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Investigating Public Perception and Understanding of Biochar from Rice Stubble in Punjab & Implications for SDGs

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Abstract

The issue of burning of rice stubble in Punjab releases many harmful pollutants and particulatematter into the air, including carbon dioxide, carbon monoxide, nitrogen oxides, Sulphur dioxide, and volatile organic compounds. This leads to the deterioration of air quality, posing serious health risks to the population, especially those with respiratory conditions. Additionally,the smoke and pollutants from stubble burning can travel long distances, affecting not only Punjab but also neighbouring regions. The high levels of air pollution caused by rice stubble burning have been a major concern for public health and environmental sustainability in the region. This study focuses on the issue of rice stubble burning in Punjab, which has been identified as a major environmental and health hazard. The objective of the study is to assess the knowledge and awareness among the public in Punjab regarding biochar and its benefits. The study aims to establish a connection between the Sustainable Development Goals (SDGs)and the benefits that can be achieved by reducing rice stubble through alternative methods likebiochar production. To gather data, a survey was conducted among individuals in Punjab. Thesurvey included a structured questionnaire covering topics such as biochar production, the current situation of stubble burning, and awareness of the associated benefits. The collected data was analysed using a logical framework analysis approach. The results of the study indicate that biochar derived from rice stubble has the potential to significantly contribute to sustainable development in Punjab. It can help address the challenges faced by farmers in managing agricultural waste, improve soil health, and increase crop productivity, aligning withthe goals of the SDGs. Government actions and support, such as providing incentives and subsidies, play a crucial role in promoting biochar production and use to mitigate the adverse effects of stubble burning.

1. Introduction

1.1. Introduction:

Punjab's agricultural practices are not only crucial for the nation's food supply but are also visually appealing. The state's fertile soil and favorable climate make it ideal for growing various crops, including wheat, rice, and vegetables. Farmers' meticulous planning and expertise ensure bountiful harvests annually, significantly contributing to food security. Punjab's sustainable farming techniques, aimed at maintaining soil fertility and conserving water resources, reflect a deep understanding of the local environment and demonstrate a harmonious coexistence between humans and nature.

However, the issue of stubble burning in Punjab has become increasingly urgent due to its severe impacts on both people and the environment. The practice of burning rice stubble residue post-harvest has gained popularity due to the need to prepare land quickly for the next crop cycle. Despite its convenience, this method has led to significant air pollution, posing serious health risks and degrading soil quality, thereby contributing to climate change. It is essential to find sustainable alternatives to stubble burning to protect public health and the environment.

Punjab, located in the northwest of India and covering 50,362 square kilometers, is renowned for its fertile landscape and agricultural heritage. With a population of around 30 million, Punjab is known as the "Granary of India," with its lush green fields reflecting the hard work and dedication of its farmers.
Biomass burning, including stubble burning, is a major source of air pollution, affecting climate chemistry and global air quality. Human activities account for approximately 90% of biomass burning, which has increased over the past century. The inhalation of pollutants from biomass burning can cause respiratory issues and damage materials and properties. In northern India, an estimated 35 million tons of crop waste are burned annually, producing large amounts of smoke and pollutants.

The combine harvester, which leaves 8 to 12 inches of paddy stalk in the fields, exacerbates the problem as the stubble left behind is of no use to farmers, leading them to burn it as a quick and cheap solution for clearing fields. Additionally, intensive farming over the past few decades has strained the soil, reducing its fertility and nutrient availability. In Punjab, the efficiency of NPK fertilizers has dropped, leading farmers to use more nitrogen to maintain crop yields, resulting in increased nitrate concentrations and pesticide residues in the environment. The adoption of a rice-wheat cropping system has further increased crop diversity but also contributed to these environmental issues.

1.2. Research Objectives:

- To determine the connections between the SDGs and the Biochar product made from rice stubble.
- To evaluate the level of knowledge and awareness among the public of Punjab regarding biochar and its benefits, and to identify areas where further education and awareness is needed.

2. Literature Review

Stubble burning involves intentionally setting fire to agricultural residues like unused stalks and stubble after harvest to clear fields for the next crop. In the case of rice, stubble burning is commonly done before planting wheat. Crop residues retain significant nutrients: about 25% of nitrogen (N) and phosphorus (P), 50% of sulfur (S), and 75% of potassium (K) uptake by cereal crops. Burning paddy straw results in considerable nutrient loss, estimated at 59,000 tons of nitrogen, 20,000 tons of phosphorus, 34,000 tons of potassium, and 3.85 million tonnes of organic carbon (Sidhu et al., 2007). Despite its detrimental impact on soil nutrition and atmospheric pollution, stubble burning remains prevalent among farmers. Rice cultivation spans nearly 160 million hectares globally, producing around 760 million tonnes annually (FAO, 2018). By 2035, the demand is projected to reach 555 million tonnes, up from the current 503 million tonnes (FAO, 2018). Open burning of rice straw is a common waste management practice, particularly in Asian countries, which produce over 70% of the world's rice (G. Singh et al., 2021). In India, rice and wheat crop residues are major contributors to stubble burning, with Punjab, Uttar Pradesh,

Haryana, and Maharashtra being the primary states involved (Garg et al., 2008). Large-scale burning in the rice-wheat system of Punjab, Haryana, and Western Uttar Pradesh poses significant environmental and health hazards due to GHG emissions and nutrient loss (Jain et al., 2014). Punjab cultivates rice on approximately 29.61 lakh hectares, generating about 18.74 million tons of paddy straw in 2021. Table 1 details the area under paddy cultivation and paddy straw generation in Punjab for the years 2020 and 2021. Stubble burning in Punjab significantly contributes to air pollution, affecting human health and the environment (A. Srivastava, 2017; Reddy, J., 2019). In 2022, approximately 19.65 million tons of residue were burned in Punjab (MNRE, 2009; Pathak Himanshu et al., 2010). The primary cause of stubble burning is the need to clear fields quickly for the next crop. The narrow window between the rice harvest and wheat sowing leaves farmers with insufficient time for proper residue management, necessitating burning (Ravindra et al., 2018). Many farmers are unaware of alternative residue management techniques and perceive burning as the simplest method (Vadrevu et al., 2019). Mechanical harvesters leave a significant amount of straw in the field, which is challenging to manage without burning (Mittal et al., 2009; Pratika and Sandhu, 2020). The shift towards mechanization and intensive agriculture has led to a decline in agricultural labor, making manual residue management impractical (Parmod et al., 2015). The stubble burning season in Punjab typically occurs from mid-September to November, leading to significant smoke emission and reduced air quality due to inversion conditions (Chawala & Sandhu, 2020). Table 2 details the progression of burnt area in Punjab during Kharif 2022. In 2022, stubble burning in Punjab emitted 580.8 thousand tonnes of pollutants, including 6800.97 tonnes of GHGs and particulate matter (IARI, 2022). Burning crop residues releases various air pollutants, contributing to global warming and biodiversity loss (Bhuvaneshwari et al., 2019). Stubble burning increases the risk of forest fires due to improper management. In 2022, satellites detected 21,480 farm fires in Punjab (IARI, 2022). Burning residues negatively impacts soil by increasing runoff, reducing infiltration capacity, and exacerbating erosion (De Bano et al., 1998; Vermeire et al., 2004; McCarty et al., 2009). Stubble burning contributes to respiratory diseases, eye irritation, and accidents due to poor visibility (Batra, 2017; J. Singh et al., 2018). Burning stubble reduces fodder availability and disrupts the ecosystem, affecting crop-friendly insects and animals (Jyothsna, 2019). Effective management of crop residues includes animal feed production, in-situ management, mulching, and biochar production. Table 3 outlines the different management techniques for rice stubble in Punjab. PepsiCo India has initiated a pilot program in Punjab to produce biochar from crop residues using retort kilns, aiming to improve soil health and reduce pollution (TOI, 2023). Biochar production and usage can significantly reduce GHG emissions and improve soil quality (IARI, 2021). The Punjab Agricultural University (PAU) in Ludhiana has developed a method to convert stubble into biochar, which can reduce environmental pollution and improve soil fertility (The Tribune, 2023). The global biochar market is expected to grow significantly, driven by increasing demand for sustainable agriculture and environmental conservation (Grand View Research, 2023). This literature review highlights the significant impact of rice stubble burning on the environment and human health, particularly in Punjab. Existing policies and management practices aim to mitigate these impacts, with biochar emerging as a promising alternative for sustainable agriculture and residue management.

Global hunger worsened considerably in 2020 due to the impact of COVID-19, with about one-tenth of the world's population estimated to be undernourished (WHO, 2021). Reduced calorie intake and poor nutrition have long-term effects on children's cognitive development (World Bank, 2022). Factors such as

poverty, inequality, unsustainable food systems, lack of investment in agriculture, inadequate safety nets, and poor governance are causing stagnation or reversal in combating hunger. According to GHI projections, the world is unlikely to reach a low level of hunger by 2030. Research by Dr. Manisha Bhatia and Dr. Pawan Kumar Sharma, published in the International Journal for Multidisciplinary Research Academy in 2023, highlights that hunger is a growing issue in Punjab, an economically prosperous state known for the Green Revolution and high food production. Despite being a significant contributor to India's central reserve of rice and wheat, Punjab has not fully translated its agricultural growth into improved nutritional conditions. This indicates flaws in the state's development model.

3. Methodology

3.1. Study Area

3.1.1. Location

Punjab, located in the north-western part of India, spans an area of 50,362 square kilometers (19,445 square miles), with its coordinates ranging from approximately 29°30’N to 32°32’N latitude and 73°55’E to 76°50’E longitude. It is bordered by Pakistan to the west, Jammu and Kashmir to the north, Himachal Pradesh to the northeast, Haryana to the southeast, and Rajasthan to the southwest. Punjab is renowned for its fertile landscape, with a diverse terrain that includes semi-arid regions and undulating hills in the northeast.

Figure 4 Map: Districts of Punjab

3.1.2. Demography

Punjab has a population of approximately 30 million people, making it the 16th most populous state in India. The state exhibits a high population density, with around 550 individuals per square kilometer owing to its rich agricultural lands and settlements. Punjabi is the official language, and Sikhism predominates as the primary religion, although Hindus, Muslims, and other minorities are also well-represented. Punjab places a strong emphasis on education, boasting a high literacy rate supported by numerous universities and colleges.

3.1.3. Climate situation

Punjab experiences a diverse climate characterized by hot summers, monsoon rains from July to September, and chilly winters starting in October. The region near the Himalayan foothills receives substantial rainfall, while the plains further south are relatively dry. Major festivals like Lohri and Diwali are celebrated during the winter months, making this period culturally significant. The optimal time to visit Punjab is from October to March.

3.2. Methods

This study adopts a flexible mixed-methods approach combining qualitative and quantitative data to comprehensively explore various aspects related to stubble burning and biochar production in Punjab.

3.2.1. Literature review: content analysis

A systematic review of literature was conducted using Science Direct and Google Scholar, focusing on stubble burning, rice husk management, air quality impacts, and biochar production. A predefined set of keywords and Boolean operators facilitated the identification of 120 relevant studies, which were screened based on inclusion criteria such as peer-reviewed status and relevance to Punjab. This process resulted in 35 studies being selected for qualitative analysis, exploring themes like environmental impacts and policy interventions.

3.2.2. Assessing knowledge and awareness of Biochar and its benefits in public ofPunjab.

A structured questionnaire was developed to gauge public understanding of biochar among a representative sample of 50 individuals from Punjab. The survey, conducted via Google Forms, covered topics including biochar production, benefits, and applications. Responses were analyzed to identify common perceptions and knowledge gaps regarding biochar's potential in mitigating stubble burning issues.

3.1.1. Identifying SDGs

The UN SDG metadata repository was utilized to align the study with specific SDGs relevant to biochar production and its environmental implications in Punjab. This involved selecting appropriate indicators and targets to frame the research within the context of global sustainability objectives.

3.2. Data Collection

Primary data collection involved administering surveys to farmers and the general public in Punjab, focusing on perceptions of biochar's efficacy in carbon sequestration and sustainable agriculture. The responses were analyzed to extract insights into public awareness and potential barriers to biochar adoption.

3.3. Ethical Considerations

Ethical guidelines were strictly followed to ensure participant consent, privacy, and non-discrimination throughout the study. Measures were implemented to minimize potential harm and ensure voluntary participation, with protocols in place for data confidentiality and participant welfare.

3.4. Limitations

Several limitations were acknowledged, including the challenge of documenting long-term impacts of biochar usage, the specificity of findings to Punjab's unique conditions, and the variability in biochar properties affecting study outcomes. Scaling up biochar technology presents logistical and cost challenges beyond experimental settings, impacting its practical application in agricultural systems.

4. Result and Discussion

4.1. SDG Identification:

The Sustainable Development Goals (SDGs) provide a framework for addressing global challenges related to poverty, hunger, health, education, equality, and the environment. One critical SDG is Zero Hunger (SDG 2), which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. Another relevant SDG is Responsible Consumption and Production (SDG 12), which focuses on sustainable consumption patterns, resource efficiency, and waste reduction. Additionally, combating climate change (SDG 13) is crucial for mitigating its adverse effects on the environment and societies worldwide.

4.1.1. SDG 2:

Rice stubble-derived biochar can contribute significantly to achieving SDG 2 by addressing challenges faced by farmers in managing agricultural waste, enhancing soil health, and increasing crop productivity. The conversion of rice stubble into biochar through pyrolysis offers a sustainable alternative to burning, which contributes to air pollution and climate change. The process helps in maintaining soil fertility, improving nutrient retention, and promoting sustainable agricultural practices. Challenges include limited alternatives for stubble disposal, time constraints during crop sowing, and cost considerations. Policy implications involve promoting sustainable farming practices and reducing agricultural waste through biochar utilization.

Analysis of Key Targets

- Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality.

Analysis of Key Indicators

- Indicator 2.4.1: Proportion of agricultural area under productive and sustainable agriculture.

SDG2 Target 2.4 and Indicator 2.4.1 can be addressed to assist combat hunger by fostering flexible agricultural practises, sustainable food production systems, and a decrease in stubbleburning. By putting these strategies into reality, we can boost output while preserving ecosystems and enhancing soil and land quality. This can assist in addressing the problems posed by climate change, severe weather, and other catastrophes that might worsen food insecurity.

4.1.2. SDG 12:

Biochar production from rice stubble aligns with SDG 12 by promoting sustainable consumption and production patterns. It offers an environmentally friendly solution to agricultural waste management, reducing greenhouse gas emissions and enhancing resource efficiency. Biochar serves as a soil amendment that improves water retention, nutrient availability, and overall soil health, thereby reducing reliance on synthetic fertilizers and supporting sustainable agriculture. Policy frameworks can encourage the adoption of biochar technology and support its integration into mainstream agricultural practices.

Analysis of Key Targets

- Target 12.1: Implement the 10-year framework of programs on sustainable consumption and production, all countries acting, with developed countries taking thelead, considering the development and capabilities of developing countries. (UN SDGmetadata repository)

This target emphasizes the importance of all countries, with developed countries taking the lead, in considering the development and capabilities of developing countries.

In relation to this target, biochar derived from rice stubble holds potential in achieving benefits and sustainability in consumption and production. This process not only helps in managing agricultural waste but also produces a valuable product that can be used in variousapplications. The use of biochar derived from rice stubble can contribute to sustainable consumption and production in several ways. Firstly, it provides an alternative to burning ricestubble, which is a common practice in some regions and contributes to air pollution and greenhouse gas emissions. By converting rice stubble into biochar, it reduces the environmental impact associated with its disposal. Secondly, biochar has the potential to enhance soil fertility and agricultural productivity. When applied to soil, biochar can improveits water-holding capacity, nutrient retention, and microbial activity. This can lead to increased crop yields and reduced reliance on synthetic fertilizers, promoting sustainable agricultural practices.

By implementing the use of biochar derived from rice stubble, countries can contribute to theachievement of Target 12.1 by promoting sustainable consumption and production practices.This includes reducing waste, mitigating environmental impacts, improving soil health, and diversifying energy sources. It is important for both developed and developing countries to collaborate and share knowledge and resources to ensure the successful implementation of biochar as a sustainable solution.

Analysis of Key Indicators

- Indicator 12.1.1: Number of countries developing, adopting, or implementing policy instruments aimed at supporting the shift to sustainable consumption and production.

This indicator focuses on the number of countries taking action to shift towards sustainable consumption and production patterns. By specifically targeting rice stubble reduction and management, countries can contribute to sustainable agricultural practices, reduce air pollution, and mitigate climate change impacts. Policy instruments can include regulations, incentives, and support mechanisms that encourage farmers to adopt alternative practices formanaging rice stubble. These practices may involve using the stubble for biochar production,composting, or incorporating it back into the soil as organic matter. By promoting

these sustainable alternatives, countries can reduce the need for burning, which in turn improves air quality, soil health, and overall environmental sustainability.

4.1.3. SDG 13:

Sustainable Development Goal 13 focuses on taking urgent action to combat climate change and its impacts. Biochar production using rice stubble can contribute to achieving this goal inseveral ways.

Analysis of Key Targets

- Target 13.2: Integrate climate change measures into national policies, strategies, andplanning.

Biochar production can help in achieving this target by providing a sustainable solution for managing agricultural waste, specifically rice stubble, which is often burned after harvest. Byconverting rice stubble into biochar instead of burning it, greenhouse gas emissions can be reduced, contributing to climate change mitigation efforts. (Li et al., 2023)

Analysis of Key Indicators

- Indicator 13.2.1: Number of countries that have integrated mitigation, adaptation, impact reduction, and early warning into primary, secondary, and tertiary curricula.

While this indicator may not directly relate to biochar production, it highlights the importanceof integrating climate change measures into various aspects of society, including education. Educating farmers and stakeholders about the benefits of biochar production and its role in reducing greenhouse gas emissions can help in achieving this indicator.

4.1.4. Identification of Potential Challenges and Successes

SUCCESS	*CHALLENGES*
• **Waste Management**: Biochar production from rice stubble offers a sustainable waste disposal solution. • **Climate Change Mitigation**: Biochar sequesters carbon and reduces greenhouse gas emissions. • **Soil Health**: Enhances soil fertility, nutrient retention, and water capacity, boosting productivity. • **Renewable Energy**: Biochar production generates renewable energy. • **Resource Efficiency**: Utilizes organic waste, increasing efficiency and reducing waste.	• **Technology and Infrastructure**: Requires appropriate, scalable technology and infrastructure. • **Awareness and Education**: Limited knowledge among farmers hinders adoption. • **Economic Viability**: Needs cost-effectiveness and market demand for sustainability. • **Policy Framework**: Lack of supportive policies and regulations.

4.1.5. Implications for Policy and Decision-Making

In the context of policy and decision-making, there are implications to consider based on theinformation provided. Agriculture based Researchers are working on the production of biochar, specifically from rice stubble. This approach aims to prevent the burning of rice stubble, which is a common practice that contributes to air pollution and greenhouse gas emissions. Instead, the biochar produced is being utilized in various ways.

One application mentioned is sending the biochar to NTPC, farmers, cement factories, and other industries. This suggests that biochar is being used as a resource in these sectors, potentially for purposes such as composting or as a component in cement production. By diverting rice stubble towards biochar production and utilizing it in these industries, there is a potential to reduce waste and contribute to sustainable practices.

It is important to note that the work being done with biochar is currently in the pilot phase. This implies that further research, testing, and evaluation are necessary to assess its effectiveness and feasibility on a larger scale. However, there is an expectation that biochar production could contribute to carbon sequestration in the future. This means that biochar hasthe potential to capture and store carbon for an extended period within the soil, which can help mitigate climate change by reducing greenhouse gas emissions.

The use of biochar derived from rice stubble presents an opportunity for sustainable waste management and carbon sequestration. However, it is crucial to conduct further studies and assessments to determine the viability and impact of this approach.

4.2. Assessment of Knowledge and Awareness of Biochar and its Benefits in public ofPunjab

A survey of 50 individuals in Punjab assessed their awareness of biochar. The findings indicated that 41.2% had heard of biochar, while 43.1% had not, and 15.7% were uncertain. This suggests a significant knowledge gap. Additionally, 88% were unaware of any biochar production facilities in Punjab.

Key Findings and Insights

1. **Current Knowledge**:
   - 41.2% knew about biochar, while 43.1% did not.
   - 15.7% were unsure, indicating a need for clearer information.
2. **Awareness of Production Facilities**:
   - Only 12% were aware of biochar production facilities in Punjab, highlighting a lack of awareness about local production capabilities.
3. **Stubble Management**:
   - 72% supported alternative methods to manage stubble instead of burning, indicating a positive outlook towards sustainable practices.
4. **Perception of Biochar**:
   - 43.1% correctly identified biochar as a soil amendment.
   - 41.2% were unsure of its definition, suggesting educational gaps.
5. **Environmental Benefits**:

- 37.3% were aware of the environmental benefits, while 43.1% were not.
- 19.6% were uncertain, indicating mixed awareness levels.

6. **Interest in Biochar**:
   - 80.4% showed interest in learning more about biochar, reflecting a positive attitude towards its potential benefits.
7. **Sustainable Development**:
   - 54.9% believed biochar could contribute to sustainable development in Punjab, while 17.6% disagreed, and 27.5% were uncertain.
8. **Government Policies**:
   - 61.6% deemed government promotion of biochar as very important.
   - 60% favored incentives and support for adoption, while 28% suggested subsidies, and 12% recommended penalties for non-compliance.

Recommendations

Policymakers should support research, development, and implementation of biochar production to promote sustainable practices. Addressing the knowledge gap through targeted educational campaigns can help farmers make informed decisions about biochar adoption, improving soil health, agricultural productivity, and reducing environmental impact. Promoting biochar use aligns with sustainable development goals, including climate change mitigation and food security.

Future scope

Biochar has a promising future but requires overcoming challenges in policy, logistics, and public perception. Successful adoption needs partnerships among researchers, policymakers, industry, and farmers. Creating alliances can expedite best practices, technology transfer, and information sharing. Establishing market incentives, such as funding support, tax breaks, and certification programs, can attract investment, foster innovation, and accelerate commercialization of biochar technologies.

5. Conclusion

The research underscores the significant potential of biochar production from rice stubble to contribute to sustainable development in Punjab, aligning with SDGs like Zero Hunger (SDG 2), Responsible Consumption and Production (SDG 12), and Climate Action (SDG 13). Biochar can help manage agricultural waste, improve soil health, and increase crop output, offering a sustainable alternative to stubble burning, which contributes to pollution and climate change. Despite some awareness, a considerable portion of respondents lacked knowledge about biochar's benefits, indicating a need for more informational resources. Positive attitudes towards biochar adoption highlight potential interest in its advantages. Government support through incentives and subsidies could play a crucial role in promoting biochar use. Additional research with a larger, more diverse sample is recommended to gather comprehensive insights. By embracing biochar production and proactive stubble management, Punjab can advance towards sustainable development and a healthier environment.

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