Crop Residue Management in India

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Crop residue management choices should be measured on the premise of productivity, gain, and environmental impact. These criteria would overlap with those employed in the approach of ecological intensification for intensive crop production systems aiming to fulfill the increasing demand for food, feed, fiber, and fuel, while meeting acceptable standards of environmental quality.

Keywords: agricultural residue ; stubble burning ; alternative management practices ; valorization

1. Introduction

Stubble burning is a practice where fire is purposely put to the stubble which remains after grains, such as paddy, wheat, rice, corn, etc., have been harvested. This represents an important source of atmospheric aerosol and gas emissions, hence having a potential effect on the global air quality and environmental chemistry. Open-field biomass burning is a longstanding method for land clearing and improvements in land use to dispose of living and dead vegetation, used globally. It has been estimated that humans account for nearly 90% of biomass combustion, although only a small portion of natural fires are responsible for the overall amount of vegetation burnt [1]. Over the past few decades, biomass burning has increased worldwide. In India alone, the total amount of crop residue and the burnt was estimated to be 516 million tones and 116 million tonnes (Mt), respectively, in the year of 2017–2018, approximately generating 176.1 Mt CO 2, 10 Mt of CO, 0.31 Mt CH 4, 0.008 Mt N 2O, 0.151 Mt NH 3, 0.814 Mt NMVOC, 0.453 Mt PM 2.5 (particulate matter) and 0.936 Mt PM 10 [2]. Stubble burning has many environmental impacts and consequences, compared with alternatives such as ploughing stubble back in the field or harvesting them for industrial purposes. However, there are inadequate data on the impacts of crop stubble burning. Extrapolation has been commonly used in estimating the pollution factors in the database of farm residues, which may result in high uncertainty in the emission figures. It is well known that, due to agricultural field burning during the harvest season, air quality is greatly affected. Aerosol and gaseous pollutant source profiles from an agricultural fire are needed to assess their contribution to ambient air quality. Agricultural field burning has created many environmental problems, utilizations of crop residues for such as cattle feed, compost with manure, rural roofing, biomass fuel, beverage production, packaging materials, wood, paper, and bioethanol, etc., should be explored and promoted. In the following sections, the detrimental environmental impacts of open burning of the agricultural residues are discussed in detail and current approaches for managing these crop residues are also presented.

2. Effects of Stubble Burning

The burning of crop residues generates various environmental issues. The most adverse effects of crop residue burning embody the emission of greenhouse gases (GHGs) that contribute to global climate changes. In addition to that, enhanced levels of PM and other air pollution that cause health hazards, loss of diversity of agricultural land, and the deterioration of soil fertility [3]. The burning of the crop stubble in an open field influences soil fertility, eroding the sum of soil nutrients.

The major emissions of polluting gases and PM, as well as aerosols and trace gases as a result of crop residue burning, are listed in **Table 1** and **Table 2** . The PM released from the burning of crop residues is 17 times higher than that of the emissions from various other sources like motor vehicles, waste incineration, and industrial waste [4]. Intrinsically, the crop residue burning among the northwest vicinity of the country contributes to a considerable amount of about 200 organic carbon compounds in terms of the national emissions budget [5]. Street et al. [6], have anticipated that about 730 Mt of biomass was burned annually in Asian countries, and among them, India is in 18th position. Crop residue burning will increase the PM within the atmosphere and contribute to temperature change considerably. The fact that the fine black and also brown carbon (primary and secondary) would change sun light absorption and hence contribute to the global climatic change [7][8][9][10].

Table 1. Major pollutants released into the atmosphere during crop residue burning [11].

Category	Pollutant	Source
Particulate matters	$PM_{2.5}$ and PM_{10}	Condensation after combustion of gases and incomplete combustion of organic matters
	PM_{100}	Incomplete combustion of in-organic materials, particles on burnt soil
Gases	CO	Incomplete combustion of organic matters
	CH_4	Incomplete combustion of organic matters
	O_3	A secondary pollutant formed due to the reaction of nitrogen oxide and hydrocarbon
	NO, NO_2 N_2O	Oxidation of fuel-N or N_2 in the air at high temperatures
	Polycyclic aromatic hydrocarbons (PAHs)	Incomplete combustion of organic matters

Table 2. Emission levels of air pollutants during harvesting season in Haryana and Punjab (Source: Delhi Pollution Control Committee [DPCC], 2016).

Pollutants	Area in Delhi	Current Level ($\mu g/m^3$)	Permissible Limit ($\mu g/m^3$)
$PM_{2.5}$	Punjabi Bagh	650	60–80
PM_{10}	Punjabi Bagh	1000	60–80
CO	IGI Airport	6.3	2–4
SO_2	IGI Airport	29.8	60–80
NO_X	Anand Vihar	167	60–80

As well known, the emission of toxic gases from burning of the crop residue could lead to coughing asthma, emphysema, bronchitis, irritation of the eye, an opacity of the corneas, and skin disorders. Inhaling of PM can lead to intensifying persistent cardiac and pulmonary ailments and is related to the premature deaths of people who are already suffering from these illnesses [12]. About half of the world's population now lives in urban areas, which facing sever air pollution issues that adversely affects human health through the cardiovascular and respiratory systems [13]. Air pollution results in metabolism diseases like eye irritation, bronchitis, asthma, etc. Increasing individuals' sickness mitigation expenses and, additionally, poignant ones' operating capability. Annually, 3.3 million people are dying prematurely due to air pollution around the world. If air emissions continue to rise, this number will double by 2050 [12]. The Organization for Economic Cooperation and Development (OECD) estimates that in Delhi NCR alone, air pollution contributes to approximately 20,000 premature deaths and this number is expected to increase to 30,000 by 2025 and to 50,000 by 2050 (OECD, 2016). **Table 2** shows that current pollutant emission levels in most areas of Delhi are way off the permissible limits.

According to the Department of Agriculture, Government of Punjab, the soils of Punjab typically contain low nitrogen content, low to medium phosphorus, and moderate to high potassium. Besides, the organic carbon in the soil has decreased to very low, and insufficient levels and organic manure and crop residue have not been properly applied. Production of 7 t/ ha rice and 4 t/ha wheat extract more than 300 kg of nitrogen, 30 kg of phosphorus, and 300 kg of potassium from the soil per hectare. The burning of crop residues contributes to the depletion of soil organic carbon, according to the Department of Soil, Punjab Agricultural University. Moreover, CO 2 and soil nitrogen balance changes quickly, and nitrogen is converted into nitrate, leading to depletion of 0.824 million tons of nitrogen-phosphorus-potassium (NPK) from the soil annually.

3. Alternative Methods to Open Burning

In order to implement sound selections of alternative crop residue management methods, it is necessary to scientifically perceive the short and temporary effects of various crop residue management practices and to develop new residue management technologies that are cost-efficient and environmentally acceptable.

Similar results reported that the incorporation of rice residue 3 weeks prior to sowing the wheat crop increased the amount of wheat only in clay loam soil and not in sandy loam soil [14]. This study also showed that organic carbon increased by 14–29% when the crop residues were incorporated in the soil. Incorporation of rice residue into the soil within 30 days before sowing wheat crops led to lower yields of grape wheat relative to those when the rice residue was burned [15]. Moreover, rice stubble incorporation into the soil has a beneficial effect on physical, chemical, and biological soil properties such as pH, organic carbon, the ability of water retention and bulk soil density. According to Mandal et al. [16], the impacts on the physicochemical properties of the soil over 7 years of various crop residue management practices (incorporated, removed and burned) are comparatively. Both **Table 3** and **Table 4** clearly show that methods of handling the rice residue for soil nutrient conservation are in the following order: in situ incorporation > removal of the rice residue from the land > stubble burning.

Table 3. Comparison of impacts of different residue management practices on soil properties in Ludhiana, Punjab [17].

Soil Property	Crop Residue Management		
	Incorporated	Removed	Burned
Total P (mg/kg)	612	420	390
Total K (mg/kg)	18.1	15.4	17.1
Olsen P (mg/kg)	20.5	17.2	14.4
Available K (mg/kg)	52	45	58
Available S (mg/kg)	61	55	34

Table 4. Impacts of different residue management practices on soil properties [16].

Physiochemical Properties of the Soil	Crop Residue Management		
	Incorporated	Removed	Burned
pH	7.7	7.6	7.6
EC (dSM^{-1})	0.18	0.13	0.13
Organic C (%)	0.75	0.59	0.69
Available N (kg/ha)	154	139	143
Available P (kg/ha)	45	38	32
Available K (kg/ha)	85	56	77
Total N (kg/ha)	2501	2002	1725
Total P (kg/ha)	1346	924	858
Total K (kg/ha)	40480	34540	38280

Although crop residue retained in the field plays a positive role in recovering soil quality and reducing environmental pollution caused by stubble burning, seeding of wheat in the field with rice residue retained was a challenge until the development of a happy seeder machine recently. The ‘Happy Seeder’, incorporating mulching and drilling of stubble in a single unit, is a promising new method [18], where the stubble is cut and gathered before seeding, and the cut stubble is then deposited as a mulch behind the seed sower.

In contrast to other biomass to produce bioenergy, using crop residues for large-scale production of bioenergy, there are several challenges to address with respect to both efficiency and economy. For instance, crop residues commonly contain a high content of alkaline ash which would pose operating issues (corrosion and deposition) in boilers for electricity generation. Cost-wise, since the crop residues are bulky, so the feedstock transportation and processing (crushing/pelletizing) costs would be high for centralized large-scale power plants. While it might not make it profitable for large bioenergy plants fuelled by crop residue, it can be adopted as small-scale energy suppliers for households and smaller communities. For instance, digestive biogas can be easily used as a bioenergy source for households.

4. Government Support and Policies

India is a country rich in legislation concerning pollution. Scientists, engineers, environmentalists, and government officials are also aware of the harmful consequences of the practice of stubble burning of agricultural residues on human health, soil, soil fertility and the environment. There are 11 major pollution control laws in India and many different regulations for implementation of these laws [19]. However, in order to avoid the burning of the straw, Section 144 of the Code is called upon by the Government to prohibit paddy burning but is difficult to implement, likely due to insufficient efforts having been made to increase the awareness of farmers about the serious impacts of stubble burning practices [20]. Nevertheless, the government must play more active roles in implementing all measures or practices planned or suggested by the various government or non-government groups, environmental scientists, and activists at the ground level in order to put an end to this damaging activity of stubble burning.

Instead of working on solutions, the government has not even come out with the final version of its much-touted National Clean Air Plan (NCLAP) yet. The present Prime Minister of India, Narendra Modi and his cabinet ministers signed off on the plan in early 2018. The expenditure is far less than the $600 million per year that National Institution for Transforming India (NITI Aayog), a government policy advisory group, had initially proposed to the government. As per the proposed plan, money will be given to growers in three states bordering Delhi–Punjab, Haryana, and Uttar Pradesh to subsidize 80% of the cost of machinery for extracting crop residues from the fields, so as to avoid burning. Farmers are welcoming the plan since most of them cannot afford the machinery on their own. While this is an important step, it will depend on how quickly the scheme is rolled out at a scale that can make a difference. Other proposals put forward to deal with the stubble include purchasing crop residue by the state electricity company NTPC as a fuel in its coal-fired power stations.

(1) Providing farmers with incentives not to burn crop residue outdoors. (2) Facilitation of maximum land cover using agricultural conservation practices. (3) Promoting the sustainable, environmentally friendly, and cost-effective use of surplus crop residues for generating bioenergy in power plants. (4) Crop residues should be classed as recycled fertilizers, and their use as fertilizers or amendments should receive government support. (5) Increasing subsidy rates for farmers who retain and utilize their crop residues. (6) There should not be free power as the same policy has resulted in the installation of high-powered tube wells that draw water from deep within the earth. (7) Promoting in situ management of crop residues by fast decay by chemical or biological means and mulching by mechanical means. (8) Promoting the use of machines such as double disks, zero tillage and happy seeders. (9) Valorization of crop residues for useful products, for example, compost, organic manure and biochar as a renewable fuel for power generation or as a soil amendment to improve soil health and fertility. (10) Increasing the awareness of farmers on the serious impacts of the open field burning practice.

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