KNOWLEDGE BRIEF

5

The potential of the off-farm production, marketing and use of organic & biofertilisers in Africa

DeSIRA LIFT

Authors:
Bernhard Freyer
Pierre Ellssel
Fortunate Nyakanda
Stéphanie Saussure

Key messages

1. Organic and biofertilisers (OFBF) demonstrate strong potential in addressing soil fertility, enhancing crop yields and contributing to the nutrient cycle in Africa. The rise of organic agriculture partly explains the increase in commercial OFBF production, marketing and demand in some countries, in particular Egypt and South Africa.

2. To unlock Africa's potential for soil health and agricultural productivity, a holistic approach is crucial. Such a systems approach emphasises an integrated fertiliser strategy, with soil health as its central goal. This includes conducive land tenure policies, encouraging long-term farmer investments in soil health.

3. Meaningful support for local and national initiatives on OFBF must be scaled. This requires a comprehensive cross-sector policy framework, including green waste collection, waste processing and distribution, quality assurance and on-farm application. Alignment with continental and regional policies (e.g. CAADP, Ecological Organic Agriculture Initiative or the new Soil Initiative for Africa) is essential. Policy efforts should support private-sector initiatives with sustainable access to finance, minimise bureaucracy for product approval processes and enforce quality standards for OFBF.

4. Recycling organic waste can potentially cover 20-40% of an agricultural system's nutrient requirements. Primary sources of organic waste include biomass from agricultural processing, households and human excreta. Currently, organic waste streams are underutilised. Early-stage waste separation is crucial to make household waste-based organic fertiliser production economically feasible and enhance the quality of organic fertilisers.

5. Waste-based organic fertiliser can yield various positive environmental impacts. These encompass mitigating soil and water contamination, reducing greenhouse gas emissions from landfills, increasing soil humus and nutrient content, improving nutrient availability and water holding capacity for soils, elevating the water table and positively influencing climate change mitigation. Resource recovery and reuse projects demonstrate heightened economic viability when external environmental and human health costs are internalised and positive effects are accounted for.

6. Successful organic fertiliser businesses hinge on a multi-stakeholder approach to value chain development. The absence of viable business plans specifically targeting the use of organic waste for the reuse and recycling market is often a key factor leading to failure, particularly when the primary focus is solely on diverting waste from landfills to reduce waste volumes without considering market demands of processors of (organic) waste. Investments across the value chain are needed, including technological advancements in waste separation and collection, processing, quality control and efficient distribution systems.

7. Biofertilisers can stimulate soil microbial activity or reinforce plant defence mechanisms. Rhizobia have the potential to enhance nitrogen fixation in grain and forage legumes but require further development for optimal utilisation, including adaptation to acidic soils. Fungal-based biofertilisers are mostly in research stages, calling for a wider exploration of practical applications. Biofertilisers face challenges, such as sensitivity to factors like temperature, humidity and contamination, throughout production, storage, transport and application.

8. Research on OFBF and soil amendments, including biochar and liming, is recommended to establish an evidence base on product efficacy. Biochar holds promise as a soil amendment, especially for acidic soils. Thorough analysis of nutrient and carbon content, along with microbiological characteristics, will assist in developing robust standards for OFBF products.

9. Waste management regulations exist in almost all case study countries. In some countries, a regulatory framework for OFBF exists and others also have standards for OFBF. However, the subsequent application and enforcement of these regulations is lacking. Establishing policies that ensure quality control and hygiene, with standards, regulations and certification mechanisms, is crucial for OFBF.

10. Subsidies and incentives throughout the OFBF value chain, including tax reduction for technologies, can boost technology investment, improve production and support market development, contributing to sustainable land use and food production strategies.

1. Introduction

Agricultural productivity on the African continent, particularly in sub-Saharan Africa (SSA), ranks among the lowest globally (Bjornlund et al., 2020). One contributing factor is the extensive degradation of soils in many regions (Jones et al., 2013; Nkonya et al., 2016). Consequently, there is a high demand for nutrient sources and measures to halt soil degradation and improve soil health, aiming to enhance agricultural production. While one option is to increase the use of inorganic fertilisers, this alone would only address part of the problem. The remediation of soil degradation also hinges on an elevated application of organic matter and the reduction of soil acidity, amongst others. Even if inorganic fertilisers would be available, affordable and used more widely, factors such as low soil organic matter content, micronutrient deficiencies and/or high soil acidity hinder the effectiveness of such fertilisers. Therefore, on-farm solutions to enhance organic matter content and increase soil nutrient availability, e.g. through good agronomic practices, are necessary conditions to improve soil health and crop yield.

While there is extensive research and advice on the application of inorganic fertilisers, there is less attention on the production, use and effectiveness of organic and biofertilisers (OFBF), as well as soil amendments. This scoping study focuses on the potential of the off-farm production and marketing of OFBF to contribute to soil health in Africa. It emphasises that, considering nutrient exports and losses, further exploration of strategies for the off-farm production of OFBF can provide another complementary strategy towards a comprehensive solution to improve soil health and crop yield in Africa.

The study uses a country case study approach and includes a review of existing literature and 89 qualitative key informant interviews, spanning the entire OFBF value chains across 12 African countries: Egypt (Northern Africa); Cameroon, Côte d'Ivoire, Ghana, Senegal (Western and Central Africa); Ethiopia, Kenya, Rwanda, Uganda (Eastern Africa); and Malawi, South Africa and Zimbabwe (Southern Africa).

2. Current status of off-farm produced organic fertilisers

Organic fertilisers are plant- or animal-based materials which are retrieved from agricultural, forestry, fishery, or biomass from algae, water hyacinth or municipal residues. The fertilisers occur in solid or liquid forms, as well as in natural (e.g. farmyard manure, slurry) and processed forms (e.g. compost, meals, sludge). Organic fertilisers are known for their positive effects on soil fertility, soil organic matter content, and macro- and micro-nutrient balances. Compost is recommended for all types of crops, including vegetables and fruit trees. In arable production, it is commonly used for potatoes and other root crops but less so for maize due to its lower impact on yield. Moreover, these composts are often applied to high-value or export crops (e.g. organically certified crops).

There are four main waste streams, including household food and green waste (any residues from green spaces), market waste, human excreta and agricultural by-products (residues from processing and slaughterhouses), which are processed into compost or liquid organic fertilisers. The conversion of organic waste into bio-slurry, insect frass fertiliser and vermicompost are currently of minor relevance in terms of volumes.

The commercial production of organic fertilisers is still in its early stages in Africa. Smaller businesses gather animal manure and use local resources like crop residues, household waste and wild plants (such as tithonia or water hyacinth) to produce compost. Some businesses enhance their products by adding mineral or inorganic fertilisers to ensure consistent nutrient content. Larger businesses tend to focus on compost production, using municipal household and green waste, market waste, slaughterhouse residues and human waste (e.g. Egypt, Ghana). Organic fertiliser production based on vermicomposting (Ethiopia, Uganda, Zimbabwe) or black soldier fly (Kenya) is on the rise.

The estimated quantities currently produced reveal great variations among countries, ranging from less than 5 000 t/year in Cameroon, Malawi and Rwanda to 20 000 to 70 000 t/year in Côte d'Ivoire, Kenya, Senegal and South Africa, and over 100 000 t/year in Egypt, Ethiopia and Ghana. Nigeria appears to have one of the highest organic fertiliser production capacities (500 000 t/year) (Dalberg, 2023) compared with other countries in SSA, while one of the single largest commercial producers exists in Egypt with an annual compost production of around 120 000 t.

Prices show great variations across countries, ranging from 35 to 100 EUR per 50 kg for inorganic fertilisers and <1 to 65 EUR per 50 kg for organic fertilisers. When considering prices per macro-nutrients (nitrogen – N, phosphorus – P, kalium – K), inorganic fertilisers tend to be more cost-effective. In Senegal, for example, one ton of NPK (15:15:15) fertiliser is priced at approximately 800 to 1 100 EUR. To match the nutrient values of this fertiliser, one would need about four to five times the amount of a compost fortified with chicken manure and phosphate with NPK (4:3:3) which is priced at about 300 EUR per ton, totalling about 1 200 to 1 500 EUR. However, conducting such a simplified calculation may not account for all relevant costs and benefits, such as potential improvements in soil health due to the added value of organic matter and micronutrients in organic fertilisers, or the different levels of soil responsiveness to different types of fertilisers.

Soil amendments such as biochar are not widely produced across the case study countries and limited mention has been made of its demand in interviews. However, one interviewee reported successful results in field trials using a combination of biochar and urine, yielding outcomes comparable to inorganic fertilisation. Nevertheless, further investigation is needed to ascertain the agronomic impact and economic feasibility of production.

The off-farm production of organic fertilisers holds potential for development, thereby contributing to the recycling of nutrients and organic matter in agriculture at local and national levels. This is particularly evident when considering the combined use of household waste, human excreta and agricultural by-products. The increasing urbanisation can be an opportunity if the environment is conducive and functional due to market proximity, affordable transport costs, higher purchasing power of farmers, opportunities for the export of organic products and attraction of private capital due to economies of scale.

" Various existing technologies are effective, but the challenge lies in producing a high-quality product and implementing policy measures that encourage farmers to utilise them. The primary concern is not the technology itself but the entire value chain, from sourcing waste as a resource to delivering the final product to the market. This includes considerations of waste quality, related issues affecting waste quality, and the logistical challenges in waste collection and treatment." (International consultant/expert)

3. Current status of off-farm produced biofertilisers

Biofertilisers can stimulate plant nutrition processes, are used as plant strengthener and bio-pesticide, and indicate potential for yield improvements, specifically in dry and tropical climates (Schütz et al., 2018). The term "biofertilisers", used interchangeably with "biostimulants", refers to a diverse array of microbial-based products incorporating plant teas, mycorrhizal fungi and beneficial bacteria, that claim to increase soil fertility, improve crop resistance or stimulate root and/or crop biomass. The majority (80%) of biofertilisers compromise products with N-fixing properties; a minority (14%) of products include P-solubilising properties (BioFit, 2015).

"According to our research, as well as by [research of] others, the yield of many crops increased by 16% to 52% when these crops received the recommended doses of biofertilisers (azotin, phosphatin, potassiomag)." (Researcher, Heliopolis University, Egypt)

The global market share of biofertilisers in Africa is estimated at about 5% only (BioFit, 2015; Raimi et al., 2021).[1] The most advanced market in Africa for biofertilisers and producers can be found in South Africa. Most of the biofertilisers marketed in SSA are imported and not always adapted to local conditions (cf. Masso et al., 2015).

"Quality standards and testing are missing. And enforcing the standard is what is more important because to have a standard that you don't enforce is as good as you don't have a standard. There are many products spilling in (from outside Africa) but you don't know if the product is tested, if it is good, if it is really working. So, they might sell it for a low price which affects finally the development of good products which might cost more but work in the end." (Biofertiliser/rhizobia producer, Malawi)

The effectiveness of rhizobia, a type of nitrogen-fixing bacteria that form symbiotic relationships with legumes, is well documented (dos Santos Sousa et al., 2022; Kaschuk et al., 2010). The use of rhizobia can significantly increase nitrogen fixation in legume crops and respective crop yield, and hence reduce or eliminate the need for inorganic nitrogen fertiliser and improve soil health. The nitrogen-fixing potential of rhizobia can range from 50 to 300 kg/ha/year, 20 to 40 kg/ha/year for Azotobacter and 20 to 160 kg/ha/year for Azospirillum (Kumar et al., 2022). Low soil pH levels can inhibit rhizobia's effectiveness in nitrogen fixation. In such cases, the contribution of legumes to the overall nitrogen budget is limited. In addition, crops like forage legumes and leguminous alley crops are currently limited in use and therefore make insignificant contributions to both the carbon and nitrogen balance, resulting in a negligible positive impact on crop yield. On the other hand, legumes in intercropping systems or grain legumes are more commonly used and have a more substantial impact.

"With the use of inoculants, you can possibly increase your legume yield to about a plus of 40%. However, this also goes hand in hand with the application of good agricultural practices and good pest and disease management." (Biofertiliser/rhizobia producer, Malawi)

Rhizobia for grain legumes are used successfully in Egypt and Malawi, with reported benefits in terms of agricultural production. Central and West Africa are the least developed regions in terms of production and usage of rhizobia-based products (cf. Raimi et al., 2021). One of the challenges regarding rhizobia production and use is the lack of access to modern technology. However, some companies are successfully producing rhizobia, for example Malawi, where a company produces currently for an area of 50 000 ha.

Plant teas, also known as compost teas or botanical extracts, and their impact on soils, plant growth and overall plant health are not yet fully understood, and the scientific evidence on their effectiveness is mixed or incomplete (Curadelli et al., 2023; De Corato, 2020). The standardisation of plant teas is still in its infancy, also in Western countries. Still, some farmers make use of plant teas and report positive outcomes.

Biofertilisers, specifically those based on arbuscular mycorrhizal fungi or other beneficial fungi, are predominantly employed in research settings at present, with limited practical application in broader contexts. Nevertheless, potential may exist for enhancing yields using arbuscular mycorrhizal fungi, as well as free-living nitrogen-fixing bacteria and phosphate-solubilising bacteria, particularly in dry and tropical climates (Schütz et al., 2018). The combination of inoculation of beneficial fungi and bacteria, and the combination of N-fixer and P-solubilisers can lead to better results, as well as the additional combination with organic fertiliser (Bamdad et al., 2022; Ye et al., 2020).

Challenges in biofertiliser application include limited understanding about storage, dosage and application technology, resulting in uncertainties and variable outcomes. Microbial contaminants are common problems influencing the quality of biofertilisers; hence the properties of carrier materials need to be well maintained to secure shelf life and ultimately product quality. Issues stem from incomplete knowledge of bacterial multifunctionality, complex interactions in soils, and varying responses to biotic and abiotic factors. Technical challenges in formulation and inconsistent practical results are further important obstacles (cf. Faye et al., 2013; Herrmann et al., 2015; Masso et al., 2013; Masso et al., 2015).

"A lot of biofertiliser products are fake and so it's absolutely a waste of money if you buy those things. And unfortunately, in Kenya, there's a lot of those products on the market. There are some of them that do work. Some of rhizobia inoculants for legumes. Some of the trichoderma that are being promoted, they do work. Sometimes they have pest and disease suppressing properties. But 90% of the products are fake. And also, those products you find in the Kenyan market, you find them partly because there's not a very effective registration process. So, companies just bring in products, there's no real screening of effectiveness or shelf life or anything." (Researcher 1, International Institute of Tropical Agriculture (IITA), Kenya)

Despite the challenges, some of the biofertilisers may hold promise as a sustainable and environmentally friendly solution for optimising both chemical and biological processes in soils, while also potentially contributing to

1] *The figures and estimates used in the BioFit report (BioFit, 2015), as well as by Raimi et al. (2021), are mostly retrieved from market research institutes such as www.marketsandmarkets.com. The original data sources and assumptions of these reports can thus not be verified as they are not publicly available (for free).*

overall plant health. Their ability to enhance soil health, promote nutrient uptake, and enhanced coping with pests and diseases could make them valuable tools for improving crop yields and reducing the environmental impact of agriculture. For organic farmers, biofertilisers align with their natural science understanding of enhancing soil and plant health by fostering the diversity and abundance of micro-organisms. As research and development continue, biofertilisers may play an increasing role in agricultural productivity.

4. Commercial OFBF production

The commercial production of OFBF is still in its early stages in Africa. It is impossible to determine the number of organic fertiliser producers due to a lack of reliable data, but key informant interviews and internet searches suggest that there are many small initiatives. It is thought that recycling organic waste to organic fertilisers such as compost or digestate are often pilot initiatives in countries (Kalina et al., 2022; Kaza et al., 2018; Sekabira et al., 2022; Yeo et al., 2020). It can be assumed that most production plants use locally sourced organic plant material as main substrate for the composting process.

The OFBF value chains in the 12 case study countries comprise varied organisational structures and actor groups (Table 1), from individual farmers involved in informal organic and/or biofertiliser production to farmer groups engaged in collective efforts often initiated by an external organisation (e.g. Cameroon and Uganda). These small-scale operations tend to be less mechanised and more reliant on manual labour, and typically produce between one and a maximum of 50 t/year of compost. Medium-sized operations produce quantities up to 3 000 t/year, while larger operations engage in industrial-scale production of compost, exceeding 3 000 t/year and reaching up to 100 000 t/year. The latter category employs mechanisation and standardisation of operations, while smaller units work with simple technologies. Several private companies operate at a regional level, frequently using source-separated agro-processing and market waste to produce organic fertilisers.

Furthermore, various municipal-level arrangements, including public-private partnerships, contribute to this landscape to valorise waste into organic fertilisers. Private companies also play a substantial role in regional organic fertiliser production, frequently making use of locally sourced organic materials. Public-private partnerships, for instance, can be found where a municipality provides faecal sludge to a private company that engages in co-composting the sludge with green waste (e.g. the business case from South Africa). In terms of finance, many cities lack sustainable long-term planning as well as affordable operational costs due to insufficient government involvement. Public-private partnerships have been challenging due to financial, institutional and political shortcomings.

Regarding biochar, some producers have found success by marketing a combination of biochar with composts and/or other amendments, as observed in Kenya. Some interviewees expressed scepticism regarding the exclusive marketing of biochar due to a lack of knowledge about its benefits for soil fertility among stakeholders and because it is not perceived as a valuable product from a nutrient perspective. Biochar production can potentially provide additional income for farmers, for example through carbon credits.

" Biochar is produced through the incentive of carbon credits mainly, there are now different programmes. Plant Village is one, it's USAID-sponsored. They set up carbon cubes, where farmers are trained on how to produce biochar. This is artisanal technology, Kon-Tiki. And they get through a standard which is accepted by voluntary markets. It's Biochar for Life who buys the credits and then trades it. Farmers get 70 USD per ton of biochar, which is about a week's work. They say they're looking both at using invasive species, but also at excess residues such as maize shanks, rice husk as feed stock for biochar production." (Researcher, International Institute of Tropical Agriculture (IITA), Kenya)

Across the 12 case study countries, 25 companies producing biofertilisers have been identified. In the realm of medium-sized private companies, the business owners often come from academia, as seen in Egypt. They use technical knowledge and expertise from their research activities to select and produce specific beneficial bacterial strains. Notably, a company in Malawi that produces rhizobia received technical support from an international research institute. There are also non-governmental organisations (NGOs) and civil society organisations promoting and supporting the local production of biofertilisers across the different countries.

" We started in 2014, we have seen more and more customers. We got repeated buyers because they've seen the benefit. The market is increasing. We were the first, we were the only ones in 2014. Now there are about two to three new companies joining into the business. So, there's acknowledgement of the technology and uptake. But we could produce much more. Currently, we are producing 30% to 50% of possible capacity." (Biofertiliser/rhizobia producer, Malawi)

Biofertilisers are frequently imported from India or Europe, or produced by public research institutes in partnership with private companies. For example, the French company Éléphant Vert manufactures biofertilisers and distributes its products through commercial subsidiaries and branches across the case study countries. Certain small initiatives engaged in compost production incorporate imported biofertiliser products into their compost preparations.

Table 1. Examples of organic and biofertiliser actors identified in the scoping study

Organisational form	Actor (groups)	Production size	Value-added products	Raw material source	Actors	Examples
Private (informal)	Single farmer	**<10 t/year**	Compost, biochar	From the own farm: animal dung, crop residues, (wild) plant collections (tithonia) **Extern:** fortified with inorganic fertiliser	**1**	Observation by an interviewee from Malawi
Private (informal), NGOs	Neighbourhood initiatives/farmer groups (village/ community level), NGOs	**<20 t/year**	Compost, insect frass	From the own farm and neighbourhood: animal dung, crop residues, (wild) plant collections (tithonia), market wastes **Extern:** fortified with inorganic fertiliser or rock phosphate	**3**	Initiative by NGO Self Help Africa producing insect frass from household and market wastes (Uganda)
						Initiative by Forum for Agricultural Advisory Services (CAMFAAS) and its local partner REA-Cameroun (Cameroon)
						PELUM's member organisations are establishing (bio)fertiliser units to educate farmers about crafting their own organic inputs (Uganda)
Public, public informal,[2] private-public partnerships	Municipality	**>500 t/year**	Compost	Agro-processing and market residues, human excreta, slaughterhouse waste	**3**	Co-composting of human and other organic waste. Cooperation between private and public entity (Ghana, South Africa); Ghana - Accra Compost & Recycling Plant (ACARP)
Private (formal)	Private company (district/regional)	**20–120 000 t/year**	Fortified) compost, biochar, liquid organic fertiliser	Agro-processing residues, market residues, rock phosphate, inorganic fertiliser, human excreta, slaughterhouse waste, plant residues/wild plant collection (tithonia)	**19**	Radi Organics, Family Green, Nang et Compagnie (Cameroon); Beni Suef (Egypt); Eco Green (Ethiopia); Jaasgrow Ltd. (Ghana); RegenOrganics, SafiOrganics (Kenya); Environmental Industries, Almena Organic Fertiliser, Green Finger Organic Fertiliser (Malawi); Éléphant Vert, Biotech Services Senegal (Senegal); Talborne Organics (South Africa); Glowish Agro Solutions, Rootzone Africa Ltd., Vermipro Ltd. (Uganda); ZimEarthworm Farms, Flight Serve Enterprises Ltd. (Zimbabwe)
Private (formal)	Private company (regional)	**<10 000 litre/year**	Biofertiliser	Various raw materials; imported biofertilisers mixed with organic materials; fermented plant juices	**5**	Radi Organics (Cameroon); Eco Index Agro Solutions Ltd. (Ghana); Biotech Services Senegal (Senegal); Lindros Whole Earth Consultancy (South Africa) Vermipro Ltd. (Uganda)
Private (formal)	Private company (national/ international)	**n.a.**	Biofertiliser (powder/ liquid)	Nationally sourced bacteria strains	**2**	Royal Green Biotech (Egypt)
				n.a.		Éléphant Vert (Senegal)
Public, private (formal)	Public research institutes, private company (national)	**15 - 30 t/year**	Biofertiliser (rhizobia)	National and international sources	**2**	Department of Research and Specialist Services (Zimbabwe); Agri Inputs Suppliers Limited (AISL) (Malawi)

Source: Key informant interviews

2] In the context of waste collection in Africa, the term "public informal" refers to waste collection services that are provided by individuals or groups who are not formally employed by the government or a private company. The term "public" in this context refers to the fact that these collectors are providing a service that is of benefit to the public, even though they are not formally employed by the government. The term "informal" refers to the fact that these collectors are not operating under the same regulations and standards as formal waste collection companies.

The financial sustainability of OFBF-producing enterprises remains fragile without financial or other support from either governments or private donors. Financial assistance for business development varies widely, with some enterprises receiving indirect subsidies from city authorities providing land and buildings, e.g. for compost production. Most interviewed OFBF producers anticipate financial benefits with increased production and growing demand, especially for the organic agriculture export sector and for high-value crops around cities. Challenges include the expenses associated with modernising and mechanising processing technology, the need to import specific equipment, high land rental costs, and for organic fertiliser production specifically, implementing waste collection and sorting.

" We are profitable largely due to the scale that we operate at with our largest costs being feed stock, the purchasing of organic materials and transporting it to our site. There isn't high quality enough equipment that matches what we need domestically, so we import it. The same for spare parts. And then you pay at least 30% import tax on a vehicle that's assembled outside of the country." (Organic fertiliser producer, Kenya)

Subsidies or tax incentives for OFBF producers are non-existent or limited, yet the modernisation and expansion of these enterprises rely on external financial support through incentives such as subsidies, contributions from international donors and/or access to credit and credit schemes with feasible interest rates. In general, key informants emphasised the considerable market potential for OFBF, provided that specific challenges are effectively addressed.

The African Organisation for Standardisation (ARSO) has developed an African Organic Fertiliser Standard in 2020 with the aim to harmonise standards across African member countries.[3] Fertiliser standards refer to a set of established guidelines, specifications or quality criteria that are developed and enforced by regulatory authorities or agricultural organisations to ensure the quality, safety and effectiveness of fertilisers used in agriculture. The Council of Ministers of the Economic Community of West African States (ECOWAS) adopted a regulatory framework in 2012 that laid down rules on the quality of fertilisers (including organic fertilisers) in member states (ECOWAS Commission, 2012). However, not all countries seem to have adopted or harmonised organic fertiliser standards yet. Among the 12 case study countries, eight have developed standards for organic fertilisers, including biofertilisers.

5. Farmers' demand for organic and biofertilisers and its application

Farmers' demand primarily centres around compost made from plant residues, sometimes including incorporated animal manure, as it is the most familiar option among farmers. Due to the relatively high prices of most composts, as well as challenges related to transport facilities and costs, application rates tend to be too low to cover all the nutrients' needs of the crops. Often, small amounts are combined with inorganic fertiliser applications to enhance their efficiency which is relevant from an agronomic point of view. Typically, compost application rates are far below 5 t/ha. It must be highlighted that organic agriculture for export is an important use of organic fertilisers.

" I think commercial examples that show financial viability exist (waste-based compost). Again, what is going to immediately drive the development is again higher value crops, horticulture. I don't even see avocados or coffee applying it because they have just such larger areas to apply. (...) In the current situation, I'm almost sure it will not be smallholders using it for staple crop production." (Biofertiliser/rhizobia producer, Malawi)

Since 2020, and in response to crises disrupting the global fertiliser market, the demand for alternatives to inorganic fertilisers like compost has been steadily increasing in most countries. For example, a noteworthy increase was reported in Kenya, with production doubling or even tripling in the last two to three years. In Uganda, a notable surge in demand was reported for bio-slurry from treatment plants, exceeding the supply. In Cameroon and South Africa, however, no increase in OFBF demand can be confirmed within this study.

" The market development has been very good over the last years. We are in pretty good shape at this point, and largely because of the brand that we have built. People trust us, respect us and have seen us for the last seven years talking directly with farmers." (Organic fertiliser producer, Kenya)

The evolution of the demand for OFBF depends on various factors. Some of them are the same for inorganic fertilisers (level of the ratio input price/output price, access to markets, etc.) to make profitable investments in agriculture. Others are specific to OFBF, such as (lack of) quality control, improved product descriptions, exclusion of contaminants, training, demonstration, advertisement strategies, and research to assess their impact on soil health and crop yield, as well as cost-benefit analyses. In countries or regions with low land tenure security or high land rental rates (e.g. Cameroon), long-term investments in soil health through organic fertilisers (or trees) can be inhibitive.

" The biggest challenge was to convince and educate farmers on the importance and usefulness of the product (fortified compost)." (Organic fertiliser producer, Kenya)

3] Currently, only the draft version ARS 1490:2018 is available online.

From a farmer's perspective, the value for money of organic fertilisers is important. High transport and distribution costs can result in a relatively high price in the absence of subsidies, while the effect on crop yield may be less obvious in the short term. Farmers show reluctance to adopt OFBF also due to their familiarity with inorganic fertilisers. Regarding organic fertilisers specifically, concerns persist about increased workload and the perceived lower short-term impact on crop yields primarily associated with compost, especially where farmers cultivate rented land. To build trust, companies often initially offer OFBF for free as part of their advertising campaigns and provide training and field demonstrations. Especially the latter has been reported to be key by many interviewed OFBF producers.

" Farmers need to see results, then they switch much easier to new practices. So, it needs demonstrations so that farmers are convinced about new practices or products." (Researcher, Heliopolis University, Egypt)

The value of compost or other organic matter amendments is often not well-understood or appreciated, as inorganic fertilisers have long been the central focus of educational activities such as extension services. Key barriers hindering the use of compost include limited transport access, lack of demonstration trials and research, crop-specific recommendations, insufficient advisory services and training, unequal quality of the compost in terms of nutrients, and delayed nutrient availability for crops resulting in a lower impact on crop yield in the short term.

The provision of subsidies for inorganic fertilisers is widespread in African countries, while this is an exception for organic fertilisers. In recent years, Ghana and Senegal have started to provide subsidies for organic fertilisers. In Ghana, the government procures as much as 80% of the compost production from certain companies, which is then distributed directly to farmers through their national subsidy programme. The Senegalese government initiated organic fertiliser subsidies in 2021, initially providing support for 3 000 tons. This allocation was later increased to 10 000 tons in 2022. The allocation of monetary resources to agricultural budgets for inorganic fertiliser subsidies varies significantly among countries and from year to year. For instance, in 2022, Rwanda allocated approximately 0.8 million USD[4] for fertiliser subsidies, while in 2021, Malawi dedicated a substantial 150 million USD towards this purpose (De Weerdt & Duchoslav, 2022).

Demand for compost derived from human excreta is limited due to social or cultural barriers, insufficient or unclear regulatory frameworks, as well as a lack of quality control and technical equipment to ensure a hygienic product. In contrast, due to the limitations of inorganic fertilisers, human excreta or sewage sludge are in high demand in some regions (e.g. Kampala, Uganda).

Liquid organic fertilisers (bio-slurry) are generally in less demand, with some exceptions such as Uganda, primarily because their transport is challenging and depends on the raw material base of the product. The impact on crop yield is a topic of debate due to significant differences in nutrient content. Bio-slurry is primarily used for arable crops.

Liquid organic fertilisers in the form of plant teas are offered with varying quality, and there are mixed opinions about their relevance for soil fertility and crop yield. Certain liquid fertilisers are applied to the soil, while others are directly sprayed onto the crops. Some crops, such as pineapple, are particularly well-suited for absorbing liquid fertilisers through their leaves. The demand is rising in cases where farmer groups apply them successfully, but in cases where farmers expected them to function as inorganic fertilisers with immediate and substantial impact on crop yields, they have been disappointed.

In general, the market for biofertilisers is growing worldwide. The need for more environmentally friendly technologies and the growth of the market for certified organic products are the main drivers (du Jardin, 2015). However, biofertilisers are not widely promoted by governments in Africa and while some advisory services specialise in them, the majority does not value these products, except for rhizobia, which are more widely recognised than other biofertilisers.

The demand for and use of mycorrhizal fungi are limited, with research stations being the main drivers of demand rather than farmers. In the case of rhizobia, demand is increasing, as it can significantly increase nitrogen fixation and grain yield (Kumar et al., 2022; Schütz et al., 2018), and thus serve as a valuable pre-crop for cereals. However, rhizobia do not perform well under acidic soil conditions, which can lead to declines in demand when farmers observe no benefits in terms of crop yield and are unaware of the soil's acidity, as reported by interviewees in Ethiopia. Moreover, the quality of rhizobia can sometimes be insufficient (e.g. due to inadequate storage or transport conditions).

Other micro-organism-based products, such as effective micro-organisms and bokashi, are primarily used by organic farmers (South Africa), although demand is not very high. Some farmers also produce these biofertilisers themselves. Farmer and advisory service knowledge about biofertiliser products in general is limited, which also hampers further demand.

6. Potential supply of organic matter and macronutrients

There is great potential for the (re)circulation of organic matter and its nutrients from household food and green waste, human excreta, wastewater, agro-processing waste and the contained organic matter and macro- and micronutrients to close urban-rural nutrient flows (Kaza et

4] Available at https://allafrica.com/stories/202211080076.html, accessed 14 March 2024.

al., 2018; Lenhart et al., 2022). At the same time, externalities such as greenhouse gas emissions, environmental pollution and human health burdens can be reduced (Friedrich & Trois, 2011; Rajoo et al., 2020; Tomita et al., 2020). For example, Drechsel et al. (2007) found a nitrogen depletion of 3 kg/capita/year in rural areas and a nitrogen accumulation in urban areas of about 4 kg/capita/year based on estimates for four West African cities. There is thus potential for African agricultural systems to cover part of their nutrient needs by restructuring the urban-rural nutrient cycle toward agriculture (cf. Meinzinger et al., 2009; Obsa et al., 2022; Perez-Mercado et al., 2022).

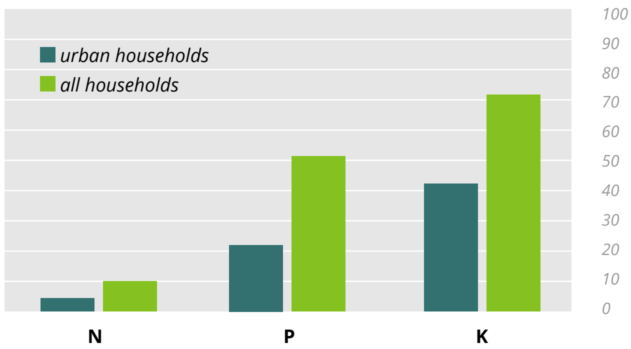
However, there are limited data available on volumes of agricultural by-products or waste in Africa that could potentially be used for organic fertiliser production. For Ethiopia, a study by the Food and Agriculture Organization of the United Nations (FAO) (2018) estimated unused agro-industrial by-products at about 1 million t/year (dry matter). Assuming a nutrient content range of 1% to 2% (Green, 2015; Musa et al., 2020; Roy et al., 2021), this translates to an estimated 10 000 to 20 000 tons of NPK. This nutrient reserve could potentially support cultivation across approximately 200 000 to 400 000 hectares with a demand of 50 kg N per hectare, covering 1% to 2% of Ethiopia's cropland requirements. The compost produced from urban household food and green waste across the 12 case study countries could theoretically supply about 31 000 t N/year, 31 000 t P/year and 84 000 t K/year. Recycling all (urban and rural) household food and green waste into compost can supply 71 000 t N/year, 71 000 t P/year and 141 000 t K/year in theory.

Figure 1 converts these volumes into the potential of household waste-based compost to meet the nutrient demands of maize (based on the cultivated areas in 2021) in the 12 case study countries.[5]

"And basically, what we're working with is an assumption that in most contexts, if you were really restructuring the system, you could meet between 20% and 40% of the nutrient requirements of an agricultural system within a specific boundary. In most cases I'm comfortable saying that somewhere around a quarter of the nutrient needs could be met through recycled nutrients. And that's only the plant nutrients. So that doesn't speak at all to carbon, which we know that chemical fertilisers don't provide carbon back to soils, which is fundamental." (Researcher, ETH Zurich)

Another untapped source of nutrients – human excreta – contains significant amounts of nutrients which could contribute to about 28% of the world's current NPK consumption in agriculture (Otoo & Drechsel, 2018) or 22% of global phosphorus demand (Mihelcic et al., 2011).

Figure 1. Potential nutrient supply of compost based on household waste in Africa (authors' calculations)



Potential nutrient supply of compost based on household food and green waste, in % of nutrient demand of cultivated maize in 2021

The theoretical nutrient potential present in human excreta across the 12 case study countries sums up to approximately 3.4 million t/year of NPK. In comparison, the total fertiliser imports amounted to 2.8 million t/year of NPK, while the overall agricultural consumption reached 4.4 million tons of inorganic fertilisers (NPK) within the same 12 countries in 2019.[6] In theory, the combined human excreta produced accounts for approximately 77% of the current NPK nutrients consumed in agriculture in the 12 case study countries. However, it is important to note that the current application of inorganic fertilisers is generally low, except in Egypt and specific regions or farms in South Africa and Zimbabwe.

Various interviewees highlighted the potential of using various sources of waste for organic fertilisers.

"(...) there's lots of the faecal sludge. And in the countries where we work, 95% of all the faecal sludge comes from on-site sanitation systems, it's not in sewage systems. We don't speak about sewage sludge, for which we also have business models, but that's more for landscaping. There's always a risk of heavy metals. So, we speak about on-site sanitation, about septic tanks and the septic is rather clean. It has microbial risks, but we can eliminate those. And co-composting nitrogen-rich faecal sludge with carbon-rich municipal organic waste can produce quite a good product." (Research co-ordinator, International Water Management Institute (IWMI))

Recycling human excreta presents a promising way to address sanitation issues and agricultural demand for both organic matter and nutrients and is hence also well aligned with the circular economy approach. However, it requires careful planning, community engagement, appropriate technology and strong regulatory frameworks to ensure that the benefits are maximised while minimising potential risks. More concise quantifications as well as estimations of the nutrient content of these waste sources are needed at both national and regional levels, to offer more precise information on potential nutrient and organic matter recovery.

5] Own calculation; population data for 2021 from the World Bank; household food and green waste data from Kaza et al. (2018), who indicate the food and green waste fraction as 43% of total waste generated per capita; total maize yield across 12 African countries (yield data from FAOSTAT for 2021); low anticipated average nutrient contents in compost N (0.5%), P (0.5%), K (1%) (e.g. Kabasiita et al. (2022)); average anticipated uptake rates of maize for N (13 kg/t), P (2.5 kg/t), K (3.6 kg/t) (Setiyono et al., 2010).

6] Own calculation; population data from the World Bank; data on human waste from Rose et al. (2015); human faeces calculated with (kg/capita/year; median): 13.9 DM; N = 0.7; P = 0.2; K = 0.3; human urine calculated with (kg/capita/year; median): N = 4.0; P = 0.3; K = 0.7; data from FAOSTAT on total agricultural use and total imports of chemical fertilisers (amount nutrient: N, P2O5, K2O) in 2019 in the 12 African countries.

7. Waste management and recycling policies, laws and regulations

In many countries, organic waste recycling lacks policy prioritisation, often with non-existent policies, inadequate enforcement or unfavourable incentives. Currently, only a small fraction of organic waste is being processed into organic fertilisers across the 12 case study countries. South Africa may be an exception, as the country formulated a National Organic Waste Composting Strategy in 2013, with some communities currently diverting up to 50% of organic waste from landfills (DEFF, 2020).

Household and garden residues are an important waste fraction, but their recycling is hampered by the prevalent mixing with various non-organic waste materials, as source separation is mostly absent. Proper organic waste collection is currently an exception, and the quantities collected and utilised for organic fertiliser production remain minimal. Market waste sometimes faces competition as animal feed. Human excreta collection is limited and ensuring hygienic processing can be a challenge. Agricultural by-products, particularly residues from processing, are sometimes recycled and reused within large export-oriented farms.

Generally, non-source segregated organic waste composts tend to have nutrient contents below 1% for nitrogen (N), phosphorus (P) and potassium (K) (e.g. Kabasiita et al., 2022; Roy et al., 2021; Sultana et al., 2021), and are thus considered soil amendments (EU, 2019). Higher nutrient values are typically achieved through waste sorting and treatment with a biodigester (Möller & Müller, 2012), black soldier flies (frass fertiliser) (Beesigamukama et al., 2022) or worms (vermicompost) (Mupambwa & Mnkeni, 2018), or when household or agricultural waste is co-composted with human excreta (Castro-Herrera et al., 2022). In some cases, composts are enhanced with chicken manure or inorganic fertiliser to increase nutrient concentrations. The final nutrient contents depend on multiple factors.

To overcome the various obstacles, waste management must be institutionalised through appropriate policies, laws and regulatory frameworks to facilitate the recycling of nutrients and organic fertiliser production from organic waste. The majority of African countries lack specific laws on waste management; instead, they have general environmental laws with subsections that address waste management, such as health policy, environmental policy, etc. (Shi et al., 2021). Policies in most countries do not prioritise organic waste recycling, do not even exist, the enforcement is lacking, or incentives are not favourable for recycling (Kaza et al., 2018; Lenhart et al., 2022, p. 63; Shi et al., 2021). However, some countries have formulated a national organic waste composting strategy, such as South Africa in 2013, with some communities in South Africa already diverting up to 50% of organic waste from landfills (Chitaka & Schenck, 2023). Furthermore, various countries in Africa have recently started to establish agendas with regard to fostering increased organic waste recycling towards organic fertiliser production and use. For example, in 2022, Kenya has passed the Sustainable Waste Management Act (Republic of Kenya, 2022); Rwanda the Integrated Solid Waste Management Strategy; Ghana established organic fertiliser guidelines and a national technical team on organic fertiliser promotion; Senegal started organic fertiliser subsidies. All 12 case study countries have established strategies, policies or legal frameworks to tackle waste management, with nine including references to recycling and organic fertiliser production.

8. Challenges, opportunities and recommendations for scaling the organic and biofertilisers sector

OFBF have the potential to significantly enhance soil health and crop yields, while also reducing environmental pollution and human health risks. Additionally, they can create employment opportunities and generate additional income. Based on insights from the scoping study, we propose recommendations for developing OFBF value chains to fully harness their potential in Africa.

Promote holistic approaches to soil health

Optimising soil health at the farm level is essential for developing OFBF value chains and enhancing entire farming systems. This requires an integrated soil health strategy that includes all fertiliser types and involves adapting farming systems and agronomic practices with soil health as the central focus. Agroecological approaches can play a key role in achieving this holistic strategy.

Develop OFBF research and curricula in Africa

Many key informants emphasised the lack of awareness, education and training for farmers, agricultural extension services and agrodealers regarding the benefits, proper handling and application of OFBF. The prevailing lack of knowledge and awareness surrounding OFBF aligns with the predominant emphasis on inorganic fertilisers among agricultural advisory services in most countries but also the fragmented discourse in science. Effectively combining inorganic, organic and biological fertilisers for optimal results requires specific skills and knowledge, which are frequently lacking and not offered via advisory services. It involves integrating scientific and local knowledge, experimentation and field demonstrations.

Most existing research on OFBF (including its funding) originates from outside Africa. Africa-based research on OFBF and soil amendments, including biochar and liming, is crucial for building the necessary evidence base on product efficacy and for developing robust standards for OFBF products. However, African research institutes face challenges such as lack of funding and equipment, particularly for laboratory analysis of soils and OFBF products. Some research trials are organised by medium-sized companies in Africa but their resources and equipment are also constrained.

Education is a key challenge with a need to renew the curricula for students and technicians to address soil health more holistically. African universities lack courses introducing students to agroecology and OFBF in their educational programmes. However, recent developments at some African universities offering curricula on agroecology are encouraging.

Support financial viability and access to private and public finance for OFBF producers

Successful OFBF businesses rely on a multi-stakeholder approach to value chain development. The production costs of off-farm produced organic fertilisers are typically high, or labour intensive for less mechanised operations. Further challenges are the need for suitable technology for collecting, processing, storing and applying organic fertilisers. In the case of biofertilisers, common challenges are limited access to technology and equipment, as well as limited capacity to select, multiply and produce more advanced biofertiliser products such as arbuscular mycorrhizal fungi, rhizobia and specific bacteria strains such as P-solubilisers. Investments across the value chain are necessary, including technological advancements in processing, waste collection, segregation and efficient product distribution systems.

Access to finance is crucial for improving production. Some companies benefit from financial support of international donors and research initiatives to purchase equipment. Accessing credit through financial service providers, however, is hampered by conditions (interest rates, collateral requirements). Public-private arrangements, such as blended finance, can provide solutions to facilitate access to finance for OFBF producers.

Encouraging private-sector financing, characterised by accessible capital and fair subsidies relative to inorganic fertilisers, can play a pivotal role in fostering the sustainable growth of OFBF. Subsidies and tax incentives aimed at fostering technology adoption or lowering energy costs should be extended to OFBF producers. Increasing the availability of state-subsidised organic fertilisers to farmers is also recommended.

Improve urban waste management systems

There is great potential for the recycling of organic matter and its nutrients from organic waste such as household, food and green waste, human excreta, wastewater, slaughterhouse residues, agro-processing waste to close the rural-urban nutrient flows. The entire urban waste management system needs to be (re)designed with biowaste in mind to optimise the recycling of (urban) household food and green waste and human excreta for fertiliser production.

Inappropriate handling of (organic) waste results in externalities such as greenhouse gas emissions from landfills, water pollution and human health burdens. Internalising these costs ("polluter pays principle"), or using payments for ecosystem services (e.g. carbon credits), makes organic fertiliser production using organic waste financially more attractive.

Design and implement policies, regulations and certification for an OFBF-enabling environment

While some countries have taken positive steps to promote organic fertilisers (e.g. Ghana and Senegal), there is a collective need for clearer policies and streamlined regulatory processes to unlock the full potential of OFBF in agriculture. In almost all of the case study countries, waste management regulations exist but enforcement is often lacking. The countries face the shared challenge of developing and implementing comprehensive policies, regulations and certification processes for OFBF. These challenges encompass issues such as the lack of clarity and inconsistency in policies, inadequate standardisation, complex and bureaucratic registration procedures, and financial resource competition for subsidies and support with inorganic fertilisers. In particular the use of human excreta as organic fertilisers is impeded by ambiguous definitions and unclear regulations. Consequently, a grey area emerges, which exporting companies of agricultural products in particular aim to sidestep to prevent conflicts with certification schemes such as Global GAP.

Ensuring product quality is crucial, given the presence of manipulated products in the market. Verified products with a constant quality and reliability are needed to gain farmers' trust and hence foster market growth. Government support and respective enabling policies have shown to be key enablers for biofertilisers in selected developed and Asian countries (Masso et al., 2015). Harmonised standards across countries are necessary to foster trade and create a favourable business environment. Countries should develop national waste management strategies focusing on reduction, reuse and recycling (Triple R). To ensure the development of clean cities while recycling materials, it is crucial for solid waste management initiatives to be legally supported, contextually relevant and co-designed with the participation of citizens and firms. Entrepreneurs can manage the waste treatment process, but policies must drive waste segregation campaigns, raise awareness, encourage public participation and put in place efficient funding mechanisms (subsidies for firms and taxes for citizens and pollutant firms). Effective policy implementation at city level requires educating urban residents about the policies and fostering participatory strategies. Given the rapid changes in urban areas, regular studies on solid waste collection practices and the involvement of stakeholders in informal settlements are necessary to avoid a one-size-fits-all approach to policies and ensure their relevance and suitability.

Subsidies and incentives across the OFBF value chain, including tax reductions for technologies, can stimulate technology investment, enhance production and facilitate market development, thereby supporting sustainable land use and food production strategies. Policy efforts should back private-sector initiatives with sustainable financing for off-farm OFBF production, facilitate access to finance, align with agroecology, land reform and land tenure policies, thus encouraging long-term farmer investments, and establish mechanisms to regulate the market.

Being aware of the challenges faced by smallholder farmers, such as low inorganic fertiliser application rates, limited labour and financial resources, and high land degradation, underscores the importance of comprehensive farm-specific support activities for the successful implementation of OFBF. These activities may include subsidies for commercial OFBF, ensuring accessibility, establishing acceptable pricing for certified products, deploying appropriate technology for application, disseminating knowledge about usage and expected impacts, addressing land tenure regulations and exploring options for integrating OFBF with other fertilisers.

To unlock the potential of OFBF, a comprehensive policy framework must be established, addressing environmental, urban, rural and agronomic contexts. This framework should cover waste collection and processing, as well as OFBF marketing, distribution, quality standards, certifications and on-farm application. Co-ordination across Africa, alignment with international standards and adherence to continental, regional and national policies (such as CAADP, Ecological Organic Agriculture Initiative, or the new Soil Initiative for Africa) are crucial. Robust monitoring and control systems are paramount to ensure compliance, avoid contamination and maintain continuous product quality, instilling customer confidence. Cross-sector collaboration is essential, aligning sanitation, waste management and agriculture policies to establish a circular economy.

Short country reports

Cameroon

Production and technology: A small number of farmers produce their own organic fertilisers by recycling household and local organic waste. An established formal management system for organic fertilisers produced on farms does not exist. Many farmers rely on external sources like chicken manure. Limited quantities of OFBF are produced at the community level. Some small-scale producers have registered companies and developed innovative products, such as biofertilisers that are claimed to stimulate plant growth by enhancing nutrient uptake, like fermented crop residues, tithonia-based formulas and plant mixes including neem tree. Several products are at the market such as Super Limax (a combination of manure and a biofertiliser), Winox (a foliar liquid biofertiliser or biostimulant) and Garden Fresh (a product-based plant growth hormone). The majority of municipalities in Cameroon hesitate to invest in waste management due to perceived high costs, despite the negative impact of poor waste disposal in open areas. Many Cameroonian cities have public-private partnerships with waste management companies like HYSACAM, which often prioritise waste collection and landfill disposal, lacking incentives for waste reuse. Compliance with ISO regulations related to quality processes is impeded by intricate and costly procedures, discouraging the production of OFBF. Meeting ISO quality standards and navigating ANOR (National Standards Authority) procedures present significant challenges. There are also potential health risks and the risk of contaminants like heavy metals.

Economy and markets: A well-established market for OFBF is lacking but therefore competition is also low, presenting opportunities for producers. Pricing of organic composts remains volatile and competitively priced compared to chemical fertilisers. Limited equipment and capital pose significant barriers to enter into commercial OFBF production. External donor support can aid in OFBF development. Remote and isolated areas face logistical hurdles in fertiliser delivery. Remote tracking through digital platforms helps bridge geographical gaps. Some urban areas, such as Yaoundé, have already started adopting alternative waste management strategies, including composting via a public-private partnership. Young start-ups face difficulties securing essential documents, like organic certification, due to lack of support and high associated costs. The Cameroon Forum for Agricultural Advisory Services (CAMFAAS) and its local partner, REA-Cameroun, have introduced an innovative “tontine” system (community composting scheme) tailored to the needs of farmers.

Research, education and dissemination: Despite the presence of Central Africa’s main agricultural faculty in Dschang, conventional farming methods tend to dominate, with minimal emphasis on organic agriculture or agroecology. The International Institute of Tropical

Agriculture (IITA) provides support on the dissemination of knowledge related to OFBF; further support exists via the national laboratory of the Ministry of Agriculture (MINADER), the NGO Procasud on the Joy project (Job Open to the Youth) or support via United Nations programmes. Companies often conduct their own field trials and employ door-to-door demonstrations, direct consumer engagement and collaborations with distributors. Financial support for research is necessary. Advisory services must bolster their capabilities on organic fertilisers. The educational system should incorporate organic farming. Collaboration with organisations like GIZ or Youth Professional for Agricultural Development Network, can yield significant benefits for sustainable agricultural solutions. The rise of interest in organic production and potential export opportunities could gradually increase trust and also demand for OFBF.

Policies: Stricter regulations regarding landfills and waste dumps are essential. Municipal contracts with waste service providers should be modified and updated to align with new waste management practices. The new Law on decentralisation empowers local councils to adopt their waste management. Companies should receive support, including waivers and access to public land for their activities. Strategies should be developed to address the issue of fertiliser smuggling. Policies should actively promote the use of organic fertilisers in large-scale farms and government-owned plantations. Fertiliser subsidies should extend to organic fertilisers. Taxation can be leveraged to influence on-ground activities. Organic fertiliser production should be linked with carbon credits. Addressing land tenure issues is crucial to encourage farmers to invest in organic fertiliser production and use. International policies should complement national efforts in promoting organic fertiliser use. National policies and regulations need to be revised and harmonised to facilitate the certification processes of OFBF.

Côte d'Ivoire

Production and technology: Farmers who raise livestock at home typically have small herds, resulting in limited compost production. Instead, they commonly rely on poultry manure or droppings. These farmers, whether engaged in cocoa cultivation or market gardening, are well-versed in handling manure and slurry. However, it is important to note that they primarily use raw manure rather than composted manure. The potential for compost production using agro-processing waste, municipal waste and sawdust from sawmills is generally considered to be very high. In Côte d'Ivoire, there are three main companies engaged in organic fertiliser production: Éléphant Vert (formerly Biofertil), Lonoci and Green Countries. Some agro-industrial companies may also operate small-scale compost production units. A project, funded by a Swiss palm oil producer, collects palm oil and coconut residues, converting them into compost for use in plantations. Prominent farmers or agricultural companies, employing organic practices, such as Compagnie Frutière (SCB) with sustainable and organic cocoa or cotton, utilise organic fertilisers. Some investors in this sector produce compost from agro-industrial waste, successfully sustaining their operations. Biochar derived from coconut husks is a potential option, possibly with additional inputs like urine for nutrient enrichment. Companies such as Lonoci test small biogas container units of approximately 2-3 m^3. Some market gardening companies employ a blend of droppings and inorganic fertilisers, such as urea, for their operations. Composting municipal solid waste is considered more challenging due to the need to collect unsorted waste from households. Decentralised composting of organic waste could support the growth of organic farming. Many manufacturers are committed to sustainable/organic cocoa, leading to reduced use of inorganic fertilisers and increased utilisation of organic alternatives.

Research, education and dissemination: Research on organic fertilisers from organic waste remains relatively limited. Funding opportunities for research are available through government institutes and other mechanisms. One ongoing study is examining the impact of applying 10 t/ha of compost in comparison to inorganic fertiliser. Previously, there were lectures on municipal solid waste management at the University of Abidjan, but these have now concluded. Some educational sessions have been conducted in schools to promote plastic sorting, but overall, such activities remain quite limited. In general, there is a notable lack of knowledge and regulations related to fertiliser use. Farmers need training on compost management. Farmers with access to agents from ANADER (a national rural development organisation that provides training to farmers) receive guidance, although their knowledge tends to be limited, and they often apply mineral fertilisers without fully understanding the details. Environmental concerns related to mineral fertilisers are generally not a top priority for them. Composting, and even the utilisation of compost, remains relatively rare.

Economy and market: The initial setup of composting units requires substantial investment and government or municipal assistance can facilitate the successful launch of such initiatives. Presently, there is a higher demand for compost than the production capacity can meet. Therefore, compost production is regarded as a profitable sector. Organic fertiliser production is approximately five times more costly than inorganic fertiliser. One potential solution could involve farmers contributing a portion of the raw material as a form of payment. As of now, only export-oriented or organic producers can manage the expense of compost. High transport costs, poor road conditions and considerable distances between raw material sources, processing facilities and farms pose significant challenges, both in terms of time and expenses. Managing plastic waste is another substantial issue in the process.

Policies: There is limited policy focus on OFBF and discussing environmental matters can be challenging. Regulatory measures should be put in place to govern the application of various OFBF products. The expanding field of organic farming can contribute significantly to the development of the OFBF sector. This trend aligns with the increasing consumer concern about food quality. The Ivorian government has set ambitious goals, such as reducing greenhouse gas emissions by 30% by 2030, as part of its National Determined Contributions (NDCs). To achieve these objectives, there is an opportunity for the government to provide financial support for the implementation of OFBF, possibly through mechanisms like CO_2 certificates and regulatory frameworks. Standardisation of all types of compost is essential and pricing should be based on OFBF quality.

Egypt

Production and technology: Given the significant proportion of agricultural land facing challenges like low carbon content, salinisation and desertification, Egypt presents a unique scenario. There is substantial potential for organic waste recycling into organic fertilisers across small, medium and even industrial enterprises.

A United Nations Industrial Development Organization (UNIDO) project actively supports SMEs engaged in green businesses. There are approximately 20 recognised companies involved in the production of compost and other organic fertiliser (Hoffmann et al., 2020) products in Egypt (e.g. SEKEM, Agriculture Research Centre (ARC), Miegos and Beni Suef). The largest compost producer in Egypt, namely Beni Suef, primarily supplies its compost to both large-scale organic and conventional farms. The primary constituents for organic fertiliser (Hoffmann et al., 2020) production are sourced from agricultural by-products (such as residues from rice and wheat cultivation, banana production, sugar cane and biogas digestates), alongside animal manure. Cairo employs two distinct waste collection systems, with one established by the municipality and the other being informal in nature. Regarding compost quality, heavy metals are usually not a concern unless sewage sludge is incorporated. Biochar production is at the very beginning. In the case of biochar production, potential issues may arise with toxic substances.[7] Ongoing initiatives are working towards establishing standards that govern production facilities, aiming to address and mitigate such concerns.

The biofertiliser sector is represented by an estimated 40 companies, although this segment functions more within an informal market structure (SEKEM, Chietosan, Royal Green Biotech, National Research Centre (NRC), ARC). Of particular interest are micro-organism-based products, harnessing naturally occurring microbes discovered in local fields (Royal Green Biotech).

Research, education and dissemination: Research on off-farm production of OFBF exists, but it is primarily focused on finding practical solutions for farmers rather than publication. There are some reference laboratories available for soil testing. Many farmers remain unaware of suitable products for their crops and their respective growth stages. Quality encompasses not only nutrient composition but also biological aspects. Although an official extension service exists, its effectiveness is limited. A significant number of products currently available in the market lack official recognition from the government. Consequently, the sale of compost, for instance, has led to the inadvertent spread of nematodes and fungal diseases to farmers' fields.

Economy and market: The market for commercial organic fertilisers primarily offers compost, with vermicompost and insect frass fertiliser being available to a lesser extent. Despite the rise in inorganic fertiliser prices, most interviewees do not report a significant increase in the adoption of organic fertilisers by farmers. The transport of compost can pose challenges due to the need to move large quantities, resulting in additional expenses. Despite this, OFBF proves to be notably cost-effective compared to inorganic fertilisers. Certain products are also exported to countries like Bahrain, Morocco, Saudi Arabia, Sudan and Tunisia. The current primary economic challenges include the fluctuating conversion rates between the Egyptian pound and currencies like the Euro. Expanding operations or acquiring another company has become much more costly compared to a decade ago. Subsidies for technologies should extend to OFBF similar to those for inorganic fertilisers. Integrating OFBF into official research agendas, both within the ministry and universities, is essential.

Policies: A comprehensive governmental initiative is crucial to address quality control, regulations and standards, registration guidelines, necessary laboratory equipment and accredited labs, market regulations and product standards.

Ethiopia

Production and technology: Smallholder farmers apply low rates of inorganic fertilisers and recommendations mainly focus on maize farming. Farmers depend on cow dung for cooking fuel, leading to minimal use of manure as organic fertilisers. The Ministry of Agriculture, in partnership with the Ethiopian Agricultural Transformation Agency, has created a soil fertility map. This map identifies soil deficits in various kebeles (lower administrative units). The inadequate nutrient content in agricultural soils, coupled with the scarcity of nutrient-rich forage and limited access to forage legume seeds, undermines the quality and quantity of farm organic manures. The Urban NAMA COMPOST project in Ethiopia aims to encourage the use of integrated solid waste management and urban green infrastructure strategies in cities and towns. The absence of organic waste separation presents a challenge. The emergence of SMEs producing compost from high-quality market waste is a niche that will likely persist and grow, but generally this contribution remains relatively small. The Ministry of Agriculture is advocating for small-scale composting (vermicomposting). In specific regions, a type of liquid organic fertiliser (Eco Green)

7] For example, toxic substances like polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs).

made from legumes and other residues is accessible. Yet, its nutrient content is minimal, preventing its classification as a fertiliser. Biochar production occurs sporadically at the farm level, but production has faced challenges throughout the entire production chain due to technical issues.

Research, education and dissemination: Research by ETH Zurich in co-operation with Arba Minch University develops waste separation systems using compost technology and transport trucks. NABU Germany is engaged in harvesting water hyacinths from Lake Tana, testing processing towards biogas (slurry), compost or biochar. A significant challenge revolves around the insufficient financial resources allocated to technology and laboratories needed for quality control. Awareness and acceptance of household waste recycling are notably insufficient. Advisory services offering assistance with compost application are severely constrained. Additionally, university-level curricula addressing organic waste management are lacking. The practice of agricultural extension workers educating smallholder farmers about composting and compost preparation using crop residue and animal dung is more of an exception than a standard practice.

Economy and market: In the current market, a liquid organic fertiliser and a handful of rhizobia products (e.g. Bahar Dar University) were identified, although their availability is confined to specific regions and their efficacy is often reported to be low. Various strategies for distribution and advertising are employed, but the presence of black markets is notable. The main obstacles to broader distribution of organic fertilisers are the substantial costs related to investment, transport and household waste separation. The absence of incentives for waste separation at the household level poses a significant hurdle. There is a growing number of companies engaged in composting and selling compost at competitive prices, ranging between USD 150 to USD 300 per ton. A project is exploring the possibility of generating additional income for farmers through carbon finance using CO2 certificates. A large avocado-oil producing farm in Jimma recently signed a contract to export compost to Saudi Arabia. A large international chemical company with its Ethiopian sub-branch is contemplating entering the compost market through waste collection initiatives in East Africa.

Policies: The government is increasingly considering the inclusion of OFBF on their agenda as a potential solution to mitigate the mineral fertiliser crisis. Composting is now integrated into development plans. It was seen as crucial to establish a comprehensive policy framework for OFBF that encompasses organic farming practices. This framework should encompass regulations, quality control measures, certification processes, research initiatives and subsidies across the entire organic waste value chain, spanning from households to farmers. The development of concepts and strategies should occur at multiple levels, including households, Kebele, District, Zonal and Regional geographical units. Integrating carbon credit approaches and greenhouse gas emission calculations into the strategy is essential. Notably, the national biogas programme is taking strides towards large-scale production plants (100 to 300 m^3). Waste segregation at household level is foreseen by Ethiopian Solid Waste Management proclamation in Article 11.1, however, there are no measures in place for the proper enforcement.

Ghana

Production and technology: Several companies produce organic fertilisers, but the overall production remains limited. Biofertiliser production is limited. Some initiatives use diverse husks, crop residues and market waste for biochar production. Safisana, established in the Netherlands, deals with faecal and organic waste (industries and markets), undergoing anaerobic biogas digestion, producing electricity. Accra Compost and Recycling Plant, established in 2012, collaborates with Ghana's municipalities and focuses on waste utilisation and value addition, offering granular and liquid forms of organic fertilisers. Cocoa farmers use pods for compost making. Wood vinegar has been successfully used in cocoa nurseries and other crops. Government initiatives promoting household kitchen gardens for food self-sufficiency and ecological organic agriculture contribute to a rising OFBF demand. In addition, the Ghanaian government is expanding its waste collection model across various cities creating opportunities for recycling organic waste.

Research, education and dissemination: OFBF producers collaborate with the University of Cape Coast, School of Agriculture, and established robust relationships with the Ministry of Food and Agriculture and key industry stakeholders. The International Water Management Institute (IWMI) has been actively involved in research on waste recycling. Collaborations with local SMEs have been productive, involving women managing market and food stalls, operators of public toilets, truck drivers transporting faecal sludge and farmers purchasing fertilisers. The production centres are concentrated in urban areas which creates accessibility challenges for rural farmers. Farmers who do not own land face difficulties in appreciating OFBF because they often rely on one-year leases and lease renewals are uncertain.

Accra Compost and Recycling Plant has forged a partnership with the government through the Planting for Food and Jobs Fertiliser Subsidy Programme, involving the supply of organic fertilisers. The government procures up to 80% of compost production from Accra Compost and Recycling Plant through its national programme. The remaining compost is sold through retail outlets, catering to farmers outside the government scheme. Farmer organisations also play a crucial role in product distribution. A distributor scheme for OFBF has been devised and should be extended to initiate broader media advertising, inclusive radio, direct farmer outreach, online platforms and social media. Guidelines for OFBF production are available (since 2022) and training and extension programmes are underway. Special programmes teach farmers how to transform household waste into compost, but awareness is still low. Many companies provide educational newsletters. Agronomists provide education alongside visual testimonies through demonstration greenhouses and plots, and participatory guarantee systems with additional information are established, primarily supported by importers of OFBF. Stakeholder engagement within the Ecological Organic Agriculture platform of Ghana involves scientists, organic producers and importers of OFBF to agree on acceptable practices. A guideline resulting from this stakeholder engagement has been disseminated for practical application.

Economy and market: There is a fertiliser subsidy initiative, the "Planting for food and jobs" programme. Subsidy programmes have incorporated organic fertilisers and liquid organic variants. Some OFBF producers have future plans for expanding to other African countries and beyond, with a focus on becoming leading producers of liquid organic fertilisers. Ghana heavily relies on importing organic fertiliser products for example from Europe (specifically for certified organic production for export). Organic raw materials are available and companies intend to expand their production. Competition is expected to increase over time as demand grows. Many companies rely on donors for financing. The support of organisations like the Africa Development Bank, the Dutch embassy and investments from entities like Grand Challenge Canada, the Stone Family Foundation and the Bill and Melinda Gates Foundation has been pivotal in establishing OFBF production.

Policies: Guidelines have been established for organic fertilisers in 2022. Enforcement of guidelines needs to be ensured. Guidelines are also needed for biofertilisers. Quality control and guidelines are needed for imported OFBF products. Policies should support stakeholder platforms and OFBF research, aiming at self-sufficiency in fertiliser production, encompassing both inorganic and organic fertilisers.

Kenya

Production and technology: Livestock densities, and consequently organic fertiliser usage, are typically low in smallholder settings. The efficacy of off-farm produced organic fertilisers is constrained by their low nutrient concentrations. Numerous Kenyan enterprises, e.g. Dudutech, are actively involved in large-scale compost production utilising greenhouse and other residues. Debates have emerged concerning the potential allocation of permits to extract waste from landfills for purposes of incineration and power generation. However, local communities resist this notion due to the importance of landfills for scavengers who rely on them for their livelihoods. Organic waste harbours significant energy potential, especially in the gasification process, which should be harnessed. In some cases, human excreta and faecal sludge sitting in pits is already used for biogas production. Stringent enforcement of segregated urban waste collection is essential. Implementing effective sorting protocols for organic waste can reduce the time spent removing plastics and other debris. Some initiatives produce biochar from human excreta. Numerous programmes are now incentivising biochar production through carbon credits. A notable example is Plant Village, backed by the United States Agency for International Development (USAID). Others produce organic fertilisers via black soldier fly. Several rhizobia strains are offered, but certain strains have been found to lack efficiency. Mycorrhiza is offered at the market, but around 90% are counterfeit. Trichoderma and other biocontrol products, and also rock weathering products, can be found.

Research, education and dissemination: One of the significant challenges encountered by organic and biofertiliser companies is persuading and educating farmers about the significance and benefits of organic fertilisers. Presently, advisory services have limited awareness about alternative fertilisation approaches. Education through farmer field days, inviting other farmers and conducting demonstration trials are considered crucial for implementing OFBF. While various extension activities are organised, they are still quite limited in scope. Knowledge about OFBF use and integrating it into rotational systems is crucial. In-situ biomass production is vital. Advisory services should promote OFBF and communities should be empowered to produce OFBF and energy through training programmes, all while adopting a gender-responsive approach to ensure fair participation and benefits. Some companies are active in the production of organic fertilisers, such as RegenOrganics, and pursue collaborations with institutions like Cornell University, MIT and Nairobi University. These collaborations have played a pivotal role in the research and development phase of their products. These partnerships bring valuable knowledge and advanced technologies to their endeavours. A collaboration with Cranfield University, funded by Pilot House, is dedicated to the development of an organo-inorganic fertiliser and more concise recommendations for fertiliser application rates. More demo plots (including more funding) and better knowledge on more exact application rates for the different locations and crops are necessary.

Economy and market: The Kenyan market is plagued by a notable presence of counterfeit biofertilisers, resulting in financial losses for consumers. The domestic market faces a shortage of high-quality equipment (including its spare parts) that meets specific requirements, leading to the need for imports to achieve optimal functionality. Vehicles assembled outside the country are subject to a minimum import tax of 30%. In certain cases, foreign organisations cover investment costs. While efforts sponsored by cities and improved financing terms have proven beneficial, companies still heavily rely on their own resources.

Observing the expenses at each stage of the production process, which includes waste collection, sorting and lack of tipping fees, is essential. The primary costs are associated with feedstock procurement, purchasing organic materials, sorting costs, the import of machinery and transport to processing sites or demo trials. Production costs per unit are higher compared to many European countries.

Policies: There is a deficiency of supportive measures that could expedite the development of OFBF. Policies should be put in place to encourage the production and use of OFBF, including enhancing and optimising the regulatory framework, introducing tax incentives or waivers for companies engaged in processing and treating urban waste to produce biochar and OFBF, offering assistance in locating suitable land for processing organic biomass in strategic locations, subsidising the mechanisation tools employed, such as windrow turners, and implementing subsidy programmes similar to those that subsidise inorganic fertilisers.

Malawi

Production and technology: While the government is encouraging farmers to use organic manure and compost and promoting the use of fertiliser trees alongside crops, there is also a push to diversify crops beyond maize to include legumes. The application rate of organic fertilisers is often insufficient, primarily due to the severely degraded and eroded state of the soils. Due to poor quality, only some organic farmers use OFBF. There is no comprehensive overview available about the various initiatives producing organic fertilisers. Examples are Mbeya compost based on all kind of organic materials and Bionitrate fertiliser based on urine. Currently, the factory facilities' capacity cannot meet the rising demand, which has reached 50 million litres per year. Challenges faced include the lack of subsidies, the stigma associated with using urine as fertiliser and limited production resources. Various small-scale initiatives are emerging, including a developing company named Almena, e.g. utilising kitchen waste, garden greens, greens harvested from the surrounding forest and residues from mushroom production to create liquid organic fertiliser. Other products are seaweed blends enriched with trace elements like iron, designed for foliar feeding of crops. Several rhizobia products are available in the market, originating from Brazil, Europe and India, for example. Quality is an issue. However, there are also some local companies such as Agri-Input Suppliers Ltd., who are currently producing rhizobia for 50 000 ha. Their production capacity is currently only running at 30% to 50%. There are donor-funded initiatives linked to specific programmes. The current production of organic fertilisers is insufficient to have a measurable impact on national-level production, but the amount of organic waste in the future is expected to increase due to the expansion of livestock populations through livestock pass-on programmes in various projects across the country.

Research, education and dissemination: The Department of Agricultural Research Services and the Department of Land Resources Conservation are organising trials to test OFBF. MOGA conducts chemical residue testing on samples of OFBF. The University of Kyoto has played a pivotal role in ensuring product quality of rhizobia. Advisory services collaborate with the International Institute of Tropical Agriculture (IITA) to promote rhizobia usage. Many organic fertilisers do not fulfil quality standards particularly regarding nutrient levels. Several companies are now blending them with chemical fertilisers. Community-based demonstration trials have shown significant adoption rates, such as with rhizobia. The University of Lilongwe has been instrumental in providing demonstration plots to showcase these technologies, particularly for Bionitrate. Companies should deepen their collaboration with farmer organisations like MOGA. More education, awareness raising, demonstrations across the country, product promotions (e.g. via radio) and research are required..

Economy and market: The few companies engaged in OFBF offer their products at prices significantly lower than inorganic fertilisers. They are challenged by limited production capacity to meet the growing demand. The absence of well-established distribution channels has led to high prices for farmers due to the need for extensive travel to acquire the product. There are no OFBF subsidies to either producers or farmers, but the latter benefit from projects. Some OFBF companies aim at stabilising their domestic market position with prospects of exporting toward Mozambique, Tanzania and Zambia. The market holds great potential for these products (e.g. rhizobia), provided that they maintain high quality.

Policies: The National Fertiliser Policy of 2021 is aimed at promoting the expansion of production, marketing and utilisation of both high-quality inorganic and organic fertilisers. In 2023, the government introduced an organic fertilisers policy, accompanied by a regulatory framework for standardising production, to control quality, including hygienic measures, and establish application rates. The policy strongly recommends the utilisation of organic agricultural value chain wastes and green waste as primary sources of organic fertilisers. The Malawi Bureau of Standards plans to address this in 2023. This framework should cover both organic and conventional farming. The fertiliser policy must ensure the registration and taxation of OFBF companies, while providing incentives for duty-free equipment imports. Legislation should be established to evaluate OFBF companies, accompanied by accessible quality analysis data. Private-sector financing, including affordable capital, and equal subsidies compared to inorganic fertilisers via the "Affordable Input Programme" should be considered for sustainable growth.

Rwanda

Production and technology: Rwanda currently lacks an established waste sorting regulation or system. Waste collectors either use the waste to produce organic fertilisers themselves or deposit the waste at designated dumpsites where producers can purchase the materials for organic fertiliser production. Producers, especially those catering to export markets, often procure waste materials from waste management companies. A significant obstacle is the lack of appropriate technological equipment for waste sorting, storage and delivery, particularly specialised equipment required for organic fertiliser production, often requiring imports. Competition for raw materials is another challenge, as livestock and other users also vie for organic matter. Organic fertilisers on the market undergo rigorous testing, including pilot tests, before being released. Some fertilisers often contain elevated levels of cadmium and environmentally degrading phosphorus.

Research, education and dissemination: The government has initiated support for OFBF research, but a systematic research programme is lacking. Most farmers who purchase OFBF are engaged in certified organic production for export. These co-operatives have observed increased productivity. Farmers possess a good understanding of organic fertilisers. Their typical approach involves applying compost first and then NPK later.

The Rwanda Agriculture Board provides support for soil analysis, while the Rwanda Standards Board handles testing and certification. Since 2007, Rwanda has been actively involved in training smallholder farmers in compost production. The government has launched an awareness campaign to educate smallholder farmers about the significance of utilising their composts instead of selling them. Organic fertilisers are also part of the curriculum at the university. Radio Huguka, covering 60% of Rwanda, collaborates closely with OFBF producers and farmers, using its broadcasts to share valuable information about these agricultural practices within the context of the Ecological Organic Agriculture Initiative (EOA-I). To further the development of organic farming, it is essential to support Participatory Guarantee Systems (PGS).[8]

Economy and market: Currently, the government does not provide subsidies for organic fertilisers. This poses a challenge for subsistence farmers, who predominantly rely on on-farm produced organic fertilisers. The government offers tax exemptions on equipment and packaging materials, which facilitates the startup of OFBF producers. The high cost of soil and product analysis presents a barrier to developing an appropriate fertiliser strategy.

Key barriers to the widespread adoption of commercial organic fertilisers include their limited availability in the market and their relatively high cost, although there are exceptions such as indicated by the RUNRES project (ETH Zurich in co-operation with CGIAR in Rwanda). The financial instruments that already exist target bigger projects and are very competitive. REMA and FONERWA collaborate on seed capital provisions to support specific initiatives. There are also companies importing OFBF alongside inorganic fertilisers. An increase in the volume of waste materials is foreseen but the main challenge lies in securing sufficient capital to establish compost-making businesses.

Policies: The government's recognition of OFBF as viable alternatives, as well as the development of the circular economy strategy, which aims to minimise Rwanda's carbon emissions by 2050, are both expected to have a significant positive impact on OFBF production. The Rwanda Green Growth and Climate Change Strategy is another influential factor that can drive the growth of OFBF. The Ministry of Agriculture has established a national agriculture policy, which includes provisions for both organic and inorganic fertilisers. There is a strategic plan for agricultural transformation, phase four, which encompasses organic and inorganic fertilisers. ROAM is advocating for the government to include organic inputs in subsidies to make them more affordable for farmers. Rwanda has also implemented a waste management strategy in which private companies are responsible for collecting waste from various sources, including homes, restaurants, institutions and hotels, in both urban and rural areas. Waste collection services are awarded through tenders by either the city of Kigali or district authorities, depending on the location.

Senegal

Production and technology: The trend of farmers transitioning to organic practices and to integrate OFBF is rising. There are several companies producing OFBF (e.g. Éléphant Vert, Cepad service, Biotech service, MNA, Biotope, ONAS), specialised in products like wastewater, treated sewage sludge, mixed OFBF (bokashi), black soldier flies for animal feed and compost production. Senegal established a biodigester programme, primarily centred around households. Senegal has embarked on an initiative focused on household waste management. The largest banana producer in Senegal is contemplating the establishment of four banana plantation sites with plans to produce their compost. Some regions employ trucks for periodic waste removal. Several companies have foreign origins and there are also imported products. Éléphant Vert, with Swiss origins and producing biofertilisers in Morocco, is also active in, e.g Côte d'Ivoire, Mali and Senegal. It was expected that, by 2022-23, the government would have subsidised a total of about 11 000 tons of organic fertilisers, to be expanded to 50 000 t/year. SMEs produce 30-50 tons annually, some aiming for 10 000 tons in 2022. Coastal farmers use organic manure - whether animal waste, fish remnants, or cow

8] FGS is a low-cost, locally based system of quality assurance with a strong emphasis on social control and knowledge building. This system is based on the active participation of farmers, consumers, rural advisors and local authorities in order to make decisions, visit farms, support each other and check that farmers are producing according to an organic standard. Available at https://www.fao.org/3/I8288EN/i8288en.pdf, accessed 14 March 2024.

dung - to create compost. Extensive surveys of Senegal's vegetation across various regions exist to identify plants with inherent fertility-enhancing attributes. One pressing issue is the absence of standardised regulations for organic fertilisers, leading to the emergence of numerous companies lacking the necessary expertise and experience. Efforts are underway to optimise household waste for organic fertiliser production. Initial targets include major markets, hotels and gastronomy establishments for efficient waste sorting. The private sector plays a pivotal role, often partnering with NGOs. Engaging international partners becomes crucial in disseminating the experimental vision being cultivated. Senegal's unique Sahelian environment poses challenges due to limited availability of raw materials, especially plant residues.

Research, education and dissemination: There is some research on the different types of fertilisers, however very limited. Larger agricultural companies have conducted rigorous tests of their organic fertiliser products, as well as an association of horticultural farmers near Dakar. At the farmer organisation level, assessment of the effectiveness of organic fertilisers is missing, while some are done at universities. The current agricultural education predominantly emphasises inorganic fertilisers, obstructing the transition to organic alternatives. There is an urgent need for extensive knowledge dissemination and practical testing. The sector suffers from a significant knowledge and know-how deficit.

Economy and market: Market assessments indicate a demand for approximately 400 000 tons of inorganic fertilisers and 300 000 tons of organic fertilisers. Marketing efforts are sometimes neglected and investments in this aspect are limited. The prevailing approach involves direct sales to agro-industrial companies or through a distributor network. Challenges arise from delayed state payments for subsidies, impacting cash flow and timely bank payments, emphasising the need for financial predictability. To align with the Senegalese state's agroecological approach, it is suggested to subsidise at least 50% of both organic and inorganic fertilisers.

Policies: The programme in Senegal to establish agro-poles in different regions holds promise, with two progressing well and others in various stages of development. These agro-poles serve as agricultural hubs for agri-food processors and can effectively utilise organic waste for OFBF production. Organic fertiliser producers face competition from large inorganic fertiliser companies. Certain plant-based materials are experiencing price increases due to heightened demand from broiler feed manufacturers, resulting in price hikes. Transport expenses, particularly for poultry dung, represent a significant cost, whereas vegetable-based materials are lighter and result in a 1:1 ratio of soil amendment produced. The minister of agriculture highlighted the need to move towards self-sufficiency in organic fertilisation and acknowledged that perpetual fertiliser subsidies are unsustainable. Currently, 80% of subsidies are allocated to inorganic fertilisers. The National Biogas Programme is taking steps towards promoting organic fertilisers by providing an 80% subsidy, albeit with relatively small quantities. The Horticulture Directorate plays a pivotal role in subsistence agriculture, warranting additional focus.

South Africa

Production and technology: Off-farm production of organic fertilisers has increased substantially, especially in large animal operations, producing over 100 tons of compost monthly, but in general organic fertilisers' availability is limited. Many farmers in commercial organic farming use organic fertilisers. Multiple initiatives exist to produce organic fertilisers, including compost production fulfilling NPK standards; public-private partnerships with Duzi Turf, Umgeni Water and Msunduzi Municipality facilitating co-compost production (see RUNRES project). In the latter, the public utility company provides dewatered sewage sludge, while the municipality supplies garden/green waste. Large animal operations producing 100 t of compost monthly exist. Commercial sources like extensive chicken manure are used for compost, however, antibiotic residues are reported to be an issue. One of the larger compost producers, Talborne Organics, offers certified organic fertilisers that contain various macronutrient combinations, including relevant amounts of phosphate. Biofertiliser product examples include effective micro-organisms, prepared in South Africa and also combined with compost.

Research, education and training: Current research explores the potential of OFBF, including, e.g. human, household and green waste for co-composting and biochar production from human excreta (e.g. RUNRES project). Within the project, a pilot-scale Decentralized Wastewater Treatment System (DEWATS) and pour flush urine diversion at Sikhululiwe School/Vulindlela community, led by Umgeni Water, aims to support adaptation of regulations and policies regarding human excreta and water/wastewater treatment sludge reuse. Furthermore, the use of faecal sludge-derived biochar is explored with support from Partners in Development and the local municipality of Mzunduzi. The so-called "Agroecology Living Labs" expand composting initiatives to a network of church-affiliated farmers' co-operatives and integration of faecal sludge management. Another innovation are biodigesters fed with various raw materials depending on local availability, such as feedlot waste, vegetable scraps or sewage.

The Agricultural Research Council is active to collaborate with different actors. Obstacles to organic fertiliser usage stem from knowledge gaps at all educational levels. Universities and colleges of agriculture should incorporate OFBF and organic farming into their curricula. Demonstrating the economic feasibility of biofertilisers is essential. Research funding for OFBF and organic farming is available but limited. Prioritising consumer/customer education is also crucial. Transdisciplinary innovation platform approaches (see RUNRES) should be established across the country. Farmers have more knowledge about inorganic fertilisers compared to OFBF due to the availability of support from extension services. Replacing inorganic fertilisers with OFBF is not a prevalent topic. The Farmer Association encourages the use of OFBF. To convert to organic farming, support to commercial OFBF becomes essential.

Economy and market: Main demand for OFBF comes from organic farmers and export-oriented farms. There is a substantial demand for high-quality compost. While organic fertilisers used to be more expensive than inorganic fertilisers, they are now competitively priced. Market channels include direct customer sales, retail spaces for agriculture/horticulture/floriculture, distributors providing financing to farmers and field agents representing certain products. Some OFBF producers export to several countries as part of their operations. Counterfeit OFBF products on local markets remain a concern that requires attention within the industry. Engaging with supermarket managers and franchises presents a chance to test the viability of introducing organic food sections.

Policies: A clear strategy to promote OFBF to the same level as inorganic fertilisers is missing. South Africa is aiming to simplify the registration process for "bio-remedies" (environment-friendly pesticides) through alignment with CODEX Alimentarius. This opens the possibility of incorporating OFBF into this regulatory framework. OFBF must be registered and certified through ACT 36 of the Department of Agriculture. However, lack of quality control, especially of imported products, is reported. Many organic compost producers are being pushed out of the market (due to residues such as glyphosate when using chicken manure). The government can help de-risk investments in OFBF industries through tax incentives or by becoming a market for the products, for example via Agriculture Research Council support. Policy harmonisation is necessary between departments, such as the Water and Sanitation and Forestry & Fisheries. Policy makers must prioritise research to drive meaningful development of the OFBF sector.

Uganda

Production and technology: Uganda has the lowest inorganic fertiliser application rate in the SSA region, averaging 2 kg/ha. There is no specific policy for fertiliser production. In certain Ugandan regions, smallholder farmers predominantly depend on existing natural soil fertility. Others opt for animal manure, with cow manure being a preferred choice, especially among cattle-owning farmers. With more than 70% of Uganda's waste being organic, a vast potential for resource recovery exists. Uganda's agricultural transformation is being driven by the forefront role of OFBF, aligning with sustainable practices championed by the Participatory Ecological Land Use Management (PELUM) Association (a network of over 250 organisations). PELUM's member organisations are establishing OFBF units and create a marketing platform for its members, and other NGOs such as ESAF help to link to more customers. The government does not have a direct involvement in this aspect. There are diverse activities on OFBF production, including residues from markets, industrial waste, fruit waste, coffee and banana residues, hotels and residues from farms. Products are compost, bio-slurry, some micro-organism-based products, vermicompost, nitrogen-rich crops such as tithonia, livestock excreta (from cattle, poultry and pig farms), ash, wastewater (Kampala) and rock phosphate, combination of biochar with urine, as well as black soldier fly (animal feed) and compost as by-product. Several start-up companies have ventured into organic fertiliser production (e.g. Imagine Her, supporting start-ups by youth in Uganda). A recent president's directive mandates waste recycling in urban areas in Uganda. The Clean Development Mechanism project, backed by the World Bank, aimed to establish about 12 compost plants with 70-ton daily capacity. But for several reasons, none of these, including the Mbale plant, are operational. Commercial production of biochar and pellets for energy use or materials has been successful, making it a popular option. Biogas technology is not yet widely spread. A Dutch company engaged in black soldier fly production operates in facilities owned by the Kampala Capital City Authority. A Danish company produces composts using market waste (and potentially other wastes such as faecal sludge for co-composting). Some funders focus on the socio-economic empowerment of farmers, while others, like the World Bank, emphasise reducing greenhouse gas emissions and promoting local compost usage among smallholder farmers. The product quality of OFBF differs as no continuous monitoring of products exists.

Research, education and dissemination: There is limited public funding available for research in the field of OFBF. PELUM is actively involved in multiple projects aimed at promoting the production, management, application and consistent supply of organic fertilisers. The Organic Knowledge Hub for Eastern Africa (operating within the broader Knowledge Centre for Organic Agriculture) seeks to enhance farmers' capabilities in learning and experimenting with organic fertiliser production and application. Advisory services have played no role as yet but the in-house advisory services have been very instrumental in pushing the OFBF products. The presence of government agricultural extension services would significantly bolster farmers' demand for bio-based products. Training opportunities are provided by NGOs and the private sector. The African Women Leaders in Agroecology mentorship programme, supported by PELUM, and another supportive organisation, Imagine Her, are actively involved in assisting small OFBF production initiatives. Tooro Kingdom trains organic farmers, NOGAMU, in collaboration with institutions like Uganda Martyrs University, contributes to OFBF development by offering expertise, training and trials. Development agencies assume a pivotal role by investing in training centres and demonstration plots showcasing various organic agriculture technologies.

Economy and market: Many waste transport entities function as formidable enterprises. Challenges are logistics and costs. The primary buyers of commercial organic fertilisers are predominantly commercial farmers, particularly those engaged in coffee, banana and tea cultivation.

Policies: The prevalence of counterfeit products underscores the necessity of certifying the origin of external inputs. Lack of control led to the spread of coffee wilt disease across Uganda, significantly impacting coffee quality. To foster OFBF production, enabling policies that extend support through incentives or tax breaks should be introduced, including research funding at universities. The National Bureau of Standards introduced OFBF standards in 2023.

Zimbabwe

Production and technology: Zimbabwe possesses ample organic waste resources that can be tapped for production, including compost toilets, market and abattoir waste, aquatic weed, pig dung and various raw materials sourced, e.g. from the municipality of Harare. Main challenges for organic fertiliser production are power shortages and increasing transport costs that could raise prices. The use of human excreta via biogas and slurry as a source of raw materials is a viable option; vermicompost is of high relevance. The Environmental Management Agency initially awarded a tender to remove weeds from Harare's water sources, providing another source of organic raw materials. The government's Soil Research Institute in Marondera houses the second-largest rhizobium plant in Africa, trailing only South Africa, with strains of rhizobium for crops like groundnuts, sugar beans, soya beans, peas and pasture legumes such as lucerne, lablab and sun hemp (Crotalaria juncea), co-ordinated by Wageningen University & Research (WUR); however, the technology used is quite old. OFBF are primarily used for horticulture, tobacco and floriculture.

Research, education and dissemination: Actors involved in OFBF dissemination are the chili and tobacco companies, farmer organisations, the Potato Association and the Department of Agriculture Extension Services. Advertising efforts utilise local newspapers, radio, television, but mostly social media platforms. Literature on OFBF and information about raw materials is quite limited in Zimbabwe. The quality of most OFBF remains untested. Research institutes, agricultural colleges, the Tobacco Research Board and Marondera Horticulture Research Station do research and demonstrations. Some NGOs and agricultural colleges are actively involved in supporting demonstration plots. ZimEarthworm Farms, in collaboration with the Agriculture Extension Services, conducted experiments involving water hyacinth and Hydrocleis to feed worms and produce vermicompost. Research assistance is given by WUR through projects like N2Africa. United Nations agencies operating in Zimbabwe support organic fertiliser production. Russian comfrey, pigweed and water hyacinth should be studied to produce organic fertilisers for vegetable production. The government has endorsed the commercial organic fertiliser Nutrich vermi Compost by ZimEarthworm Farms for use in the national climate-smart production project.

Economy and market: Advertising of OFBF is conducted through local newspapers, radio, television and various social media platforms. Merchandisers are stationed in numerous retail outlets; a network of agricultural input shops distributes other agricultural inputs. The business is not highly profitable due to processing and transport costs and high labour costs. The market price for organic fertilisers is approximately half the price of inorganic fertilisers. There is a lack of a robust marketing strategy, adequate support resources and unscrupulous dealers. The quantity of organic food exports and local organic food consumption is directly linked to the use of OFBF. Shifting the focus from inorganic fertilisers towards OFBF could significantly enhance their adoption among farmers.

Policies: There exists a policy and legal framework that facilitates a favourable environment for production and marketing, but there remains a crucial need for a comprehensive OFBF policy, including standardisation for off-farm produced OFBF, with active participation from the Standards Association of Zimbabwe, and the integration of OFBF into government food security programmes, such as the presidential input programmes. The involvement of key ministries, such as the Ministry of Agriculture, Fisheries, Water, Climate and Rural Development, the Ministry of Finance and Economic Development and the Ministry of Industry and Commerce, which oversees taxation and border control of the import of raw materials, raises questions about the sustainability of this strategy. Policies should be established to ensure that biodegradable waste is not disposed of in dumpsites but made available to organic fertiliser manufacturing companies. Institutions generating waste should adopt climate-smart waste management policies and regulatory frameworks. City councils and similar institutions should invest in waste management technology. There is support from EU countries for conservation agriculture and the green agricultural economy. A statutory instrument is in progress to bolster organic farming, with a special emphasis on fertilisers. The Ministry of Agriculture, Fisheries, Water, Climate and Rural Development is actively developing an agroecology and organic farming strategy.

Glossary

- **Biochar**
  Biochar is a form of charcoal, a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. It is defined by the International Biochar Initiative as "the solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment". Biochar may increase soil fertility. Biochar is mainly used as a soil amendment or mixed with other fertilisers. It is known to improve soil nutrient availability, aeration in soil and soil water filtration. Biochar can also have a critical impact on soil fertility, manifesting either alkaline or acidic properties depending on its source material and production conditions. This introduces potentially harmful chemical characteristics and may influence the activity and diversity of soil micro-organisms.

- **Biocontrol**
  "The control of one organism by another. Biocontrol agents used in plant productions are living organisms protecting plants against their enemies, i.e., reducing the population of pests or diseases to acceptable levels. Modes of action may include competition, antibiosis, parasitism and also Induced Systemic Resistance which is mediated by the plant." (du Jardin, 2015, p. 7

- **Biofertiliser**
  "A biofertiliser is any bacterial or fungal inoculant applied to plants with the aim to increase the availability of nutrients and their utilisation by plants, regardless of the nutrient content of the inoculant itself. Biofertilisers may also be defined as microbial biostimulants improving plant nutrition efficiency." (du Jardin, 2015, p. 7)

- **Bio-slurry**
  Bio-slurry is a nutrient-rich mixture collected from animal manure, particularly in straw-poor stable systems. It can also be derived from anaerobic digestion of organic waste, including animal manure, human excreta and household waste, in biogas digesters. Bio-slurry comprises solid and liquid residues remaining after the biogas production process.

- **Biostimulants**
  A "plant biostimulant means a product stimulating plant nutrition processes independently of the product's nutrient content with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere: (a) nutrient use efficiency; (b) tolerance to abiotic stress; (c) quality traits; (d) availability of confined nutrients in soil or rhizosphere." (EU, 2019)

- **Bokashi**
  Bokashi is a Japanese term referring to a composting method that ferments kitchen organic waste using a mix of beneficial micro-organisms. It involves anaerobic fermentation with an inoculant containing lactic acid bacteria, yeast and phototrophic bacteria, breaking down a variety of organic materials, including meat and dairy products. The resulting pre-compost is often buried in soil or added to traditional compost piles. In addition, the process produces a nutrient-rich liquid known as "bokashi tea".

- **Compost**
  Organic matter that has undergone decomposition through microbial activity, resulting in a nutrient-rich, humus-like material. Composting is a controlled process where biodegradable waste, such as kitchen scraps, yard trimmings and/or manure, is broken down into a stable, soil-enriching product through the action of micro-organisms.

- **Digestate**
  Digestate is obtained through anaerobic digestion from separate bio-waste collection at source, the organic fraction of mixed municipal household waste, sewage sludge, industrial sludge or dredging sludge, and/or animal by-products (EU, 2019). In this document, the term "digestate" is used interchangeably with "bio-slurry".

- **Frass fertiliser (insect frass)**
  Frass fertiliser, also known as insect frass, refers to the excrement or droppings produced by insects such as black soldier flies. Insect frass contains a variety of nutrients, including nitrogen, phosphorus, potassium and other trace elements. The specific nutrient composition of frass may vary depending on the insect species and its diet.

- **Inorganic fertiliser**
  An inorganic fertiliser is a fertiliser containing or releasing nutrients in a inorganic form, other than an organic or organo-mineral fertiliser (EU, 2019). In this document, the term "inorganic fertiliser" is employed interchangeably with the terms "mineral fertiliser", "chemical fertiliser", or "synthetic fertiliser".

- **Microbial plant biostimulant**
  A microbial plant biostimulant consists of a micro-organism or a consortium of micro-organisms.

- **Nitrogen-fixing bacteria**
  Nitrogen-fixing bacteria are micro-organisms capable of transforming atmospheric nitrogen into fixed nitrogen (inorganic compounds usable by plants). Nitrogen is the most limiting plant nutrient in agro-ecosystems, at the same time increasing use of nitrogen-containing fertilisers increases greenhouse gas emissions and groundwater contamination. Biological nitrogen fixation is an eco-friendly source of nitrogen that can reduce the use of nitrogen fertilisers.

- **Organic fertiliser**
  Materials of animal or plant origin used to feed plants; they may be made from manure, guano, compost and residues of biogas production. Organic fertilisers can be of solid or liquid nature, containing organic carbon (Corg) and nutrients of solely biological origin. The minimum of nutrients should be at least 1% by mass of total nitrogen (N), 1% phosphorous (P2O5) and 1% potassium (K2O) (EU, 2019).

- **Organo-mineral fertiliser**
  An organo-mineral fertiliser is a co-formulation of inorganic and organic fertilisers (EU, 2019).

- **Phosphate-solubilising bacteria**
  Phosphate-solubilising bacteria are beneficial bacteria capable of solubilising inorganic phosphorus from insoluble compounds. These bacteria increase plant-available phosphorus by modifying either rhizosphere soil processes or promoting plant traits, which lead to increased phosphorus uptake. Phosphorus is often unavailable for plant uptake due to its complexation with metal ions in the soil. Phosphate-solubilising micro-organisms can solubilise insoluble phosphates in soils by different mechanisms, making phosphates available for plant uptake. The use of these bacteria can contribute to more sustainable and environmentally friendly agricultural practices.

- **Sludge (faecal)**
  Sludge, specifically referring to faecal sludge, is a semi-solid mixture of human excreta, water and solid wastes that accumulates in on-site sanitation systems, such as septic tanks or pit latrines. It is the residue generated from the decomposition of organic matter in human excreta and the settling of solids in the containment system.

- **Soil amendment**
  "Any material such as lime, gypsum, sawdust, compost, animal manures, crop residue or synthetic soil conditioners that is worked into the soil or applied on the surface to enhance plant growth. Amendments may contain important fertiliser elements, but the term commonly refers to added materials other than those used primarily as fertilisers."[9]

- **Vermicompost**
  Vermicompost is a nutrient-rich organic fertiliser and soil conditioner produced through the process of vermicomposting. This method involves the use of specialised earthworms, typically red wigglers (*Eisenia fetida*), to break down organic waste materials, such as kitchen scraps and plant residues. The worms consume the organic matter and their digestive processes, combined with microbial activity, transform the waste into a dark, crumbly and highly fertile compost known as vermicompost. This end product is valued for its well-balanced nutrients, beneficial micro-organisms and improved soil structure.

9] Available at https://www.soils.org/publications/soils-glossary/browse/s, accessed 14 March 2024.

References

Bamdad, H., Papari, S., Lazarovits, G., & Berruti, F. (2022). Soil amendments for sustainable agriculture: Microbial organic fertilizers. *Soil Use and Management*, 38(1), 94-120.

Beesigamukama, D., Subramanian, S., & Tanga, C. M. (2022). Nutrient quality and maturity status of frass fertilizer from nine edible insects. Scientific Reports, 12(1), 7182.

BioFit. (2015). *BIOFERTILIZERS towards sustainable agricultural development. BioFit Project Report - 2015 1 BG01 KA202 014258 - Funded by Erasmus+ of the European Union*. Retrieved from https://www.bio-fit.eu/bio-fit-book

Bjornlund, V., Bjornlund, H., & Van Rooyen, A. F. (2020). Why agricultural production in sub-Saharan Africa remains low compared to the rest of the world–a historical perspective. *International Journal of Water Resources Development, 36*(sup1), S20-S53.

Castro-Herrera, D., Prost, K., Schäfer, Y., Kim, D. G., Yimer, F., Tadesse, M., . . . Brüggemann, N. (2022). *Nutrient dynamics during composting of human excreta, cattle manure, and organic waste affected by biochar* (0047-2425). Retrieved from

Chitaka, T. Y., & Schenck, C. (2023). Developing country imperatives in the circular bioeconomy: A review of the South African case.

Curadelli, F., Alberto, M., Uliarte, E. M., Combina, M., & Funes-Pinter, I. (2023). Meta-Analysis of Yields of Crops Fertilized with Compost Tea and Anaerobic Digestate. Sustainability, 15(2), 1357.

Dalberg. (2023). *Enterprise and Market System Analysis of the Organic Fertilizer Sector in Nigeria. Validation Workshop, 29 March 2023. Discussion document (unpublished). Study commissioned by the Foreign Commonwealth and Development Office (FCDO)*. Retrieved from

De Corato, U. (2020). Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: A review under the perspective of a circular economy. *Science of the Total Environment, 738,* 139840.

De Weerdt, J., & Duchoslav, J. (2022). *Are fertilizer subsidies in Malawi value for money?* (Vol. 46): Intl Food Policy Res Inst.

DEFF. (2020). *NATIONAL WASTE MANAGEMENT STRATEGY 2020. Department Enviroment, Forestry and Fisheries. Republic of South Africa.* 71, p. Retrieved from https://www.dffe.gov.za/sites/default/files/docs/2020nationalwaste_managementstrategy1.pdf

dos Santos Sousa, W., Soratto, R. P., Peixoto, D. S., Campos, T. S., da Silva, M. B., Souza, A. G. V., . . . Gitari, H. I. (2022). Effects of Rhizobium inoculum compared with mineral nitrogen fertilizer on nodulation and seed yield of common bean. A meta-analysis. *Agronomy for Sustainable Development, 42*(3), 52.

Drechsel, P., Graefe, S., & Fink, M. (2007). *Rural-urban food, nutrient and virtual water flows in selected West African cities* (Vol. 115): IWMI.

du Jardin, P. (2015). Plant biostimulants: Definition, concept, main categories and regulation. *Scientia horticulturae, 196,* 3-14.

Reglement C/REG.13/12/12 RELATIF AU CONTROLE DE QUALITE DES ENGRAIS DANS L'ESPACE CEDAO. Soixante-neuvieme session ordinaire du Conseil des Ministres. Abidjan 30 novembre - 2 decembre 2012. 15 pp., (2012).

EU. (2019). Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003. Official Journal of the European Union (EU), June 25th, 2019, (2019).

FAO. (2018). *Availability and utilization of agroindustrial by-products as animal feed. Food and Agriculture Organization of the United Nations, Rome, 2019*. 64 pp. Retrieved from https://www.fao.org/documents/card/en?details=CA3600EN%2f

Faye, A., Dalpé, Y., Ndung'u-Magiroi, K., Jefwa, J., Ndoye, I., Diouf, M., & Lesueur, D. (2013). Evaluation of commercial arbuscular mycorrhizal inoculants. *Canadian Journal of Plant Science, 93*(6), 1201-1208.

Friedrich, E., & Trois, C. (2011). Quantification of greenhouse gas emissions from waste management processes for municipalities–A comparative review focusing on Africa. *Waste management, 31*(7), 1585-1596.

Green, B. W. (2015). Fertilizers in aquaculture. Editor(s): D. Allen Davis, In Woodhead Publishing Series in Food Science, Technology and Nutrition, Feed and Feeding Practices in Aquaculture, Woodhead Publishing.

Herrmann, L., Atieno, M., Brau, L., & Lesueur, D. (2015). Microbial quality of commercial inoculants to increase BNF and nutrient use efficiency. *Biological nitrogen fixation,* 1031-1040.

Hoffmann, M., Swanepoel, C., Nelson, W., Beukes, D., Van der Laan, M., Hargreaves, J., & Rötter, R. (2020). Simulating medium-term effects of cropping system diversification on soil fertility and crop productivity in southern Africa. *European Journal of Agronomy, 119*, 126089.

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., . . . Kilasara, M. (2013). *Soil atlas of Africa*: European Commission.

Kabasiita, J. K., Opolot, E., & Malinga, G. M. (2022). Quality and fertility assessments of municipal solid waste compost produced from cleaner development mechanism compost projects: A case study from Uganda. *Agriculture, 12*(5), 582.

Kalina, M., Ogwang, J. Ò., & Tilley, E. (2022). From potential to practice: rethinking Africa's biogas revolution. *Humanities and Social Sciences Communications,* 9(1), 1-5.

Kaschuk, G., Leffelaar, P. A., Giller, K. E., Alberton, O., Hungria, M., & Kuyper, T. W. (2010). Responses of legumes to rhizobia and arbuscular mycorrhizal fungi: a meta-analysis of potential photosynthate limitation of symbioses. *Soil Biology and Biochemistry, 42*(1), 125-127.

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: a global snapshot of solid waste management to 2050*: World Bank Publications.

Kumar, S., Sindhu, S. S., & Kumar, R. (2022). Biofertilizers: An ecofriendly technology for nutrient recycling and environmental sustainability. *Current Research in Microbial Sciences, 3*, 100094.

Lenhart, M., Pohl, M., Kornatz, P., Nelles, M., Sprafke, J., Zimmermann, C., . . . Vanzetto, S. (2022). *Status-Quo of organic waste collection, transport and treatment in East Africa and Ethiopia (DBFZ Report, 45). Leipzig: DBFZ. VII, 94 S. ISBN: 978-3-946629-87-0. DOI: 10.48480/5qsb-t569*. Retrieved from https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-45

Masso, C., Jefwa, J., Jemo, M., Thuita, M., Tarus, D., & Vanlauwe, B. (2013). Impact of inadequate regulatory frameworks on the adoption of bio-fertilizers (eg PGPR) technologies: a case study of sub-Saharan Africa. Recent advances in biofertilizers and biofungicides (PGPR) for sustainable agriculture,.(Eds MS Reddy, RI Ilao, PS Faylon, WD Dar, R Sayyed, H Sudini, KVK Kumar, A Armanda) pp, 276-286.

Masso, C., Ochieng, J., & Vanlauwe, B. (2015). Worldwide contrast in application of bio-fertilizers for sustainable agriculture: lessons for sub-Saharan Africa. *Journal of Biology, Agriculture and Healthcare, 5*(12), 34-50.

Meinzinger, F., Kröger, K., & Otterpohl, R. (2009). Material flow analysis as a tool for sustainable sanitation planning in developing countries: case study of Arba Minch, Ethiopia. *Water science and technology, 59*(10), 1911-1920.

Mihelcic, J. R., Fry, L. M., & Shaw, R. (2011). Global potential of phosphorus recovery from human urine and feces. *Chemosphere, 84*(6), 832-839.

Möller, K., & Müller, T. (2012). Effects of anaerobic digestion on digestate nutrient availability and crop growth: A review. *Engineering in life sciences, 12*(3), 242-257.

Mupambwa, H. A., & Mnkeni, P. N. S. (2018). Optimizing the vermicomposting of organic wastes amended with inorganic materials for production of nutrient-rich organic fertilizers: a review. *Environmental Science and Pollution Research, 25,* 10577-10595.

Musa, A. M., Ishak, C. F., Karam, D. S., & Md JAAFAR, N. (2020). Effects of fruit and vegetable wastes and biodegradable municipal wastes co-mixed composts on nitrogen dynamics in an Oxisol. *Agronomy, 10*(10), 1609.

Nkonya, E., Johnson, T., Kwon, H. Y., & Kato, E. (2016). Economics of land degradation in sub-Saharan Africa. *In Economics of land degradation and improvement–a global assessment for sustainable development* (pp. 215-259): Springer, Cham.

Obsa, O., Tadesse, M., Kim, D.-G., Asaye, Z., Yimer, F., Gebrehiwot, M., . . . Prost, K. (2022). Organic Waste Generation and its valorization potential through composting in Shashemene, southern Ethiopia. *Sustainability, 14*(6), 3660.

Otoo, M., & Drechsel, P. (2018). *Resource recovery from waste: business models for energy, nutrient and water reuse in low-and middle-income countries:* Routledge.

Perez-Mercado, L. F., Perez-Mercado, C. A., Vinnerås, B., & Simha, P. (2022). Nutrient stocks, flows and balances for the Bolivian agri-food system: Can recycling human excreta close the nutrient circularity gap? *Frontiers in Environmental Science, 10*, 956325.

Raimi, A., Roopnarain, A., & Adeleke, R. (2021). Biofertilizer production in Africa: Current status, factors impeding adoption and strategies for success. *Scientific African, 11*, e00694.

Rajoo, K. S., Karam, D. S., Ismail, A., & Arifin, A. (2020). Evaluating the leachate contamination impact of landfills and open dumpsites from developing countries using the proposed Leachate Pollution Index for Developing Countries (LPIDC). *Environmental Nanotechnology, Monitoring & Management, 14*, 100372.

Rose, C., Parker, A., Jefferson, B., & Cartmell, E. (2015). The characterization of feces and urine: a review of the literature to inform advanced treatment technology. *Critical reviews in environmental science and technology, 45*(17), 1827-1879.

Roy, E. D., Esham, M., Jayathilake, N., Otoo, M., Koliba, C., Wijethunga, I. B., & Fein-Cole, M. J. (2021). Compost quality and markets are pivotal for sustainability in circular food-nutrient systems: a case study of Sri Lanka. *Frontiers in Sustainable Food Systems, 5*, 748391.

Schütz, L., Gattinger, A., Meier, M., Müller, A., Boller, T., Mäder, P., & Mathimaran, N. (2018). Improving crop yield and nutrient use efficiency via biofertilization—A global meta-analysis. *Frontiers in Plant Science, 8*, 2204.

Sekabira, H., Nijman, E., Späth, L., Krütli, P., Schut, M., Vanlauwe, B., . . . Feyso, A. (2022). Circular bioeconomy in African food systems: What is the status quo? Insights from Rwanda, DRC, and Ethiopia. *Plos one*, 17(10), e0276319.

Setiyono, T., Walters, D., Cassman, K., Witt, C., & Dobermann, A. (2010). Estimating maize nutrient uptake requirements. *FIELD CROPS RESEARCH, 118*(2), 158-168.

Shi, Y., Wang, Y., Yue, Y., Zhao, J., Maraseni, T., & Qian, G. (2021). Unbalanced status and multidimensional influences of municipal solid waste management in Africa. *Chemosphere, 281*, 130884.

Sultana, M., Jahiruddin, M., Islam, M. R., Rahman, M. M., Abedin, M. A., & Solaiman, Z. M. (2021). Nutrient enriched municipal solid waste compost increases yield, nutrient content and balance in rice. *Sustainability, 13*(3), 1047.

THE SUSTAINABLE WASTE MANAGEMENT ACT NO. 31 OF 2022. Published by the National Council for Law Reporting with the Authority of the Attorney-General. 23 pp., (2022).

Tomita, A., Cuadros, D. F., Burns, J. K., Tanser, F., & Slotow, R. (2020). Exposure to waste sites and their impact on health: A panel and geospatial analysis of nationally representative data from South Africa, 2008–2015. *The Lancet Planetary Health, 4*(6), e223-e234.

Ye, L., Zhao, X., Bao, E., Li, J., Zou, Z., & Cao, K. (2020). Bio-organic fertilizer with reduced rates of chemical fertilization improves soil fertility and enhances tomato yield and quality. *Scientific Reports, 10*(1), 1-11.

Yeo, D., Dongo, K., Mertenat, A., Lüssenhop, P., Körner, I., & Zurbrügg, C. (2020). Material flows and greenhouse gas emissions reduction potential of decentralized composting in sub-Saharan Africa: A case study in Tiassalé, Côte D'Ivoire. *International journal of environmental research and public health,* 17(19), 7229.

About this knowledge brief

This knowledge brief addresses the main findings and key messages of a scoping study aimed to identify the potential of the off-farm production of organic fertilisers and biofertilisers in 12 selected case study countries in Africa. The scoping study includes the analysis of commercial organic fertiliser and biofertiliser production, the marketing system, the related advisory system, research activities, and the acceptance and application in smallholder farms. The full report of the scoping study is available at https://www.desiralift.org/resources/

This knowledge brief forms an extended summary of the full report and provides:

- an overview of the production and markets for commercial organic and biofertilisers in 12 selected African countries;
- information about the practices, economy, research, advisory services and legal conditions for the development of commercial organic and biofertilisers;
- orientation for different actors on how to further develop the commercial organic and biofertiliser production, application and efficiency in the future.

This knowledge brief highlights that strategies for off-farm production of organic and biofertilisers that cover nutrient exports and losses and increase soil nutrient availability could form part of a wider solution to improve soil health in Africa by remediating soil degradation and increase African self-sufficiency in nutrients for agricultural production.

Findings of the scoping study are based on a literature review and a total of 89 key informant interviews in 12 selected case study countries in Africa: Cameroon, Côte d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Malawi, Rwanda, Senegal, South Africa, Uganda and Zimbabwe. The study cannot claim to be exhaustive as the findings are mainly based on the knowledge and expertise of the interviewees, supplemented with literature review and calculations based on secondary data.

The scoping study (and this knowledge brief) on the potential of the off-farm production, marketing and use of organic and biofertilisers in Africa was requested by the European Commission, Directorate General for International Partnership (DG INTPA). DeSIRA-LIFT, a service facility to DG INTPA for the DeSIRA Initiative, started the scoping study on behalf of DG INTPA.

Citation:

Bernhard Freyer, Pierre Ellssel, Fortunate Nyakanda, Stéphanie Saussure. 2024. The potential of the off-farm production, marketing and use of organic and biofertilisers in Africa. Knowledge Brief 5. DeSIRA-LIFT

Disclaimer

This publication has been realized within the DeSIRA-LIFT project financed by the European Commission / DG INTPA (FOOD/2021/424-11) and implemented by member organisations of the Agrinatura (CIRAD, ISA, NRI, SLU, WUR) and EFARD networks (COLEAD). The content of this publication is the sole responsibility of the author(s) and does not necessarily represent the views of Agrinatura, EFARD or the European Commission.

Funded by the European Union

Website:
https://www.desiralift.org/
LinkedIn:
https://www.linkedin.com/company/desira-lift
Email:
info@desiralift.org

Address:
Wageningen Centre for Development Innovation

P.O. Box 88
6700 AB Wageningen
The Netherlands