Use of Remote Sensing and GIS for Crop Residue Management in India

Anil Malik

(Urban Planner-Architect)
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Abstract—*The poor air quality in the National Capital Region has been blamed partly on the burning of crop stubble by farmers in Punjab, Haryana, Rajasthan and Uttar Pradesh. The Delhi-NCR region has recently witnessed unprecedented levels of air pollution with the particulate matter exceeding hazardous limits (nearly 10 times of prescribed standards). The smoke from burning of crop stubble (amounting to approximately 32 million tonnes annually) accounts for about one-quarter of the most dangerous air pollution in the winter months. It not only impacts the health of the people, leading to severe respiratory problems, but also damages soil quality. Sustainable long-term solutions are the need of the hour to combat this issue that assumed alarming proportions.*

Remote sensing and GIS is a tool which helps to create and manage spatial and non - spatial data. Remote sensing is the practice of collecting data by observing at a distance which is most often done by observation of earth surface from above, from either an aircraft or a satellite. Products of such observations are aerial photographs and satellite imageries which are timely, periodic, accurate and reliable spatial data. Integrated computer tools for handling, storing, processing, analyzing and representing of spatial and geo referenced data is called Geographic Information System(GIS). Crop residue management is a major challenge in India. The crop residue generated during harvesting hamper tillage and seeding operations and there is very limited window for the sowing and planting of subsequent crop. Therefore open-field burning of crop residue is the common practice in India. Of about 90 million tone of surplus cereal residues, rice and wheat constitute nearly 85% which are burned on-farm annually. Of the total crop residues burned globally, currently India contributes nearly one third. Field burning of crop residues causes increased concerns over public health and environmental problems such as greenhouse effect and ozone layer depletion. Remote Sensing and GIS can be used for monitoring crop residue burning and thus better crop residue management can be ensured. . As burning of crop residue become frequent, remote sensing and GIS becomes preferable tool for Planners, Administrators, Environment Specialists and Pollution Control Boards for effective management of crop residue. Remote sensing helps to provide accurate and periodic spatial data and GIS helps in creating land suitability analysis and crop residue mapping of larger regions.

1. INTRODUCTION

According to the estimates of Sardar Patel Renewable Energy Research Institute (2004), about 72 Million tonnes of crop residues are burnt on-farm. According to the IIT Kanpur Report, crop residue burning contributes approximately 140 $\mu g/m^3$ towards PM10 and 120 $\mu g/m^3$ towards PM2.5. Pathak et al. (2010) have estimated that about 93 Million tonnes of crop residues are burnt on-farm in the country. Adverse effect of crop residue burning includes loss of nutrients; impact on soil properties and emission of greenhouse and other gases. The burning of crop residues immediately increases the exchangeable NH_4 +N and bicarbonate extractable P content, but there is no build-up of nutrients in the profile. Long-term burning reduces total N and C, and potentially mineralizable N in the upper soil layer (IARI 2012). Seeking to provide a cost-effective and eco-friendly solution to farmers to deal with the problem of stubble burning, even the scheme released by cabinet committee on economic affairs (CCEA) approved an INR 1,151 crore scheme to promote in-situ (in the farm itself) management of crop residue in Punjab, Haryana, Uttar Pradesh and Delhi is not working properly which results in raising air pollution levels in the capital and neighbouring states every winter.

1.1 Crop Residue

Punjab, Haryana, western Uttar Pradesh and parts of Uttarakhand have nearly 4 million hectares of rice and wheat cropping area. This area produces 34 million tons of rice stubble in a year and 23 million tons of residue is burnt. After the paddy is harvested starting mid-October, wheat has to be sown latest by mid-November. This is because in order to obtain maximum yield from the wheat crop, it has to be sown by mid-November to attain required growing period of 140-150 days before it is ready for harvest in mid – April. The paddy stubble also has little economic value as animal feed. Therefore the most viable option available to farmers to prepare the field for wheat crop in such a short window period (15-20 days) is to burn the standing stubble. This short timespan in which the stubble is burnt coincides with the Diwali season in the country, adding to the winter time pollution woes experienced in the capital. It a complicated problem but the solution has to come from within the agricultural community. As the farmer is the main stakeholder, for any policy design to succeed, he has to be part of the solution.

Crop residue burning is a global problem. It is burnt in all parts of the country where combine harvesters are used and there are no incentives for the retrieval of residue from the field. It is done even in Bihar, West Bengal, Madhya Pradesh and the southern states. It is witnessed in other parts of Asia as well. There is a strong correlation between the use of combine harvesters specially for rice harvesting and burning activity as the rice stubble produced from combines is of little economic value to the farmer. The use of combine harvesters without considering the fate of the residue after taking out the grain is a case of 'half innovation' where a technology is introduced without holistically evaluating the benefits as well as the negative effects, which often prove detrimental in the long run. Rice-wheat cropping system, wherever it prevails, leads to stubble burning, especially in areas where rice is harvested using combines. In southern India, burning is not as prevalent. Farmers there follow a rice-rice cropping system, and farmers resort to puddling (which is tillage of paddy field in the flooded soil conditions). However, in coastal parts of Andhra Pradesh and parts of Tamil Nadu, water scarcity is leading to a shift from rice toward maize cultivation, which in turn, is resulting in stubble burning.

1.2 Carbon Emissions Release

It is estimated that burning of 1tonne of rice straw accounts for loss of 5.5 kg Nitrogen, 2.3 kg phosphorus, 25 kg potassium and 1.2 kg Sulphur besides, organic carbon. Generally crop residues of different crops contain 80% of Nitrogen (N), 25% of Phosphorus (P), 50% of Sulphur (S) and 20% of Potassium (K). If the crop residue is incorporated or retained in the soil itself, it gets enriched, particularly with organic C and N. Heat from burning residues elevates soil temperature causing death of beneficial soil organisms. Frequent residue burning leads to complete loss of microbial population and reduces level of N and C in the top 0-15 cm soil profile, which is important for crop root development. Crop residues burning is a potential source of Green House Gases (GHGs) and other chemically and irradiative important trace gases and aerosols such as CH_4, CO, N_2O, NOX and other hydrocarbons. It is estimated that upon burning, Carbon (C) present in rice straw is emitted as CO_2 (70% of Carbon present), CO (7%) and CH_4 (0.66%) while 2.09% of Nitrogen (N) in straw is emitted as N_2O. Besides, burning of crop residue also emits large amount of particulates that are composed of wide variety of organic and inorganic species. Many of the pollutants found in large quantities in biomass smoke are known or suspected carcinogens and could lead to various air borne/lung diseases.

1.3 Effects of burning Crop Residue

Adverse consequences of on-farm burning of crop residues burning of crop residues leads to release of soot particles and smoke causing human and animal health problems. These gases are of major concern for their global impact and may lead to increase in the levels of aerosols, acid deposition, increase in troposphere ozone and depletion of the stratospheric ozone layer. These may subsequently undergo trans-boundary migration depending upon the wind speed/direction, reactions with oxidants like OH, leading to physic-chemical transformation and eventually wash out by precipitation. Many pollutants found in large quantities in biomass smoke are known or suspected carcinogens and could be a major cause of concern leading to various air-borne/lung diseases Remote sensing helps in identifying the area where crop burning is practiced by use of aerial photographs and satellite imageries. GIS helps in mapping of these areas, devising the extent area and pattern of this burning, and mapping of affected areas. Present paper tries to analyze use of these technologies in monitoring of crop residue burning in Indian scenario.

2. CROP RESIDUE MANAGEMENT PRACTICES

2.1 Ex-Situ Management Practice

Both in situ and ex situ agricultural management practices can be adopted to manage crop residue. Ex situ practices involve taking the residue away from the field and converting it to compost or baling rice residue for power plants (Lohan et al., 2014). However, there are trade-offs for ex-situ management of crop residues, and they are not always economically viable or sustainable. Labour availability and costs are a problem, and therefore composting is not an economically viable option for the farmer. Baling is also not a viable option as the baler costs more than 10 lakhs, and the operational window to use it is 10-15 days. For the rest of the year it lies unused, and even the depreciation costs cannot be recovered. Moreover, taking out residues from the field and not recycling them back are counterproductive for soil health.

2.2 In-Situ Management Practice

The in-situ practices involve managing the residue at the site of production. There are technologies like Rotavator, and mulcher but they are not entirely suitable and could lead to higher production costs and delayed planting of wheat crop. The concurrent use of super Straw Management System (SMS) and Turbo Happy Seeder efficiently takes care of the residue and also brings down the operational cost of preparing the field for the next crop. It performs three operations at one go hence increasing time efficiency: shredding the harvested crop, spreading the stubble across the swath and simultaneously sowing the wheat seeds (Sidhu et al., 2015). Scientific studies have shown that it saves approximately 10 Lakh litres of water on day one of seeding crop, increases profit amounting to Rs 20,000 - Rs 25,000 per hectare per year for a farmer. Gradually, it also leads to a reduction in the use of nitrogen fertilizers by the farmers. It eventually results in reduction in emissions of greenhouse gases from the agricultural fields. In situ management with technology that takes care of the crop residue, not only comes with multiple benefits to the farmer, but also helps them in reducing risks and increasing profitability and can be the plausible solution to prevent burning.

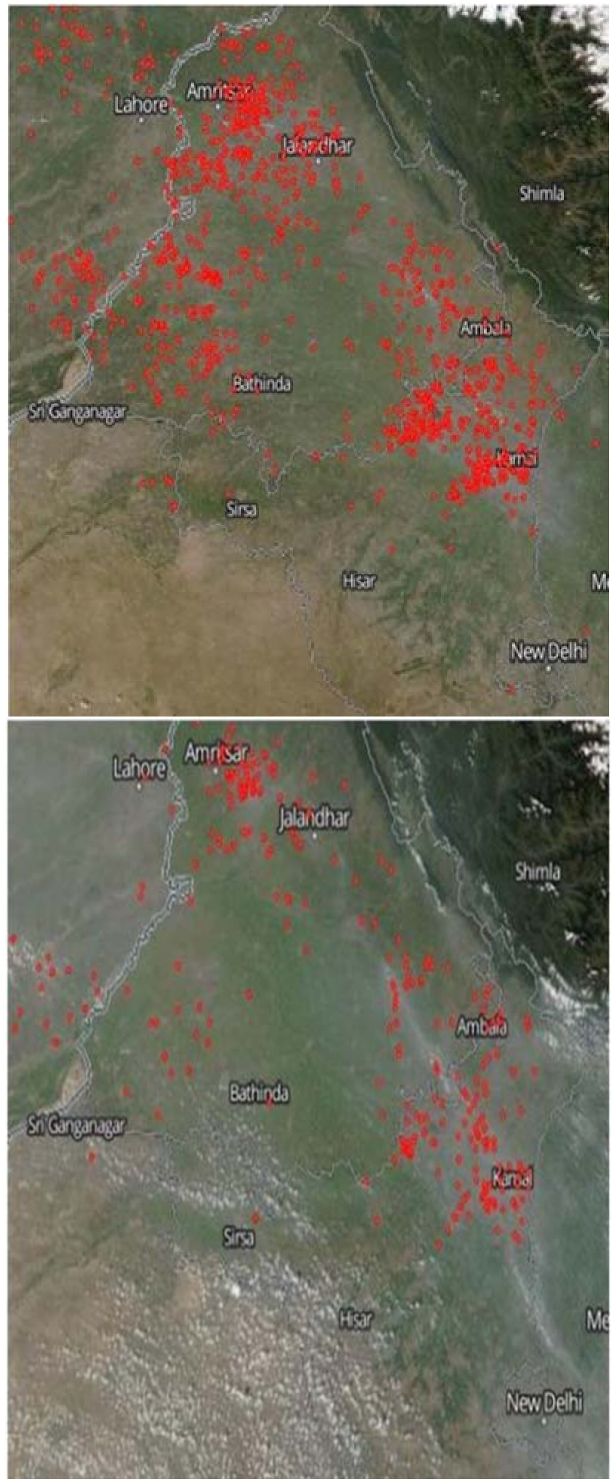
2.3 Technology Intervention

The practical implications of the use of technology are often not accounted for. It is imperative to consider the farmer's perspective before professing a new technology. Promotion of new technology also demands a change in the mind-set of farmers while creating awareness. The farmers need to be properly educated about the new interventions and community examples should be set to enable a wide spread use. For example, with the use of the Happy Seeder, the cost of production has gone up due to increased demand of urea in the field. The technology is also not economically viable due to the increased use of diesel. These inferences are drawn from practical application of the technology.

It is essential to let the farmers modify the techniques according to their needs as the diverse agricultural conditions in the country demand. Poor investment capacity of farmers, lack of machinery and herbicides, lack of awareness, lack of knowledge about the CA varieties and hybrids etc., are some of the pertinent issues that demand action. Also, the focus of the research in agricultural technology should be to design machinery compatible with small land holdings as the number of small farmers outweigh the big farmers in India.

2.4 Conservation Agriculture

Conservation Agriculture is a set of soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity. CA has proven potential to improve crop yields, while improving the long-term environmental and financial sustainability of farming. The practice of Conservation Agriculture (CA) involves sowing of wheat seeds in the field with the standing residue. The immediate sowing not only increases the growing period of wheat but also helps the crop to deal with the lodging and heat stress. It is a very cost-effective measure that saves the cost of tillage operations and results in a benefit of Rs 2000 per acre to the farmer, along with higher yield. This practice can also be a viable method for managing stubble and prevent burning. In particular, planting two varieties of wheat namely HDCSW 18 and HD 3117 (developed at IARI) in CA conditions can comprehensively mitigate the need for crop residue burning.



Picture1: NASA imagery depicting fires on agricultural lands in Punjab and Haryana on Oct 11, 2014 (Above) and Oct 07 2014 (Below) during winter season crop harvesting period

Source: NASA (National Aeronautics and Space Administration)

3. REMOTE SENSING AND GIS FOR CROP RESIDUE MANAGEMENT

Both these technologies help in mapping district-wise burning pattern, extent and area of burning, visible impact of smoke in adjoining states and impacts of fire incidents (PRSC, 2015) By further introducing ICT tools dissemination of information regarding fire event, conviction by district authorities etc. can be done (Hooda et al) with ground truth validation and the information shared becomes reliable and action can be taken against the persons engaged in crop residue burning.

3.1 Remote Sensing

Remote sensing has been proven to be an effective tool for monitoring cropping practices. Due to a large variety of on-board sensors on an increasing number of civilian satellites, the spectral and temporal properties of the land surface resulting from human practices can be captured and monitored at different spatial and temporal scales. However, a detailed literature analysis showed that less than 10% of the publications on remote sensing and agriculture actually focus on cropping practices. Crop residues are managed under conservation tillage programs to leave as much as possible on the surface for minimization soil erosion and for improving water quality. Because current methods for measuring crop residue cover are tediuous and somewhat subjective, there is a need for new methods to measure residue cover that are rapid, accurate, and objective.

We discuss the potential for discriminating crop residues from soils using reflectance and fluorescence techniques and examine experimentally the changes in wheat residue fluorescence during weathering. The fluorescence of crop residue was a board band phenomenon with emissions extending from 420 to 600 nm for excitation of 350-420 nm. Soils had low intensity broad band emissions over the 400690 nm region for excitations of 300-600 nm. We found that the fluorescence intensities for the crop residues were much greater than the fluorescence of the soils, but as the crop residues decompose, their blue-green fluorescence intensities approach the fluorescence of the soils. We conclude that fluorescence techniques are less ambiguous and better suited for discriminating crop residues from soils than the reflectance methods. However, the potential problems, that must be addressed to implement the fluorescence technique, are adequate excitation energy must be supplied to induce fluorescence andthe fluorescence signal is small relative to normal, ambient sunlight.

3.2 Methodology

The suggested methodology for such mapping and alarm generation is as follows:

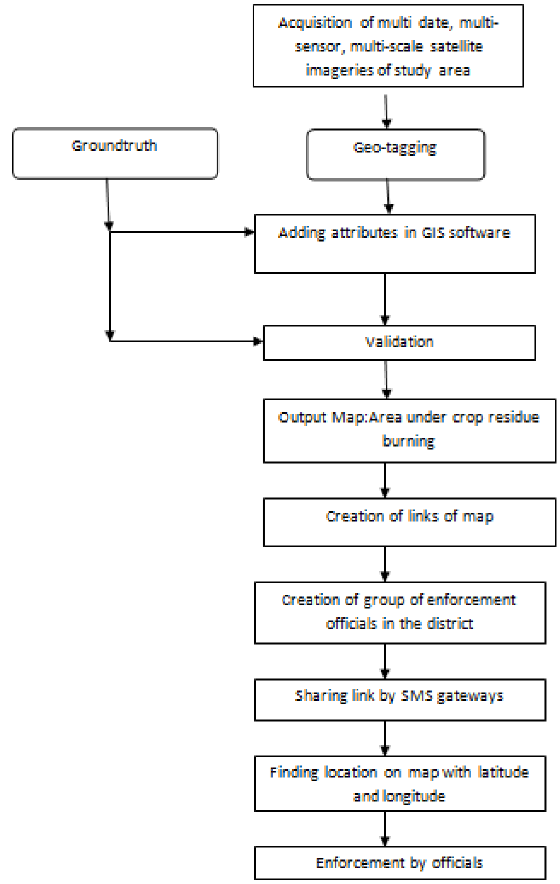


Figure 1: Methodology Flowchart

Methodology by Haryana Space Application Centre, Hissar.

3.3Geographical Information system

Agricultural production systems are highly vulnerable to variations in climate, soil and topography of different regions. For sustainable agricultural management, all these factors need to be analyzed on spatio-temporal basis. The advanced techniques like remote sensing, global positioning system and geographical information system can be of great use for their assessment and management. Remote sensing and GIS are very important tools having wide range of applications to tackle these issues. These technologies have manifold applications in agriculture including crop discrimination, crop growth monitoring / stress detection, crop inventory, soil moisture estimation, computation of crop evapo-transpiration, site-specific management / precision agriculture, crop acreage estimation and yield prediction. Timely and reliable information on crop acreage, growth condition and yield estimation can be highly beneficial to the producers, managers and policy planners for taking tactical decisions regarding food security, import/export and economic impact. Such information on regional basis can be made available with the use of remote sensing and GIS techniques. Remote sensing and GIS can also be used very effectively in land use / land cover analysis as well as damage assessment because of drought, floods and other extreme weather events An attempt has been made in the present study to review, analyze and evaluate the latest information regarding the application of remote sensing techniques for crop monitoring, crop condition assessment and yield estimation for sustainability of agriculture and natural resources under changing climatic scenarios.

4. NATIONAL GREEN TRIBUNAL GUIDELINES

Following are the various guidelines issued by National Green Tribunal on the matter of conflict between different states on the issue of crop residue management:

4.1 The National Policy for Management of Crop Residue, 2014 prepared by the Ministry of Agriculture, Government of India shall in conjunction with the Action Plan prepared by the States of Rajasthan, Uttar Pradesh, Haryana and Punjab shall be implemented in all these States now, without any default and delay.

4.2 All these State Governments and NCT Delhi shall immediately take steps to educate and advise the farmers through media, Gram Panchayats and Corporations that crop residue burning is injurious to human health, causes serious air pollution and is now banned or prohibited by law. They shall also be educated that the agriculture residue can be extracted and utilized for various purposes including manufacturing of boards, fodder, rough paper manufacturing and as a raw material for power generation etc.

4.3 Every State Government to this application shall evolve the mechanism for collection of crop residue, its transportation and utilization for appropriate purposes. 19 Such mechanism shall be implemented directly under the control of the State Authorities.

4.4 In the event of any conflict or contradiction between the National Policy for Management of Crop Residue, 2014 and the Action Plan prepared by the State Governments, the National Policy for Management of Crop Residue 2014 shall prevail.

4.5 In cases of persistent defaulters of crop residue burning, an appropriate coercive and punitive action could be taken by the concerned State Government including launching of prosecution under Section 15 of the Act of 1986.

4.6 Where on the one hand State Governments are directed to provide incentives for farmers for not burning agriculture residue in the open and on the other hand they are required to take into consideration passing of such direction, including withdrawal of assistance provided to the farmers if they persist with the defaults.

4.7 All the States which have issued Notification prohibiting agriculture crop residue burning shall ensure that the Notifications are enforced rigorously and proper action is taken against the defaulters. Any person or body that is found offending this direction would be liable to pay Environmental Compensation.

5. CONCLUSION

The solution/ proposal may include technological ideas for management of crop residue such as:

5.1 Suitable machinery for collection, chopping and in situ incorporation of straw to improve soil moisture and help activate the growth of soil micro-organisms.

5.2 To come up with a solution to deal with air pollution in the Capital during the winter due to stubble burning, government should come up with a method to convert agro-waste into pulp that can be used to make bioethanol, paper and tableware.

5.3 Farmers currently burn rice straw in the field as it is a waste product. However, the process should be developed to help farmers earn profits from this waste product, which when burnt in the farms of Punjab and Haryana brings down the air quality of the region.

5.4 Solution to the problem of stubble burning will not only ensure a pollution-free Delhi but also create rural employment by creating wealth from waste and contribute to sustainable development by starting a bio-economy.

5.5 Initiatives for converting the removed residues "into enriched organic manure through composting.

5.6 Initiatives to set up biomass based power generation plants.

5.7 Production of ethanol, paper and packaging ' material from the crop residue.

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