 of land is used to grow rice, accounting for 60% of rice production worldwide and 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). Rice-wheat cropping system is dominant in the Indo-Gangetic Plain (IGP) which comprises of parts of Pakistan, India, Bangladesh, and Nepal. IGP is producing enormous quantity of rice straw and it is usually not used as feed for animals (Badarinath et. al., 2006). Almost 90-95% of Paddy area in Punjab, Haryana and Western UP 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. Nearly 5504 sq. km. of wheat crop area and 12685 sq. km. 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 single date satellite data for both the seasons (Badrinath et..al., 2006). As residue burning and ploughing the fields is a gradual process Singh et. al., (2009) used multi-sensor characteristics for the accurate assessment of crop residue burnt areas at regular interval for two districts of Punjab. The multi-temporal image difference technique using three different indices (NDVI, NBR and GEMI3) were used to identify crop straw burnt areas. Moderate resolution LISS-III data was found to be useful for accurate estimation of burned surface. Area estimation of burnt paddy straws for major paddy growing districts of Haryana was attempted by Yadav et. al., (2014a & 2014b) 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 ground- based hyper spectral data.

Bio-energy shares about 10 percent of total energy consumption and it is expected that this source will play

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greater role in near future (Jiang et. al., 2012). There is an increasing interest in converting crop residues to energy products due to new emerging technologies and rising energy prices (Idania et. al., 2010; Scarlat et. al., 2010). There are number of studies that indicate the existence of potential of electricity generation through the usage of crop residue as a fuel in power generation plants (Jingura and Matengaifa, 2008; Karaj et. al., 2010; Hiloidhari and Baruah, 2011; Nguyen et. al., 2013). Hiloidhari and Baruah (2011) found 16 different types of crop residue in Sonitpur district of Assam, India. According to Jingura and Matengaifa (2008) biomass can provide 47 percent of the energy consumption in Zimbabwe and crop residue is major component of this biomass. Thus crop residue has potential of usage of energy generation besides feeding of animals and improvement of soil fertility. Moreover, environmental advantage connected with this change from burning of residue to electricity generation can be revealed from the fact that this change has no competition with food or cash crops and no land use change is required (Barz and Delivand, 2011). Likewise, Karaj et. al. (2010) analyzed the existence of potential of electricity generation in Albania through biomass (bio-energy crops, agricultural and forestry residues and wastes). Study of Ergudenler and Isigigur (1994) identified agricultural residue as a potential fuel for sustainable electricity generation in Turkey and has less environmental impacts and results in the reduction of net emissions of CO_2, SO_2 and NOx as compared to thermal power plants in which lignite is major source of fuel. Moreover, this act has adverse negative impacts on the environment because of greenhouse gas emissions. So by using this residue for electricity generation, one can avoid the problem of greenhouse gas emissions and intensity of problem of electricity shortage. The present study has been attempted with the following objectives.

2 OBJECTIVES

- To estimate Rice straw burning area in major rice growing districts of Haryana.
- To assess power generation potential from the burnt biomass of rice straw.

3 MATERIAL AND METHODS

3.1 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 they contribute more then 84%) of the paddy straw burning areas in the state (Figure 1). The geographical area of these ten districts is 1574, 2538, 2702, 2317, 2520, 1530,1268, 4277, 2122 and 1768 sq. km. 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 267 mm in Western district Sirsa to 964 mm in most northern district Yamunanagar (State Statistical Abstract of Haryana, 2013). For all the districts wheat is the dominating/major crop during Rabi season and paddy is the dominating/major crop during Kharif season.

3.2 Data Used

3.2.1 Remote Sensing and Collateral Data

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

Table 1: IRS Satellite data used in digital analysis

Crop of Study	Satellte & Sensor	Date of Acquisition
Paddy	Resourcesat-1/2 AWiFS	14/10/2013, 16/10/2013, 23/10/2013, 28/10/2013, 02/11/2013, 11/11/2013, 16/11/2013, 21/11/2013, 26/11/2013

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 straw burnt areas of rice, associated crops and land features during digital classification of satellite data.

Fig. 1: Location Map of Study Districts

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3.3 METHODOLOGY

3.3.1 Estimation of Rice Straw Burning Area

Digital image analysis was carried out using Geomatica, ERDAS Imagine and Arc GIS software packages using complete enumeration approach. Details of the steps involved in digital analysis are described elsewhere (Anonymous, 1990 and Patel et. al., 1993, Yadav et. al., 2008, Hooda et. al., 2008, Yadav et.al., 2014a and b). This 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. (Figures 2 to11). Such a procedure has been successfully used for rice (Kalubarme & Vyas, 1990), Oilseeds (Sharma et.al., 1991), Sugarcane (Saroha et.al.,1999), for Saanthi Paddy (Hooda et.al, 2008) and for Burning wheat/paddy straw (Yadav et. al., 2014a & 14b) in the past.

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. To improve the accuracy, mask of non-agricultural classes were generated and used during classification. The burnt straws, associated crops and other land features were identified using ground truth data. The mask of mixed classes was prepared and image under the mask was reclassified to segregate the burnt straw from associated land features. A combined mask was prepared from multi phased classified images. The area of the mask out images was classified and per cent burnt straws area was computed.

3.3.2 Estimation of Burnt Rice Straw Biomass

Average Harvest index values and average yield values of rice were used for the computation of total biomass and Non-grain/Non-economic (NG/NE) biomass for each crop using the below given formulae.

Biomass / ha. = (Grain Yield / Harvest Index)* 100

NG/NE Biomass/ha. = (Biomass-Grain Yield)

Total Biomass = (Biomass * Crop Area)

Total NG / NE Biomass = (Crop Area*NG / NE Biomass)

3.3.3 Estimation of Surplus Burnt Rice Straw Biomass

Surplus rice straw biomass was computed as described elsewhere by Yadav et. al., 2011. Assessment of surplus rice biomass is based on the field surveys in all the blocks of districts using respondent's answer of three categories of the farmers viz large, medium and marginal, regarding the production and consumption of rice biomass based upon the pre-designed questioner. Within each district the sample villages were identified based on crop variation, agro-ecological zonation and productivity status for the crop. Minimum 10 villages in each district were selected as sample villages for field data collection (3 respondents per village). Using the survey data surplus biomass was computed as follows:

Surplus Biomass = (Total N.G./N.E. Biomass) – (Domestic Use+Selling as fodder)

3.3.4 Computation of Power Generation Potential

The crop biomass requirement for generation of 1 MW electrical power for 6500 hrs in a year is used as published by Tata Energy Research Institute (2003) and available in literature. In the project districts at district-level power generation potential was computed using the availability of crop surplus biomass for power generation.

4. RESULTS AND DISCUSSIONS

Sowing/planting of rice in Haryana takes place during June to July and harvested during from first fortnight of October to first fortnight of November. As the fields are immediately required for the sowing of next crop the farmers have easy way out to go for burning of straw in the field. District wise rice straw burning area along with their per cent contribution in the total paddy cropped area of the district for the year 2013 are given in Table 2 and depicted in Figure 2 and 3. Figures 2 indicate the classified images with satellite images in the background for all the study districts. The yellow color indicates the identified crop residue burning areas.

Total rice straw burning area in the ten project districts was observed to be 208.34 thousand hectares which is 20.29% of the total rice cropped area in these districts. Study indicates that concentration of burnt rice straw 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 3 and Figure 3). Concentration of burnt paddy straw 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 straw burning area was observed (Table 2, Figure 2 & 3).

District level as well as for project districts total biomass, non-grain/non-economic biomass, surplus biomass and power generation potential from surplus biomass is given in Table No. 3 and depicted in Figure 4 to 7. The total biomass and NG/NE rice crop biomass available for project districts is 1875.0 and 1087.5 thousand tones respectively. For rice all non-grain biomass was assumed to be surplus as it is not even eaten by the cattle's and mostly used for burning in the field, household and brickilns. This assumption is observed in the computation surplus biomass. Out of total NG/NE rice biomass approximately 95% i.e., 1028.5 thousand tonnes is available as surplus in the project districts and its power generation potential is 102.9 MW.

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Table 2: Rice Straw Burning Area In Districts of Haryana (2013)

Sr. No.	District /Parameter	Paddy Area ('000 ha.)*	Straw Burning 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

*Department of Agriculture, Haryana

The top 4 districts comprising Karnal, Kurukshetra Fatehabad and Kaithal contribute nearly 82.62% of the total power generation potential in the project districts using surplus biomass of rice. Geographically, these are contiguous districts and therefore, offer scope for power plants (Table No. 3, Figure 4-7). The power generation potential was significant in the group of above mentioned districts using as surplus biomass. One western district Sirsa and one northern district Ambala also contribute nearly 14.70% of the total power generation potential using surplus biomass of rice also offer scope for power plants. Rest of the districts having very less availability of burnt rice straw biomass.

Table 3: Total, NG/NE, Surplus Biomass and Power Generation Potential from Surplus Biomass of Rice Straw in Districts of Haryana (2013)

Sr. No.	Dist./ Parameter	Total Biomass ('000 t)	NG/NE Biomass ('000 t)	Surplus Biomass ('000 t)	Pow. Gen. Potential (MW)
1	Ambala	111.9	64.9	56.2	5.6
2	Fatehabad	360.3	208.9	200.0	20.0
3	Jind	24.5	14.2	13.5	1.4
4	Kaithal	323.5	187.6	163.4	16.3
5	Karnal	463.1	268.6	263.5	26.3
6	K/Shetra	391.6	227.1	222.8	22.3
7	Panipat	5.8	3.4	3.0	0.3
8	Sirsa	170.9	99.1	94.9	9.5
9	Sonepat	7.3	4.2	3.7	0.4
10	Y/Nagar	16.2	9.4	7.4	0.7
	Total	1875.0	1087.5	1028.5	102.9

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 rice straws burnt area and consequently the power generation potential.

5. CONCLUSIONS

In the present study due to non availability of more useful multi-date cloud free LISS-III digital data, in season multi-date AWiFS data was used. The data was found to be useful due to its better temporal resolution. Resourcesat 1 & 2 AWiFS with short wave infra-wave along with NDVI of all dates provided segregation of rice straw burnt areas. For a small state like Haryana complete enumeration approach is useful to improve accuracy along with masks of non agricultural classes such as water bodies, settlement, forest, plantation and wastelands etc. Total rice straw burnt area in the ten project districts was observed to be 208.34 thousand hectares. Study indicates that extent of burnt rice straw 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 straws burning was observed. Low rice straw burning in Jind, Yamunanagar, Sonipat and Panipat districts may be due to manual harvesting and low land holding. The surplus burnt rice straw biomass available in the project districts is 1028.5 thousand tonnes and power generation potential from this biomass is 102.9 MW. The top 4 districts comprising Karnal, Kurukshetra Fatehabad and Kaithal contribute nearly 82.62% of the total power generation potential in the project districts using surplus biomass of rice. The data base created may serve as a good decision support system in identifying suitable sites for setting up of crop biomass based small power generation plants. By using this residue for electricity generation, one can avoid the problem of greenhouse gas emissions and intensity of problem of electricity shortage. More frequent satellite data availability is required for such studies. Regular monitoring of rice straw burning area using satellite data is required for controlling the menace of crop straw burning in open fields and to monitor the effect of campaign against the dangerous practice.

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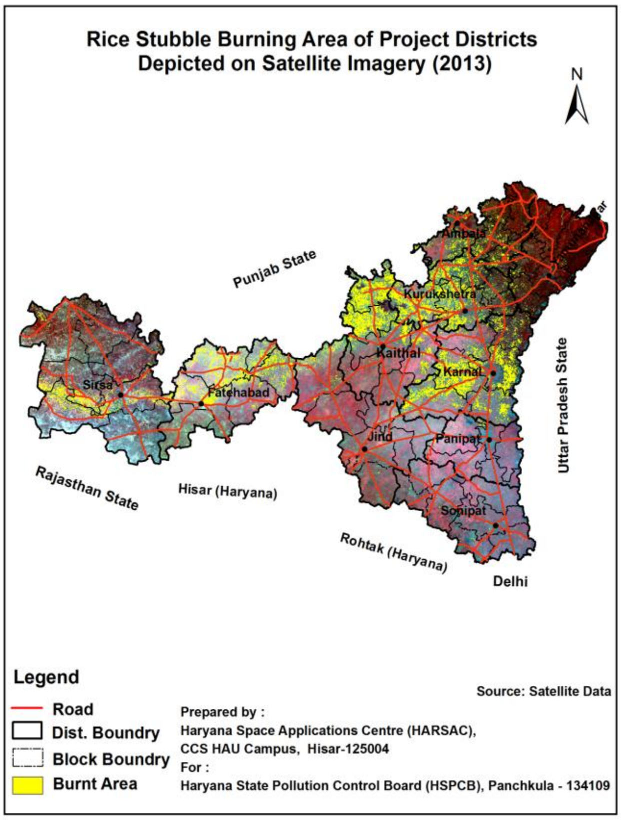

Figure 2: Rice Straw Burning Area in Project Districts Depicted on Satellite Image

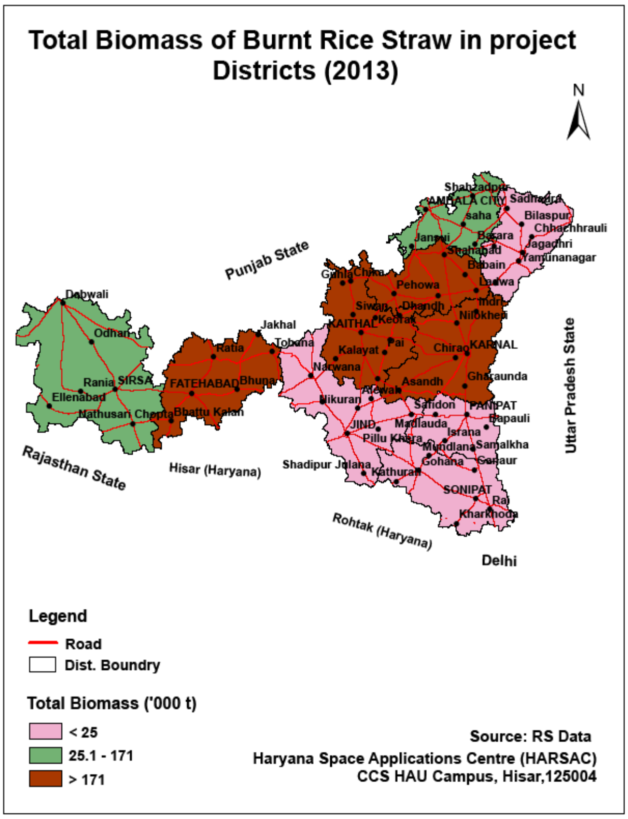

Figure 4: Total Biomass of Burnt Rice Straw in Project Districts

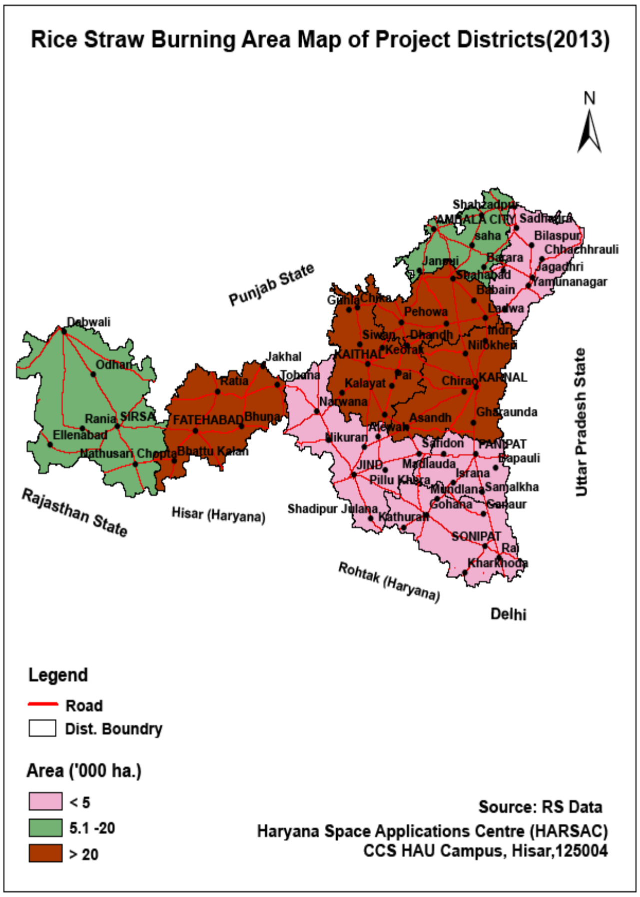

Figure 3: Rice Straw Burning Area Map of Project Districts

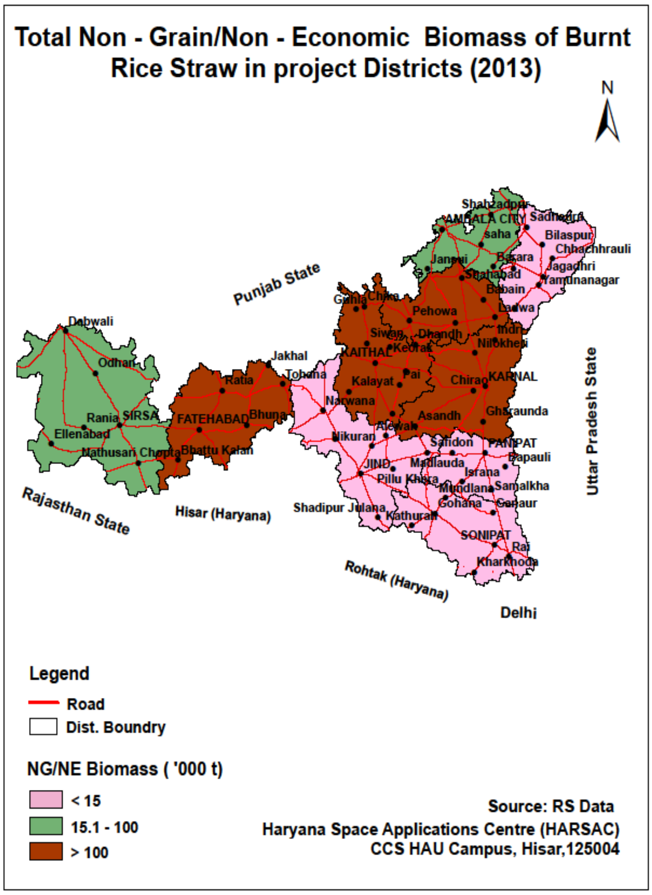

Figure 5: Total Non-grain/Non-economic (NG/NE) Biomass of Rice Straw in Project Districts

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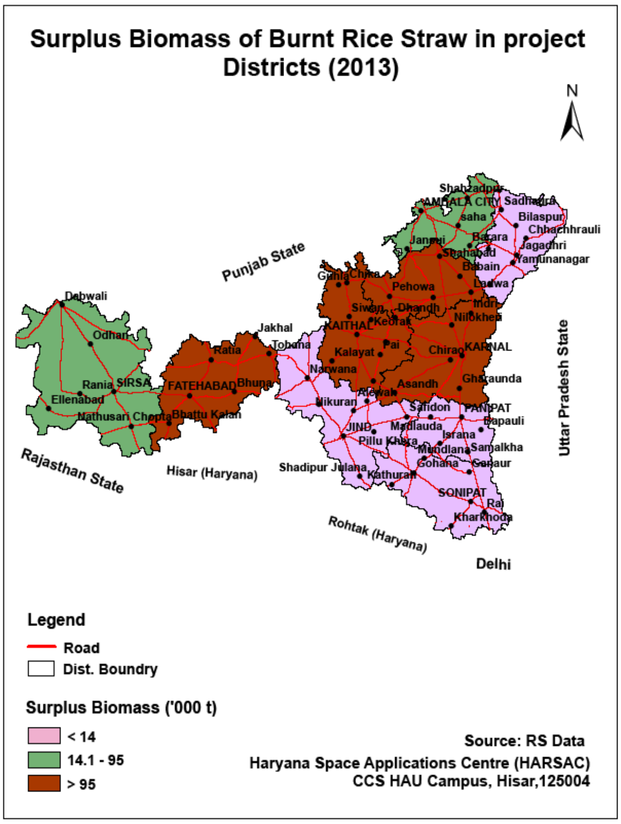

Figure 6: Surplus Biomass of Burnt Rice Straw in Project Districts

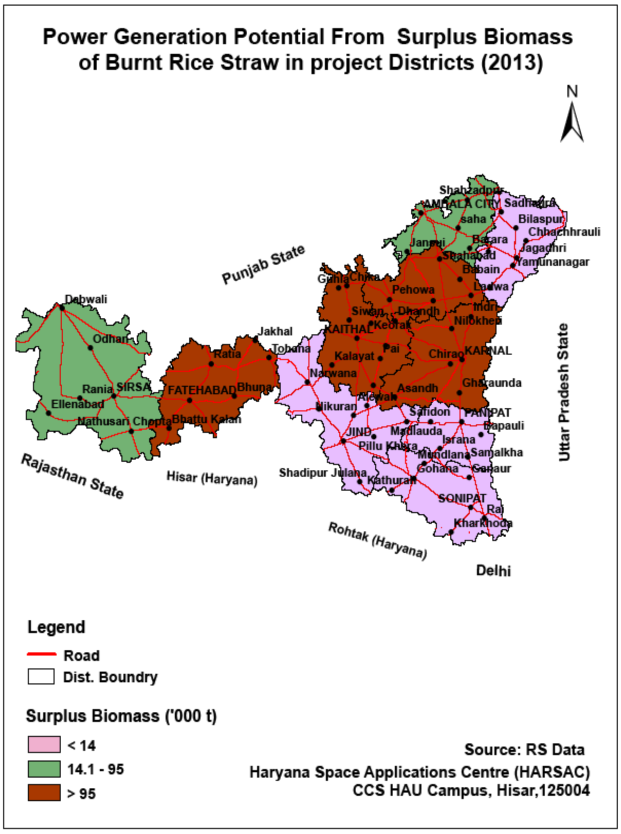

Figure 7: Power Generation Potential from Surplus Biomass of Burnt Rice Straw in Project Districts

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