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A review on zero tillage as a sustainable approach for crop residue burning

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Abstract
The management of crop residues is extremely important because it contains plant nutrients and enhances the soil-plant-atmospheric continuum. Burning biomass not only pollutes the atmosphere, but also contributes to the loss of important essential plant nutrients. In north-west states of India, especially in Punjab and Haryana, the disposal of crop residues primarily paddy has turned out to be a huge problem, resulting in farmers preferring to burn the residues in-situ. There are adverse effects on human health, soil health and the atmosphere from the burning of crop residues. In order to maintain the crop/paddy residues in situ, the timely availability of conservation agriculture machinery is of greatest importance. The processing and transport of sufficient crop/paddy residue mass is tedious, so the management of ex-situ residues is not yet an economically viable choice. For this vast dilemma, zero tillage is a promising solution. Agricultural waste opens up vibrant possibilities for its flexible use and can be used if residues are properly collected and handled. It is a requirement for zero tillage to be used for surplus residue. There is an urge to raise awareness among farming communities to enable them to understand the significance of zero tillage for crop residues to Indian agriculture's sustainability and resilience.

Keywords: Zero tillage, crop residues, soil health, environmental hazards, sustainable agriculture

Introduction
Conservation agriculture is a resource-saving agricultural crop production system that, in this era of climate change, aims to achieve fair benefit along with high and sustained production levels while simultaneously preserving the environment (FAO, 2010) [10]. The three interlinked principles of conservation agriculture are (i) continuous minimum mechanical soil disturbances, (ii) preservation of permanent organic soil coverage, and (iii) diversified crop rotations (FAO 2010) [10]. One component of conservation agriculture, zero tillage, refers to soil management systems that result in crop residues covering at least 30 percent of the soil surface (Jarecki and Lal, 2003) [21]. After harvesting, the remains of the field crops are of immense value, a natural resource that contributes to the structure and fertility of the soil. Few prefer to use crop residues as an alternative to feed livestock, compost and mushroom cultivation with nutritional added value, and even they are burned in fields, although there is a major possibility of bioenergy spawning for rural supply and production (Monforti *et al*., 2013; Bhattacharyya, 2014; Hayashi *et al*., 2014) [28, 7, 18]. China (Jiang *et al*., 2012) [23], Indonesia (Wati *et al*., 2016) [48], Nepal (Gupta, 2011) [15], Thailand (Suramaythangkoor and Zhengguo, 2012) [46], Malaysia (Koopman and Koppejan, 1997) [24], Japan (Yukihiko and Yamamoto, 2005) [50], Nigeria and the Philippines (Gadde *et al*., 2016) [11] use crop residues as energy sources, while the Philippines (Gadde *et al*., 2016) [11], Israel, China (Jiang *et al*., 2012, Liu *et al*., 2008) [23, 26] use crop residues as energy sources. Open residue burning is a common practise both in Asia (18) and elsewhere, i.e. China (Yang *et al*., 2008) [49], the United States of America, the Philippines (Gadde *et al*., 2016) [11], Thailand (Gadde *et al*., 2016) [11], Indonesia(5), Taiwan (Gadde *et al*., 2016) [11], Pakistan (Ahmed and Ahmad, 2013) [1], Nepal (Gupta, 2011) [15] and India (Gupta, 2011, Sarkar *et al*., 1999) [15, 37]. India is an annual producer of 371 million tonnes (mt) of gross crop residue, of which 27-36 percent and 51-57 percent are wheat and paddy residues (Hayashi *et al*., 2014) [18]. It is estimated that the bio-energy potential produced annually from different residual agricultural masses is 4.15 EJ, equivalent to 17% of the aggregated principal energy consumption of India (MNRE;

Hiloidhari *et al*., 2014; Lohan *et al*., 2013) [19, 27]. Uttar Pradesh (53-60 mt) is India's leading waste generation state, followed by Punjab (44-51 mt), Maharashtra (46-56 mt) and West Bengal (MNRE, 2014) [19]. Cereal crops (paddy, wheat, maize, millets) contribute 70% of the residue of which paddy crops contribute 34% (Bhattacharyya *et al*., 2015; Jain *et al*., 2014) [6, 20], but the results of the characterization study revealed that 84% of the burning of crop residues is from the paddy-wheat system (RWS) while the remaining 16% is from other crop rotations (Shafie, 2016, Singh, 2016) [38, 41] As animal feed, the extreme amount of residue from wheat, barley and pearlmillet is used, while cotton and red gramme stubbles are used at home as firewood fuel. Mustard husks are mainly associated with brick kiln fuel (Kumar *et al*., 2015, Sangeet and Kumar, 2016) [25, 36]. Paddy residues, which are the paddy cultivation's most generous agricultural biomass, have a vital role to play (Shafie, 2016, Shiun, 2008) [38, 40]. The residue of the paddy crop is burnt in situ, which is a traditional management practise in northwestern (NW) India Punjab, Haryana and Uttar Pradesh as well. Whereas, in the rest of the world, it is used as cattle feed, thatching for houses in rural areas, fuel for domestic cooking and industry, mulching material, compost producing, power generation, biofuels, and boilers for parboiling paddy (Singh and Panigrahy, 2011) [35]. Gujarat, Maharashtra, Tamil Nadu, Bihar, Assam, West Bengal and Jammu & Kashmir With a global outlook for the practise of burning agricultural residues in NW India, 20% of organic carbon (OC) and elemental carbon (EC) are adding to the total budget for emissions from the burning of agricultural waste. Organic and elemental carbon from the burning of crop residues were calculated to release 505, 968 Gg y^{-1}, 5992 Gg $y^{-1}$and 182,932 Mg y^{-1}, respectively. The projected values for CH_4, CO, N_2O, and NO_x emissions from paddy and wheat straw burning in India in 2000 are 110, 2306, 2 and 84 Gg respectively (Gupta *et al*., 2004) [14]. Bearing in mind the above facts, this review was assembled. We hypothesised that the sustainable and eco-friendly management and use of crop residues will certainly enable the state governments of NW India to formulate policy. Various stakeholders such as agricultural scientists, engineers, growers, agricultural industry owners, farm machinery manufacturers, custom hiring service centres, NGOs, policymakers and decision-makers were assisted by the idea of residue management in socio-economic and biophysical circumstances to maintain a clean and healthy environment while preserving income and soil health for growers.

Consequences of burning of crop residue

During the paddy harvesting seasons, incineration of crop residue in North West India has become an important source of atmospheric pollution (Punia *et al*., 2008; Badarinath *et al*., 2008; Auffhammer *et al*., 2006; Andreae and Merlet, 2001) [31, 4, 3, 2]. This practice has a detrimental effect on the population's health and also affects the regional climate and the development of crops. Burning of crop residues leads to aerosol and trace gas emission degradation of air quality Some studies have been performed to achieve stats behind air quality degradation due to aerosol and trace gas emissions (Oanh *et al*., 2011) [29]. These gases and aerosols are composed of carbonaceous matter that plays a vital role in global climate change and can contribute to a regional rise in aerosol levels, acid deposition, tropospheric ozone rise, and stratospheric ozone layer depletion. After carbon dioxide emissions, black carbon emissions are the second-largest contributors to current global warming (Ramanathan and Carmichael, 2008) [34]. Incinerating fields are an unregulated combustion phase in which, along with carbon monoxide (CO), unburnt carbon (as well as traces of methane, i.e. CH4), nitrogen oxides (NOx) and comparatively less sulphur dioxide (SO2), carbon dioxide (CO2), the key product of combustion, is released into the atmosphere. 3 kg of particulate matter, 60 kg of carbon monoxide, 1460 kg of carbon dioxide, 199 kg of ash and 2 kg of sulphur dioxide are released by the burning of one tonne of paddy straw. It also releases vast amounts of particles consisting of different organic and inorganic species. Approximately 70%, 7% and 0.66% of C present in paddy straw are released as CO_2, CO and CH4, respectively, while 2.09% of N in straw is released as N2O upon incineration (Galanter *et al*., 2000) [13]. The estimated annual contribution from the burning of crop residues was 0.10 Tg of SO2, 0.96 Tg of NOx, 379 Tg of CO2, 23 Tg of CO and 0.68 Tg of CH4. During paddy residue burning, the estimated value of PM2.5 mass concentration varies from 60 to 390 mg m-3 with the main contribution of organic carbon (OC: 33 percent), while contribution from EC centres in Patiala district of Punjab state at 4 percent (Gadde *et al*., 2016) [11]. About 50 per cent of OC is obtained from water soluble organic carbon during harvesting (Singh *et al*., 2010) [9]. For three factors, a significant increase in the quantity of PM10 and PM2.5 was observed in Mandi-Govindgarh *viz*. (i) the threshing process leading to the capture of particles of rice husk in the air, (ii) the shattering process leading to the capture of dry wheat seed shell, and (iii) the burning of stubble. The PM10 and PM2.5 values showed a decreasing trend during the post-harvesting season due to the reduced amount of stubble burning and pollutant dispersion. In comparison to the PM2.5 concentrations, the ratio of the average BC concentration showed that BC includes about 11.9 percent of the fine particulate matter gathered at all field burning experiment sites and about 14.7 percent for chamber simulation (Wati *et al*., 2016) [48].

Health threats to humans, birds and animals due to burning residues of crops

The incineration of crop residues leads to the release of toxic air pollutants, which can have a significant effect on human health. In addition to causing respiratory problems such as asthma, coughing, exacerbated chronic heart diseases and lung ailments, it can also affect infants, geriatrics and pregnant women (Treets *et al*., 2003; Singh *et al*., 2009) [45, 35]. Several studies have also reported greater risks of exposure to benzene for leukaemia, blood bone marrow disease, vertigo, somnolence, headache, nausea, aplastic anaemia, and pancytopenia and myelodysplastic syndrome cytopenia (Chandra and Sinha, 2016) [8]. The annual average concentration of benzene will decrease the mitigation of crop residue burning and ensure agreement with the National Ambient Air Quality Standards. Extreme lifetime cancer hazard calculations for children and adults due to benzene are 25 and 10 per million inhabitants, correspondingly above the threshold of 1 per million inhabitants of the United States Environmental Protection Agency (USEPA) (Chandra and Sinha, 2016) [8]. It also decreases the count of Red Blood Cells (RBC) in humans and adversely affects the body's oxygen carrying capacity. Animal wellbeing has also been adversely affected by inhaling small particulate matter (FPM). It induced inflammation of the cornea and temporary blindness and persistent bronchitis that contributed to conditions like asthma. Extreme exposure has contributed to a possible reduction in milk yield and often to animal death due to the conversion of normal Hb to deadly Hb due to high blood CO2 and CO levels (Dikshit and Singh, 2010) [9]. The pests and microorganisms of farmer's mates, such as bacteria, earthworm, etc., die due to burning. In the gaps, reptiles, such as mice, frogs, earthworms, lizards, die. The leaves of the trees burn and the greenery is lost all around. Owing to this activity, birds' nests are also shattered. Sparrows, eagles, vultures are becoming extinct; Singh *et al*., 2009 [45], stubble burning is one of the key causes of this).

Impact on soil health of crop residue burning

Heat from residue burning increases the temperature of the soil, allowing bacterial and fungal species to die. The death is temporary, however, as the microbes regenerate after a couple of days. However, repetitive burning in the field permanently decreases the microbial population. The exchangeable NH4 and bicarbonate extractable P content is immediately increased by burning, but there is no buildup of nutrients in the profile (Rajput *et al*., 2014) [33]. In the 0–150 mm soil layer, long-term burning lowers total N and C and potentially mineralized N. The burning of residues destroys soil-beneficial micro flora and fauna and eliminates a substantial portion of the organic material, thus depleting the fields' organic matter (Singh *et al*., 2010) [9]. Straw burning was estimated to increase the soil temperature at a depth of 10 mm to 33.8–42.2 ° C (Gupta *et al*., 2004) [14]. Approximately 23-73 percent of nitrogen is lost and the soil depth of fungal and bacterial populations is immediately reduced to 25 mm. The straw burning increased the soil temperature to such a high degree in the top 75 mm that the carbon-nitrogen balance in the soil changes rapidly (Singh *et al*., 2010) [9]. Oh. 3.6.5. Residue burning affects the budget for nutrients and the depletion of energy and damages the properties of the soil, thereby calling for change in harvesting technology and sustainable paddy-wheat system management. The carbon, nitrogen and sulphur present in the straw are completely burned and lost to the burning atmosphere. The retained crop residues enrich the soil, with organic carbon and nitrogen mainly. These nutrients, which come at a premium, must then be replenished by organic or inorganic fertilisers. In addition to the maximum amount of C, 80% of N, 25% of P, 50% of S and 20% of K present in straw are lost due to burning (Sangeet and Kumar, 2016) [36]. 6.1 kg N, 0.8 kg P, and 11.4 kg K contain one tonne of paddy residue (Jat *et al*., 2013). Paddy straw burning results in an intact loss of approximately 79.38 kg ha−1 N, 183.71 kg ha−1 P and 108.86 kg ha−1 K (Jat *et al*., 2013). Burning paddy straw residue causes losses of 3.85 mt of SOC, 59,000 t of N, 20,000 t of P and 34,000 t of K in Punjab state alone (Gupta *et al*., 2003) [17]. 26.1 mt C, 0.35 mt N is released every year due to the burning of crop residues, reported by Sahai *et al*., 2011 [35]. Due to straw burning, plants and trees standing on bunds, road sides and canal sides of 2–3 m height are adversely affected. There is also loss of microflora and fauna found in the soil. Loss of plant nutrients / vegetation Burning of residues affects the budget of nutrients and the loss of energy and damages the properties of the soil, thereby calling for progress in harvesting technology and sustainable paddy-wheat system management. The carbon, nitrogen and sulphur present in the straw are completely burned and lost to the burning atmosphere. The retained crop residues enrich the soil, with organic carbon and nitrogen mainly. These nutrients, which come at a premium, must then be replenished by organic or inorganic fertilisers. In addition to the maximum amount of C, 80% of N, 25% of P, 50% of S and 20% of K present in straw are lost due to burning (Sangeet and Kumar, 2016) [36]. 6.1 kg N, 0.8 kg P, and 11.4 kg K contain one tonne of paddy waste (Jat *et al*., 2013) [22]. Paddy straw burning results in an intact loss of approximately 79.38 kg ha−1 N, 183.71 kg ha−1 P and 108.86 kg ha−1 K (Jat *et al*., 2013) [22]. Burning paddy straw residue causes losses of 3.85 mt of SOC, 59,000 t of N, 20,000 t of P and 34,000 t of K in Punjab state alone (Gupta *et al*., 2003) [17]. 26.1 mt C, 0.35 mt N is released every year due to the burning of crop residues, reported by Sahai *et al*., 2011 [35]. Due to straw burning, plants and trees standing on bunds, road sides and canal sides of 2–3 m height are adversely affected. Due to burning, which results in biodiversity destruction, the micro flora and fauna present in the soil are also destroyed (PPCB, 2016) [32].

Effect of retention of crop residues under Zero tillage

By reducing upward heat flux from the soil, crop residues under zero tillage increase the lowest soil temperature in winter and decrease the soil temperature during the summer due to the shading effect. During the decomposition of higher-C: N crop residues and soil alkalinity by adding lower-C: N crop residues such as legumes, oilseeds and pulses, crop residues play an important role in improving soil acidity by releasing bases such as hydroxyls (Pathak *et al*., 2011) [30]. Crop residues also aid in the sequestration of soil carbon (Jain *et al*. 2014) [20]. For crop residues, especially from wheat and rice crops, there is a large C: N ratio of 70:1 to 100:1. Around 30-40 percent of C supplemented by crop residues becomes decomposed in about 2 months (Beri *et al*., 1992) [5]. As long as added C remains in the soil, it causes immobilisation of applied N. I decreased weed growth, (ii) decreased weedicide costs, (iii) improved soil physical, chemical and biological characteristics, (iv) plant nutrient recycling, (v) decreased fertiliser use in the next successive crops are the advantages of maintaining the remaining crops on the soil surface. Residues are converted into a plant nutrient reservoir, preventing nutrient leaching, raising cation exchange capacity (CEC), providing a pleasant biological N-fixation environment, raising microbial biomass, improving the function of enzymes such as dehydrogenase and alkaline phosphatase. Moreover, by reducing evaporation losses by up to 45 mm and increasing water holding capacity by 5-10 percent during the wheat growing season, residue retention on the soil surface helps to retain soil moisture. Owing to the shading effect of residues in the summer season, residue retention also decreases soil temperature and, due to the decrease in upward soil heat flow, raises the lowest soil temperature. It also improves infiltration, reduces the formation of soil crust, and runoff. Zero tillage makes a greater commitment to boosting soil quality, productivity, emissions reduction and sustainable agriculture in crop residue management (Gupta, 2012) [16]. For direct seeding of successive crops in loose and anchored straw loads up to 10 t ha-1, advanced zero-till seed-cum-fertilizer drill / seed planter technology (happy seeder, spatial zero seed cum fertiliser drill) has been developed (Sharma *et al*., 2014) [39]. In the management of crop residues for weed control, soil moisture and nutrient conservation, these advances are extremely useful.

Conclusion

The lack of resource conservation technology machinery is the first limitation to in-situ management of crop residues, and other limitations are the unavailability of residue-based power plants and bio-char units for ex-situ residue management. Instead of strict law enforcement, the government should promote alternative approaches to avoid residue burning and provide need-based assistance. As feed, fuel and industrial raw material for livestock, residue is of great economic importance. Complications related to the management of crop residues, by contrast, remain complex in different regions and related to socio-economic needs. The efficacy of the legally prohibited incineration of crop residues is limited due to a lack of adequate farmers' education on the effects of incineration on soil, human and animal health. While farmers are aware of the adverse effects of paddy straw burning at the farm level, the lack of economically viable and sufficient machinery and alternatives for the disposal of paddy residue are limited. For crop residue incineration as well as assortment, gasification as a boiler fuel, transformation into briquettes and preparation of successful harvesters, ex-situ alternatives should be promoted. Promoting organic recycling practises and incentives for farmers will ensure the maintenance of conventional practises that contribute to emissions and waste of potential resources. In-situ alternatives for crop residue management are required for the practise and implementation of zero tillage, which will reduce residue burning.

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