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IMPACTS OF BIOMASS BURNING ON ECOSYSTEM SERVICES

G K Dinesh[1*#], D K Sharma[1], M Sinduja[2], V Sathya[3], S Karthika[4], S Kiruthiga[5], P Sivasakthivelan[6]

[1]ICAR-Indian Agricultural Research Institute, New Delhi, India

[2]National Agro Foundation, Chennai, India

[3]Tamil Nadu Pollution Control Board, Chennai, India

[4]Tamil Nadu Agricultural University, Coimbatore, India

[5]University of Madras, Chennai, India

[6]Annamalai University, Chidambaram, India

Abstract

Burning biomass poses a severe concern and is currently a hot topic. In India, about 85–90% of biomass is burned in the field. Burning agricultural crop residue also contributes to the release of various pollutants that are harmful to human health. It also has a negative effect on the many ecosystem services, including those that are regulating, providing, sustaining, and cultural. It impacts pollinators, reduces soil fertility, changes soil structure, and influences how naturally pests and diseases are controlled. It lessens nematode, microbe, earthworm, insect, and pathogen biodiversity. Burning biomass removes nutrients, which has a significant impact on the ecology. Biomass burning removed around 2400, 35, 3.2, 21 and 2.7 kg of carbon, nitrogen, phosphorous, potassium, and sulphur from the soil. The cost to add those nutrients back to the soil using the replacement cost technique is Rs. 30834. The economic benefits of biomass include its usage as a source of energy, biofuel, compost, gasification, and bio-methanation. The effects of burning biomass and the uses of biomass must be understood by all parties involved.

Introduction

India is a highly populated agrarian country and although approximately 16.5% of India's GDP is devoted to agriculture, the industry nevertheless employs the majority of workers (around 42.3% in 2019)(Gulati and Juneja 2022). In 2022, the output of food grains reached a record high of 314.51 million tonnes (Mt) (Jha *et al*. 2022). The agricultural leftovers left behind after grain harvest are referred to as biomass. It is anticipated that the crop leftovers (biomass) from the food grains comprise roughly 500-550 Mt of biomass(Devi *et al*. 2017). These biomass crop wastes are utilised for mulching, livestock feed, manuring etc. But mostly they were burnt on the field itself for the preparation of field for following season harvest. The time was extremely less forfarmers to manage them efficiently and it needs some money or work to go for manure preparation or others.

In the Indo-Gangetic plains, the crop remnants of rice, wheat, maize, cotton, sugarcane, millets, and mustard were primarily burned in fields (IARI 2012). It is quite frequent in North West India notably in National Capital region (NCR) *i.e.*, Delhi, Haryana, Rajasthan, and Uttar Pradesh. Meanwhile, feed costs are climbing up significantly. The burning of biomass was centred in Punjab. From October 1 to November 10, the crop was largely burned.Burning agricultural crop residues can release pollutants such as CO_2, N_2O, CH_4, CO, NH_3, NO_x, SO_2, NMHC, VOCs, and SVOCs (Zhang *et al*. 2011, Jain *et al*. 2014). Burning crop leftovers also depletes resources and nutrients (Jain *et al*., 2014). Crop residues lose all of the carbon, 89–90% of the nitrogen, 25% of the phosphorus, 20% of the potassium, and 50% of the sulphur, which contributes to air pollution

(Raison 1979, Ponnamperuma 1984, Lefroy et al. 1994). According to studies by Jain et al., (2014), nutritional loss is 0.394% N, 0.014% P_2O_5, and 0.295% K_2O Mt/year, respectively.

Burning biomass alters the composition of the atmosphere, which may affect the radiation budget and contribute to climate change (Koppmann *et al*. 2005, Streets *et al*. 2006). Increased ozone, carbon monoxide, and aerosol levels as a result of biomass burning are a severe problem as well (Khodmanee and Amnuaylojaroen 2021). Regional, global, and radiative forcing are all impacted by aerosols (Jain *et al*. 2014). A false widespread belief is that biomass burning exclusively occurs when crop wastes are burned in agricultural areas. However, it also occurs as a result of deforestation, shifting agriculture, savannah fires, and the burning of fuel wood (Zhang *et al*. 2011).Forest burning accounts for the majority of biomass burning on a worldwide scale, with 2020 Tg (or about 25% of total burning) coming in second (Crutzen and Andreae 1990, Andreae and Merlet 2001, Chang and Song 2010).

Agricultural residue generation in India and burning of biomass

According to research by Jain *et al*., (2014), cereals provide 361.85 million tonnes of biomass, oilseeds 28.72 million tonnes, fibre crops 122.37 million tonnes, and sugarcane 107.50 million tonnes. Uttar Pradesh, Punjab, and Maharashtra are the top three states for residue burning, contributing around 60, 51, and 46 million tonnes, respectively. Jain *et al*., (2014) also calculated the amount of leftovers burned according to the crops. Cereals make up roughly 58% of the total, followed by sugarcane, oilseeds, and fibres at 17%, 5%, and 20%, respectively. Rice makes up over 53% of the grains, followed by wheat, millets, and maize at 33%, 7%, and 7%, respectively.

According to Mandal *et al*., (2004) findings, 350 Mt of crop residues were thought to have been produced. India has a gross crop residue potential of 696.38 million tonnes per year. Crop leftovers from cereal crops total roughly 364.27 million tonnes each year (Venkatramanan *et al*. 2021).The burned agricultural residues were calculated by Jain *et al*. and the IPCC using coefficients (2014). According to the IPCC coefficients, 131 million tonnes of biomass were burned in the year 2008–2009, whereas Jain and colleagues estimated 98 million tonnes of biomass were burned in the same year.

Ecosystem services

The benefits that humans derive from ecosystems are known as ecosystem services. These consist of provisioning services like food and water, regulating services like preventing floods and diseases, cultural services like spiritual, recreational, and cultural advantages, and supporting services like nutrient cycling that preserve the circumstances for life on Earth (Dinesh 2022).They are divided into four categories. They are provisioning, regulating, supporting and cultural services. Sometimes, the impact of climate change and anthropogenic interventions increases ecosystem disservices, which are often known as negative impacts(Dinesh *et al*. 2022).

Impacts of biomass burning on provisioning services

Products derived from ecosystems, such as genetic resources, food and fibre, and fresh water, are examples of provisioning services. Biomass burning indirectly impacts the food production by soil nutrients loss and destruction of soil organic carbon and biota. Biomass burning negatively impacts the production of food, fibre, fuel and fodder. Loss of provisioning services refers to how residue burning reduces agricultural profitability, either by raising production costs or lowering yields. Other negative effects besides yield reductions include lost job possibilities, a lack of raw materials for industry, a lack of feed, and higher input costs for farmers like irrigation and fertiliser(Kumar *et al*. 2019).

Impacts of biomass burning on supporting services

Ecosystem services that must be present in order for all other ecosystem services to be produced is known as supporting services. Examples include the creation of biomass, the creation of atmospheric oxygen, the formation and retention of soil, the cycling of nutrients and water, and the supply of habitat. Biomass burning destructs lot of supporting services provided by the natural and agro ecosystems.

1Impacts on soil

Burning has the following effects on soil, carbon dioxide emissions from soil organic matter, it also makes the soil's nitrogen balance fluctuates drastically, it also causes loss of different soil nutrients. According to Kumar *et al*., (2015), in the 0–15 cm layer, nitrogen is fully lost into the atmosphere due to crop residues burning. According to Gupta *et al*., (2004), a temperature increase of 33.8-42.2°C results in a loss of 27-73% nitrogen. According to some other research, every 10t of crop output removes 750kg of NPK from the soil. According to PAU, 0.824 mt of NPK nutrients were lost from the soil. Nematodes, microorganisms (bacteria, fungus, and actinomycetes), beneficial insects, weeds, snakes and reptiles, snails and mesofauna, are all lost due to biomass burning.

Nutrient losses as a result of burning biomass

Crop residue burning results in loss of nutrients as well as pollution. As a result of burning biomass, various amounts of nutrients were lost. The table below highlights the important nutrients that have been lost.The quantity of various nutrients lost as a result of the on-farm burning of rice straw, wheat straw, and sugarcane waste were also assessed in the study by (Jain *et al*. 2014). Burning sugarcane waste caused the most nutritional loss, followed by burning rice bran and wheat straw. Each year, the burning of sugar cane waste resulted in the loss of 0.84 Mt, 0.45 Mt, and 0.14 Mt of nutrients, of which 0.39 Mt were nitrogen, 0.014 Mt potassium, and 0.30 Mt were phosphorus.

Table. 1 Nutrient losses reported in various literatures

Nutrients	**Lefroy *et al*., (1994)**	**Mandal *et al*., (2004)**	**Gadde *et al*., (2009)**	**Swamy *et al*., (2021)**
C	-	-	-	2400 kg
N	80-90%	80%	25%	35 kg
P	25%	25%	25%	3.2 kg
K	20%	21%	75%	21 kg
S	50%	4-60%	50%	2.7 kg

Aerial pollution results from the loss of all of the carbon (C), 80–90% of the nitrogen (N), 25% of the phosphorus (P), the potassium (K), and the sulphur (S) that are contained in agricultural residues (Raison 1979, Ponnamperuma 1984, Lefroy et al. 1994). The quantity of various nutrients lost as a result of the on-farm burning of rice straw, wheat straw, and sugarcane waste was also assessed in the study mentioned above. Burning sugarcane waste caused the most nutritional loss, followed by burning rice bran and wheat straw. Each year, the burning of sugar cane waste resulted in the loss of 0.84 Mt, 0.45 Mt, and 0.14 Mt of nutrients, of which 0.39 Mt were nitrogen, 0.014 Mt potassium, and 0.30 Mt were phosphorus. The nutrient losses reported in various literatures were tabulated in the **Table.1**. The major states of Punjab, Uttar Pradesh, Haryana, and Maharashtra are where the majority of crop wastes were burned on farms. The three main crops whose leftovers are dealt with on farms are rice, wheat, and sugarcane. Large-scale agricultural waste burning from the rice-wheat system in Punjab, Haryana, and western Uttar Pradesh raises major issues with pollution, health risks, and nutritional loss in addition to GHG emissions.

Impact of biomass burning on microbes

As a result of residue burning, the amount of microbial biomass is significantly decreased, but it gradually rebuilds or grows each year. According to research by Pietikäinen & Fritze, (1993), it takes about 36 years for the amount of microbial biomass to return to its pre-burning levels. According to research by Liu *et al*., (2007), the Microbial Biomass Number grew by 14.2% within 5 years and by 29.8% within 10 years. Unburned sites also had MBC and MBN that were 1.5 times greater than burnt sites. Kumar *et al*., (2015)reported that a 50% reduction in microbial population. Gupta *et al*., (2004) estimated that the top 2.5 cm of soil lost bacterial populations. Microbial activity and quantity affect soil productivity and nutrient cycling, they are essential for preserving soil fertility(Jenkinson and Ladd 1981). The majority of microbes were capable of detoxifying, accumulating, and effluxing metal ions, played a significant part in ecosystem(Sinduja *et al*. 2022a, 2022b). Additionally, they developed effective molecular mechanisms and ran particular metabolic pathways (Sinduja *et al*. 2022c).The numerous fires that frequently occur in this temperate wet region have a detrimental effect on the density and variety of soil microorganisms as well as soil structure. Burning significantly reduces the microbial biomass of these soils, whose recovery might take up to 13 years.

Impacts of biomass burning on earthworms:

Pheretimaalexandri, one of the largest and most prevalent species of earthworms at Medziphema, Nagaland, North Eastern India, is impacted by biomass burning. Few studies, including those by Reddy (1983) and Satchell (1983)reported the decrease in earthworm populations following fire episodes. In burnt castings, fire increased the amount of P_2O_5 and K_2O that was readily accessible while decreasing the pH and percentage of organic carbon. There is no research on how fire affects worms. Studies on the impact of fire on North Eastern Indian soils show declines in organic carbon content and increases in P_2O_5 and K_2O availability (Arunachalam and Arunachalam 2000). Alternatively, crop residues left in the soil as mulching material can positively impact the earthworm population and increases in the soil (Sharma *et al*. 2017).

Impacts of biomass burning on regulating services

The benefits derived by managing environmental processes, such as, for instance, the control of climate, water, and some human diseases, are known as regulating services.

Effects of burning biomass on honey bees

On three study blocks in the United States' Green River Game Management Area, pollinating insects were sampled. A total of 7921 floral guests from 21 families and four orders. The most numerous and diversified order, comprising 56.8% of all floral visitors, was the hymenoptera. Diptera include two families and 13 species, making up 23.6% of all floral visits. Unexpected outcomes in subsequent years Halictidae growing annually. In the burnt site and unburned areas listed below, both the orders of Hymenoptera and Diptera were significantly decreased (Campbell and Hanula 2007).

Impact of biomass burning on soil organic carbon

Burning biomass has an adverse effect on soil organic carbon, which has entirely decreased as a result. The effects of biomass burning were discovered by Parker et al., (2010)from the experiments at depths of 0-5 cm and 5–10 cm.After burning, the proportion of soil organic carbon decreased in both depths, although the fall in the 0-5 cm depth was 15% more than i 5-10 cm level, and Scott et al. (1999)reported a similar finding in their research.Since there was a lot of organic matter and enough oxygen at the 0–5 cm depth, strong combustion and eventual oxidation of organic C into the atmosphere resulted from the intensive combustion in this zone. Additionally, soil moisture, organic matter, variations in texture, structure, and water holding capacity largely prevented the vertical transfer of surplus heat into the soil, reducing the impact of the heat on the top 5-10 cm of the soil. The findings suggested that the effects of heat on soil organic carbon are realistically substantial and should be opposed, especially by farmers who believe that burning biomass is the most effective approach to lower production costs. This is particularly feasible when farmers have the financial means to invest in mechanical tillage and agricultural techniques.

Emissions from biomass burning

Burning agricultural crop residue also contributes to the release of particulate matter, smoke, greenhouse gases (CO_2, N_2O, CH_4), air pollutants (CO, NH_3, NO_x, SO_2, NMHC), volatile organic compounds (VOCs), and greenhouse gases (CO_2, N_2O, CH_4) that are harmful to human health. The emissions from biomass burning showed in various literatureswere tabulated in the **Table. 2.**

Table. 2 Emissions showed in various literatures (Gg/year)

Pollutants	Venkataraman *et al.*, (2006)	Gupta *et al.*, (2004)	Gupta & Sahai, (2005)	Badarinath *et al.*, (2006)	Badarinath *et al.*, (2006)
BC	102-409	-	-	-	-
OC	399-1529	-	-	-	-
OM	663-2303	-	-	-	-
CO_2	224-638	-	-	-	-
CO	13-81	2138	2305	113	261
SO_2	66-238	-	-	-	-
NO_x	393-1540	78	84	8.6	19.8
CH_4	420-1486	102	110	1.33	3
NMVOC	2039-7406	-	-	-	-
NH_3	189-661	-	-	-	-
N_2O	-	2.2	2.3	-	-
PM_{10}	-	-	-	13	30
$PM_{2.5}$	851-3317	-	-	12	28.3

Impacts of biomass burning on cultural services

The non-material benefits that individuals derive from ecosystems via spiritual development, cognitive growth, introspection, leisure, and aesthetic experience are known as cultural services. These benefits include, for example, social networks, interpersonal relationships, and aesthetic ideals. The biomass burning indirectly impacts the cultural and aesthetic values of the human.

Effects of burning biomass on human health

Humans and other creatures are affected by the release of toxic compounds such as polychlorinated dibenzo-p-dioxins, polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzofurans (PCDF), and dioxins(Maceira *et al*. 2022). The negative effects including,animals dyingwhen their blood contains excessive levels of CO_2 and CO.$PM_{2.5}$ stimulates asthma, changes blood haemoglobin, lowers milk output, increases bronchial attack symptoms, and causes more pain in pregnant women and children.Biomass burning also creates problems in cardiovascular and respiratory conditions(Chaitanya *et al*. 2022).

Methods for calculating the cost of burning biomass

For estimating the cost of loss in the ecosystem services through the biomass burning includes, replacement cost method, restoration cost approach, relocation pricing method and government payments procedure(UNEP 2014)**(Fig. 1).**

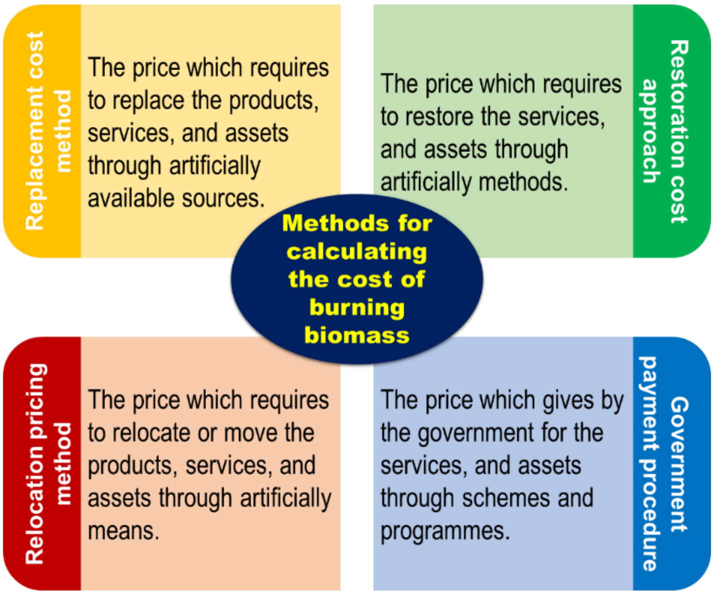

Fig. 1 Methods for calculating the cost of biomass burning and ecosystem disservices

Method for calculating replacement cost

According to the studies by Dinesh *et al*.(2021) and UNEP(2014), from the replacement cost method, Rs. 432 required to replace the nitrogen content in the soil, Rs. 171 for phosphorus content, Rs. 385 for potassium content, Rs. 25,000 for soil carbon content and Rs. 4846 for sulphur content. The calculationfor cost of biomass burning and ecosystem disservices were tabulated in the **Table. 3.**

Table. 3 Cost of biomass burning through replacement cost method

Nutrient	%	Nutrients required	Quantity required	Price
N	46	35	76.08	432.17
P	16	3.2	20	171.2
K	60	21	35	385
C	50	2500	5000	25000
S	13	35	269.23	4846.15
				Rs. 30834.53

Alternatives for biomass burning:

Alternatives to burning biomass include several profitable applications for crop waste, although farmers seldom adopt them. Crop wastes may be used to grow mushrooms, make compost, generate electricity, create biofuel, and feed them to cattle. In rural and village settings, it is also employed for thatching, mat production, and toy manufacturing (IARI 2012). Farmers in India typically rely on agricultural waste for feeding livestock. But because it is tasteless, difficult to digest, and contains a lot of silica (Gupta *et al*. 2004, Kumar *et al*. 2015). Sincesilica is hazardous to cow health, Punjab uses rice leftovers on cattle far less frequently than other provinces (Kumar *et al*. 2015). Farmers are reluctant to carry crop leftovers due to the high cost of transportation and poor bulk density, according to Venkataraman *et al*., (2006), who also note that the use of crop residue as fodder was high in locations where the crop residue was greater.In IGP, conservation agriculture is becoming more popular as it utilises crop residues in the field itself as mulching (Dinesh *et al*. 2019, 2021). The compost heap may be successfully prepared to use crop leftovers. One of the most significant and vital energy sources in India is biomass. According to studies by Murali et al.(2008), India has the capacity to produce 511,041 tonnes of agricultural leftovers annually that may be used to generate biomass electricity.

Power plant in Fazilka–An alternative for North-Western India

Fazilka, Punjab, home to Asia's first biogas power plant. Running entirely in paddy straw. Harnessing 45% of the energy in biomass(Yadav *et al*. 2022). Northern India alone can generate 25,365 GW of power from 2.2 mt of biomass. Commercial-scale use of paddy straw for the generation of biomethane and bioethanol. Enhance biomass for use in home stoves Biomethane has tremendous potential and can take the place of gasoline as a transportation fuel. Manure produced by biogas plants can help with paddy cultivation. If the government begins to invest in this technology, 20% of the pollution issue in Delhi and the NCR will be solved in the next eight to nine years. Sampoorna Agri Venture Private Limited, a single firm, receives consulting services from IITians.Can replace up to 96.4% of Punjab's coal-based power facilities' entire output of energy(Yadav *et al*. 2022).

Conclusion

Crop burning diminishes the services offered by nature, which are difficult to substitute, and crop wastes have considerable economic worth as feed, fuel, livestock feed, and industrial raw materials. All stakeholders must be aware of the effects of burning biomass and its significant usage. It is crucial to emphasise that estimating the economic impact of losses to nature and ecosystems caused by burning straw is a challenge owing to the lack of knowledge on how these factors influence the soil, environment, and society or at least the long-term impacts. The incentives for not burning straw may encourage local innovators to come up with sustainable crop residue management strategies that maintain soil health while maintaining a clean and safe environment.

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