Chronicle of Bioresource Management 2026, 10(3): 060-064

Chronicle of Bioresource Management
An International E-magazine

September, 2026 | Popular Article

DOI: HTTPS://DOI.ORG/10.23910/3.2026.7368

From Waste to Wealth: Transforming Odisha's Acid Soil through Fly Ash - Based Value-Added Products for Sustainable Agriculture

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Citation: Sahoo et al., 2026. From Waste to Wealth: Transforming Odisha's Acid Soil through Fly Ash - Based Value-Added Products for Sustainable Agriculture. Chronicle of Bioresource Management 10(3), 060-064. HTTPS://DOI.ORG/10.23910/3.2026.7368.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author have declared that no conflict of interest exists.

Abstract

Fly ash, a major by-product of coal-based thermal power plants, is generated in large quantities across India, creating significant challenges for its safe disposal and management. However, its diverse mineral composition offers considerable potential for beneficial agricultural applications. Fly ash contains silica, calcium, magnesium, potassium, sulphur, iron and several micronutrients that can contribute to improved soil properties, nutrient availability and crop growth when applied at appropriate rates. In Odisha, where soil acidity is a major constraint to agricultural productivity, the utilisation of fly ash-based value-added products provides a promising and sustainable approach to soil and crop management. Such products can be prepared by integrating fly ash with organic amendments, including farmyard manure, rice straw compost and poultry manure, thereby combining the nutrient and soil-conditioning benefits of industrial and agricultural residues. These amendments can help ameliorate soil acidity and improve physical, chemical and biological properties, leading to better plant growth and productivity. In addition, the incorporation of organic materials may improve the overall efficiency and safety of fly ash utilisation by balancing its chemical properties and enhancing its agronomic value. The development and use of fly ash-based value-added products further help in promoting the recycling and sustainable management of industrial and agricultural wastes. This approach can contribute to environmentally sound agricultural practices, particularly in acid soils of Odisha, while reducing the dependence on conventional soil amendments and supporting circular resource utilisation. Thus, judicious use of fly ash in combination with organic amendments represents a practical, economical and sustainable strategy for enhancing soil health and agricultural productivity.

Keywords:

Acid soil management, fly ash, heavy metals, organic amendments, organic compost, rice-black gram

Article History

Article ID: CBM7368
Received on 27th July 2026
Received in revised form on 02nd September 2026
Accepted in final form on 15th September 2026

1. Introduction

Soil acidity is one of the major challenges affecting agriculture in Odisha. Nearly 8.67 million hectares, accounting for about 70% of the state's cultivated land, are affected by acidic soils (Mishra

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et al., 2020). These soils reduce nutrient availability, increase aluminium and iron toxicity, suppress beneficial microbial activity and restrict root growth, leading to poor fertiliser-use efficiency and lower crop yields, particularly in rice-based cropping systems (Fageria et al., 2011; Das et al., 2024). Although liming materials such as calcite and dolomite are widely used to reclaim acid soils, their limited availability and higher cost make large-scale adoption difficult in Odisha (Mishra et al., 2020). This highlights the need for affordable and sustainable alternatives that can improve soil health and support agricultural productivity.

Managing this industrial by-product has remained a major environmental concern. Interestingly, fly ash contains useful plant nutrients such as calcium, magnesium, silica, sulphur and several micronutrients that can improve soil properties and support crop growth (Pandey and Singh, 2010; Ram and Masto, 2014). However, because it contains very little organic carbon and nitrogen, fly ash alone cannot provide balanced nutrition for crops. Blending fly ash with organic materials such as farmyard manure, rice straw compost and poultry manure creates value-added products that improve soil quality while encouraging the productive reuse of an industrial by-product (Yao et al., 2015). This approach offers a practical pathway towards healthier soils, better crop productivity and more sustainable resource management in Odisha.

2. Problem Context

Soil acidity is a major limitation to agricultural productivity in Odisha, affecting about 8.67 million hectares (nearly 70% of the cultivated area). Acidic soils reduce nutrient availability, cause aluminium and manganese toxicity, suppress microbial activity and lead to 20–30% yield losses in rice-based systems. Although liming materials such as calcite and dolomite are effective, their availability is inadequate to meet the annual requirement of over 3.26 million tonnes. Across India, about 340 million tonnes of fly ash were generated during 2024-25. Despite its beneficial nutrient content and soil-improving properties, its agricultural use remains limited, making it a valuable yet underutilised resource for sustainable crop production.

3. Odisha: A Unique Opportunity

Odisha presents an interesting situation where two seemingly unrelated challenges exist side by side. On one hand, thermal power plants in regions such as Talcher, Angul, Kaniha, Jharsuguda, and Sundargarh generate large amounts of fly ash every year. On the other hand, farmers in many parts of the state struggle with acidic soils that affect crop productivity. Bringing these two issues together opens up new possibilities. Fly ash, when properly processed and utilised, can help improve acid soils and transform a disposal concern into a useful resource for agriculture. At the same time, Odisha produces large quantities of fly ash from coal-based thermal power plants located in Talcher, Angul, Kaniha, Jharsuguda and Sundargarh. At the same time, Odisha produces around 150 million tonnes of fly ash annually. Rich in calcium, magnesium and silica, fly ash offers a low-cost alternative for acid soil reclamation and helps address disposal concerns.

4. What Makes Fly Ash Useful in Agriculture?

The agricultural value of fly ash lies in its mineral composition. It contains appreciable amounts of silica, calcium, magnesium, sulphur and several micronutrients required for plant growth. These elements contribute to improved soil fertility, better nutrient uptake and enhanced biological activity in the soil. Such improvements can ultimately support higher crop productivity. In the case of rice, the silica supplied through fly ash is of special significance because silicon is known to promote stronger plant growth and improved crop performance, as shown in Table 1.

Table 1: Major chemical components of fly ash and their agricultural importance

Component of FA	Typical range (%)	Agricultural Importance
Silicon dioxide (SiO_2)	40–60	Enhances rice growth and stress tolerance
Aluminium oxide (Al_2O_3)	20–35	Structural mineral component
Iron oxide (Fe_2O_3)	4–15	Source of iron
Calcium oxide (CaO)	1–12	Helps neutralize soil acidity
Magnesium oxide (MgO)	0.5–5	Essential secondary nutrient
Potassium oxide (K_2O)	0.5–4	Improves crop growth and yield

5. Why Convert Fly Ash into Value-Added Products?

Although fly ash contains useful minerals, it lacks carbon

and nitrogen, and its direct application may not provide optimum benefits. To address this limitation, fly ash-based value-added products have been developed by blending fly ash with farmyard manure, rice straw compost and poultry manure in Figure 1. These organic materials enrich fly ash with carbon, beneficial microorganisms and essential nutrients, creating a balanced soil amendment that improves soil fertility and overall soil health, as shown in Table 2.

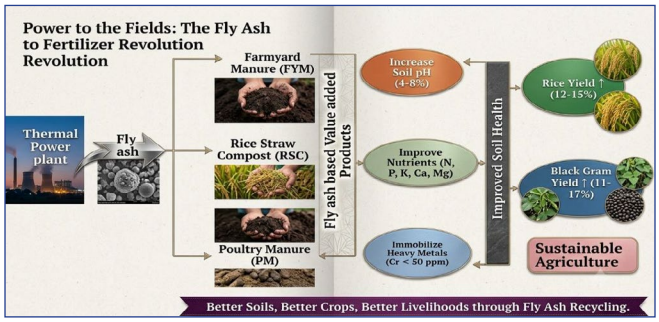

Figure 1: Recycling fly ash into value-added soil amendments for healthier soils, higher crop yields, and sustainable agriculture

Table 2: Soil amendments and their role in improving soil fertility

Material	Major Characteristics	Contribution to Soil
Fly Ash (FA)	Rich in silica, Ca, Mg and micronutrients	Improves pH and nutrient supply
Farmyard manure (FYM)	High organic carbon and microbes	Improves soil structure and fertility
Rice Straw Compost (RSC)	Rich organic matter and potassium	Enhances microbial activity
Poultry manure (PM)	Rich in N, P and K	Supplies readily available nutrients

6. What the Field Trials Revealed

Field studies conducted following standard ICAR protocols demonstrated the effects of fly ash-based value-added products on soil properties, crop productivity and heavy metal accumulation

- **Soil pH enhancement:** The field trials showed that average soil pH increased by **0.2-0.4 units** after a single application, corresponding to **4-8%** enhancement in soil. The neutralisation improved nutrient availability, particularly nitrogen, phosphorous with reducing aluminium toxicity.
- **Nutrient Status:** Application of fly ash-based value-added products enhanced available N and P levels by **10-15%** with an increase in Ca and Mg and improved root proliferation, indicating better nutrient uptake efficiency (Varshney et al., 2022).
- **Yield enhancement:** Field trial demonstrated yield increases of **12-15%in rice** and **11-17% in black gram,** confirming significant productivity gains under real farming conditions.
- **Environmental Safety:** Post-harvest soil and grain analysis revealed that there was **no significant increase in heavy metal** contents, confirming that fly ash-based value-added products are environmentally benign and safe for ecological health (Yao et al., 2015; Varshney et al., 2022).

Figure 2: Seasonal crop cultivation: Upper panel, black gram during the Rabi season; lower panel, rice during the *kharif* season

7. A Sustainable Solution for Acid Soil Reclamation

Soil acidity is one of the major challenges affecting agriculture in eastern India, particularly in Odisha. Acidic soils limit the availability of essential nutrients, increase aluminium toxicity and restrict root growth, leading to poor crop performance, lower yields and reduced fertiliser-use efficiency (Fageria and Baligar, 2008; Sharma et al., 2025). Therefore, improving the health of these soils is essential for enhancing agricultural productivity and supporting sustainable farming in the region.

Fly ash-based value-added products are emerging as an effective and sustainable option for improving acid soils while making productive use of an industrial by-

product. Naturally rich in calcium, magnesium, silica and several micronutrients, fly ash helps reduce soil acidity, improves nutrient availability and enhances soil quality (Jala and Goyal, 2006; Basu et al., 2009). The benefits of fly ash become even greater when it is combined with organic amendments such as farmyard manure, rice straw compost and poultry manure. These materials enrich the soil, support beneficial microorganisms, improve root growth and create favourable conditions for better crop performance (Varshney et al., 2022).

Applying fly ash together with organic amendments helps crops absorb nutrients and water more efficiently, leading to healthier plant growth and higher productivity. For small and marginal farmers, fly ash-enriched compost prepared from locally available materials offers a cost-effective and environmentally friendly way to improve acid soils. Besides enhancing soil health, this approach encourages the beneficial use of industrial by-products, promotes resource recycling and supports more sustainable agricultural practices (Pandey and Singh, 2010).

8. Benefits in Rice-Based Cropping Systems

Rice, the principal crop of Odisha, responds well to fly ash-based value-added amendments. These products improve soil conditions, resulting in better root growth, increased tillering, enhanced nutrient uptake and improved grain development. The silica present in fly ash also strengthens plant tissues, making rice more tolerant to moisture stress, pests and diseases while reducing lodging. As a result, farmers can achieve more stable and productive rice cultivation.

The benefits extend to pulse crops such as black gram and green gram, which are commonly grown after rice. Fly ash-based amendments improve soil health, promote root development and nodulation, and enhance biological nitrogen fixation, leading to healthier plants, better pod formation and higher seed yield. When integrated with balanced nutrient management, these amendments not only improve pulse productivity but also enhance soil fertility for subsequent crops, making them an effective option for sustainable rice–pulse cropping systems in Odisha.

9. Environmental Benefits

The agricultural use of fly ash not only benefits crop production but also contributes to environmental sustainability. Large quantities of fly ash generated from thermal power plants require safe and productive utilisation. Incorporating fly ash into agricultural practices provides an effective way to recycle this industrial by-product while reducing the burden of its disposal. When converted into value-added soil amendments, fly ash can help improve soil health, enhance resource-use efficiency and support sustainable crop production. This approach encourages the reuse of materials that would otherwise remain underutilised and promotes the concept of a circular economy, where waste materials are transformed into valuable resources. By linking waste management with agricultural development, fly ash-based technologies offer a practical pathway towards both environmental protection and improved farm productivity.

10. Safe Use of Fly Ash

The presence of trace heavy metals in fly ash is an important consideration for its agricultural use. In the present study at KVK, Santhapur, Odisha, fly ash-based value-added products did not cause heavy metal accumulation beyond permissible limits. Post-harvest soil analysis showed chromium (Cr) levels below 50 ppm, within FCO guidelines, while other heavy metals also remained within safe limits. The combined use of organic materials such as farmyard manure, rice straw compost and poultry manures likely reduced metal mobility and plant uptake. These findings suggest that the judicious application of fly ash-based products can promote sustainable crop production without significant risks of heavy metal contamination.

11. A Promising Option for Farmers in Acid Soil Regions

Farmers growing crops on acid soils often face poor nutrient availability, low fertiliser-use efficiency and reduced yields because soil acidity limits nutrient uptake. Fly ash-based value-added products prepared from locally available fly ash and organic materials such as farmyard manure, rice straw compost and poultry manure provide a practical solution. Their regular application improves soil pH, root growth and nutrient availability, creating favourable conditions for better crop growth and productivity. Additionally, these amendments promote the beneficial use of industrial by-products and agricultural residues, converting waste into valuable resources for sustainable agriculture and environmental

benefits.

12. The Way Forward

Fly ash-based value-added products demonstrate how an industrial by-product can be transformed into a valuable resource for agriculture. In Odisha, where both fly ash generation and soil acidity are major concerns, this approach offers a practical solution for improving soil health and crop productivity while promoting the productive use of waste materials. With continued research, field demonstrations and farmer awareness programmes, fly ash-based amendments have the potential to become an important tool for sustainable agriculture and acid soil management in the state. By converting waste into a useful farm input, this technology truly reflects the concept of "Waste to Wealth" and supports a more resilient and environmentally friendly farming system.

13. Conclusion

Fly ash, when appropriately utilised in combination with organic amendments, will be a valuable resource for sustainable agricultural development. The preparation and application of fly ash-based value-added products can contribute to the amelioration of soil acidity, improvement of soil fertility and enhancement of crop productivity. Continued research, long-term field evaluation, farmer awareness and institutional support are therefore essential for wider adoption.

14. References

Das, T.P., Mohanty, S., Karubakee, S., Parija, S., 2024. Acid soils and their management for enhancing crop productivity. In: Soil to Harvest: An Integrated Approach to Agronomy and Soil Science, pp. 89–99.

Fageria, N.K., Baligar, V.C., Jones, C.A., 2011. Growth and mineral nutrition of field crops, 3rd ed. CRC Press, Boca Raton, FL.

Jala, S., Goyal, D., 2006. Fly ash as a soil ameliorant for improving crop production-a review. Bioresource Technology 97, 1136–1147.

Mishra, A., Nayak, R.K., Chander, G., Reddy, M., Choudhari, P., 2020. Management of acidic soils. In: Mapping the Nutrient Status of Odisha's Soils. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), pp. 50–55.

Pandey, V.C., Singh, N., 2010. Impact of fly ash incorporation in agricultural soils. Agriculture, Ecosystems & Environment 136, 16–27.

Ram, L.C., Masto, R.E., 2014. Fly ash for soil amelioration: A review on the influence of ash blending with inorganic and organic amendments. Earth-Science Reviews, 128, 52–74.

Sharma, U.C., Datta, M., Sharma, V., 2025. Toxicity and tolerance. In: Soil Acidity: Management Options for Higher Crop Productivity, pp. 323–425. Springer Nature Switzerland, Cham.

Varshney, A., Dahiya, P., Sharma, A., Pandey, R., Mohan, S., 2022. Fly ash application in soil for sustainable agriculture: An Indian overview. Energy, Ecology and Environment 7, 340–357.

Yao, Z.T., Ji, X.S., Sarker, P.K., Tang, J.H., Ge, L.Q., Xia, M.S., Xi, Y.Q., 2015. A comprehensive review on the applications of coal fly ash. Earth-Science Reviews 141, 105–121.