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Review Article

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India's Crop Residue Burning Problem and Its Potential Solution

Chaudhary MM[1]*, Chaudhary BA[2] and Lalani S[3]

[1]Centre for natural Resources management, India

[2]Cotton research sub-station, India

[3]Gujarat State Fertilizers & Chemicals Limited, India

***Corresponding author:** Mahendra M Chaudhary, Centre for natural Resources management, India, Tel: 9429290698; Email: mahendrachaudhary349@gmail.com

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Abstract

Crop residue burning has become a major environmental problem of India, as it causes air pollution as well as deteriorate the soil health includes loss of nutrients, organic matter and decline microbial population. India generates a large amount of crop residues (686 MT). In the absence of adequate sustainable management practices, approximately 135 MT crop residues is burned every year in India out of total availability. Consequently, a variety of alternative approaches should be considered as substitutes for open field burning, i.e., smart mechanization, livestock feed and shelter, mushroom cultivation, straw composting, biochar production, residue incorporation, surface retention and mulching, energy source, crop residues as liquid organic fertilizer and also as value added production.

Keywords: Crop Residue Burning; Biochar; Straw

Abbreviations

MGNREGA: Mahatma Gandhi National Rural Employment Guarantee Act; NMHC: Non-Methane Hydrocarbon; NMVOC: Non-Methane Volatile Organic Compounds; SVOCs: Semi Volatile Organic Compounds; WHO: World Health Organisation; TERI: The Energy and Resources Institute; Kt: kilo Tonnes; CPC: Civil Procedure Code; IARI: Indian Agricultural Research Institute; NOLF: Novel Organic Liquid Fertilizer; DWSR: Direct-Wet Seeded Rice; RSM: Rice Straw Mulch.

Introduction

India, the second largest agro-based economy with year-round crop cultivation, generates a large amount of crop residues (686 MT). In the absence of adequate sustainable management practices, approximately 135 MT crop residues are burned every year in India out of total availability. Crop residue burning has become a major environmental problem of India, as it causes air pollution as well as deteriorate the soil health includes loss of nutrients, organic matter and decline microbial population. It is crucial to maintain a threshold level of organic matter in the soil for maintaining physical, chemical and biological integrity of the soil and for sustained agricultural productivity. Efficient use of biomass by converting it as a useful source of soil amendment is one way to manage soil health and environment. In this context, smart mechanization, livestock feed and shelter, mushroom cultivation, straw composting, biochar production, residue incorporation, surface retention and mulching, energy source, crop residues as liquid organic fertilizer and also as value added production are a few effective sustainable techniques that offers a significant, multidimensional opportunity to transform large scale agricultural waste streams from a financial and environmental liability to valuable assets.

Reasons Behind On-Farm Burning of Crop Residues

Time Constraint: In North-West state of India, the paddy crop is usually harvested between the first to last weeks of October and then farmers sow the wheat crop from the first week of November.

- When paddy is harvested by a combined harvester and thresher, the machine leaves behind a significant length of stubble on the field. This prevents other machines from sowing wheat seeds.
- With only 10-15 days between the paddy-harvesting season and the wheat-sowing time, forced farmers burn the stubble to quickly eliminate the paddy stubble.
- Hence there is a very short period between paddy harvesting and wheat sowing. Hence due to lack of time for field preparation, they usually go for burning of the residue.

Resource Constraint: Labourers are required to remove the rice straw from the field and it is considered a labour-intensive process.

- For the harvesting of rice crop, the labourers from the states of Eastern Uttar Pradesh and Bihar are primarily employed in the North-West India. When the MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) in 2006 was introduced, this time onwards it led to significant shortage of labour.
- Due to lack of human resource and high cost of wages the residue conservation is highly difficult.

Farm Mechanization: With the introduction of combine harvester, large residue loads remained in the field, making sowing of succeeding crop relatively more difficult.

- By using sickle, the farmers cut the residues very close to the ground and whatever the residue left that is very minimum and will not hinder for sowing of next crop, but with combine harvester about 25-30 cm stubble remains above the ground level.
- The north-western part has about 75% of the cropped area under combines harvesting. On using combine harvesting about 80% of the residues are left in the field as loose straw that finally ends up being burnt on farm.

Financial Constraint: Large farmers can afford the amount by purchasing the costly equipment for the fields as well as for other purposes, but the marginal and small farmers are not able to purchase the implements to plough back the stubbles to mix back into the soil particularly for the managing of crop residues as there is a lot of burden for those farmers to spend that much amount on these implements.

Pest and Pasture Management: It also provides a fast way of controlling weeds, insects and diseases, both by eliminating them directly or by altering their natural habitat.

Adverse Effect of On-Farm Burning of Crop Residues

Emission of Greenhouse Gas and Other Gas

- ✓ Increases the quantity of air pollutants such as CO_2, CO, NH_3, NO_X, SO_X, Non-methane hydrocarbon (NMHC), Non-methane volatile organic compounds (NMVOC), Semi volatile organic compounds (SVOCs).
- ✓ Burning of 98.4 MT of crop residue has resulted in emission of nearly 8.57 MT of CO, 41.15 MT of CO_2, 0.037 MT of SOx, 0.23 MT of NOx, 0.12 MT of NH_3, 1.46 MT NMVOC and 0.65 MT of NMHC, where CO_2 is 91.6% of the total emissions. Remaining 8.43% consisted of 66% CO, 2.2% NO, 5% NMHC and 11% NMVOC.
- ✓ One ton of rice straw on burning releases about 60 kg CO, 1460 kg CO_2, 199 kg ash and 2 kg SO_2.

Increased Levels of Particulate Matter

- ✓ Usually, PM in the air is categorized as $PM_{2.5}$ or fine and PM_{10} or coarse based on the aerodynamic diameter and chemical composition
- ✓ The WHO standard for permissible levels of $PM_{2.5}$ in the air is 10 μg/m^3, and according to the India's National Ambient Air Quality Standard, the permissible level for $PM_{2.5}$ is set at 40 μg/m^3.
- ✓ The PM are lightweight, stay in air for a longer time and causes smog.
- ✓ The annual contribution of $PM_{2.5}$ due to burning of paddy residue in the Patiala district of Punjab was estimated to be around 60 to 390 μg/m^3
- ✓ It is estimated that burning of crop residues in situ releases about 627 kilo tonnes (Kt) of PM_{10} and 4677 Kt of carbon monoxide to the atmosphere annually in India The Energy and Resources Institute (TERI).

Pollutants	Area in Delhi	Current Level (μg/m^3)	Permissible Limit (μg/m^3)
$PM_{2.5}$	Punjab Bagh	650	60-80
PM_{10}	Punjab Bagh	1000	60-80

Table 1: Emission level of air pollutants in Delhi during harvesting season in Haryana and Punjab.

Loss of Nutrients

- ✓ According to NPMCR, it is reported that burning of one ton of straw accounts for the loss of entire amount of organic carbon, 5.5 kg of nitrogen, 2.3 kg of phosphorous, 25 kg of potassium and 1.2 kg of sulphur.

- ✓ If the crop residue is incorporated or retained in the soil itself, it gets enriched, particularly with organic Carbon and Nitrogen

Decline microbial population

- ✓ Soil temperature, pH, moisture and soil organic matter are some of the soils properties that are greatly affected due to burning.
- ✓ During burning of crop residue, soils temperature increases up to 33.8 °C to 42.2 °C. Thus, burning not only disturbs soils natural environment but also have an adverse effect on microbial population of soil.
- ✓ Most of the soil microorganisms are mesophilic having 37°C as their optimum temperature. The sudden increase in temperature during burning results in decline of microbial population up to a depth of 25 mm.
- ✓ Low microbial declines organic matter decomposition which affects aggregate formation and stability.
- ✓ Studies have shown a decline of 30-50% in bacterial population on burning.

Government Intervention

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
- ✓ The National Environment Appellate Authority Act, 1997
- ✓ States like Rajasthan, Punjab and Haryana imposed fines between Rs. 2500 to Rs. 15,000 on farmers indulging in crop-burning.
- ✓ Under (NPMCR) promote the technologies for optimum utilization and *in-situ* management of crop residue 2018-19.

Crop Residues Management and it's Alternative Use (Potential Solution):

Smart Mechanization:

Straw Baler: It cuts the straw from combine harvested fields and makes bundles.

Stubble Shaver: Cuts and mixes the straw in the field and reduced subsequent farm operations.

Straw Reaper/Combine: It cuts the standing straw left in the field after combining and throw it in a trolley at the rear.

Happy Seeder: Simultaneously cuts the standing straw, planting wheat seed and throw the straw on the planted seeds.

Singh, et al. [1] recorded significantly the highest grain and straw yields of wheat by planting with happy seeder than using rotavator and farmer practices at Kapurthala and Patiala. Significantly higher grain yield and biological yield of wheat were recorded with treatment PAU cutter cum spreader (M_2) + PAU happy Seeder with press wheel [2].

Livestock Feed and Shelter:

- ✓ 50% is directly used for the animal feed
- ✓ Used as thatching material
- ✓ Used for bedding material
- ✓ Conserved as hay and use it in lean period
- ✓ In Construction of Animal shed

Mushroom Cultivation:

- ✓ Wheat and rice straws are excellent substrates for the cultivation of mushrooms.
- ✓ In India, there is huge availability of these paddy straw which enhances the profitability of farmers and can be considered as one of the sustainable substrates for mushroom cultivation

Straw Composting:

- ✓ These way plant nutrients can be recycled, enhance the soil microbial population, reduce fertilizer requirement and improve soil quality.
- ✓ In dry areas direct application of straw, may not be suitable, because it takes more time to decompose, in such case composting is a better option.
- ✓ Recently the Indian Agricultural Research Institute (IARI) developed a bio-decomposer technique also called as 'Pusa Decomposer' which converts the crop stubbles into compost.
- ✓ It takes around 20 days for the degradation process to be completed.

Dadhich, et al. [3] recorded significantly the highest grain, straw yield as well as available N, P and K by the application of 100% RDF. However, there was maximum availability of the same nutrients as well as grain and straw yield with application of pigeon pea, mustard and chickpea stover compost as compared to 50 % RDF of rice. Moharana, et al. [4] studied that application of rice straw compost + 50% NPK for four years recorded with maximum microbial biomass carbon and significantly higher grain and straw yield of wheat and green gram than other treatments.

Biochar production:

- ✓ Biochar is a carbon rich charcoal-like substance created by heating of biomass (organic matter) in low oxygen conditions (pyrolysis).
- ✓ It can potentially play a major role in the long-term storage of carbon in soil.
- ✓ It is used as a soil improver for both carbon sequestration and soil health benefits.

Chaudhary, et al. [5] observed significantly higher porosity as well as OC and minimum BD with application of bio char @ 12 t/ha and the highest grain weight of wheat with application of 75 % RDF + Biochar @ 12 t/ha. Ullah, et al. [6] revealed that significantly the highest total OC, biomass and grain yield were recorded with application of sugarcane bio char @ 10 t/ha as compared to other treatments. Patel [7] recorded minimum BD and significantly highest WUE, OC %, NUE, weight of cob and ultimately grain yield per plant of maize with application of biochar @ 2.5 t/ha.

Residue Incorporation:

- ✓ Crop residues are incorporated completely or partially into soil by ploughing.
- ✓ Above ground portion chopped into small size and can be incorporated by power-tiller.
- ✓ Incorporation of straw increases soil organic matter and N, P and K contents in soil.
- ✓ But leads to temporary immobilization of nutrients (e.g., Nitrogen)
- ✓ Extra nitrogenous fertilizer needs to be added to correct the high C:N ratio at the time of residue incorporation.

Mandal, et al. [8] observed significantly the highest total porosity as well as wheat grain yield and minimum BD with combine application of FYM plus incorporation of straw as compared to sole application of the same and straw burning. Kachroo, et al. [9] recorded significantly the highest microbial count with incorporation of 5 t/ha crop residue as compared to left over stubbles and without crop residues on soil in rice-wheat cropping system. Dhar, et al. [10] indicated that significantly highest grain yield, straw yield, OC % as well as available N, P and K recorded with incorporation of straw @ 5 t/ha before 20 days of sowing of wheat with green manuring @ 5 t/ha.

1.1.1. Surface Retention and Mulching

- ✓ Surface mulching of crop residues is a technique in which the residues from the previous crop are left on the soil surface without being incorporated
- ✓ This method is prevalent in no-till or conservation tillage practices.
- ✓ It is better option for conservation of soil and avoiding water losses by evaporation.
- ✓ It also reduces the weed seed germination and helps in building of soil microbial populations results in improving soil health.

Sutaria, et al. [11] found that the minimum BD with groundnut shell @ 5 t/ha as mulch in groundnut pearl millet intercropping system. However, significantly higher OC %, available N and K were recorded with farm waste @ 5 t/ha. Whereas higher available P observed using wheat straw @ 5t/ha. Besides these, significantly higher available S recorded with application of groundnut shell @ 5 t/ha. Significantly higher rice grain yield recorded by Devasinghe, et al. [12] in direct-wet seeded rice (DWSR) by using rice straw mulch (RSM) as compared to without weeding and using chemical. Mathukia, et al. [13] recorded significantly higher soil moisture % and grain yield and minimum BD with wheat straw @ 5 t/ha as mulch as compared to other treatments.

Energy Source

- ✓ In comparison with other renewable energy sources such as solar and wind, biomass source is storable, inexpensive, energy-efficient and environment-friendly.
- ✓ Availability of residues, transportation cost and infrastructural settings (harvest machinery, modes of collection, etc.) are some of the limiting factors of using residues for energy generation

Crop residues as Liquid Organic Fertilizer

- ✓ Banana pseudostem sap is obtained as a byproduct during extraction of fiber.
- ✓ It is a rich source of plant nutrients and growth regulators.
- ✓ On an average, from one hectare banana plantation around 12000 to 15000 liters sap is obtained.

Uses

- ✓ Can be used in all crops as foliar application
- ✓ Reduces the use of chemical fertilizers
- ✓ Suitable for use in organic farming system
- Fernando, et al. [14] recorded significantly the highest seed yield of cowpea by application of 1% pseudo stem sap solution as top dressing with recommended N, P and ½ K as basal dose as compared to increased doses of pseudo stem sap solution. Chakraborty, et al. [15] revealed that application of 1.0% (v/v) Novel Organic Liquid Fertilizer (NOLF) recorded maximum fruit yield of strawberry.
- ✓ Crop residues as value added product.

Conclusion

Undoubtedly, the lack of proper management of abundant crop residue has an adverse influence on the environment and human health not only in India but also in the world and agricultural field burning has created many environmental problems, particularly causing a threat to the soil health and the emission of toxic gases. Consequently, a variety of alternative approaches should be considered as substitutes for open field burning, *i.e.,* smart mechanization, livestock feed and shelter, mushroom cultivation, straw composting, biochar production, residue incorporation, surface retention and mulching, energy source, crop residues as liquid organic fertilizer and also as value added production.

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