

ECONOMICAL SOLUTION FOR CROP RESIDUE MANAGEMENT IN NORTH-WESTERN INDIA

¹Seeta Ram Meena, ²Dr.Shailendra Kumar Patidar
¹M.TECH student, ²Professor
¹Department of Civil Engineering
¹Indian Institute of Technology, Kanpur, India
²National Institute of Technology, Kurukshetra, India

Abstract: As per recent studies, crop residue burning in India released 176 Mt CO₂, 10 Mt CO, 0.936 Mt PM₁₀, 0.814 Mt NMVOC, 0.453 Mt PM_{2.5}, 0.31 Mt methane, 0.151 Mt NH₃, and 0.008 Mt N₂O. Objective of the present study is economic analysis of bio-fuels production methods for N-W India using crop residue. As per the study net profit/loss occurred by using various crop residue management methods like, using biomass pellets in thermal power plants as fuel, biogas production at community level, bio-CNG production at industrial level and bio-power generation plants equal to, Rs.2.398 crores (loss), Rs.1142.68 billion (loss), Rs. 22.165 trillion (profit) and Rs. 4.95 trillion (profit) respectively. Thereby the method of bio-CNG production is best economically.

Index Terms: - Crop Residue, Air Pollution, Economical Analysis of Bio-Fuels Production Methods

I. INTRODUCTION

Stubble or Crop Residues are the materials that remain after a crop has been harvested. These materials are burnt in-situ which produces various pollutants namely, CO₂, CO, particulate matters (i.e., PM₁₀ & PM_{2.5}), Non-Methane Volatile Organic Compounds (NMVOC), NO_x and methane. According to Venkatramanan et al. (2021), The crop residue burning in the year 2017 released pollutants like 176 Mt of CO₂, 10 million tonnes of CO, 0.936 million tonnes of PM₁₀, 0.814 million tonnes of NMVOC, 0.453 Mt of PM_{2.5}, 0.31 Mt of methane, 0.151 Mt of NH₃, and 0.008 Mt of N₂O. These pollutants not only increase temperature of globe but also creates various disease in the human related to respiratory system, Cancer and others. In India the burning of crop residue occurs during pre-monsoon (April to May) and post-monsoon (October to November). The farmers generally burns crop residue in the field because (1) Less time gap between crop harvesting and sowing new crop, (2) lack of financial viable options to manage it. The crop residue can be managed by using either of two methods namely, In-situ crop residue management methods and ex-situ crop residue management methods. They are having their own merits and demerits. In-situ residue management method is economical but required more time to manage so farmers generally not adopt it. Ex-situ crop left-over management methods are very costly so farmers not adopt them. These methods require more initial investment but generate lot of revenue. North-western Indian states (Ladakh, Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Rajasthan, Delhi, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Goa, and Uttarakhand) are primarily agrarian produced around 384.25 Mt/year crop residue and majority of which burnt in the field and produce various pollutants (Meena et al., (2023, Preprint). In India some states governments has started initiative for managing crop residue using happy seeder machine and Biofuel productions. In this paper we will discuss different crop residue management methods and finding best method for managing crop residue economically.

II. METHODS OF CROP RESIDUE MANAGEMENT

2.1 In-situ Crop Residue Management Method

In-situ management methods are method used for managing crop residue on the site using some techniques. There are various methods like soil incorporation is used for integrating crop residue in-situ. This method generally takes long time so not used by farmers. But it also alters crop productivity. Singh et al. (1996) reported that this method reduced productivity if the crop residue applied on the field just before few days of the crop sowing. But the Singh et al. (2001) showed that the productivity of the wheat considerably increase when they applied straw in the field 21 days prior to sowing. According to Sidhu and Beri (2005) soil incorporation not only increase crop productivity but also increase soil physical, chemical and biological properties. So it is best method.

Mulching is a method in which first we remove crop residue from the field for making it fit for crop then we applied a protective layer of crop left-over in the field to minimize erosion of soil, evaporation and enrich the soil and suppress weeds (Olaf, 2002). There are two kinds of mulching process tillage mulching and no-tillage mulching. In the tillage mulching required partial removal of the residue from the field for some times then applied after preparing the soil. No-tillage method is generally used by farmers because in it crop left-over remained on the field during harvesting of the crop.



Fig.1 No-tillage: mulching (Porichha et al., 2021)



Fig.2: Tillage mulching (Porichha et al., 2021)

In the Fig.1 is showing no-tillage mulching and Fig.2 is representing tillage mulching method for management of the crop left-over in the field.

2.1.1 Limitations of In-situ crop residue management methods

In-situ crop residue management can't adopted on a large scale because the time between harvesting a crop and sowing a new crop in the field is very short (approximately 25 to 30 days), this is insufficient time for in-situ methods. In-situ methods capacity to manage 2 to 4 tonnes/ha biomass per year, but Northwestern India produced much more crop residue equal to 384.25 Mt/year. Therefore this method is not viable option for managing crop residue.

2.2 Ex-situ Crop Residue Management Methods

These methods are used for managing crop residue far away from the site. In these methods crop residue is used for production of the compost or manure, Bio-char, Fodder, Baling and Bio-fuels. It can be achieved by composting in which the organic matter converted into manure or compost under aerobic conditions. The product of the composting further utilized as fertilizer.

Bio-char production is the process in which the crop residue converted into the bio-char with the help of pyrolysis (low temperature thermochemical conversion process) (Amonette et al., 2009). Bio-char is the carbon-rich, porous and fine-grained materials. It is a porous material so increased water retentivity (Lehmann et al., 2009), increase nutrient retention, increase pH and earthworm population and declined fertilizer usages (Tyron, 1948; Gaunt et al., 2009). Fodder means food given to animals rather than they forage themselves. The crop residue is the cheap and easily available materials used for feeding sheep's, cow, goat and other animals (Gummert et al., 2020).

Baling is the methods in which the crop residue converted into the bale with the help of the happy seeder machines shown in Fig.3. Converted bales stored or transported for further usages (Porichha et al., 2021).



Fig.3 Happy seeder machine (Porichha et al., 2021)

Biofuels production is the method, in which biomass is converted into biofuel using agriculture residue direct combustion (direct firing or co-firing), Gasification with help of the steam, Generation of the electricity by the combustion of the fuel-gas mixture, Biogas production using crop residue by simply anaerobic digestion of it (Jenkins et al., 1998) .

2.2.1 Economical viable option for Ex-situ crop residue management in North-western India

As we discussed in the section 2.1.1 that the in-situ crop residue management method is not able to manage crop residue of North-western India. So we need Ex-situ crop residue management method to manage crop residue of North-western India. We did economic analysis of following ex-situ crop left-over management method for north western India. Using biomass pellets in the thermal power plants as fuel, Biogas production from crop residue at community level, Production of Bio-CNG at industrial level, Power generation from crop residue.

III. DATA COLLECTION AND METHODOLOGY

We collected data from the different source for different method.

Using biomass pellets in the thermal power plants as fuel: By using following data taken from Sokhansanj et al., 2023; Purohit and Chaturvedi, 2018, we did economic analysis of this method.

Total installed capacity of power plant = 119904.30 MW

Coal consumption rate = 4000 tonnes/ MW

Plant factor = 85%

Biomass pellets substitutions = 10%

Cost of the biomass at plant site = Rs. 10 per kg of pellets

Cost of coal = Rs. 6/kg

Cost of production of power = Rs.3.05/Kwh

Methodology: We estimated total revenue generate by the selling of the power produced by plant and expenditure for establishing and handling the plant. It is not economical for managing North-western India crop residue because it provides net loss is equal to 2.398 crores.

Biogas production from crop residue at community level: We collected data from the biogas plant at Ludhiana center developed by AICRP on energy in Agriculture and Agro industries.

Methodology: Using data collected from the biogas plant at Ludhiana estimated benefits raised due to selling of LPG cylinder and expenditure due to operational costs (including labour charges for straw/ dung collection, unloading, loading and labour wages) and fixed costs (including depreciation and interest on capital investment), and then compared cost and benefits and find out that net loss =Rs.1142.68 billion.

Production of Bio-CNG at industrial level: We collected data from paddy straw based biogas generation plant established at the Fazika in Punjab. It is joint venture established with collaboration of M/S sampurn Agri-venture Pvt. Ltd. and IIT Delhi.

Methodology: Using data obtained from the plant we calculated benefits occurred due to selling of Bio-CNG and compost and Expenditure due to operational costs (including cost of purchasing paddy straw, lease rent for the land used for the plant and straw storage, storage cost of paddy straw, size reduction, unloading, loading costs for the feed material, salary of manpower, repair and maintenance cost, interest on operational capital and fixed cost due depreciation and interest on capital investment. Cost benefit analysis of it given net benefits equal to = Rs.22.165 trillion.

Power generation from crop residue: We collected data form the two plants M/s. Green Plant Energy Pvt. Ltd., Jalandhar and other plant Sukhbir Agro Energy Ltd., both plants established in the Punjab.

Methodology: We estimated benefits due to selling of electricity and costs including operational costs due to selling of paddy straw, labour costs, repair and maintenance cost and storage cost and fixed costs due to depreciation and interest on capital. It provided net profit = Rs.4.95 trillion.

IV. RESULTS AND CONCLUSIONS

Economic analysis of various methods of bio-fuels production done and results are tabulated in Table 1.

Table 1: Economic Analysis of Various Methods of Bio-fuel Production

Methods	T.C(Total Cost)	T.B(Total Benefits)	N.P/L(Net Profit or Loss)	Remarks
Using Biomass pellets in the Thermal Power Plants as fuel	-	-	Total loss of revenue = 2.398 crores	Installed capacity of thermal power plant using coal =119904.30 MW for which only 47.96MT/year crop residue can be used. Total residue generated for N-W =384.25MT/year Therefore this method is incapable for management of C.R.

Biogas production from crop residue at domestic/community	Rs.2725.69 billion	Rs.1583.01 billion	Net loss =Rs.1142.68 billion	It can be used but the loss of revenue is too much so not viable option for N-W C.R.M
Industrial level production of Bio-CNG from C.R	Rs.24.175T	Rs.46.34T	Net Profit = Rs.22.165T	It is best method for crop residue management of N-W India
Power generation from crop residue	Rs.14.02T	Rs.18.97T	Net Profit = Rs.4.95T	It is second best option for N-W CRM

From the Table 1 it is clear that industrial level production of Bio-CNG give maximum profit is equal to Rs. 22.165 trillion following power generation from crop residue give profit equal to Rs.4.95 trillion and other methods give loss. So these two methods are viable options economically. But bio-CNG production from crop residue at industrial level is best.

V. CONCLUSIONS

As per results of the study shown in Table 1, It is clear that Bio-CNG production and Bio-power generation using crop residue are viable option economically. But Bio-CNG production method provides maximum benefits equal to Rs.22.165Trillion. So It is best method economically.

VI. ACKNOWLEDGEMENTS

I am grateful to National Institute of Technology Kurukshetra and Indian Institute of Tropical Meteorology, Pune for giving me opportunity to work on this topic. I thank you to Professor (Dr.) Shailendra Kumar Patidar for his constant guidance.

REFERENCES

- [1] Amonette, J.; Joseph, S. 2009. Characteristics of biochar: Micro-chemical properties. In Bio-char for Environmental Management: Science and Technology; Lehmann, J., Joseph, S., Eds.; Earth Scan: London, UK, pp. 33–52.
- [2] Gaunt, J. and Cowie, A. 2009. Biochar greenhouse gas accounting and emission trading. In Biochar for Environmental Mgt: Science and Technology; Lehmann, J., Joseph, S., Eds.; Earthscan: London, UK, pp. 317–340.
- [3] Gummert, M. et al. 2020. Rice Straw Overview: Availability, Properties, and Management Practices. In: Van Hung, N., Hung, N., Chivenge, P., Douthwaite, B. (eds) Sustainable Rice Straw Management. Springer, Cham. https://doi.org/10.1007/978-3-030-32373-8_1
- [4] Jenkins, B.M., Baxter, L.L., Miles Jr., T.R. and Miles, T.R. 1998. Combustion Properties of Biomass. Fuel processing Technology, 54, 17-46.
- [5] Lehmann, J. and Joseph, S. 2009. Biochar systems. In Biochar for Environmental Management: Science and Technology; Lehmann, J., Joseph, S., Eds.; Earthscan: London, UK, pp. 147–168.
- [6] Olaf, E. 2002. Crop residue mulching in tropical and semi-tropical countries: An evaluation of residue availability and other technological implications. Journal of Soil and Tillage Research, 67, 115–133.
- [7] Porichha, Gaurav & Hu, Tracy & Rao, Kasanneni & Xu, Chunbao. 2021. Crop Residue Management in India: Stubble Burning vs. Other Utilizations including Bioenergy. Energies. 14. 4281.
- [8] Purohit, P., Chaturvedi, V. 2018. Biomass pellets for power generation in India: a techno-economic evaluation. Environmental Science and Pollution Research, Springer, 25, 29614–29632.
- [9] Singh, Y.; Singh, B. 2001. Efficient management of primary nutrients in the rice-wheat system. Journal of Crop Production, 4:23-86.
- [10] Bijay-Singh and Yadvinder-Singh. 2003. Management of crop residues in rice-wheat cropping system in the Indo Gangetic plains. In: Nutrient Management for Sustainable Rice-Wheat Cropping System (Yadvinder-Singh, Bijay Singh, VK Nayyar and Jagmohan Singh, eds.). pp.286-301

[11] Sidhu, B. S., & Beri, V. 2005. Experience with managing rice residues in intensive rice-wheat cropping system in Punjab. In I. P. Abrol, R. K. Gupta & R. K. Malik (Eds.), Conservation agriculture: Status and prospects (pp. 55–63). New Delhi: Centre for Advancement of Sustainable Agriculture, National Agriculture Science Centre.

[12] Sokhansanj, S. , Yadav, Y. , Lau, A. , Yadvika, . , Verma, K. and Karwasra, N. 2023. Advanced Strategies to Mobilize Crop Residue to Replace Coal in India. Journal of Sustainable Bioenergy Systems, 13, 57-72.

[13] Meena, Seeta Ram; Meena, Guman Singh.2023. Estimation of Bio-energy Potential in Northwestern India Using Crop Residue, 05 June 2023, PREPRINT (Version 1) available at Research Square [<https://doi.org/10.21203/rs.3.rs-2953404/v1>]

[13] Tryon, E.H.1948. Consequence of charcoal on certain physical, chemical, and biological properties of forest soils. Journal of Ecological monographs, 18, 81–115.

[14] Venkatramanan, V.; Shah, S.; Rai, A.K. and Prasad, R.2021. Nexus between Crop Residue Burning, Bioeconomy and Sustainable Development Goals over North-western India. Frontiers in Energy Research, 26, 56-80.

List of Figures



Fig.1 No-tillage: mulching (Porichha et al., 2021)



Fig.2: Tillage mulching (Porichha et al., 2021)



Fig.3 Happy seeder machine (Porichha et al., 2021)

