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Burning issues of paddy residue management in north-west states of India

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A B S T R A C T

Disposal of paddy residue has turn out to be a huge problem in north-west Indian states, resulting farmers prefer to burn the residues in-situ. Paddy residue management is of utmost important as it contains plant nutrients and improves the soil-plant-atmospheric continuum. Burning biomass not only pollutes environment and results in loss of appreciable amount of plant essential nutrients. The objectives of the review paper is to access the amount of residue generation, its utilization in-situ and ex-situ, emphasize harmful effects of residue burning on human health, soil health and environment of north-west states of India specially in Punjab and Haryana. This paper also discusses the possible strategies, financial and socio-economic evaluation of the paddy residue management technologies and accentuates the assessment of range of potential policy instruments which would offer avenues for sustainable agriculture and environment. Timely availability of conservation agriculture (CA) machinery is of utmost significance to manage the paddy residues in-situ. Collection and transportation of voluminous mass of paddy residue is cumbersome, therefore, ex-situ residue management is still not an economically viable option. The agricultural waste opens vivid options for its versatile usage and is possible if residue is collected and managed properly. It is a prerequisite for surplus residues to be used for CA. There is an urge to create awareness among farming communities to incline them to understand importance of crop residues in CA for sustainability and resilience of Indian agriculture.

1. Introduction

The remains of the field crops after harvest is of enormous use which is a natural resource that add to soil structure and fertility. Their deployment may differ among various countries. Few opt to use crop residues as an option to feed animals, nutritional added value compost, and mushroom cultivation and even they are burnt in fields, whereas there is relevant possibility of spawning bio-energy for rural supply and development [1–3]. China [4], Indonesia [5], Nepal [6], Thailand [7], Malaysia [8], Japan [9], Nigeria and Philippines [10,11], utilizes crop residues as source of energy, whereas Philippines [10,11], Israel, China [4,12] uses it for composting while Lebanon, Pakistan [13,14], Syria [15], Iraq, Israel, Tanzania, China [12,16] and African countries involve these to offer it feed for animals [1,11,17]. Open residue burning is a common practice in Asia [18] and in other countries as well i.e. China [12,17,19], USA, Philippines [10,11], Thailand [10], Indonesia [5], Taiwan [10], Pakistan [13,14], Nepal [6] and India [6,20,21].

India is an annual gross crop residue producer of 371 million tons (mt), of which wheat and paddy residues constitutes 27–36% and 51–57% respectively [2,6]. The bio-energy potential annually generated from various residual agricultural mass is estimated to be 4.15 EJ, equivalent to 17% of India's aggregated consumption of principal energy [22–24]. Uttar Pradesh (53–60 mt) is a leading state of India for residue generation followed by Punjab (44–51 mt), Maharashtra (46–56 mt) and West Bengal [22]. Cereal crops (paddy, wheat, maize, millets) contributes 70% residue of which paddy crop is the contributor of 34% [25–28], however, results from the characterization analysis had revealed 84% of crop residues burning is from paddy-wheat system (RWS) while remaining 16% is from other types of crop rotations [17,29]. The extreme amount of residue from wheat, barley and pearl-millet is used as animal fodder, whereas stubbles of cotton and red gram are used as firewood fuel at household. Mustard husks are chiefly engaged to the fuel for brick kilns [30,31]. Paddy residues, which are

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Fig. 1. *In-situ* burning of paddy crop residue.

the most generous agricultural biomass from the paddy cultivation, have a crucial part to act on [17,32]. The paddy crop residue is burnt in-situ (Fig. 1), which is a common management practice in north-west (NW) India viz. Punjab, Haryana as well as Uttar Pradesh. Whereas, in rest of the country viz. Gujarat, Maharashtra, Tamil Nadu, Bihar, Assam, West Bengal and Jammu & Kashmir uses it as cattle feed, thatching for houses in rural areas, fuel for domestic cooking and industry, mulching material, compost making, power generation, biofuels, and in boilers for parboiling paddy [8,18,29,33,34]. With a global outlook of practicing agricultural residue burning in NW India, it is a contributor of 20% organic carbon (OC) and elemental carbon (EC) towards the overall budget of emission from agricultural waste burning. It was estimated that OC, EC and SPAHs from crop residue burning releases 505,968 Gg y^{-1}, 5992 Ggy^{-1} and 182,932 Mgy^{-1}, respectively. In India, in the year 2000, the predicted values of CH_4, CO, N_2O, and NO_x emissions from paddy and wheat straw burning are 110, 2306, 2 and 84 Gg respectively [2,21].

Keeping in view the above facts, the present article focuses assessment and management related to paddy remains, their generation, utilization and approximation of energy generation from paddy residue in NW states of India. This paper showcases the practice of paddy residue burning along with the magnitude of pollution caused and its impact on soil health, human health and environment. Moreover, the site specific relevant technologies developed for residue management, energy requirement during residue management practices and alternative use of paddy residue as cited in various literatures is also discussed. We hypothesized that management and utilization of crop residues in a sustainable and eco-friendly manner would definitely help in policy formulation by State Governments of NW India. The concept of residue management as per socio-economic and bio-physical conditions helped various stakeholders such as agricultural scientists, engineers, farmers, agro industry owners, farm machinery manufacturers, custom hiring service centers, NGOs, policy formulators and decision makers to keep clean and safe environment while sustaining farmer's income and soil health.

2. Methodology

2.1. Area, production and productivity of paddy-wheat crop in NW India

The area, production and productivity of paddy crop of NW states of India (Punjab and Haryana) is sourced from the Agricultural statistics at a glance [35], Statistical Abstract of Punjab [36], Haryana [37] and India [38]. Since the problem of paddy residue burnt is in combine harvested area under paddy-wheat crop rotation, therefore, area that fall for burning of paddy residue was calculated by subtracting the area under basmati variety of paddy, and area of zero/ happy seeder technology under combine harvested paddy crop. The residue of basmati/scented variety is not burnt in in-situ field and is extensively in use as animal fodder. Basmati is a famous variety of paddy crop raises a superior price; therefore, manual harvesting is the suited practice to minimize grain loss while it may has elevated loss when associated with combined harvesting [6]. About 90% of paddy area in Punjab and 75% in Haryana is harvested by combine harvester and this practice is increasing in different regions of the country where the paddy-wheat system is practiced [39–44].

2.2. Determination of amount of paddy residue available in the region

Paddy crop residue includes leaves, straw and husks that are left behind after the crop has been harvested. The quantity of paddy crop residues generated in NW states of India was estimated by crop-to-residue ratio (CRR) method. The CRR values were determined by an earlier study conducted [45,46] and used to find out the total crop residue production and its surplus value in the state in 2014–15. Total crop residue generated was predicted as:

$$Total\ \ crop\ residue\ generated\ (CRR)\ =\ Area\ covered\ by\ the\ crop\ (Ai)\ x\ yield\ of\ the\ crop\ (Yi)\ x\ crop-to-residue\ ratio\ of\ the\ crop\ (CRRi).$$

2.3. Estimation of power generation potential

The estimation of power generation assumes that the total biomass residue is restricted for electrical output in its end use [21,22,45]. Potential for power generation from biomass is calculated as follows:

$$Power\ generation\ potential\ (MWe)\ =\ Total\ available\ biomass\ (kilo-tons\ yr^{-1})\ x\ Energy\ content\ of\ biomass\ (MJ\ kg^{-1})\ x\ Net\ power\ cycle\ efficiency.$$

The energy content of biomass (on a dry, ash-free basis) is similar for all plant species, laying in the range 17–21 MJ kg^{-1}. For calculation work, lower range values had been taken with an assumption of taking minimum possible power generation potential on yearly.