



September, 2026

Popular Article

DOI: [HTTPS://DOI.ORG/10.23910/3.2026.7415](https://doi.org/10.23910/3.2026.7415)



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Citation: Bhattacharyya et al., 2026. EcoLime+: Turning Industrial Waste into a Green Solution for Odisha's Acidic Soils, When Healthy Soil Becomes the Biggest Challenge. Chronicle of Bioresource Management 10(3), 065-069. [HTTPS://DOI.ORG/10.23910/3.2026.7415](https://doi.org/10.23910/3.2026.7415).

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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.

Keywords:

Acidic soils, basic slag, compost, ecolime+, fly ash, rice, soil health

Article History

Article ID: CBM7415

Received on 11th August 2026

Received in revised form on 05th September 2026

Accepted in final form on 19th September 2026

EcoLime+: Turning Industrial Waste into a Green Solution for Odisha's Acidic Soils, When Healthy Soil Becomes the Biggest Challenge

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Abstract

Soil acidity is one of the most serious challenges limiting agricultural productivity in Odisha, affecting nearly 70% of the state's cultivated land. Acidic soils reduce nutrient availability, lower fertiliser-use efficiency and ultimately decrease crop yields, making farming less profitable for millions of small and marginal farmers. At the same time, Odisha's steel and thermal power industries generate enormous quantities of basic slag and fly ash, much of which remains underutilised despite being rich in valuable plant nutrients. Recognising this opportunity, the team of ICAR-Central Rice Research Institute (ICAR-CRRI), Cuttack, developed EcoLime+, an innovative soil amendment prepared by blending basic slag, fly ash and compost. The technology transforms industrial by-products into a valuable agricultural resource, offering a practical "waste-to-wealth" solution for managing acidic soils. Field demonstrations conducted under the SAFAR Project, supported by the Government of Odisha, across more than 1,000 hectares in six districts demonstrated that EcoLime+ not only improved soil health but also enhanced crop productivity. Rice yields increased by 8–17%, green gram yields by 12–19%, soil pH improved by 2–10%, and available phosphorus increased by nearly 15%. Improved phosphorus availability also created the potential to reduce DAP fertiliser consumption by 10–15%, lowering input costs for farmers. EcoLime+ represents an indigenous, climate-smart and environmentally sustainable technology with immense potential to strengthen sustainable agriculture across Odisha and other acid-soil regions of India.

1. Introduction

Healthy soil is essential for agricultural productivity, food security and farmers' livelihoods. However, soil degradation, particularly soil acidity, is a major threat to sustainable crop production. In India, nearly 49 million hectares (about 30% of the geographical area) are affected by soil acidity, especially in the eastern, north-

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eastern and coastal regions. (Mandal et al., 2019). Odisha is one of the worst-affected states, where almost 70% of the cultivated land is acidic (ICAR-NBSS&LUP, 2024). Under such conditions, essential nutrients such as phosphorus, calcium and magnesium become less available to plants, while toxic forms of aluminium and manganese become more soluble. Consequently, crops are unable to utilise applied fertilisers efficiently, resulting in poor plant growth, lower yields and reduced profitability, especially in rice-based production systems (Fageria and Baligar, 2008).

For decades, agricultural scientists have recommended liming materials such as limestone and dolomite to correct soil acidity. Although these materials are effective, their increasing industrial demand has made them relatively expensive and less accessible to farmers. In a state like Odisha, where a large proportion of limestone is utilised by steel, cement and chemical industries, the availability of affordable liming materials for agriculture has become increasingly limited. This situation highlights the need for cost-effective, locally available and environmentally sustainable alternatives that can restore soil health while improving crop productivity (Sharma *et al.*, 2025). Ironically, while farmers struggle to access affordable soil amendments, Odisha generates enormous quantities of industrial by-products every year through its rapidly expanding steel and thermal power sectors. Steel plants produce nearly 42 lakh tonnes of basic slag, and thermal power plants generate approximately 15 crore tonnes of fly ash annually. Much of these nutrient-rich materials remain underutilised and accumulate in disposal sites, creating environmental and land management challenges. However, scientific studies have demonstrated that both basic slag and fly ash possess considerable agricultural value because of their alkaline nature and their richness in calcium, magnesium, silicon and several essential plant nutrients. When used judiciously, these materials can effectively ameliorate soil acidity, improve nutrient availability and enhance soil fertility while simultaneously addressing industrial waste management (Haynes, 2009; Pandey and Singh, 2010; Sharma *et al.*, 2025). The productive utilisation of industrial by-products in agriculture reflects the principles of a circular bioeconomy, where waste generated by one sector becomes a valuable resource for another. Such an approach not only minimises environmental pollution but also conserves natural resources, promotes nutrient recycling and supports climate-smart agriculture.

Recognising these benefits, national initiatives have increasingly encouraged waste-to-wealth technologies that improve resource-use efficiency while contributing to sustainable development goals (FAO, 2021; NITI Aayog, 2022).

With this vision, the team at the ICAR-Central Rice Research Institute (ICAR-CRRI), Cuttack, under the SAFAR Project supported by the Government of Odisha, developed EcoLime⁺ an innovative value-added soil amendment prepared from basic slag, fly ash and compost. Unlike conventional liming materials that primarily neutralise soil acidity, EcoLime⁺ simultaneously improves soil health by supplying essential secondary nutrients, enhancing phosphorus availability, enriching the soil with organic matter and beneficial silicon, and improving nutrient-use efficiency. Large-scale field demonstrations conducted across acidic-soil regions of Odisha have shown that the technology not only improves soil quality and increases rice and pulse productivity but also has the potential to reduce DAP fertiliser consumption by 10-15%. By integrating soil acidity management with the beneficial recycling of industrial by-products, EcoLime⁺ represents an indigenous, climate-smart and environmentally sustainable innovation that offers new opportunities for improving farmers' livelihoods while promoting circular agriculture in India's acid-soil regions.

2. Understanding the Problem: Why Acidic Soils Reduce Crop Productivity

Acidic soils are a major constraint to crop production because low pH affects the way plants access and use nutrients. As acidity increases, phosphorus, calcium and magnesium become less available, while soluble aluminium can restrict root growth. These changes weaken nutrient uptake and reduce the efficiency of applied fertilisers. Over time, farmers may need to spend more on inputs without seeing a corresponding improvement in crop performance. Lime and dolomite have traditionally been used to correct soil acidity. However, their cost, availability and transportation can make regular application difficult, particularly for small and marginal farmers. In Odisha, where acidic soils are widespread and limestone is also required by industry, there is a clear need for practical and locally relevant approaches to soil-acidity management

3. A growing Challenge for Farmers

Correcting the problem therefore requires a solution

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that is affordable, accessible and suited to local farming conditions. This need led to the development of EcoLime⁺, which brings together basic slag, fly ash and compost. The idea is simple: use useful materials already available from industrial and agricultural sources to improve acidic soils while supporting crop productivity. In this way, soil reclamation can be linked with resource recovery rather than depending entirely on conventional amendments.

4. A Treasure Hidden in Industrial Waste

Odisha's industrial development generates substantial quantities of basic slag and fly ash. Steel industries produce nearly 42 lakh tonnes of basic slag, while thermal power plants generate around 15 crore tonnes of fly ash annually. When these materials are not put to productive use, their accumulation can create problems related to storage, land occupation and environmental management (Central Electricity Authority, 2023; NITI Aayog, 2022). Basic slag and fly ash provide alkaline components and plant nutrients, while compost contributes organic matter and additional nutrients. Together, these materials form a value-added amendment designed to improve acidic soils and support better nutrient availability (Haynes, 2009; Pandey and Singh, 2010).

Importantly, laboratory evaluation showed that potentially harmful elements, including chromium, remained within the permissible limits prescribed under the Fertiliser (Control) Order (FCO) when the material was appropriately prepared and used (FCO, 1985; amended 2021). This provides an important foundation for its responsible use in agriculture.

5. What Makes EcoLime⁺ Different?

Unlike conventional liming materials that primarily correct soil acidity, **EcoLime⁺** performs multiple functions simultaneously. It acts as a soil acidity ameliorant, a source of secondary nutrients, a supplier of beneficial silicon, an organic soil conditioner, and a nutrient-use efficiency enhancer.

6. Better Soil, and Fertiliser Savings Too

One of EcoLime⁺'s greatest strengths is improving the availability of phosphorus in acidic soil. In acidic soil, most of the phosphorus applied becomes chemically bound and unavailable to plants. EcoLime⁺ improves soil

conditions so that more phosphorus can reach the plants. This increases nutrient-use efficiency, which in turn can cut the requirement for di-ammonium phosphate (DAP) - India's most widely used fertilizer - by 10 to 15 %. At a time when fertiliser prices remain a constant worry for farmers, even this seemingly modest saving can significantly reduce the cost of cultivation.

7. The Real Test in the Fields

EcoLime⁺ is no longer confined to the laboratory. Under the SAFAR project, funded by the Government of Odisha, scientists carried out extensive field demonstrations across more than 1,000 hectares in six districts - Cuttack, Dhenkanal, Jajpur, Sundargarh, Angul and Jharsuguda. As part of this programme, scientists tested farmers' soil, prepared around 1,600 soil health cards, and educated nearly 1,500 farmers on soil health management and the use of EcoLime⁺. The product was tested not only in the paddy-pulse cropping cycle but also on horticultural crops such as cashew, lime, coconut and mango. The field results were highly encouraging. Rice yields increased by 8-17%, while green gram (moong) yields improved by 12-19%. Soil pH increased by 2-10%, available phosphorus improved by nearly 15%, and the requirement for DAP fertiliser showed the potential to decrease by 10-15%. Post-harvest analysis of soil and grain samples showed no significant accumulation of heavy metals, indicating that the application of fly ash-based value-added products did not adversely affect the heavy metal status of the soil or harvested grain. These findings support their potential for safe and environmentally responsible agricultural use when appropriately applied. Farmers participating in the demonstrations observed healthier crop growth, improved soil condition and reduced dependence on chemical fertilisers. These outcomes reinforce the importance of integrated soil acidity management and efficient nutrient use for enhancing agricultural productivity in acid soils (Fageria and Baligar, 2008). The technology has also received appreciation from the Government of Odisha for its potential to improve farmers' livelihoods while promoting sustainable resource management (Table 1).

The field experience also demonstrated that the success of a soil-health technology depends on more than its technical performance. Soil testing, farmer awareness and appropriate application are equally important. Distribution of soil health cards helped farmers understand the condition of their fields, while field

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Table 1: District-wise area coverage and observed improvement in soil pH and rice yield under EcoLime+ field demonstrations

Districts	Area covered (ha)	Increase in pH (%)	Increase in rice yield (%)
Angul	157.83	10-14	9-14
Cuttack	127.76	7-10	12-17
Dhenkanal	480.37	10-12	10-12
Jajpur	164.27	6-8	10-13
Jharsuguda	166.73	8-11	11-14
Sundargarh	124.25	6-9	8-11

demonstrations provided an opportunity to observe the application and practical use of EcoLime+ under local farming conditions.

8. A model of Prosperity from Waste

EcoLime+ illustrates a practical waste-to-wealth pathway. Materials generated by steel and thermal power industries are redirected towards productive agricultural use instead of being treated only as disposal burdens. In this way, EcoLime+ links soil-health management with resource recovery and the principles of a circular bioeconomy (Figure 1).



Figure 1: EcoLime+ Transforming industrial by-products into a sustainable solution for reclaiming acidic soils, enhancing nutrient-use efficiency, improving rice and pulse productivity, and reducing DAP fertiliser consumption in Odisha

9. A technology with Broad Potential

EcoLime+ holds strong potential for large-scale use across India's acidic-soil regions. The technology is capable of improving soil health, boosting crop productivity, and reducing dependence on chemical fertilisers through the beneficial use of industrial by-products. Although

it was initially developed and tested in Odisha, its reach can also be extended to other acidic-soil regions such as Jharkhand, West Bengal and the north-eastern states, where soil acidity remains a major barrier to agricultural production. The technology enriches acidic soil with essential secondary nutrients such as calcium and magnesium, while also making available silicon, an element important for paddy cultivation. All these elements enhance nutrient-use efficiency, strengthen plants' tolerance to environmental stress, and contribute to sustainable crop production. By bringing together the management of soil acidity, improved nutrient availability and the circular use of industrial by-products, EcoLime+ offers a practical and environmentally friendly solution for managing acidic soils across diverse agro-ecological regions (Figure 2).



Figure 2: Field demonstration and application of EcoLime+ in farmers' fields, Soil health card distribution and field application of EcoLime+ in farmers' fields

10. Beyond Yield: Building Healthier Soils for Future Generations

The true strength of EcoLime+ lies not only in increasing

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crop yields but also in rebuilding degraded soils. By enriching soils with calcium, magnesium, silicon and organic matter, EcoLime+ strengthens crop resilience against environmental stresses while supporting long-term soil fertility. Such improvements are essential for ensuring food security under changing climatic conditions.

11. The Road Ahead

EcoLime+ was developed under the SAFAR Project supported by the Government of Odisha. A patent application has been filed, and the technology has been commercialised for adaptive trials. The next step is to build wider field evidence, strengthen farmer awareness and ensure that the technology is used according to soil-test results and recommended practices. Stronger links between research, industry and farmers can help EcoLime+ become a useful component of sustainable acidic-soil management.

12. Conclusion

EcoLime+ shows how a simple idea can create meaningful change, turning industrial by-products into a useful resource for farmers. By combining basic slag, fly ash and compost, it helps improve acidic soils, nutrient availability and rice and pulse productivity, while offering potential DAP savings of 10–15%. With wider adoption, EcoLime+ can help farmers build healthier soils, reduce input costs and move towards more sustainable, resource-efficient agriculture across India's acidic-soil regions.

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