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Crop Residue Burning in India: Potential Solutions

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Abstract
India is the second largest agro-based economy with year-round crop cultivation, produces a large amount of agricultural waste, including crop residues. In the absence of adequate sustainable management practices, approximately 92 seems a very small number of metric tons of crop waste is burned every year in India, causing excessive particulate matter emissions and air pollution. Crop residue burning has become a major environmental problem causing health issues as well as contributing to global warming. Composting, biochar production and mechanization are a few effective sustainable techniques that can help to overcome the issue while retaining the nutrients present in the crop residue in the soil. The government of India has attempted to curtail this problem, through numerous measures and campaigns designed to promote sustainable management methods such as converting crop residue into energy. The solution to crop residue burning lies in the effective implementation of sustainable management practices with Government interventions and policies. However, effective implementation of these techniques also requires us to look at other socioeconomic aspects that had not been considered. The agricultural waste sector can benefit immensely from some of the examples from other waste sectors such as the municipal solid waste (MSW) and wastewater management where collection, segregation, recycling and disposal are institutionalized to secure an operational system. Even though the issue of crop residue burning touches number of sectors, such as environment, agriculture, economy, social aspects, education, and energy, the past governmental efforts mainly revolved around agriculture and energy.

Keywords: India; agricultural waste; crop residue; field residue; process residue; crop residue burning; biochar; composting; biogas; policy challenges

1. Introduction

The agricultural industry plays a prominent role in the overall economic growth of the world. However, there is little discussion on the management of agricultural waste in the published literature. It couldbe related to the fact that agriculture industry is not regulated as the municipal solid waste (MSW). The MSW is mainly governed by public entities such as municipalities and hence the generation and management data are collected, recorded, and analyzed in the public domain. Waste materials derived from various agricultural operations are defined as agricultural wastes. As per the United Nations, agricultural waste usually includes manure and other wastes from farms, poultry houses and slaughterhouses; harvest waste; fertilizer run-off from fields; pesticides that enter water, air or soils; salt and silt drained from fields [1–3]. Agricultural waste is predominantly handled by the owners of the agricultural land which is predominantly in the private sector, with negligible public sector involvement. The growing demand for food in developing countries have led to tremendous increase in food production around the world. The multitude of agricultural activities increases the amount of agro-products produced and this results in overall increase in environmental pollution and waste generation. Large stretches of wasteland have been converted to arable lands due to developments in water management systems, modern agro-technologies and large-scale agrochemical deployment [1]. These measures have resulted in global environmental pollution and increased complexity in the disposal of agricultural waste. However, the national agencies are continuously developing policies and possible options to manage these wastes, which includes their conversion to reusable resources. The harvest waste, which is more popularly termed as crop residue can contain both the field residues that are left in an agricultural field or orchard after the crop has been harvested and the process residues that are left after the crop is processed into a usable resource. Stalks and stubble (stems), leaves, and seedpods are some common examples for field residues. Sugarcane bagasse and molasses are some good examples for process residue [2, 4, 5].

Crop Residue: Composition And Decomposing Mechanisms

General types of crop residues produced by the main cereal crops and sugar cane are summarized in the these crop residues, specifically as a field residue is a natural resource that traditionally contributed to the soil stability and fertility through ploughing directly into the soil, or by composting. Plant biomass is mainly comprised of cellulose, hemicellulose and lignin with smaller amounts of pectin, protein extractives, sugars, and nitrogenous material, chlorophyll and in organic waste [6-8]. Compared to cellulose and hemicellulose, lignin provides the structural support and it is almost impermeable. Lignin resist fermentation as it is very resistant to chemical and biological degradation [8,9]. The non-food-based portions of crops such as the stalks, straw and husk are categorized under lginocellulosic biomass [5]. The major agricultural crops grown in the world—maize, wheat, rice and sugarcane, respectively, account for most of the lignocellulosic biomass.

Because of its resistance to chemical and biological degradation by fungi, bacteria and enzymes, the lignin layer is usually pretreated with the lignin degrading microorganisms to break down the lignin layer and degrade cellulose and hemicellulose matter to the corresponding monomers and sugars for effective biomass to fuel conversion [6]. The pretreatment could be mechanical, chemical, physico-chemical and biological. These methods result in increase of the accessible surface area, porosity and decrease in crystallinity of cellulose and hemicellulose and degree of polymerization.

The management of agricultural waste using microbes could also be an excellent option for the detoxification of the soil and mitigation of environmental pollution [11]. Microbial populations degrade the complex substances present in the biomass to simpler ones that can be reused or recycled through environmental processes. The techniques adopted can either be aerobic or anaerobic, depending on the nature of bacteria, fungi or algae involved in the degradation [12].

Adverse Impact Of Crop Residue Burning On The Environment

The burning of crop residues generates numerous environmental problems. The main adverse effects of crop residue burning include the emission of greenhouse gases (GHGs) that contributes to the global warming, increased levels of particulate matter (PM) and smog that cause health hazards, loss of biodiversity of agricultural lands, and the deterioration of soil fertility [10]. Crop residue burning significantly increases the quantity of air pollutants such as CO2, CO, NH3, NOX, SOX, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), semi volatile organic compounds (SVOCs)and PM [16,17]. This basically accounts for the loss of organic carbon, nitrogen, and other nutrients, which would otherwise have retained in soil [10,14].

The PM emitted from burning of crop residues in Delhi is 17 times that from all other sources such as vehicle emissions, garbage burning and industries [15]. As such the residue burning in the north west part of India contributes to about 20% of organic carbon and elemental carbon towards the overall national budget of emission from agricultural waste burning [10]. Crop burning increases the PM in the atmosphere and contributes significantly to climate change. One contributor to global climate change is the release of fine black and also brown carbon (primary and secondary) that contributes to the change in light absorption [7, 18, 19]. Usually PM in the air is categorized as PM2.5 and PM10 based on the aerodynamic diameter and chemical composition (PM2.5 or fine, particulate matter with aerodynamic diameter <2.5 _m and PM10or coarse, particulate matter with aerodynamic diameter <10 _m). Lightweight particulate matter can stay suspended in the air for a longer time and can travel a longer distance with the wind [14, 20]. The effect of particulate matter gets worsened by the weather conditions, as the particles are lightweight, stay in air for a longer time and causes smog. The annual contribution of PM2.5 due to burning of paddy residue in the Patiala district of Punjab was estimated to be around 60 to 390 mg/m3 [10].

Sustainable Management Practices For Crop Residue

Alternative measures have long been suggested by scientists and agriculturalists over the past decade to counter crop residue burning, but due to a lack of awareness and social consciousness among the farmers these measures have not been fully implemented. In this section information on three such agricultural applications that have either been overlooked or skipped due to various reasons are presented. They are: composting, biochar, and in-situ management through mechanical intensification.

Composting

Composting is the natural process of rotting or decomposition of organic matter by micro-organisms under controlled conditions [23]. As a rich source of organic matter, compost plays an important role in sustaining soil fertility and thereby helping to achieve sustainable agricultural productivity. Addition of compost to the soil improves physio-chemical and biological properties of the soil and can completely replace application of agricultural chemicals such as fertilizer and pesticides. Higher potential for increased yields and resistance to external factors such as drought, disease and toxicity are the beneficial effects of compost amended soil [23-25]. These techniques also help in higher nutrient uptake, and active nutrient cycling due to enhanced microbial activity in the soil.

During composting, the organic matter is acted upon in two phases

(i) Degradation: The first phase of degradation starts with breakdown of easily degradable organics like sugars, amino and organic acids. The aerobic microorganisms consume oxygen and release carbon dioxide and energy. The first thermophilic phase is dominated by high temperature, high pH and humidity, essential for activating the microorganisms and proceeds for several weeks to months [27]. During this phase, it is also ensured that the substrate is properly cooled with sufficient supply of oxygen [28].

(ii) Maturation: The second phase continues for few weeks, with breakdown of more complex organic molecules followed by decrease in microbial population. There is a change from thermophilic to mesophilic phase with a decrease in temperature to 40–45 _C [26, 28, 29]. Further at the final stage, temperature declines to an ambient value and the system becomes biologically less active. Finally, a dark brown to black color soil-like material is produced. This soil-like material also exhibits an increased humus content and decreased carbon-nitrogen ratio with a neutralized pH [23]. Eventually the biomass is transformed to a material rich in nutrients, which can improve the structural characteristics of the soil [30].

Biochar

Biochar is a fine-grained carbon rich porous product obtained from the thermo-chemical conversion called the pyrolysis at low temperatures in an oxygen free environment [33]. It is a mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions [34]. When amended to soil, highly porous nature of the biochar helps in improved water retention and increased soil surface area. This has made an increased interest in applying charcoal, black carbon and biochar as soil amendment to stabilize soil organic content. These techniques are viewed as a viable option to mitigate the GHG emissions while considerably reducing the volume of agricultural waste. The process of carbon sequestration essentially requires increased residence time and resistance to chemical oxidation of biomass to CO2 or reduction to methane, which leads to reduction of CO2 or methane release to the atmosphere [8,9]. The partially burnt products are pyrogenic carbon/carbon black and becomes a long-term carbon sink with a very slow chemical transformation, ideal for soil amendment [31,32]. It mainly interacts with the soil matrix, soil microbes, and plant roots [35], helps in nutrient retention and sets off a wide range of biogeochemical processes. In India currently, the biochar application is limited and mainly seen in in villages and small towns. Based on its wide applicability, it could be more valuable to promote biochar method in India.

In-Situ Management With Mechanical Intensification

In-situ application of the crop residue is adopted by many farmers as it is a natural process. This method also imparts certain benefits to the soil. There are two main way of conducting field applications, but both methods involve leaving crop residue on the farmland after harvesting. How they differ is based on what happens with tillage in the next season. In the first method, planting in the next season is carried out without tillage or with less tillage and in the other method crop residue is incorporated into the soil by mechanical means during tillage [36]. While in-situ management of crop residues can offer long-term cost savings on equipment and labor, both methods need special (new) equipment, e.g., machinery for crop residue incorporation into soils or no-till seeing equipment. Crop residue retention with no-tillage is mostly practiced in the North America and about 40% of the cropland across the United States alone is cultivated with no-till practice [34].

The National Policy for Management of Crop Residue [10] specifically mentions in-situ management through methods such as direct incorporation into soils and mulching as methods that should be promoted in India not only to control crop residue burning but also to prevent environmental degradation in the croplands.

Government Intervention

Stringent measures to mitigate crop burning and further to regulate crop waste management require involvement of the appropriate Government agencies. Several attempts were made by the Government of India to introduce and educate the agricultural community about the best practices of agricultural proposals were also formulated by environmentalists and Government officials to curb crop residue burning and to promote the usage of alternative sustainable management methods. Some of the laws that are in operation pertaining to crop residue burning are: The Section 144 of the Civil Procedure Code (CPC) to ban burning of paddy; The Air Prevention and Control of Pollution Act, 1981; The Environment Protection Act, 1986; The National Tribunal Act, 1995; and The National Environment Appellate Authority Act, 1997. Particularly, in the states of Rajasthan, Uttar Pradesh, Haryana and Punjab stringent measures have been taken by the National Green Tribunal (NGT) to limit the crop residue burning [10, 22].

National Schemes and Policies

The Government of India recently directed the National Thermal Power Corporation (NTPC) to mix crop residue pellets (nearly 10%) with coal for power generation [21]. This helped the farmers with a monetary return of approximately Rs. 5500 (77 USD) per ton of crop residue. These lucrative measures are yet to be in action and it can be profitably exploited by the farmers. Few measures, associated with bio-composting are run by the Indian government. The Rashtriya Krishi Vikas Yogna (RKVY), State Plan Scheme of Additional Central Assistance launched in August2007 is a government initiative, as a part of the 11th Five Year Plan by the Government of India [22].

In addition to above, the Ministry of Agriculture of India recently developed a National Policy for Management of Crop Residue (NPMCR) [7]. The following are the main objectives of the NPMCR, [6]:

1. Promote the technologies for optimum utilization and in-situ management of crop residue, to prevent loss of valuable soil nutrients, and diversify uses of crop residue in industrial applications.
2. Develop and promote appropriate crop machinery in farming practices such as modification of the grain recovery machines (harvesters with twin cutters to cut the straw). Provide discounts and incentives for purchase of mechanized sowing machinery such as the happy seeder, turbo seeder, shredder and baling machines.
3. Use satellite-based remote sensing technologies to monitor crop residue management with the National Remote Sensing Agency (NRSA) and Central Pollution Control Board (CPCB).
4. Provide financial support through multidisciplinary approach and fund mobilization in various ministries for innovative ideas and project proposals.

Summary and Conclusions

Crop residues are one branch of agricultural wastes that have posed especial challenges due to their vast volume and lack of capacities to manage them. Taking the fact into account that rice and wheat that usually produce the majority of crop residue being the major staples of India, the large-scale cultivation of these crops to feed the ever-increasing population has obviously led to generation of large quantities of crop residue. On an average 500 Mt of crop residue is generated yearly in India. While a majority of it is used for fodder, raw material for energy production, etc., still there is a huge surplus of 140 Mt out of which92 Mt is burnt each year, mainly in the northern states such as Punjab, Haryana and Uttar Pradesh. Especially the small-scale farmers resort to burning of crop waste as it is an inexpensive alternative due to the lack of technical awareness and lack of proper disposal opportunities. Large scale burning of crops increases CO_2, CO, N_2O and NOx in the atmosphere and has led to alarming increase in theair pollution. There was an frighten deterioration of the air quality in the northern India to nearly twice the permissible Indian standard and ten times higher than the WHO standard.

The Indian Government has attempted many interventions to cope up with the problem of crop residue burning through different campaigns. The Indian Agricultural Research institute (IARI), Indian Ministry of New and Renewable Energy (MNRE) are continuously promoting research and innovative measures to handle crop waste without burning. The National policy for management of crop residue (NPMCR) recently formulated by the Central Government, has laid out policies and regulations to be undertaken by the local agencies to resolve crop burning and initiatives to word sustainable management practices. Continued air pollution especially in the months of November and December suggest that above policies have not fully prevented crop burning. The real reasons behind the crop residue burning have more socioeconomic roots rather than agricultural or waste management ones. In lieu of this, sustainable solutions have been implemented that involve methods to feed the nutrients in the crop residue back into the same crop lands. Relatively overlooked bio-based products such as biogas, biochar andin-situ management with mechanical intensification are recognized as viable option for crop waste utilization. Guidelines could be formulated for composting in rural areas and enforce on all farmers through farmers association. The mechanization in harvesting can considerably reduce crop residue, and the equipment needed could be given in subsidy by the local bodies to the farmers. Individual small-scale farmers do not have the capacity to establish a long-lasting solution. The local government, the municipality, or a farmers' association should fill this void and launch community programs to assist such as equipment rentals, waste transportation, and possible linking of waste to where it can be needed as raw materials. Educating the farming community and empower them with technical as well as socio economic assistance. They should be educated about the advantage of reduced agrochemical cost due to the utilization of compost and the extra revenue they can receive through other type of recovery programs such as energy production.

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