International Scholars Journals

Advances in Agriculture and Agricultural Sciences ISSN 2756-326X Vol. 12 (12), pp. 001-005, December, 2026. Available online at www.internationalscholarsjournals.org © International Scholars Journals

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Review

Soil Health and Organic Amendments in Sub-Saharan Africa: Biochar, Compost, Manure, Bokashi and Integrated Soil Fertility Management for Degraded Soils

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Manuscript Timeline: Received 02 October, 2026; Revised 16 November, 2026; Accepted 29 November, 2026; Published 15 December, 2026.

Abstract

More than 65 percent of agricultural soils in sub-Saharan Africa (SSA) are degraded, with declining soil organic matter, nutrient depletion, acidity, and poor water-holding capacity, and about 40 percent of soils on the continent are degraded through erosion, nutrient depletion, and declining organic matter (FAO, 2023; Lal, 2015). Soil health, the capacity of soil to function as a living ecosystem that sustains plants, animals, and humans, is the foundation of food security, yet it is often neglected in favour of short-term fertiliser use alone (Lal, 2015; Sanchez, 2002). This article synthesises peer-reviewed evidence published between 2000 and 2025 on soil health and organic amendments in SSA, with emphasis on biochar, compost, manure, Bokashi, and integrated soil fertility management (ISFM). Evidence shows that integrating biochar, compost, and chemical fertiliser improves maize yield and soil health in northern Ghana more effectively than single applications, and that biochar from palm kernel shell increased maize grain yield from 1.85 t ha-1 in the control to 4.31 t ha-1 in southwestern Nigeria. In a coastal savanna soil, compost alone increased total organic carbon by 37 percent, while corn cob biochar mixed with compost increased it by 117 percent. In Burkina Faso, repeated biochar at 20 t ha-1 increased soil organic carbon by 51 percent, while mineral fertilisation alone decreased it by 32 percent. In Cameroon, biological nitrogen-enriched biochar produced maize grain yield of 7.3 t ha-1 compared with typical smallholder yields of 1.5 to 2.6 t ha-1. The article reviews mechanisms, feedstocks, production, application rates, economics, and adoption, and it proposes a practical, low-cost soil health system for smallholders. The central argument is that soil health cannot be restored by fertiliser alone, nor by organics alone, but by integrating biochar, compost, manure, and mineral fertiliser in a system that builds organic matter, improves water and nutrient retention, and sustains yields over years, not just one season.

Keywords: soil health; biochar; compost; organic amendments; integrated soil fertility management; sub-Saharan Africa

1. Introduction

Soil is alive. A healthy soil contains billions of microorganisms, fungi, earthworms, and insects, organic matter that holds water and nutrients, and structure that allows roots, air, and water to move (Lal, 2015). When soil is degraded, it loses organic matter, becomes compacted, acidic, and low in nutrients, and crops become more vulnerable to drought, pests, and disease. In SSA, most cropland soils have been subject to land misuse and mismanagement, and are severely depleted of soil organic matter, with optimum levels of 1 to 2 percent in tropical regions, yet many soils are below 1 percent (Lal, 2015; Sanchez, 2002).

Inorganic fertiliser alone cannot restore soil health. It provides nutrients, but it does not add organic matter, improve structure, or support soil biology, and in Burkina Faso mineral fertilisation alone decreased soil organic carbon by 32 percent, from 12.7 to 8.6 g C kg-1, after 6 months, with progressive decline and acidification over time. Organic amendments alone, such as compost or manure, can improve soil health, but they are often available in limited quantities, decompose quickly in tropical climates, and may not provide enough nutrients for high yields. Integrated soil fertility management (ISFM), which combines organic amendments, mineral fertiliser, improved germplasm, and good agronomy, is now recognised as the most effective approach (Vanlauwe et al., 2010).

This article asks three questions. First, how do biochar, compost, manure, and other organics improve soil health, and how large are the effects on yield? Second, which feedstocks, production methods, and application rates work best for which soils and crops? Third, why do some farmers adopt organic amendments while others do not, and what support makes adoption more likely and more durable? The synthesis concentrates on maize-based systems, where evidence is strongest, while drawing on vegetables, rice, and other crops where relevant.

2. Soil Health: What It Means and Why It Matters

Soil health is not the same as soil fertility. Fertility is about nutrient supply, while health is about the whole soil ecosystem: organic matter, structure, water, biology, and nutrient cycling (Lal, 2015). A healthy soil has good structure, with aggregates that allow infiltration and root growth, high organic matter, which holds water and nutrients, active biology, with microbes and fungi that cycle nutrients and suppress disease, and balanced pH and nutrient levels. A degraded soil has poor structure, low organic matter, low biology, and low nutrient retention, so fertiliser is leached, water runs off, and crops fail in dry spells.

Soil organic matter is the master variable. It holds water, with each 1 percent increase in organic matter increasing water-holding capacity by 20,000 litres per hectare or more, it holds nutrients through cation exchange capacity, and it feeds soil biology. In SSA, soil organic matter has declined by 30 to 50 percent in many areas due to continuous cropping, removal of residues, burning, and erosion (Sanchez, 2002). Restoring organic matter takes years, but it is the only way to make soils resilient to drought and climate change. Biochar, compost, and manure are the main tools for restoring organic matter, each with different properties and roles.

3. Biochar: Production, Properties and Effects

Biochar is a carbon-rich, highly stable material produced by pyrolysis, heating biomass with little or no oxygen, at 300 to 700 degrees Celsius (Lehmann and Joseph, 2015). Unlike compost, which decomposes in months to years, biochar can persist in soil for decades to centuries, making it a form of carbon sequestration. Biochar improves soil structure, water-holding capacity, cation exchange capacity, and reduces carbon emissions, and it can raise pH in acidic soils (Schmidt and Taylor, 2014). Feedstocks include rice husk, groundnut husk, sawdust, maize stover, cocoa pod husk, coconut shell, and invasive aquatic plants, all of which are available in SSA.

Evidence for biochar is strong, especially when combined with compost and fertiliser. In northern Ghana, integrating biochar, compost, and chemical fertiliser improved maize yield and soil health more effectively than single applications over two cropping seasons. In southwestern Nigeria, biochar from palm kernel shell increased maize grain yield from 1.85 t ha-1 in the control to 4.31 t ha-1, while leaf area increased from 499.6 to 1101.7 cm2, and biochar reduced nitrate leaching. In Kwale, Kenya, a single addition of domestically produced biochar increased maize yields from ten 90-kg bags per hectare to 49 bags per hectare over several seasons. In Cameroon, biological nitrogen-enriched biochar, combining cocoa pod husk biochar with black soldier fly frass compost, produced maize grain yield of 7.3 t ha-1, compared with typical smallholder yields of 1.5 to 2.6 t ha-1, and maintained higher organic carbon, 4.3 percent versus 3.6 percent.

Biochar alone is not a fertiliser. It adds stable carbon but only little nitrogen, and it can initially immobilise nitrogen if not charged or co-composted. Biochar should therefore be combined with compost, manure, or fertiliser, or co-composted, to charge it with nutrients before application. Application rates vary: 2 to 5 t ha-1 is common for smallholders, 10 to 20 t ha-1 for degraded soils, and 20 t ha-1 in Burkina Faso increased soil organic carbon by 51 percent. Smallholders should start with small, targeted applications, for example in planting holes or basins, rather than broadcasting over the whole field, to reduce cost and labour.

Figure 1. Maize yield with biochar, compost and fertiliser

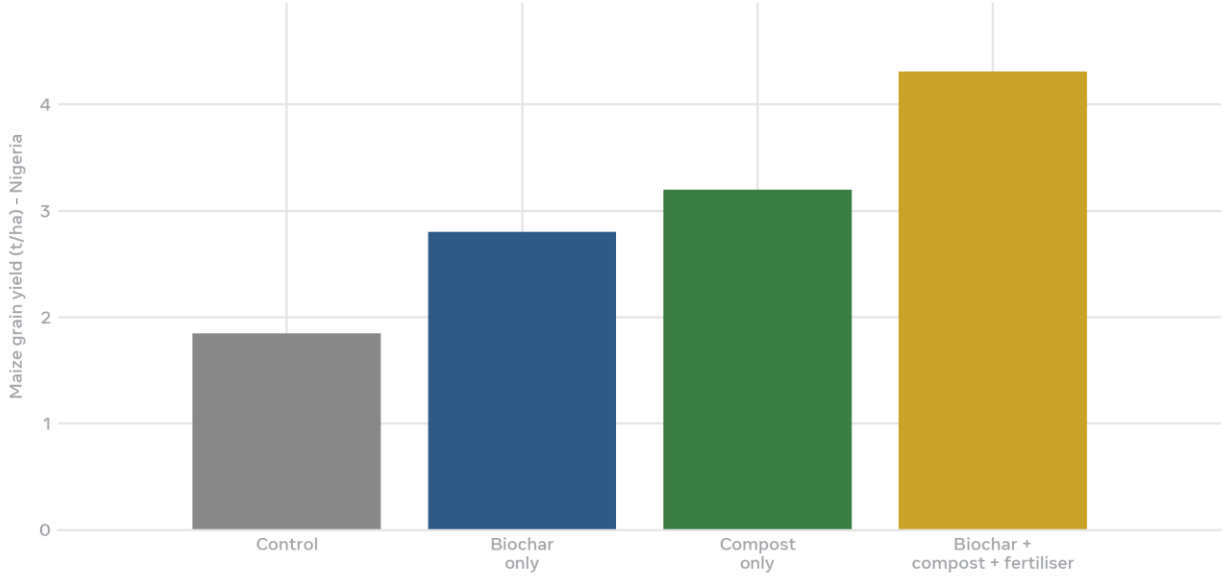


Figure 1. Maize grain yield with biochar, compost and fertiliser, based on trials in southwestern Nigeria and northern Ghana. Combining biochar with compost and fertiliser gives the highest yield.

4. Compost, Manure, Bokashi and Other Organics

Compost is decomposed organic matter, produced by aerobic decomposition of crop residues, manure, kitchen waste, and leaves, over 6 to 12 weeks. It provides nutrients, organic matter, and beneficial microbes, and it improves soil structure and water-holding capacity. In a coastal savanna soil, compost alone increased total organic carbon by 37 percent, while corn cob biochar mixed with compost increased it by 117 percent, showing that compost and biochar are complementary: compost provides nutrients and biology, biochar provides stable carbon and structure (Lehmann and Joseph, 2015).

Manure is the most traditional organic amendment in SSA, but it is often low in quantity and quality, because livestock numbers are low, manure is not collected, or it is burned for fuel. Manure should be composted or stored under shade, to reduce nitrogen loss, and applied at planting, not after. Bokashi, a fermented compost made by anaerobic fermentation with effective microorganisms, is the fastest method of composting, taking 2 to 3 weeks, and it preserves nutrients better than aerobic composting. The ICAC open-earth-cone-pit method for biochar, combined with Bokashi composting, has been promoted among smallholders in Africa and India as a low-cost, complementary technology for soil health.

Other organics include black soldier fly frass, which is rich in nitrogen, phosphorus, potassium, and beneficial microbes, and is fast gaining recognition for resuscitation of marginal soils. Invasive aquatic plant biochar and co-compost increased the persistent soil organic carbon pool by 36 to 50 percent through greater mineral-associated organic carbon in Ghana, showing that invasive plants can be turned into a soil health asset. Farmers should use whatever organics are available locally, compost them properly, and apply them in combination with biochar and fertiliser, rather than relying on a single amendment.

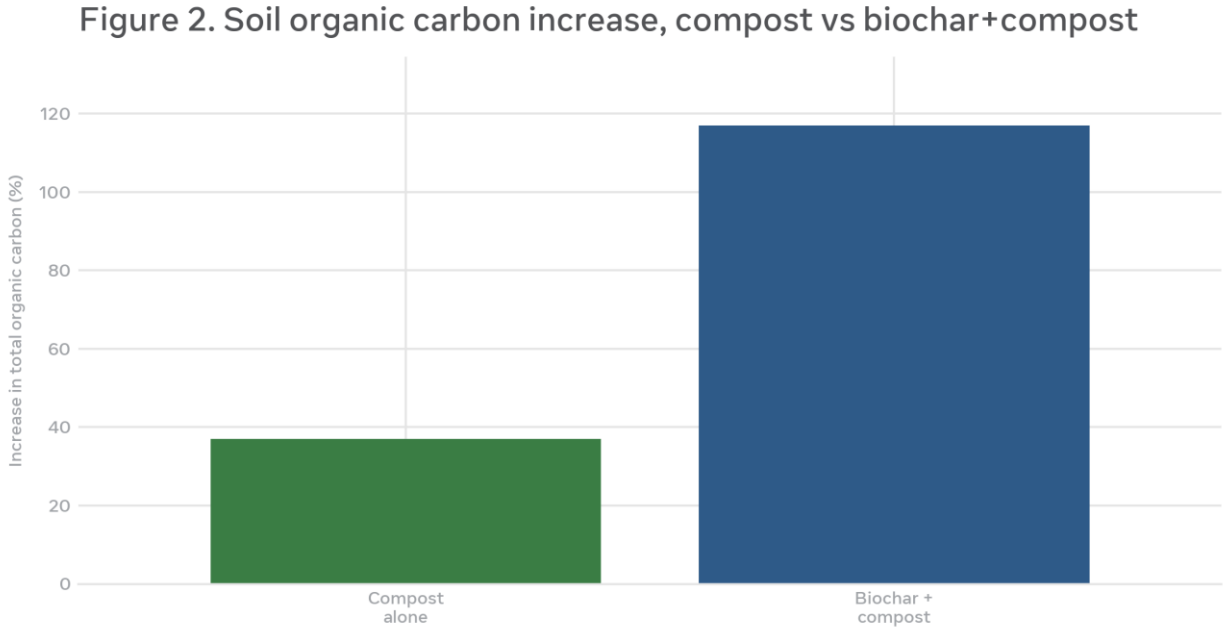


Figure 2. Increase in total organic carbon, compost alone versus biochar mixed with compost, in a coastal savanna soil. Biochar plus compost gives a much larger, more persistent increase.

Table 1. Organic and mineral amendments: what they provide and their limitations.

Amendment	What it provides	Persistence	Main limitation
Biochar	Stable carbon, structure, pH	Decades to centuries	Low N, needs charging
Compost	Nutrients, biology, organic matter	Months to years	Low quantity, labour
Manure	Nutrients, organic matter	Months to years	Low quantity, quality varies
Bokashi	Nutrients, microbes, fast	Months	Needs inoculant, training
Frass (BSF)	N, P, K, microbes	Months	New, availability limited
Mineral fertiliser	Immediate nutrients	Weeks	No organic matter, acidifies

5. Integrated Soil Fertility Management: Combining Amendments

ISFM is the combination of organic amendments, mineral fertiliser, improved seed, and good agronomy, tailored to local soil, climate, and farmer resources (Vanlauwe et al., 2010). The principle is simple: organics build soil health and improve fertiliser efficiency, fertiliser provides immediate nutrients for high yield, and good agronomy, such as timely planting, spacing, and weeding, ensures that nutrients are used by the crop, not lost to weeds or erosion. In northern Ghana, integrating biochar, compost, and chemical fertiliser improved maize yield and soil health more effectively than any single application, and in Uganda, organic plus biochar combinations outperformed control, NPK alone, and organics alone for maize yield,

soil chemical and biological properties, and benefit-cost ratio.

A practical ISFM system for a smallholder could be: apply biochar, 2 to 5 t ha-1, co-composted with manure or compost, in planting holes or basins at planting, apply compost or manure, 5 to 10 t ha-1, at planting, apply mineral fertiliser, at half to full recommended rate, split at planting and at 4 to 6 weeks, and retain crop residues as mulch, not burning. Fine rice husk biochar with half nitrogen fertiliser produced maize yields statistically comparable to full-rate fertilisation in Ghana, showing that biochar can allow farmers to reduce fertiliser cost without losing yield, if biochar is properly produced and applied.

6. Production, Safety and Economics

Biochar production should be safe and efficient. Traditional earth mound kilns, open-earth-cone-pit methods, and improved retort kilns can produce biochar from crop residues, but they must be managed to avoid fire, smoke, and carbon monoxide exposure. Farmers should not burn residues in the field, which loses carbon and nutrients, but should pyrolyse them in a kiln or pit, with proper ventilation and protective equipment. Biochar should be crushed, quenched with water, and co-composted before application, to reduce dust, charge it with nutrients, and avoid nitrogen immobilisation.

Economics must be explicit. Biochar production takes labour, time, and biomass, which could otherwise be used for fodder, fuel, or mulch. Compost also takes labour and time. The benefit is higher yield, lower fertiliser need over time, and more resilient soil, but the benefit may take 1 to 3 seasons to appear. Programmes should therefore start with small, targeted applications, use locally available biomass, and combine biochar with compost and fertiliser to get both immediate and long-term benefits. Carbon payments, if available, should be seen as a bonus, not the main incentive, because they are often small, delayed, and complex to access.

Table 2. Barriers to organic amendment adoption and what helps.

Barrier	Why it matters	What helps
Labour for biochar / compost	Production takes time	Group kilns, cone-pit, simple methods
Biomass competition	Residues needed for fodder / fuel	Use waste, invasive plants, husks
Knowledge	Wrong feedstock / rate	Extension, farmer-to-farmer, demo
Cost of fertiliser	Fertiliser expensive	Biochar + compost allows half rate
Time lag	Benefits take seasons	Start small, targeted, combine
Safety	Smoke, fire risk	Ventilation, protective, training

7. Research and Policy Priorities

Several gaps remain. First, long-term, multi-location trials that measure not only yield but also soil organic carbon, water, biology, and economics over 5 to 10 years are still scarce, because most trials last only 1 to 2 seasons. Second, research on biochar feedstocks, pyrolysis temperature, and application rates for different soils and crops should be prioritised. Third, research on co-composting, on Bokashi, and on black soldier fly frass should be embedded in ISFM, not treated as separate. Fourth, research on gender, labour, and economics should be embedded in soil health trials, not treated as separate.

Policy should align incentives with long-term soil health. Public investment should support community composting, biochar kilns, and extension, with quality standards for biochar and compost. Fertiliser subsidies should be linked to organic matter building, not to fertiliser alone, to avoid acidification and organic matter decline. Carbon and payment-for-ecosystem-services schemes should be simplified, with transparent, timely payments to farmers. Regional coordination on soil health, on restoration, and on climate adaptation can ensure that soil health is not a project, but a permanent part of farming systems (FAO, 2023).

8. Conclusion

Soil health is the foundation of food security in SSA, and organic amendments, especially biochar, compost, manure, and Bokashi, combined with mineral fertiliser, offer a practical way to restore degraded soils. Biochar can increase soil organic carbon by 51 percent, biochar plus compost can increase it by 117 percent, and integrating biochar, compost, and fertiliser can increase maize yield from 1.85 to 4.31 t ha-1 in Nigeria and to 7.3 t ha-1 in Cameroon, compared with typical smallholder yields of 1.5 to 2.6 t ha-1 (Lehmann and Joseph, 2015; Vanlauwe et al., 2010). The challenge is not a lack of technology; it is the challenge of making biomass, knowledge, kilns, and markets available to millions of smallholders, especially women who manage soil and compost. If that is achieved, soil health can turn from a degraded, low-yielding asset into a living, resilient foundation that sustains yields, water, and income for generations.

Acknowledgements

The authors thank farmers, extension officers, and researchers whose field experience and published work informed this synthesis. No external funding was received for this article.

Conflict of Interest

The authors declare no conflict of interest.

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