Identifying Effective Solutions for Crop Residue Burning in North India: A Review

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Abstract:
Crop residue burning has become a significant environmental concern, posing health risks and contributing to global warming. Crop residues can be used in a variety of ways instead of being burned, such as compost with manure, rural roofing, bioenergy, beverage manufacturing, packaging materials, wood, paper, and bioethanol, and numerous industrial applications. Overall, this review article provides an understanding of the negative effects of crop residue mismanagement in India via stubble burning, as well as other more promising crop residue management approaches that, if widely implemented, could not only reduce crop residue management's environmental impacts, but also generate additional value for the agricultural sector.

Keywords: *Crop Residue Burning, Crop Residue Management, Air pollution in India, Human health, Environmental Issues*

1. Introduction

Agriculture is regarded as one of the most important producing activities, and agricultural residue burning contributes significantly to air pollution [22]. With the advent of harvesters and their widespread use in the rice–wheat cropping system in the Indo-Gangetic Plains (IGP), a new sustainability challenge, residue management, has become a new challenge in the 21st century [5]. India creates an average of 500 million tonnes (Mt) of agricultural waste every year, according to the Indian Ministry of New and Renewable Energy (MNRE) [1].

There are a variety of residue management solutions available, including the use of machinery such as the Happy Seeder, zero tiller, baler, and others. Crop leftovers can be used as a raw material and fuel in industries such as paper/cardboard, brick kilns, bio-energy packaging, and so on. Despite the numerous options, farmers continue to have difficulty adopting crop residue management strategies [19]. Crop residue burning began in 1986, when mechanical wheat harvesting (April–May) and rice harvesting (October–November) were introduced [10]. The Indian government has taken a number of steps to reduce agricultural residue burning. The National Green Tribunal (NGT) has levied fines ranging from Rs. 2,500 to Rs. 15,000 depending on the area under burning. In addition to harsh measures, the government is attempting to persuade farmers by offering incentives and subsidies for the purchase of machinery for agricultural residue management and crop diversification [19].

According to estimates from the year 2000, about a quarter of the dry residues generated from rice and wheat crops in India are burned on open fields. According to a survey conducted in 2008-09, around 132 million tonnes of agricultural waste were burnt in the open field, with Uttar Pradesh and Punjab ranking first and second, respectively [23].

The North-western portion of the nation has been the most impacted in recent years, and its dangerous influence on the start of winters has sparked a major debate among atmospheric experts. During the months of October and November, a rapid surge in particulate matter and other dangerous substances not only disrupted people's everyday lives, but also had serious health consequences [23]. The different sources of pollution in Delhi (11.7 percent) are vehicles/transport (39.1%), industry (25.4%), households (5.7%), dust (18.1%), stubble and other biomass burning. The Intergovernmental Panel on Climate Change (IPCC 2018) report from the United Nations (UN) highlighted dramatic temperature increases, changes in sea level, and altering rainfall patterns in South Asia as examples of ongoing climate change. Furthermore, the analysis predicted an average global temperature rise of 2.6-4.8 degrees Celsius by the year 2100 as a result of rising GHG emissions [8].

This study aims to investigate the effective solutions for crop residue burning and its relationship with air pollution in North India in order to answer this review paper. Furthermore, this review comprises the following important components;

1. Agricultural waste residue generation in India
2. Reasons of Burning Crop Residues
3. Impact of Crop Residue Burning
4. Crop Residue Management

5. Suggestions and Recommendations

1. Agricultural Waste Residue Generation in India

Crop residue is the leftover plant material after crop harvesting, which includes leaves, stalks, and roots. Crop residue distribution and utilisation vary across the country, depending on the crops planted, cropping intensity, and productivity. Uttar Pradesh has the highest crop residue estimate (60 Mt). Punjab (51 Mt) and Maharashtra (46 Mt) were two other high crop residue generating regions. Cereals, fibres, oilseeds, pulses, and sugarcane accounted for the bulk of crop waste, with respective production estimates of 352 Mt, 66 Mt, 29 Mt, 13 Mt, and 12 Mt. Rice, wheat, maize, and millets produced 70 percent of the crop residue among cereal crops, followed by fibre crops (13%). Rice, wheat, and maize are primary food grains in India, accounting for a significant share of the overall crop residue output [3].

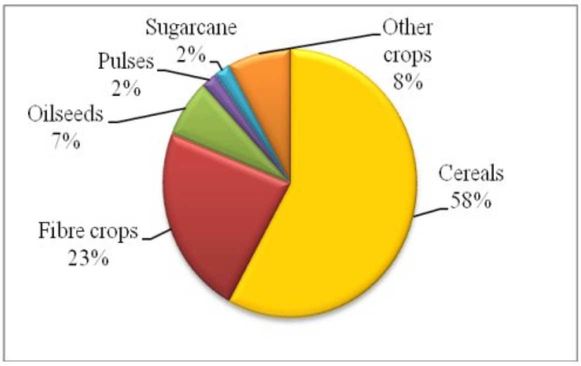

Fig. 1: The share of unutilized residues in total residues generated by different crops in India (Source: Compiled by Saroj Devi, Charu Gupta, Shankar Lal Jat*, M.S. Parmar. Data taken from MNRE, 2009

Cereals are the highest provider of surplus residues in India, which are frequently in-situ burned. Fiber, oilseed, legumes, and sugarcane are other crops that produce a lot of waste (Figure 1) [3].

2. Reasons of Burning Crop Residues

2.1 Short time between harvesting and sewing

In NW India, the interval between paddy harvesting and wheat sowing is 7–10 days for basmati/scented rice and 15–20 days for coarse grain rice [9]. In the field, this rice crop residue load can be up to 7.5 t ha1. Later on, it becomes a hindrance for the next crop, and in the absence of paddy residue management methods, farmers prefer to burn the paddy residues in the field as integration or collection is considered excessively costly [7].

2.2 Labour Scarcity and Growth in Farm Mechanization

Between 1970 and 2012–2013, the contribution of agricultural employees to total workers in Punjab state fell from 62.67 percent to 35.96% [4]. Human power in Punjab state decreased from 7.5 percent to 0.69 percent between 1960 and 2012–13, owing to increases in mechanical power from 17 to 76 percent and electrical power from 1.7 to 23.5 percent [7].The cost of cleaning the field by hand is higher than the fines levied by the government [22]. As a result, it is no longer a viable option for agricultural residue burning. The number of combine harvesters in the country has risen substantially, from around 5000 in 1990–1991 to 13,800 in 2012–13 [4]. On the contrary, combine harvesters tend to leave a massive amount of residue (up to 9.0 t ha1) in the field after harvest, and farmers are not equipped or prepared to deal with the massive amount of residue left in the field to burn [7].

2.3 Other reasons

Some farmers have complained that insufficient straw storage facilities and a lack of market utilities for leftover drive them to burn stubble in the fields to get rid of it. Some farmers have also discovered that burning in-situ lowers tractor fuel expenditures due to the inclusion of left-over stubble by roto-till-drill. For the most part, farmers lack incentives and equipment to reduce stubble burning [7].

3. Impact of Crop Residue Burning

3.1The Effects of Crop Residue Burning on Human health

Incineration of crop residues contributes to the release of harmful air pollutants that can have serious consequences for human health, such as aggravating chronic heart disease and lung ailments, as well as causing respiratory problems such as asthma and coughing; this is especially true for children, the elderly, and pregnant women [7]. According to socioeconomic research conducted in 2008-09, the overall yearly welfare loss in Punjab state owing to health harm induced by air pollution produced by rice residue incineration is Rs. 76 million [2].

3.2 The Effects of Crop Residue Burning on the Environment

During the winter months of October and November, dry weather, moderate relative humidity (40–70 %), and light blowing breezes (1–2 ms1) from the northwest aid in the formation of aerosols and their progressive transit up the Himalayan Mountain range through the Indo-Gangetic Plain [11]. Because of these favourable conditions, emissions move thousands of kilometres from their initial burning area (Punjab, Haryana, and western Uttar Pradesh) and cover the whole Indo-Gangetic Plain from West to East; the Arabian Sea and central India are also affected but unnoticed [17].

3.3 The effects of Crop Residue Burning on soil health

The burning of agricultural residues, according to the Department of Soil at Punjab Agricultural University, adds to the depletion of soil organic carbon. Long-term burning minimises 0–15 cm of soil loss, as well as total nitrogen, biomass, possibly mineralized nitrogen, and organics. The residue burning raises soil temperatures to around 35.8–42.2 C at 10 mm depth, with semi-permanent effects reaching up to 15 cm of the uppermost soil. Furthermore, repeated burning lowers the carbon content of the soil, kills beneficial microflora and fauna [12].

4. Crop Residue Management

4.1 In-situ incorporation

In-situ integration of combining collected wastes with increased decomposition to advance nutrients in the soil can be beneficial. The integration of residues into soil improves soil health parameters such as pH, organic carbon, infiltration rate, and water holding capacity [7]. Farmers oppose in situ inclusion because stubble takes a long time to decompose in the soil. According to the Punjab Department of Agriculture, less than 1% of farmers practise in situ crop stubble integration [12].

4.2 Mulching

Crop residue retention on the soil surface has several advantages, including: i) less weed development, ii) cheaper weedicide costs, iii) enhanced physical, chemical, and biological characteristics of soils, iv) plant nutrient recycling, and v) decreased fertiliser usage in succeeding crops [18]. Surface preservation of leftovers protects the fertile soil surface from wind and water erosion [13]. Mulch increased root length densities by 40% as compared to no mulch, owing to the preservation of soil moisture in deeper layers [18].

4.3 Biochar and Composting

According to research published by the European Union's Joint Research Centre, treating soil with biochar helps to retain soil carbon for hundreds of years. Biochar increases plant health and development by amending the soil. Furthermore, producing biochar locally from crop leftovers can assist in lowering carbon footprints by 38–49%. Agricultural waste provides a nutrient-rich meal for earthworms, and the use of earthworms produces high-quality compost [6].
In 2020, a biodecomposer (a product including bacteria and fungi strains) created by the Indian Agricultural Research Institute, PUSA, was tested on agricultural leftovers. The product is an aqueous solution that may decompose organic raw materials, crop leftovers, animal wastes, and other pollutants [21].

4.4 Mushroom framing

Paddy straw is an important element in the development of mushrooms in Punjab, although farmers typically substitute wheat straw for paddy straw due to its benefits [9,18]. Mushroom growing is a profitable agri-business venture that creates food from rice and wheat straw while simultaneously advocating for the ecologically safe disposal of this by-product [20].

4.5 Use of Rice Straw for Biogas

Plant ligno-cellulosic compositions are so difficult to decompose and may be used as a raw material for biofuels. Plant biomass is pre-treated for decomposition by selected microorganisms and transformed into monomers and sugars, acting as an efficient bio-fuel [1]. Biogas is mostly made up of methane gas and nutrient-rich waste [14]. Biofuels have the potential to provide up to 17% of India's fuel consumption [15].

4.6 Livestock feed and other farm uses

Crop wastes have traditionally been used as animal feed in India, with the necessary addition of supplemental nutrients. Wheat straw is commonly used as livestock feed. On the other hand, rice crop leftovers are unpleasant and poor in digestibility, making them unsuitable for use as animal feed. Paddy straw is commonly used as bedding and as a shed for cattle in the winter, which protects the cattle from the harsh cold and minimises the possibilities of damage and lameness [23,9].

4.6 Other Industrial uses

Straw, peanut shell, cob, cotton bar, soybean rod, weed stems, leaves, sawdust, bark, and other solid wastes are crushed, pressed, compacted, and formed into pellets using a pellet mill. Paddy straw is utilised as a plastic reinforcing material and it is shredded into small 1.5–2 mm pieces and blended with polypropylene [16].

5. Suggestions and Recommendations

5.1 Local governments should prevent agricultural residue burning through awareness campaigns that include training, demonstrations, and capacity development. There is a need for more study on the economic viability and trade-offs of alternate agricultural residue uses [53].

5.2 Farmers will be rewarded if they do not burn their crop waste in the open. Farmers that keep their crop remains on the field will receive a higher subsidy rate since crop dregs are a complement to chemical fertilizers [7].
5.3 There is a need to draw farmers' attention before the burning season in July and August, or February and March, rather than after burning episodes, so that they have enough time to consider alternate alternatives. Encourage women and small and landless farmers to engage in diverse residue management activities, which can increase income and nutrition security [53].

5.4 Energy plant establishment is supported in order to use surplus crop residue for energy generation in a sustainable, environmentally friendly, and cost-effective manner. Priority should be given to decentralized power generation in IGP utilizing rice straw [7]. At the moment, power generation from rice straw is somewhat more expensive than other methods, but the government can provide subsidies and incentives to encourage biomass energy production [5].

5.5 Crop residue should be classified as recycling or additives, such as lime or gypsum. Their use in agriculture should be subsidized in the same way that other mineral fertilizers or amendments are [7].

5.6 Free energy should not be offered since the same strategy has resulted in the development of high-powered tube wells, which are responsible for overdrawing water from deep under the ground [7].

5.7 In-field management, quick decomposition by chemical or biological techniques, and mechanical straw mulching must all be encouraged [6]. Strengthen research to create a microbe or biological process that accelerates the decomposition of rice straw and allows farmers to use the straw as a useful organic material to enhance soil health [5].

5.8 Mulching of crop stubble would be aided by the employment of machinery such as double disc coulters, zero tillage, and happy seeders [7].

5.9 Paddy waste from the fields might be collected and utilised to make valuable products such as compost, organic manure, and bio-char to increase soil health and fertility, as well as gasification as an alternate fuel for power generation [7].

5.10 On a cooperative basis, small farmers may be able to use a tractor with a high horse-power section for deep cutting. It is more beneficial to inform small farmers about the importance of chaff production from rice wastes [7].

5.11 Government should encourage crop diversification in the IGP. There should be a support award for oil seed and pulse crops to encourage farmers to diversify. Promote short-duration rice varieties such as HKR-47, PR-114, and PR-126, which complete their crop cycle (seed to seed) in 120 days [5].

5.12 Creating a market for crop residues by encouraging young people's innovative business ideas through collaborative research and collaboration with other rice producing countries. This issue might be addressed through the People's Science Movement [60].

6. Conclusions

Crop residues are one type of agricultural waste that has presented unique issues owing to its large volume and lack of management capacity. Crop residue burning can be replaced by a combination of stubble in soil/in situ incorporation, crop stubble as animal fodder/cattle shed and bed preparation, wheat and paddy straw in mushroom farming, rice straw mulching, back in the soil after composting, domestic fuel, prioritised for renewable energy generation like fuel for power plants, biogas and biochar/bioethanol preparation, making pellets, raw materials for the paper and pulp industry, and mixing with plastics, agricultural diversity should be implemented. By supporting new business ideas, a market for straw should be created. In conclusion, this article provides an overall understanding of the negative effects of open burning of crop residues on ecology and the environment, as well as more promising alternative crop residue management practises that, if widely implemented, could not only reduce the environmental impacts of crop residue management, but also generate additional value for the agricultural sector globally.

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