Exploring the off-farm production, marketing and use of organic and biofertilisers in Africa

A scoping study | March 2024

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DeSIRA LIFT

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Final report

Exploring the off-farm production, marketing and use of organic and biofertilisers in Africa: A scoping study

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Table of contents

Tables

Figures

Abbreviations

AMF	Arbuscular mycorrhizal fungi
Az	Azotobacter
Azo	Azospirillum
BF	Biofertiliser
BGA	Blue-green algae
BNF	Biological nitrogen fixation
BSF	Black soldier fly
DM	Dry matter
EUR	euro
FGW	Food and green waste
FM	Fresh matter
IF	Inorganic fertiliser
MSW	Municipal solid waste
Mt	Megaton
n/a	Not available
Non-AMF	Non-arbuscular mycorrhizal fungi
OF	Organic fertiliser
OFBF	Organic and biofertilisers
PGPR	Plant growth promoting rhizobacteria
PSB	Phosphate solubilising bacteria
Rh	Rhizobium
SME	Small and medium-sized enterprise
SSA	sub-Saharan Africa
SWM	Solid waste management
t	Metric ton
USD	United States dollar

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 microorganisms.

- **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)

- **Bioslurry**

Bioslurry 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 waste, and household waste, in biogas digesters. Bioslurry 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, 2019b, Article 47a)

- **Bokashi**

Bokashi is a Japanese term referring to a composting method that ferments kitchen organic waste using a mix of beneficial microorganisms. 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 microorganisms.

- **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, 2019b, Article 47a). 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 mineral form, other than an organic or organo-mineral fertiliser (EU, 2019b, Article 47a). 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 microorganisms 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.

- **Non-microbial plant biostimulant**

A non-microbial plant biostimulant is a plant biostimulant other than a microbial plant biostimulant.

- **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 (C_{org}) and nutrients of solely biological origin. The minimum of nutrients should be at least 1% by mass of total nitrogen (N), 1% phosphorous (P_2O_5) and 1% potassium (K_2O) (EU, 2019b).

- **Organo-mineral fertiliser**

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

- **Phosphate-solubilising bacteria**

Phosphate-solubilising bacteria (PSB) 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 microorganisms 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 onsite sanitation systems, such as septic tanks or pit latrines. It is the residue generated from the decomposition of organic matter in human waste 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. Compare soil conditioner."[1]

- **Soil conditioner**

"A material which measurably improves specific soil physical characteristics or physical processes for a given use or as a plant growth medium. Examples include sawdust, peat, compost, synthetic polymers and various inert materials. See also soil amendment."[2]

- **Soil improver**

"A soil improver [...] has the function of maintaining, improving or protecting the physical or chemical properties, structure or biological activity of the soil to which it is added." (EU, 2019b)

- **Vermicompost**

Vermicompost is a nutrient-rich organic fertiliser and soil conditioner produced through the process of vermicomposting. This method involves the use of specialized 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 microorganisms, and improved soil structure.

[1] https://www.soils.org/publications/soils-glossary/browse/s

[2] https://www.soils.org/publications/soils-glossary/browse/s

1 Executive summary

This scoping study provides valuable insights into the status of organic fertilisers and biofertilisers (OFBF) production and marketing in 12 selected African countries. The study specifically focusses on the (potential of) off-farm production and marketing of OFBF; on-farm nutrient recycling (e.g. use of manure, compost) is explicitly not considered. Data and information were gathered through a review of academic literature, websites, reports and public databases. In addition, a total of 89 key informant interviews were conducted. Findings will contribute to recommendations for policy development on soil health and crop yield, including the formulation of strategies and programs in crucial areas such as research, production and technology, value chain development, the economy, markets, and capacity development. However, this study cannot claim to be exhaustive as the findings are mainly based on the knowledge and expertise of the interviewees. Therefore, further country-specific analysis is necessary to provide a comprehensive and in-depth understanding of OFBF.

1. Current state of organic and biofertilisers production

Organic fertilisers

This study reveals that organic fertiliser use is in its early stages across 12 African countries. South Africa stands out with its 2013 National Organic Waste Composting Strategy, with some communities diverting up to 50% of organic waste. Nigeria has a high production capacity (500 000 t/year), while Egypt harbors one of the single largest producer of organic fertilisers (120 000 t/year). The total off-farm production is around one million t/year across the 12 countries, varying by country.

Four main waste streams (household and green waste, market waste, human waste, and agricultural by-products) are processed into compost, and in some cases towards bioslurry. However, recycling is hindered by lacking waste segregation at source. Waste collection challenges persist, limiting overall organic fertiliser production. Market waste sometimes competes as animal feed, while collection of human waste is limited.

Non-source segregated waste composts have generally low nutrient contents (below 1% N, P, K). Higher values (1-3% N, 1-2% P, 1-3% K) result from waste sorting, biodigesters, use of black soldier flies, human waste or vermicomposting. Some composts are enhanced with chicken manure, mineral fertiliser or nitrogen-rich plant materials. Prices for inorganic and organic fertilisers vary widely (35 to 100 Euro / 50 kg and 0.72 to 65 Euro / 50 kg).

Biofertilisers

Biofertilisers stimulate plant nutrition processes and can improve crop yield, specifically in dry and tropical climates. While biofertilisers have seen greater development in other continents, notably Latin America and India, their production remains limited in the majority of the 12 countries of this scoping study. Most of the biofertilisers marketed in SSA are imported and not always adapted to local conditions. Various studies have reported substantial quality issues among marketed biofertiliser products.

The most advanced market in Africa for biofertilisers and producers can be found in South Africa and Egypt. Apart from them, Kenya, Malawi, and Zimbabwe seem to exhibit a more "advanced" level of production and usage, primarily relying on rhizobia-based products. In contrast, Central and West Africa are the least developed regions in terms of production and usage. In places where they are used successfully such as in Egypt and Malawi (rhizobia), benefits in terms of agricultural production are reported.

2. Current state of the demand and use of organic and biofertilisers

The demand for organic as well as biofertilisers depends on factors like quality control, improved product descriptions, advisory service, training and research on soil health impact. These factors impact consumer trust and demand – among others.

Organic fertilisers

Market development for organic fertilisers has been positive in various countries especially with recent disruptions in the global (mineral) fertiliser market. Farmers, influenced by familiarity with mineral fertilisers, hesitate to adopt organic fertilisers due to concerns about increased workload and perceived lower short-term impact on crop yield.

Companies often offer OFBF for free initially, providing training and demonstrations to build trust. Demand mainly centers around compost from plant residues. However, demand trends vary across countries. Long-term investments in soil health through organic fertilisers face barriers in regions with low land tenure security or high land rental rates.

Barriers to compost use include limited transport access, lack of demonstrations, insufficient advisory services, and delayed nutrient availability. Compost availability is restricted by limited access to materials, market competition for residues, and transport costs. Demand for compost from human excreta can be limited due to cultural barriers and lack of quality control. However, human excreta or sewage sludge are in high demand in some regions due to limited availability of inorganic fertilisers. Compost is recommended for various crops, with arable crops commonly using it for root crops. Liquid organic fertilisers (bio-slurry) face transport challenges and varying opinions on their effectiveness. Biochar's production and demand vary across countries, with skepticism about its exclusive marketing due to a lack of knowledge about its benefits. Some success has been observed when biochar is combined with compost or other amendments. Further investigation is needed to determine the economic feasibility of biochar production.

Biofertilisers

Biofertilisers are not widely promoted by governments and while some advisory services specialise in them, the majority do not value these products, except for rhizobia, which is more widely recognised than other biofertilisers. Across the 12 countries, about 25 companies producing biofertilisers have been identified. In the case of rhizobia, increasing demand has been reported, as it can significantly increase nitrogen fixation and grain yield. Quality issues and low pH values of soils limit the efficacy of rhizobia. The demand for and use of *mycorrhizal fungi* are very limited, with research stations being the main drivers of demand rather than farmers. *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. 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 as such products are promoted for organic farming.

3. Potential supply of organic matter and macronutrients to produce organic fertilisers

Domestic off-farm production of organic fertilisers has potential for development, aiding nutrient and organic matter recycling in agriculture, especially through combined utilisation of household waste, human waste, and agricultural by-products.

There is great potential for a (re)circulation of organic matter and its nutrients (resource). The recycling of organic wastes such as household, food and green wastes, human excreta, wastewater, agro-processing wastes and the herein described organic matter and macro- and micronutrients can help closing urban rural resource flows and recovery of these elements. At the same time externalities such as greenhouse gas emissions, environmental pollution and human health burdens can be reduced.

In many contexts, there is potential for agricultural systems to cover their nutrient needs, at least in parts, by the recycling of nutrients if the nutrient recirculation system would be (re)structured appropriately toward agriculture. For example, the compost produced from urban households' food and green waste across the 12 African countries of this study, could theoretically supply about 31 000 t/N/year, 31 000 t/P/year, and 84 000 t/K/year which, for example, could cover 4% of N, 22% of P, and 42% of K demand of the maize cultivated in the year 2021 (calculation by the authors). When conducting the same calculation but assuming that total households' food and green waste including urban and rural households is recycled, theoretically 71 000 t/year (10% of N), 71 000 t/year (51% of P), and 141 000 t/year (71% of K) could be supplied (calculation by the authors).

Regarding agricultural by-products from processing no or only few general quantifications or estimations exist - to our knowledge - for agricultural by-products or wastes that are produced off-farm in the studied countries. For Ethiopia, FAO estimated unused by-products at about one megaton/year (dry matter). Regional, urban and national assessments are needed for detailed information.

When assessing the theoretical nutrient potential present in human waste across the 12 African countries, the estimated nutrient quantities sum up to approximately 3.4 million t/year of NPK. In comparison, the total imports amounted to 2.8 million tons, and the overall agricultural consumption reached 4.4 million tons of inorganic fertilisers (NPK) within the same 12 countries in the year 2019. In theory, the combined human waste produced in these 12 countries accounts for approximately 77% of the current NPK nutrients consumed in agriculture within the same 12 countries. However, it is important to note that the current application of mineral fertilisers is generally low. Recycling human waste presents a promising way to address sanitation and agricultural demand for both organic matter and nutrients and is hence also well aligning 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.

4. Challenges and opportunities for scaling the organic and biofertilisers sector

Holistic approach

To unlock farms' inherent potential for soil fertility and overall productivity, a holistic approach is crucial. Apart from developing OFBF value chains, this involves optimizing entire farming systems. Such a systems approach emphasizes an integrated fertiliser strategy, with soil health as a central goal.

Research

Currently, in the majority of countries testing infrastructure is lacking, and research on OFBF is limited due to scarce funding. Focusing on OFBF can fill a crucial gap, as current fertiliser research predominantly centres on inorganic fertilisers, despite the potential benefits of organic alternatives. Increased research on OFBF and soil amendments, including biochar and liming, can establish the needed evidence base on product efficacy and will assist in developing robust standards for organic and biofertiliser products. Scientific trials should explore the combined application of on-farm organic matter recycling, off-farm organic fertilisers, biofertilisers, soil amendments and mineral fertilisers to identify the most efficient strategies.

Economy and markets

The financial viability of off-farm organic fertiliser production often faces challenges due to high production costs. However, some companies benefit from support provided by international donors and research initiatives. Positive socio-economic impacts from OFBF use can be achieved through centralized or decentralized organic waste collection, processing, and distribution systems – depending on the local context. Successful OFBF businesses rely on a multi-stakeholder approach to value chain development. Investments across the value chain are necessary, including technological advancements in processing, waste collection, segregation, and efficient product distribution systems. Ensuring product quality is crucial, given the presence of manipulated products in the market.

Knowledge, education and training

There is a weak awareness, education and training for farmers, agricultural extension services and agro-dealers regarding the utility, handling and application of OFBF. Education and training initiatives play a vital role to overcome cultural and traditional barriers to the adoption. Ensuring qualified advisory services and educational staff is imperative, alongside the establishment of field demonstrations. These measures can effectively promote awareness and understanding, facilitating the adoption of OFBF on a wider scale.

Policies, regulations, certification

The future potential of off-farm OFBF appears promising for enhancing soil health and crop yields, reducing environmental pollution and human health burdens, while offering employment opportunities and additional income.

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, processing, OFBF production, marketing, distribution, quality standards, certifications, and on-farm application. Coordination across Africa, alignment with international standards, and adherence to continental, regional, and national policies (such as CAADP, EOA-I, 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.

In many countries, a regulatory framework for OFBF exists; however, the subsequent application and enforcement is lacking. Encouraging integrated policies that incorporate OFBF into existing agricultural practices alongside inorganic inputs is vital. Policies should be consistent, well-enforced, gender-sensitive, and adaptable to changing environments. Cross-sector collaboration is essential, aligning sanitation, waste management, and agriculture policies to establish a circular economy.

While certain countries may have implemented some of the recommendations outlined in this report, there remains a significant gap in the effective action needed to ensure practical application. To effectively implement these recommendations, it is crucial to engage in further discussions and make necessary adjustments to align with the current context, state, planning activities, and priorities within each specific country. Interventions and necessary actions span across diverse sectors and are interconnected, underscoring the importance of implementing them collectively for ultimate success.

Countries should develop national waste management strategies focusing on reduction, reuse, and recycling (Triple R). Entrepreneurs can manage the waste treatment process, but policies must drive segregation campaigns, raise awareness, and encourage public participation.

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, encourage long-term farmer investments, and establish mechanisms to regulate the market.

Being aware of the challenges faced by smallholder farmers, such as low mineral fertiliser application rates, limited labour and financial resources, and high soil erosion, underscores the importance of comprehensive farm-specific support activities for the successful implementation of OFBF. These activities may include subsidies for OFBF use, 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.

2 Introduction

2.1 Rationale

Agricultural productivity on the African continent, and in sub-Saharan Africa (SSA) in particular, is among the lowest in the world (Bjornlund et al., 2020), while land and resource degradation is prevalent throughout many countries (Jones et al., 2013; Nkonya et al., 2016). Food and nutrition insecurity remains a widespread phenomenon in many African countries (FAO, 2020), which has been further negatively impacted by the Covid-19 pandemic and the Russian war in Ukraine. These events have disrupted value chains, energy markets, and caused export restrictions and therefore related decreases in availability of food (imports), agricultural products and production inputs such as inorganic fertilisers, leading to a sharp increase in prices and price volatility (Abu Hatab, 2022; FAO, 2021, 2022; UN, 2022). It is feared that these crises will have an ongoing negative impact on production and availability.

African smallholder farmers are particularly affected by surging import prices for fertilisers (UN, 2022), and it is these smallholders who are central to agricultural production in Africa, producing about 70% to 80% of the agricultural output on the continent (IAASTD, 2009; Lowder et al., 2014).

Due to limited access (e.g., internal transport and distribution system and/or market access, lacking cash and credit), generally high costs and import dependence in many African countries, the use of inorganic fertilisers by smallholder farmers has always been low (AU, 2019). And even where inorganic fertilisers are used more widely, factors such as low soil organic matter content, micronutrient deficiencies and/or high soil acidity hinder the effectiveness of such fertilisers (Kihara et al., 2016; Liverpool-Tasie et al., 2017; Vanlauwe et al., 2015). However, there is a high demand for nutrient sources for agricultural production in Africa and in SSA in particular. And if African countries are to become more resilient to global shocks and increasingly self-sufficient in fertiliser production, new pathways and a variety of solutions will be required. The increase of inorganic fertiliser production facilities and use in Africa may be a part of the solution (Stewart et al., 2020; Vanlauwe et al., 2023). However, it cannot be the sole solution due to various reason as described above. Organic matter addition to soils used for agriculture and respective nutrient sources are essential to foster soil health and fertility (Stewart et al., 2020).

Strategies for off-farm production of economically viable 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. These organic and biofertilisers, however, need to be safe, efficient, available and affordable to the majority of smallholder farmers, and continuously available in the respective markets.

Both off-farm produced organic fertilisers and biofertilisers can be understood as part of the toolbox of agroecological measures, as they contribute to closing regional nutrient cycles. In contrast to inorganic fertilisers these products provide, among other benefits, diverse trace elements, contribute positively to the organic matter and carbon content of the soil, increase nutrient availability and strengthen soil anti-phytopathogenic potential. This study therefore focuses on *off-farm organic and biofertilisers* (OFBF) in Africa, and particularly in sub-Saharan Africa. The study specifically aims to address the current lack of information regarding the *off-farm* production, marketing and use of OFBF involving actors such as farmers' organisations, non-governmental organisations (NGOs), and small and medium-sized enterprises. This study also aims to contribute to the policy dialogue at continental, regional and country level by providing evidence for policy makers to identify potential investments in Africa to improve soil health through the production and use of OFBF.

However, it is self-evident that in addition to these "new types" of fertilisers, farmers need to adapt their cropping systems through practices such as crop rotation diversification, legume integration, soil cover, reduced tillage, recycling of on-farm solid and liquid organic fertilisers, agroforestry and alley cropping, quality ensured seeds and efficient water supply systems to enhance soil health and consequently production (e.g., Beillouin et al., 2021; ELD-Initiative & UNEP, 2015; HLPE, 2019; Kichamu-Wachira et al., 2021).

2.2 Objectives

This scoping study aimed to identify the potential of the off-farm production of organic fertilisers and biofertilisers in 12 selected countries in Africa. This 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 specific objectives of the study are to provide:

(1) an overview of the production and markets for commercial organic and biofertilisers in 12 selected African countries;
(2) information about the practices, economy, research, advisory services and legal conditions for the development of commercial organic and biofertilisers;
(3) orientation for different actors on how to further develop the commercial organic and biofertiliser production, application and efficiency in the future (timeframe 2030).

3 Methodology

3.1 Scope of the study

The study used a country case study approach, distributed across the sub-regions of Africa. Key informant interviews and existing literature were the main sources of information. As part of the information was not easy to collect, the level of detail was adapted and balanced between qualitative and quantitative information.

A system for rapid analysis of the 'ecosystem' of organic and biofertilisers (including challenges and opportunities) was conducted in 12 countries with a focus on new emerging actors including:

- A description of the current state of the production of organic and biofertilisers (in the 12 selected countries) with a qualitative analysis of the types of actors, the origin of organic matter (from farms, cultivated areas, waste along specific value chains, urban waste including human excreta), a rough estimate of the quantity produced (in comparison of chemical fertilisers) and prices.
- A description of the current state of the demand and use of organic and biofertilisers (in the 12 selected countries) with a qualitative analysis regarding the type of crops, type of farms, type of farming systems: organic, conventional, etc.
- An assessment of the potential supply of organic matter (in the 12 selected countries) to produce organic and biofertilisers (along value chains and urban area).
- The identification of challenges and opportunities to the scaling of the organic and biofertilisers sector in Africa, and (policy) recommendations to address these.

3.2 Geographical scope and country selection

In total 12 African countries were selected for the scoping study. The selection of countries was balanced between African sub-regions (North, East, West, South) and agro-ecological zones (arid to semi-arid, sub-humid to humid) (Figure 1). According to Schütz et al. (2018), the impact of biofertilisers on yields is most pronounced in dry climates. Therefore, agro-ecological zones were considered when selecting countries to allow for a balance between different climatic zones. In addition, the existing network of the expert group conducting the scoping study, was considered for country and case study selection, as well as current (research) activities and market developments in the respective countries.

Figure 1. Selected countries for the scoping study

3.3 Literature review

A desktop review was conducted using peer reviewed academic and grey literature, technical reports, websites, and publicly available databases such as FAOSTAT. The review includes the whole value chain of off-farm produced organic fertilisers and biofertilisers with a focus on the selected countries. Due to the limited scope of the assignment, the literature search was not conducted as a systematic review. Findings have been summarised in chapter 4.

3.4 Empirical research

Key informant interviews

The empirical part of this scoping study (see chapter 5) includes interviews with key informants to gather qualitative information. The questions for the interviews were reserved for information that does not allow for an initial quantification, as well as for assessing the history, development and current status, and expected future development(s) of off-farm produced organic fertilisers and biofertilisers.

The interview content follows a structured approach using key informant interviews, which include predefined questions, primarily in a 'closed' format, along with some 'open' questions. The reporting timeline for organic and biofertilisers covers the period from 2018 (pre-Covid-19) to the present, and, for older companies, extends into the future, with discussions encompassing perspectives up to the year 2030.

Key informant selection

Interview participants, comprising key actors or informants, were chosen through a process involving the outcomes of the literature review, the networks of the project team, and an extensive internet search. Organic and biofertilisers are analysed along their entire value chain. Therefore, target groups of key informants comprise producers, scientists, policy makers, farmers, farmers' organisations (Addae et al.), advisory services (AS), governmental (GO), inter- (IGO) and non-governmental organisations (NGO) (Table 1).

Table 1. Key informants in selected countries

Country	Key informants	Total
1. Cameroon	Producer (3), scientists (2), AS (1), NGO (1)	7
2. Côte d'Ivoire	Scientists (2)	2
3. Egypt	Producer (2), scientists (2), IGO (1)	5
4. Ethiopia	Producer (1), scientists (3), AS (1), NGO (1)	6
5. Ghana	Producer (5), scientists (1), policy maker (1), AS (3), NGO (1)	11
6. Kenya	Producer (2), scientists (2)	4
7. Malawi	Producer (4), scientists (1), policy maker (1), FO (1), NGO (1)	8
8. Rwanda	Producer (2), scientists (1), policy maker (1), AS (1), FO (1)	6
9. Senegal	Producer (2), AS (1), NGO (4)	7
10. South Africa	Producer (3), scientists (3), policy maker (1), farmer (1), FO (1), AS (1)	10
11. Uganda	Producer (3), scientists (3), policy maker (1), FO (2), NGO (1)	10
12. Zimbabwe	Producer (3), scientists (2), farmer (1), policy maker (1), GO (1)	9
Cross-country experts	Producer (1), scientists (4), AS (1)	6
Total		**89**

Data analysis

The analysis of the data adopts a semi-quantitative approach for the predefined questions. Conversely, for the open-ended questions, we employ predetermined categories in conjunction with a grounded theory approach. In the latter method, we conduct a secondary round of analysis incorporating additional dominant keywords as supplementary categories.

4 Literature review

4.1 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) (see Table 2). The recycling of such organic material can aid in closing (regional) nutrient cycles and thus (re-)turning nutrients to the agricultural system. The use and application of organic fertilisers to agricultural land comes with various advantages such as:

- positive effects on soils chemical, physical and biological quality parameters and hence soil fertility;
- replenishment of soil organic matter losses and thus maintaining soil organic matter levels with its positive effects on soil quality and fertility;
- addition of macro- and micronutrients in balanced quantities;
- slower release of nutrients over time, e.g., compared to synthetic N fertilisers, which generally reduces the risk of losses to the environment and respective negative consequences.

However, there may also be risks, such as an increased concentration of heavy metals, undesirable organic substances, residues such as antibiotics, pathogens from animal and human residues. These risks underline the need for specific treatment for certain products (WHO, 2006). Quality control of products must also be mandatory to meet the criteria of safety.

Nitrogen (N) availability of organic fertilisers in the first year can vary between 57, 53, 14, and 4% for fresh, dried, or composted poultry (*Gallus gallus domesticus*) manure, or composted cow (*Bos taurus*) manure compared to ammonium nitrate (Griffin & Honeycutt, 2000). The impact might increase in poor soils (Antoniadis et al., 2015). Liquid organic fertilisers show in general better nutrient uptake compared to animal solid manure or plant-based compost (Kasim et al., 2011; Martínez-Alcántara et al., 2016). (Bio) slurry has also an additional longer-term effect on crop yield. If we consider the optimisation potential for reducing nitrogen losses in the processing procedures, it is also conceivable that the processing products may have a comparable or even higher overall nitrogen efficiency compared to mineral fertilisers (Bosshard et al., 2008). However, under the current technological conditions in Africa, this does not appear to be a realistic possibility. On the other hand, solid fertilisers can function as slow flowing nutrient source, provides further macro- and micronutrients or contribute to soil carbon sequestration, i.e., the increase of humus with all its positive impacts on soil fertility and an environmentally friendly production (see Table 2).

Table 2. Description of organic fertiliser types

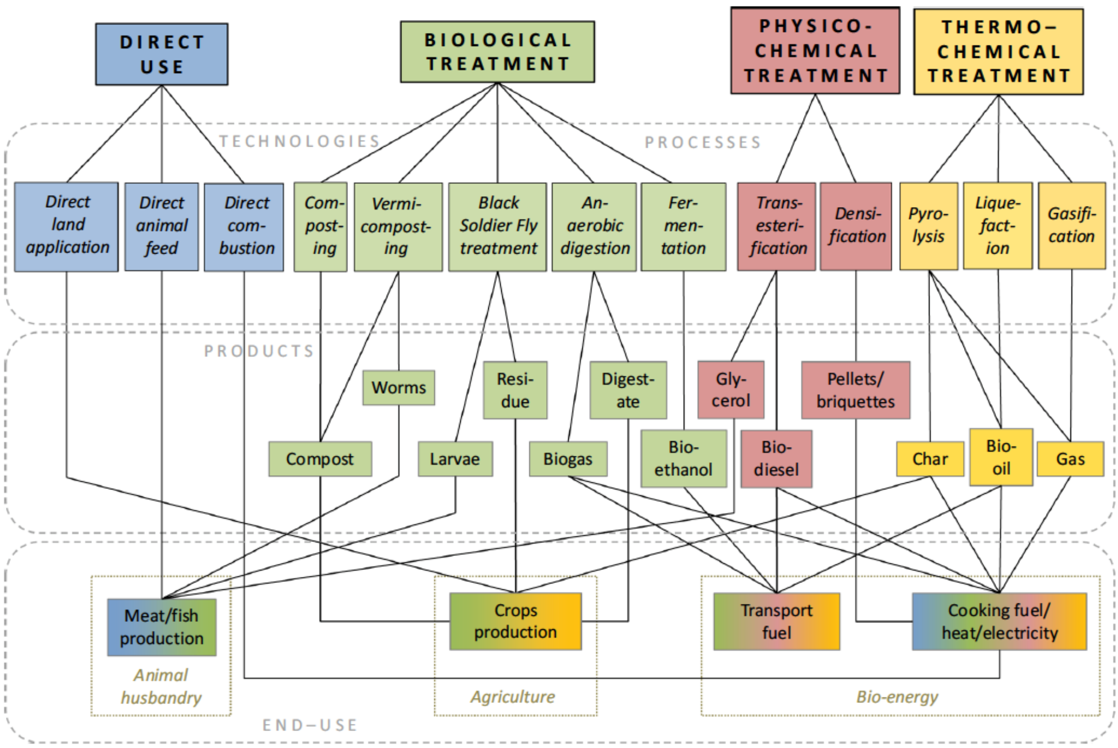
Organic fertiliser type	Description	Advantages	Literature sources
Agriculturally based products			
Farmyard manure (FYM)	Mixture of animal excrements and vegetable matter (animal bedding and feed material)	<u>Soil chemical quality:</u> ▪ can improve soil pH, micro-/macro-nutrient contents and availability ▪ soil organic carbon is likely to be higher than in farming systems without organic fertiliser application <u>Soil physical quality:</u> ▪ can improve soil texture, structure, porosity, hydraulic conductivity, bulk	Bai et al. (2018); (Blanchy et al., 2022; Carr et al., 2020); Crystal-Ornelas et al. (2021); (Fageria, 2012); Gattinger et al. (2012); Ghabbour et al. (2017); Henneron et al. (2015); Lori et al. (2022); Lori
Compost (CP)	Excrements from animal husbandry operations, including composted farmyard manure, household wastes, vegetable matter, tree bark which are composted or anaerobically fermented for biogas production		
Slurry (SL)	Liquid animal excrements, containing urine and excrements of		

Organic fertiliser type	Description	Advantages	Literature sources
	domestic animals and possibly water	density, aggregate stability and water holding capacity Soil biological quality: ▪ can improve abundance and diversity of soil macro- and micro fauna and flora	et al. (2017); Wong et al. (1999)
Biogas digestate	End product of anaerobically fermented organic materials from animal and plant origin		
Vermicompost (VC)	Vermicompost is the result of a decomposition process of organic material by different worm species		
Insect frass-substrate mixtures	Such mixtures consist of insect larvae faeces or dejecta, their feeding substrate and parts of farmed insects	▪ Adequate macro- and micro-nutrient delivery	Beesigamukama et al. (2022b)
Meals from animal origin	Meals from blood, hoof, horn, bone, meat, feather, hair, skin	▪ Can provide high amounts of nutrients, especially N	Garbowski et al. (2023); Möller (2018)
By-products of plant origin	By-products particularly from agricultural value chains and processing e.g., oilseed cake meal, cocoa and rice husks, malt culms, coffee pulps and husks, brewery residues; but also, from the wood industry e.g., sawdust and wood chips	▪ Depending on by-product used, often they are composted or processed to biochar ▪ generally improved organic matter and nutrient input	Babla et al. (2022); Garbowski et al. (2023); Le et al. (2022); Mishra et al. (2022)
Municipal and household residues and human excreta			
Sewage sludge	Originates from municipal sewage treatment plants that purify wastewater from households and industry	▪ Can provide various nutrients, especially N, P, K ▪ Pollutants pose usually a problem for application	Nunes et al. (2021)
Human excreta-based fertilisers	Such fertilisers are based on different forms of human excreta such as urine, dried faeces, composted faeces, faecal sludge, sewage, sewage sludge	▪ Can provide various nutrients, especially N, P, K ▪ improved soil physio-chemical properties and crop yield	Musazura and Odindo (2022)
Household waste	Plant-based household waste	▪ Usually composted or anaerobically fermented for biogas ▪ Organic matter and nutrient provision	Ducasse et al. (2022); O'Connor et al. (2021)
Municipal green waste/cuttings	Plant-based wastes		Tóthné Bogdányi et al. (2021)
Fishery and marine based origin			
Algae and algae products	Algae biomass is added to soils; in course of their degradation release nutrients to plants and add organic matter to soils	▪ Can improve organic matter content and soil pH, deliver plant nutrients, reduce C/N ratio	Ammar et al. (2022)
		▪ Improved P uptake efficiency	Atzori et al. (2020)
Fish meal	Made from whole fish, bycatch, or fish by-products	▪ N and P source, can improve nutrient uptake and efficiency and yields ▪ Stimulates microbial activity and root growth	Madende and Hayes (2020)
Combustion-based materials			

Organic fertiliser type	Description	Advantages	Literature sources
Wood ash	Consists of inorganic and organic residues after the combustion of wood	▪ Source of Ca, K, P, Mg ▪ Can potentially improve N+K availability and physicochemical properties of soils (in combination with charcoal)	Hamidi et al. (2021); Paramisparam et al. (2021)
Biochar	Biochar is a carbon-rich material that emerges from the pyrolysis of biomass such as agricultural or forestry wastes or residues, faecal sludge etc.	▪ Improves yield, root biomass, water use efficiency, microbial activity, soil organic carbon and greenhouse gas emissions	Schmidt et al. (2021)
		▪ Significantly reduces run-off and soil erosion	Gholamahmadi et al. (2023)
		▪ Improves yield and fertiliser use efficiency	Melo et al. (2022)

4.1.1 Organic fertiliser production and supply streams

There are various technologies and treatment options for organic waste that are specifically suitable for the recycling and production of organic fertilisers in local contexts in low- and middle-income countries (Lohri et al., 2017). Such technologies and treatments comprise: i) direct use, ii) biological-, iii) physical-chemical-, and iv) thermo-chemical treatment (Figure 2).



Source: Lohri et al. (2017)

Figure 2. Overview of organic waste treatment options, products and end-use

Current production quantities and percentage distribution among technologies of organic fertilisers produced off-farm is difficult to accurately determine in Africa, including in the countries of this scoping study, due to insufficient data availability and the lack of presence of producers on the internet. However, direct use and composting are possibly the currently most commonly applied treatments from the options presented in Figure 2, although there have been diverse efforts on the establishment of biogas production over the last two decades (Austin & Morris, 2012; Kalina et al., 2022). Nevertheless, the recycling of organic wastes to organic fertilisers such as compost or digestate is in its infancy or at pilot scale in most of the countries (Kalina et al., 2022; Silpa Kaza et al., 2018; Sekabira et al., 2022; Yeo et al., 2020). Policies in most countries either do not prioritise organic waste recycling or policies do not exist (see section 4.3), or incentives are not favourable for recycling e.g., payment per weight of waste delivered to landfill (Lenhart et al., 2022, p.63). South Africa may be an exception, as the country formulated a National Organic Waste Composting Strategy in 2013 (DEA, 2013), with some communities currently diverting up to 50% of organic waste from landfill (Chitaka & Schenck, 2023).

The AfricaFertiliser.org (AFO) initiative is monitoring and providing statistics mainly on the inorganic fertiliser markets in several countries in sub-Saharan Africa (excluding South Africa), but also provides statistics on commercial organic fertiliser production and related facilities (see Table 3).[3] Most of the production plants produce compost, but the initial substrate for the composting process is not specified. However, it can be assumed that, for most of those composting operations, the material is of locally sourced plant origin. Furthermore, it can be assumed that the composts are marketed locally, as transporting them over long distances would increase product costs and thus significantly reduce profitability or increase product prices, respectively, as reported in the key informant interviews (see section 5). From the key informant interviews and internet search, it is clear that there are many small initiatives that are not included in the AFO statistics.

Nigeria appears to have one of the highest organic fertiliser production capacities (500 000 t/year) compared to other countries in SSA. However, according to Dalberg (2023) the present demand is significantly lower in Nigeria than the production capacities. In the framework of the URBAN NAMA project[4], a composting capacity of 270 000 t/year was installed recently in Ethiopia (Mutukaa & Ermias, 2021).

According to Elfeki et al. (2017) about 68 composting facilities exist in Egypt for the processing of domestic organic wastes with a capacity of 10 t/hour, although used capacity by those plants was <40%. According to NEA (2023), a single large-scale commercial producer exists in Egypt with a yearly compost production of around 120 000 t.

The most advanced and developed production and market of off-farm produced organic fertilisers appears to be in South Africa[5] which could be explained by the fact that South Africa has one of the most developed economies in Africa. In 2011, 35% the total organic waste (garden and food waste) was recycled (DEA, 2013, p. 47), which has increased to 49% recycling rate in 2017 (DEFF, 2020, p. 12).[6]

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[3] www.africafertiliser.org

[4] https://www.undp.org/ethiopia/projects/urban-nama-compost

[5] https://www.mordorintelligence.com/industry-reports/africa-biological-organic-fertilisers-market; This can also be confirmed by searching the internet for commercial organic fertiliser companies in South Africa, which yields numerous results.

[6] However, numbers reported seem contradictory as it is also stated that out of the total waste of 55 million MT only 11% are diverted from landfill (DEFF, 2020, p. 11).

Table 3. Organic fertiliser production and/or production capacities

Country	Site of production	Specifications	Yearly production/ capacity* (tons)	Source
Benin	Allada	Compost plant	14 000*	IFDC (2023)
Burkina Faso	Ouagadougou	Compost plant	4 400*	IFDC (2023)
	Ouagadougou	Biodigester of 2 500 m^3	-	IFDC (2023)
	-	Solid organic fertiliser Liquid organic fertiliser	32 000 53 000 (litres)	PACTE (2023)
Burundi	Bujumbura	Organo-inorganic fertiliser	50 000	IFDC (2023)
Côte d'Ivoire	Adzopé	Compost plant	50 000*	IFDC (2023)
Egypt	Various	Compost production from domestic organic wastes	48 000	Elfeki et al. (2017)[7]
	-	Commercial compost production	120 000	NEA (2023)
Ethiopia	Various	Compost from MSW	270 000*	Mutukaa and Ermias (2021)
Ghana	Adjen Kotoku	Compost plant	11 000*	IFDC (2023)
	Ashaiman	Biodigester	88*	IFDC (2023)
Kenya	Various	Compost, biochar, vermicompost, Black soldier fly frass	20 000 (2023)	TECHNOSERVE (2023)
Mali	Bamako, Ségou	Organic compost	>54 000*	IFDC (2023)
Nigeria	Kaduna	Organic fertiliser (not specified)	14 000	IFDC (2023)
	Various	Compost	130 000 500 000*	Dalberg (2023)
Senegal	Dakar	n/a	5 000 n/a	IFDC (2023)
South Africa	Various	n/a	>300 000	Estimated from DEA (2013) & DEFF (2020)
Tanzania	Dar Es Salaam	n/a	n/a	IFDC (2023)
Uganda	Eastern Tororo	n/a	n/a	IFDC (2023)

*Yearly production capacity, own calculation with data from IFDC (2023): Daily production (calculated with 8 hours of operation) multiplied by 220 estimated working days per year.

Current status of off-farm produced organic fertilisers compared to inorganic fertilisers

Based on the key informant interviews conducted during the empirical inquiry, the current combined off-farm production volumes of organic fertilisers are estimated to be approximately 975 000 t/year across all 12 countries. The estimated quantities exhibit variations among countries, ranging from less than 5 000 t/year in Malawi, Cameroon and Rwanda to over 100 000 t/year in Egypt, Ghana and Ethiopia. In the selected countries included in this scoping study, smaller operations typically produce between 1 and a maximum of 50 t/year. Meanwhile, medium-sized operations produce quantities ranging from 2 000 to 3 000 t/year, while larger operations engage in industrial-scale production, exceeding 3 000 t/year and reaching up to 100 000 t/year. The latter category employs mechanisation and standardisation of operations (Table 4).

[7] The amount of compost produced is calculated with data provided by Elfeki et al. (2017). Calculation: Total capacity of 68 productions plants = 460 000 t/year with a utilisation of 35% of total capacity = 161 000 t/year. Hence, about 48 000 mt/year of compost are produced when assuming a mass reduction of compost calculated with -40% of mass reduction, -10% of coarser materials, -20% of residues, according to Cesaro et al. (2019).

At present, Africa produces approximately 30 million tons per year of inorganic fertilisers, which is double the amount consumed on the continent, with an average application rate of 22 kg per hectare. Interestingly, more than 90% of inorganic fertilisers used in Sub-Saharan Africa are imported, primarily from sources outside the continent.[8] Among the 12 countries included in this scoping study, only Egypt, South Africa, Senegal, and Zimbabwe possess their own production capacities for inorganic fertilisers. However, only Egypt achieves self-sufficiency in at least nitrogen and phosphate production. All other countries within the study rely on imports of inorganic fertilisers (Table 4).

Table 4. Estimated quantities of off-farm produced organic fertilisers in comparison to inorganic fertilisers

Country	Estimations by FAO*		Estimated from interviews
	Inorganic fertiliser production 2019 (t/year)*	Inorganic fertiliser import 2019 (t/year)*	Off-farm organic fertiliser production 2022 (t/year)**
1. Cameroon	0	92 000	<5 000
2. Côte d'Ivoire	0	211 000	≈ 60 000
3. Egypt	3 800 000	175 000	≈ 300 000
4. Ethiopia	0	426 000	<250 000
5. Ghana	0	209 000	≈ 130 000
6. Kenya	0	343 000	≈ 20 000
7. Malawi	0	118 000	<5 000
8. Rwanda	0	30 000	<5 000
9. Senegal	26 000	69 000	≈ 70 000
10. South Africa	332 000	935 000	>70 000
11. Uganda	0	23 000	<10 000
12. Zimbabwe	21 000	150 000	≈ 50 000
Total	≈ 4 179 000	≈ 2 781 000	≈ 975 000

Source: * FAOSTAT (2019) (Amount nutrient: N, P_2O_5, K_2O); **Estimated from interviews; all numbers are rounded

In this study, the off-farm production of organic fertilisers of the national producers who participated in this study and their estimated nutrient contribution is presently quite limited when compared to the imported quantities of inorganic fertilisers in the 12 study countries (Table 4). When considering the quantities reported by interviewees, it becomes evident that the nutrient contribution from off-farm produced organic fertilisers remains rather limited at present. This assessment takes into consideration that off-farm produced organic fertilisers generally contain an average of 1-3% of NPK, depending on the specific raw materials used and the production process. However, this is a qualitative assessment and may not be representative for each country.

In summary, it can be stated that only very few composting facilities serving whole towns or cities exist in Africa (Hanjra et al., 2018) or have been established but ceased to operate. For example, in Uganda about 12 municipal composting facilities had been established with a 70 t/day operational capacity through the Clean Development Mechanism of the World Bank (S Kaza et al., 2016). However, many of these -if not all- have ceased operations recently for various reasons (Interview UG-9)[9]. Similar situations are also reported for biogas projects (Kalina et al., 2022). Generally, important factors contributing to discontinued production can be the excessive dependence on technical solutions without conducting proper market analyses, evaluating transport costs, developing viable business

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[8] https://blogs.worldbank.org/voices/transformed-fertiliser-market-needed-response-food-crisis-africa

[9] https://www.pmldaily.com/news/2022/07/multimillion-mbale-garbage-compost-plant-abandoned-rotting-with-garbage.html

models, or establishing strategies for collaboration with public sector services, municipalities and farmers (Hanjra et al., 2018). Otoo and Drechsel (2018, p.7) report that challenges in financing, bureaucracy, unsupportive regulations, lacking viability of business plans to penetrate the reuse market, and slow approval processes are major bottlenecks in low- and middle-income countries for increased recycling and reuse of organic wastes. However, Otoo and Drechsel (2018) view the increasing urbanisation as an opportunity if the enabling environment is conducive and functional due to market proximity, reduced transport costs, higher purchasing power, and opportunities for export and attraction of private capital due to economies of scale. Furthermore, the authors argue that most resource recovery and reuse projects are viable if external environmental and human health costs are internalised.

The optimal integration of decentralised composting within the waste management frameworks of municipalities could be effectively achieved through an enhanced comprehension, among decision makers, of the multifaceted benefits encompassing compost utilisation, material flows, economic viability and environmental ramifications inherent to these facilities. Nonetheless, the existing body of evidence concerning the ecological gains, specifically within the context of material flow analysis (MFA) and the prospective mitigation of greenhouse gas emissions, remains limited (Yeo et al., 2020).

4.1.2 Organic fertiliser demand

The current demand for commercial organic fertilisers in Africa is challenging to determine due to the underdeveloped commercial organic fertiliser market and hence the lack of data. However, we may approach the topic by analysing the market for inorganic fertilisers and their use. The consumption of industrial NPK inorganic fertiliser in SSA has increased from about 9 kg/ha in 2010 to about 15 kg/ha in 2017 and was projected to have increased to 19 kg/ha by 2021 (AU, 2019). Most smallholder farmers still use less than 10 kg/ha (FAO, 2017), which may have fallen even further due to the recent inorganic fertiliser crisis and the decline in fertiliser imports (UN, 2022). Most African countries depend on inorganic fertiliser imports due to lacking low-cost materials, high capital requirements for investment in production facilities and low domestic demand (AU, 2019).

The benefit-cost ratio of inorganic fertiliser use is often not favourable for smallholder farmers due to high farmgate prices for fertilisers, low prices for agricultural products and high variability in annual agronomic efficiency (Sommer et al., 2013). High soil erosion rates, low soil pH and organic matter input and nutrient mining being key factors for low efficiency of applied mineral nutrient inputs.

Nevertheless, there is a significant demand for nutrient sources for agricultural production. Organic matter as carrier of nutrients and carbon are of specific interest due to widespread low fertile and degraded soils with a high demand of organic matter inputs to agricultural used soils, also to improve the efficiency of inorganic fertilisers (Sommer et al., 2013; Stewart et al., 2020). Given the current rise in inorganic fertiliser prices, demand for economically viable alternatives could also increase.

However, it is likely that the demand for commercial organic fertilisers may be impaired, as with inorganic fertilisers, if the former is economically not viable (Abaidoo et al., 2014; Danso et al., 2006; Kuwornu et al., 2017; Okuma & Isiorhovoja, 2017) - with transport costs in general and for farmers in particular also factored into the calculation (Danso et al., 2006; Liverpool-Tasie et al., 2017) - as the availability of cash and access to credit are important limiting factors for smallholder farmers (Chianu et al., 2012). However, this conclusion cannot be drawn unambiguously and may be confounded by other factors that account for the willingness to use and pay for organic fertilisers such as educational level, landownership, labour availability, knowledge of the added benefit of organic fertilisers for soil fertility, former experience with organic fertilisers and access to knowledgeable extension services (Abaidoo et al., 2014; Danso et al., 2006; Nigussie et al., 2015; Okuma & Isiorhovoja, 2017; Zondo & Baiyegunhi, 2021) as well as the year-to-year agronomic efficiency of the applied input.

Recent market studies come to different conclusions regarding the demand for organic fertilisers. A study by Dalberg (2023) concludes for Nigeria that the current demand of about 130 000 t/year is significantly below current estimated production capacities of about 500 000 t/year. A market assessment by TECHNOSERVE (2023) for Kenya shows that the two largest producers with a production of about 6 000 t/year in 2022 increase their output to about 15 000 t/year in 2023 due to an increased demand.

Another factor that can increase the demand for organic fertilisers is the market for certified organic products, specifically for export. The organic market has shown constant growth over the last decades (Willer et al., 2023). However, such organic fertiliser products need to comply with organic certification standards.

As with inorganic fertiliser, organic production facilities require investment in production plants, even though this investment requirement is likely to be lower than for inorganic fertiliser production facilities. Nevertheless, the economic production of an organic fertiliser can be a challenge, although this depends, for example, on the raw materials used (Danso et al., 2006) as well as other factors. Nevertheless, appropriate know-how and knowledge is required for the construction, operation and maintenance of such production plants.

The availability of organic raw materials on a plant and/or animal basis varies locally. Yet, the material itself can be inexpensive, but the collection and logistics of such materials can be an economic obstacle if they are, for example, not supplied in sufficiently large quantities or distances for collection are too large. However, subsidies and/or private-public partnerships may be considered as a solution (Danso et al., 2006; Otoo & Drechsel, 2018), although Silpa Kaza et al. (2018) report that such partnerships have been challenging in SSA with only few successes. Urban waste management is considered costly, and in many low-income countries, waste management competes with other expenditures such as clean water and other utilities (Silpa Kaza et al., 2018). Furthermore, insufficient infrastructure such as road networks and volatile energy provision may also pose a challenge for commercial organic fertiliser production and distribution.

4.1.3 Organic matter and nutrient recovery potential

There is great potential for a (re)circulation of resource flows globally, also described under the concept of circular (bio)economy (Haas et al., 2015; Kershaw et al., 2021). The recycling of organic wastes such as household, food and green wastes, human excreta, waste water, agro-processing wastes and the herein described organic matter and macro- and micronutrients can help closing urban-rural resource flows and recovery of these elements (Muscat et al., 2021). Drechsel et al. (2007) calculated a nutrient shift from rural to urban areas for four West African cities, where they found, for example, a nutrient depletion for nitrogen of 3 kg/capita/year in selected rural areas and a nitrogen accumulation in urban areas of about 4 kg/capita/year.

In addition to the recycling, products of added value such as food, animal feed, bioenergy, organic fertilisers etc. can be created, thus also increasing the resilience of the rural-urban food system nexus. At the same time externalities such as greenhouse gas emissions, environmental pollution and human health burdens can be reduced (Ferronato & Torretta, 2019). However, to create such closed loop systems, it needs systems-based approaches to waste management (Hanjra et al., 2018). Apart from the various challenges in low- and middle-income countries, opportunities exist as generally no “fixed” systems are yet established, e.g., a waste management system based on incineration.

Estimated figures suggest that the NPK contents from 100% of consumption-related food waste and 50% of other food waste are approximately equivalent to 4%, and human waste roughly 28%, of the current global consumption of nitrogen (N), phosphorus (P) and potassium (K), while the combined excrement of livestock (including cattle, chickens, pigs and sheep) contains twice the amount of nutrients found in the current usage of chemical fertilisers (Otoo & Drechsel, 2018, p. 6). In most contexts, if the nutrient recirculation system would be (re)structured toward agriculture appropriately, between 20 to 40% of the nutrient requirements of an agricultural system within a specific boundary could be covered (oral communication, Interview GI-1). However, depending on the context, higher nutrient (re)circulation rates may be possible even substituting inorganic fertilisers to a greater extent (Meinzinger et al., 2009; Obsa et al., 2022; Perez-Mercado et al., 2022).

Generally, non-source segregated waste composts tend to have nutrient contents below 1% for N, P, and K (e.g., Kabasiita et al., 2022; Roy et al., 2021; Sultana et al., 2021), and are thus considered soil amendments (EU, 2019a). 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., 2022a) or worms (vermicompost) (Mupambwa & Mnkeni, 2018), or when household or agricultural waste is co-composted with human waste (Castro-Herrera et al., 2022) resulting in approximately 1% or >1% of N, P, or K – however, the final nutrient contents depend on various factors.

In general, it can be stated that there is a significant untapped potential for organic waste recycling, much of which is currently unused (Lenhart et al., 2022; Sekabira et al., 2022).[10,11] Silpa Kaza et al. (2018, p. 76) estimated the production of solid waste at 174 million t/year in SSA (2016), out of which 43% are organic waste (food and green waste).[12] Moreover, in most African countries, organic waste recycling and reuse policies do not exist or are not a priority (Sekabira et al., 2022).[13]

For the provision of valid quantitative estimates of total organic wastes, it would need regional assessments using manpower on the ground and/or satellite assessments combined with ground truthing (see e.g., Engler et al., 2021; Pande et al., 2021). For the estimation of (local) nutrient recovery potentials, nutrient stock and (substance or material) flow analysis can be applied (Meinzinger et al., 2009; van der Wiel et al., 2019). As such detailed analysis is not feasible within the scope of this study, in the following sub-sections we provide some exemplary calculations on the nutrient recovery potential, using secondary data.

4.1.3.1 Food and green waste from households

Among the different organic wastes a significant potential of recirculation exists for organic fractions of municipal solid waste (MSW) including food and green wastes from households in Africa and Sub-Saharan Africa in specific (Silpa Kaza et al., 2018). About 43% of urban waste is collected in SSA, while 23% of waste ends up in landfill and 69% is openly dumped (Silpa Kaza et al., 2018). The current rates of food and green wastes (FGW) (2021) from urban households in selected countries range from 0.1 million t in Malawi to 6.7 million t in Egypt which could theoretically be converted to 0.05 and 2 million t of compost in Malawi and Egypt, respectively (Table 5). These values are likely to rise with projected increases in populations and urbanisation as total waste is expected to triple by 2050 in SSA (Silpa Kaza et al., 2018).

Assuming that the compost produced from solid, non-segregated municipal waste (see Table 5) contains low nutrient values (e.g., Kabasiita et al., 2022; Roy et al., 2021; Sultana et al., 2021), the compost produced from urban households' food and green waste across the 12 African countries of this study, could theoretically supply about 31 000 t/N/year, 31 000 t/P/year, and 62 000 t/K/year which, for example, could cover 4% of N, 22% of P, and 31% of K demand of the maize cultivated in the

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[10] https://news.scienceafrica.co.ke/why-africa-should-invest-in-insect-composted-organic-fertiliser/

[11] Lenhart et al. (2022) exemplary calculate waste generation, waste composition, recycling rates and organic waste management for Ethiopia.

[12] Kaza et al. (2018) calculated that 43% of total solid waste is composed of organic fractions. Several sources report organic waste constituting 50% to 80% of municipal solid waste (e.g., Miezah et al., 2015; Ricci-Jürgensen et al., 2020; R. Singh & Singh, 2022). However, for this report the lower (more conservative) values were used.

[13] The currently running project RUNRES (https://runres.ethz.ch/) works on rural and urban waste recycling solutions in Ethiopia, Ruanda, DRC, and South Africa.

year 2021. When conducting the same calculation but assuming that total food and green waste from urban and rural households is recycled, theoretically 71 000 t/year (10% of N), 71 000 t/year (51% of P), and 141 000 t/year (71% of K) could be supplied (Figure 3).[14]

Apart from the recycling and delivery of nutrients (inclusive micronutrients), the improvement of physical-chemical and biological properties of the soil through the addition of organic matter, delivered with the compost, are of further importance for the overall soil fertility, but also in improving the efficiency/uptake of inorganic fertilisers. Nevertheless, the agronomic and economic value of MSW-based compost need to be considered on a case by case basis according to the nutrient contents, quality of the organic material and related humus potential (Thuriès et al., 2019).

The theoretical potential supply of compost per hectare of arable land ranges from 1.4 and 0.6 t/ha/year for Egypt to 0.1 and 0.01 t/ha/year for Malawi when assuming the potential total supply from urban and rural food and green waste (FGW) conversion and the conversion from FGW from only urban areas, respectively (Table 6). Note that alternative sources like human waste are not included here.

Table 5. Food and green waste from households and potential amounts of compost in selected countries (2021)

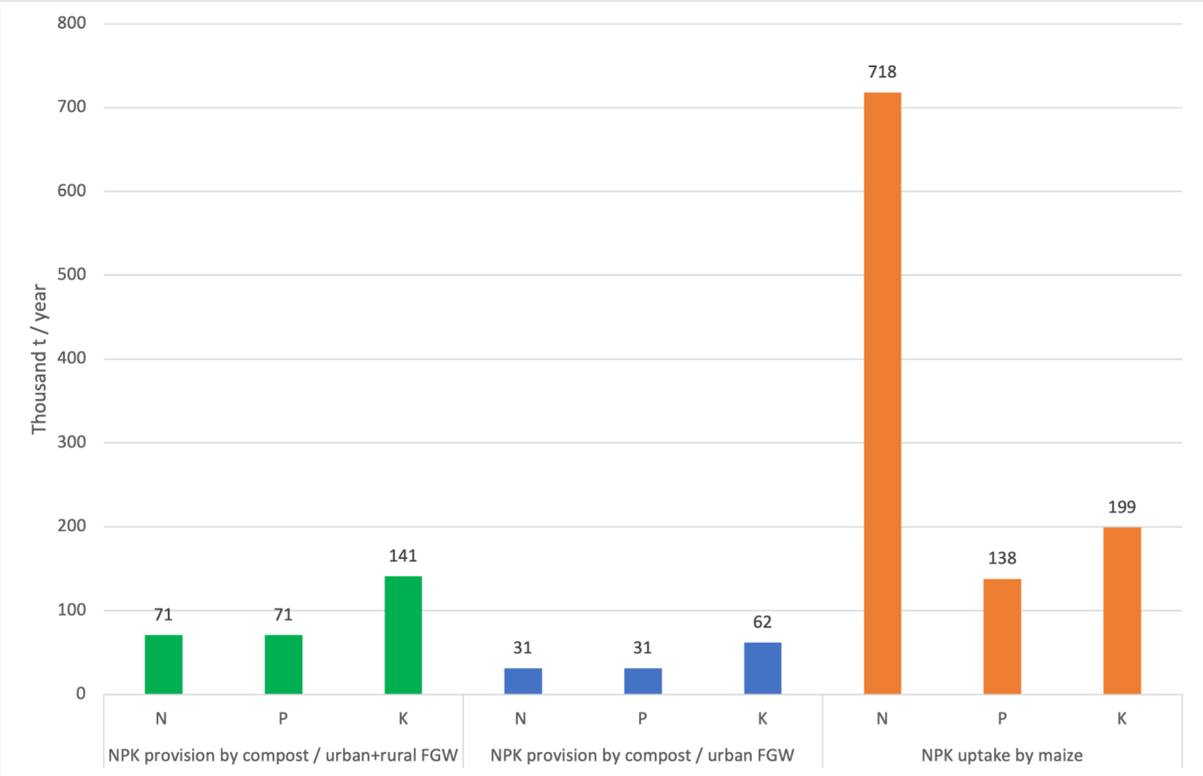
Country	Total food & green waste (FGW) from urban and rural households	Potential amount of compost from urban and rural FGW	FGW from urban households	Potential amount of compost from urban households FGW
	Million t/year			
1. Cameroon	1.8	0.5	1.0	0.3
2. Côte d'Ivoire	2.8	0.8	1.4	0.4
3. Egypt	15.5	4.6	6.7	2.0
4. Ethiopia	3.4	1	0.7	0.2
5. Ghana	2.6	0.8	1.5	0.5
6. Kenya	3.2	1	0.9	0.3
7. Malawi	0.7	0.2	0.1	0.05
8. Rwanda	2.1	0.6	0.4	0.1
9. Senegal	1.2	0.4	0.6	0.2
10. South Africa	9.1	2.7	6.2	2.0
11. Uganda	4	1.2	1.0	0.3
12. Zimbabwe	0.8	0.2	0.3	0.1

Source: own calculation, population data from World Bank[15]; waste data from Silpa Kaza et al. (2018), who indicate the food and green waste fraction as 43% of total waste generated per capita; total mass reduction of compost calculated with minus 70% (-40% of mass reduction, -10% of coarser materials, -20% of residues), according to Cesaro et al. (2019).

[14] This rough estimation shall merely show the theoretical potential. Maize has been used as an example as it is one of the most important staple crops on the African continent. The actual potential certainly depends on various factors such as compost quality (nutrient contents) which highly depends on source separation and compost process management. In addition, the integration of other technologies for waste treatment, e.g., due to high moisture contents of the municipal solid wastes, may make anaerobic digestion another possible option. Furthermore, the maize growing areas may not necessarily be near the waste generating urban areas, henceforth economic viability of transport would need to be considered in such a calculation - among others.

[15] https://data.worldbank.org/indicator/SP.POP.TOTL?name_desc=false

Figure 3. Potential provision of NPK by compost from urban and urban plus rural households' food and green waste (FGW) compared to the NPK uptake by maize cultivated across 12 African countries in 2021



Source: Own calculation; population data from World Bank[16]; waste data from Silpa Kaza et al. (2018), who indicate the food and green waste fraction as 43% of total waste generated per capita; total mass reduction of compost calculated with minus 70% (-40% of mass reduction, -10% of coarser materials, -20% of residues), according to Cesaro et al. (2019); total maize yield across 12 African countries included in this scoping study (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 N (13 kg/t), P (2.5 kg/t), K (3.6 kg/t) (Setiyono et al., 2010).

Table 6. Arable land and potential compost supply from urban and rural households' food and green waste

Country	Arable land (2020)	Potential compost supply from urban and rural FGW	Potential compost supply from urban FGW only
	million ha	t/ha/year	t/ha/year
1. Cameroon	6.2	0.1	0.05
2. Côte d'Ivoire	3.5	0.2	0.11
3. Egypt	3.4	1.4	0.59
4. Ethiopia	16.2	0.1	0.01
5. Ghana	2.5	0.3	0.20
6. Kenya	5.8	0.2	0.05
7. Malawi	3.6	0.1	0.01
8. Rwanda	1.2	0.5	0.08
9. Senegal	3.2	0.1	0.06
10. South Africa	12	0.2	0.17
11. Uganda	6.9	0.2	0.04
12. Zimbabwe	4	0.1	0.03

Source: Own calculation, data for arable land from FAOSTAT; data on compost see Table 5

[16] https://data.worldbank.org/indicator/SP.POP.TOTL?name_desc=false

4.1.3.2 Agricultural by-products

Agricultural by-products or wastes generated off-farm, comprise organic wastes from fruit/vegetable and animal markets, food processing industries such as slaughterhouses, fruit/vegetable processing, cereal flour and oil processing, breweries, etc. Agricultural by-products do not include wastes that are generated on-farm and remain on-farm. These wastes should be optimally recycled on-farm. However, some studies also calculate the potential of total agricultural by-products or wastes for potential recycling, for example, in case where residues are burned (see MoFA, 2023).

To our knowledge no or only few general quantifications or estimations exist for agricultural by-products or wastes that are produced off-farm in the countries of this scoping study. Many studies usually report on total available crop residues/wastes, recoverable crop residues or potentially available manure from livestock usually as potential biomass source for anaerobic digestion or energy potential (e.g., Mohammed et al., 2013; Nelson et al., 2021) (see Table 7). However, for a commercialised production of organic fertilisers or soil amendments, organic wastes should be used from off-farm processing operations but not converted away from farms as farms should optimally recirculate their "waste" biomass on-farm.

For example, for Ethiopia, a study by FAO estimated unused by-products at about one megaton/year (dry matter) (FAO, 2018). Assuming a nutrient content range of 1% to 2% (Green, 2015; Musa et al., 2020; Roy et al., 2021), depending on waste type and treatment process, this translates to an estimated 10 000 to 20 000 tons of nitrogen, phosphorus, and potassium. This nutrient reserve could potentially support cultivation across approximately 200 000 to 400 000 hectares with a demand of 50kg N per hectare, covering 1 to 2% of Ethiopia's cropland requirements.

We summarise available estimations from scientific and grey literature, usually for selected crops per country and where available differentiated in burnt, unused or wastes/by-products from processing (see Table 7).

Table 7. Potential amounts of agricultural by-products and crop residues in selected countries[17]

Country	Waste types	Amounts (million t/year)	Fresh matter / Dry matter	Source
1. Cameroon	Crop residues	≈ 42.0	FM	Mboumboue and Njomo (2018)
	Perennial plantation crop residues	≈ 3.2	FM	
	Animal waste	≈ 4.7	DM	
2. Côte d'Ivoire	Crop residues[f]	≈ 13.0	n/a	Zanli et al. (2022)
3. Egypt	Unused crop residues Cattle and poultry manure	≈ 24.3 ≈ 13.3	n/a n/a	Elfeki et al. (2017)
	Unused or burnt crop residues[s] Vegetable, fruit, sugar cane, sugar beet residues	≈ 15.2 ≈ 10.6	DM FM	MoFA (2023)
4. Ethiopia	Cereal, pulse, oil milling by-products Food industry by-products (incl. sugar industry) Fruit processing by-products Slaughterhouse and fishery by-products	≈ 2.3 ≈ 3.1 ≈ 1.5 ≈ 0.5	DM DM DM DM	FAO (2018)

[17] The listed waste types and the therein contained assessed crops and/or animal type may be incomplete. The potential amounts are of theoretical nature as there is an uncertainty in the numbers reported in the literature (e.g., year of survey, conversion rates used) and it is unclear for most of the residues how much of the residues are currently already used (e.g., as feed or for energy purposes etc.). A more rigorous assessment would be needed per country to draw conclusions.

Country	Waste types	Amounts (million t/year)	Fresh matter / Dry matter	Source
	Estimated unused by-products (from the above)	≈ 1.0	DM	
	Recoverable crop residues	≈ 42 - 72	DM	Tolessa (2023)
5. Ghana	Animal dung	≈ 3.4	DM	Mohammed et al. (2013)
	Fruit residues[a]	≈ 1.0	DM	
	Crop residues[b]	≈ 5.7	DM	
	Crop residues[c]	≈ 37.0	n/a	Nelson et al. (2021)
6. Kenya	Crop residues[i] Animal wastes[j]	≈ 9.0 ≈ 5.0	DM DM	Welfle et al. (2020)
	Unused banana residues Unused potato residues	≈ 4.4 ≈ 0.23	FM FM	Dulo et al. (2022)
7. Malawi	Crop residues	≈ 9.0	n/a	Gondwe et al. (2017)
8. Rwanda	Crop processing residues[o]	≈ 0.4	DM	Johansson Carne (2022)
	Crop residues[p]	≈ 7.0	n/a	Eliasson and Carlsson (2020)
9. Senegal	Crop residues[e]	≈ 1.2	FM/DM	Mbodji et al. (2022)
10. South Africa	Abattoir residues	≈ 0.3	FM	Mugodo et al. (2017)
	Food processing residues[d]	≈ 0.8	FM	
	Burnt sugar cane residues	≈ 1.4	DM	Smithers (2014)
	Wastes from malting barley Fruit residues Maize stover, wheat straw (potentially usable)	≈ 0.6 ≈ 0.2 ≈ 5.8	FM n/a DM	Oelofse and Muswema (2020)
11. Uganda	Crop residues[g] (Eastern Uganda)	≈ 7 – 8.2	DM	Roobroeck et al. (2019)
	Crop residues[h]	≈ 19	n/a	Okello et al. (2013)
12. Zimbabwe	Crop residues[q] (potentially usable) Animal wastes[r] (potentially usable)	≈ 1.8 ≈ 1.6	n/a n/a	Maqhuzu et al. (2017)

[a] Oranges, bananas, lemons, limes, mangoes, guavas, avocados, plantains, pineapples; [b] maize, sorghum, millet, oil palm fruit, paddy rice, sugar cane, cocoa beans; [c] Cassava, cocoa, coconut, coffee, groundnut, maize, millet, oil palm fruit, plantain, paddy rice, sorghum, sugarcane, sweet potatoes, cocoyam, yam; [d] clear beer, wineries, sugar mills; [e] Groundnut shells, palm kernel shells, corn cobs, rice husks, dry bulrush; [f] Cassava stalks, sugarcane tops/leaves, sugarcane bagasse, paddy rice straw and husks, oil palm (empty bunches, press fibres, fronds), plantains (shell, stipe/false trunk, leaves), banana (empty fruit bunches, stipe/false trunk, leaves), cocoa bean pods, maize (cob, husks, stover), cotton seed (hull/shell, stalk), coconut (fonds, husk, shell), coffee husks, cashew nuts shell; [g] Straw and Shank/Sheff/Shell: Maize, sorghum, rice, millet, groundnut; [h] Maize, millet, sorghum, rice, beans, groundnuts, banana, cassava, sweet potato, pigeon pea, soybean, sesame, sugar, coffee, cotton (stalks, cobs, straws, husks, trash, shells, peels, stems, vines, bagasse); [i] Maize (stalks, husks, cobs), cassava (stalk, peelings), sugarcane (residue), potatoes (stems, leaves), bananas (residues), sweet potatoes (stems, leaves); [j] Cattle, pigs, poultry, sheep, goat; [k] Bananas, mangoes, guavas, tomatoes, avocado, water melon, papaya, citrus fruits (peels, stock, leaves, pomace, stones coats, pulp, bud, stems); [l] Potatoes, cassava, sweet potatoes, beans, cabbages, spinach, pigeon pea, onion, green bean (peels, hulls, husks, trim losses, broken grain); [m] Coconuts, macadamia, groundnuts, cashew, bambara, areca, nutmeg, chestnut, walnut, hazelnut (shells, husks, kernels); [o] Cassava peels, coffee pulp and husk, maize cobs, rice husk, sugarcane bagasse; [p] Maize, sorghum, paddy rice, cassava, sweet potato, banana, beans; [q] Cereals, citrus fruit, coarse grain, fruit excl. melons, pulses, roots and tubers, tree nuts, vegetables and melons, oilcakes, sugarcane; [r] Cattle, poultry, goats, horses, mules, pigs, sheep; [s] wheat straw, other straws, maize stover, rice straw, sorghum stover, corn cobs, rice hulls, sugar cane bagasse, sugar cane leaves, cotton stalks, rice bran

4.1.3.3 Human waste

Human waste refers to the human excreta including liquid (urine), solid and semi-solid materials that are eliminated from the human body through the process of digestion and metabolism. It consists of undigested food, bacteria, water and various waste products that the body cannot use. Human excreta contain organic matter and nutrients, while urine contains significant more nutrients per unit volume compared to faeces (Ganesapillai et al., 2015).

Opportunities and challenges

Human waste contains valuable nutrients like nitrogen, phosphorus and potassium, which are essential for agriculture. Recycling excreta can help replenish soil fertility and reduce the need for chemical fertilisers, leading to improved agricultural productivity (Cofie et al., 2014; Krause et al., 2016; Meinzinger et al., 2009; Perez-Mercado et al., 2022; Wilde et al., 2022). Human waste contains significant amounts of nutrients which, if captured, could contribute to about 28% of the world's current NPK consumption in agriculture (Otoo & Drechsel, 2018, p. 6) or 22% of global phosphorus demand (Mihelcic et al., 2011).

When assessing the theoretical nutrient potential present in human waste across the 12 African countries, the estimated nutrient quantities sum up to approximately 3.4 million t/year (2.5 million t/year of nitrogen, 259 000 t/year of phosphorus and 548 000 t/year of potassium; with 85% (N), 60% (P) and 70% (K) originating from urine). In comparison, the total import and agricultural consumption of inorganic fertilisers (NPK) within the same 12 countries during the year 2019, stood at 2.8 and 4.4 million t, respectively (see Table 8). In theory, the cumulative human waste generated in these 12 countries comprises roughly 77% of the current NPK nutrients consumed in agriculture within the same 12 countries. Theoretical potential for replacing imports and contribution to consumption of inorganic fertilisers in agriculture within individual countries of this scoping study is presented in Table 8. As an example, in Uganda, there exists the theoretical possibility of replacing ten times the current quantity of inorganic fertilisers imported and consumed in agriculture through the increased recycling of human waste. It is important to note that dry matter and nutrient values can vary significantly depending on dietary habits, hydration levels and other individual factors (Rose et al., 2015).

Table 8. Inorganic fertiliser imports and use vs. potential amounts of NPK in human waste in 12 African countries

Country	Inorganic fertiliser (t/year)*		Human excreta (faeces and urine) (t/year)**
	Total inorganic fertiliser import (2019)	Total inorganic fertiliser consumption (2019)	Total NPK (2022)
1. Cameroon	92 000	83 000	167 626
2. Côte d'Ivoire	211 000	184 000	169 349
3. Egypt	175 000	1 600 000	673 386
4. Ethiopia	426 000	517 000	741 307
5. Ghana	209 000	187 000	202 351
6. Kenya	343 000	332 000	282 598
7. Malawi	118 000	117 000	98 568
8. Rwanda	30 000	30 000	82 966
9. Senegal	69 000	69 000	104 012
10. South Africa	935 000	1 100 000	366 036
11. Uganda	23 000	23 000	326 675
12. Zimbabwe	150 000	133 000	122 581
Total (rounded)	≈ 2 800 000	≈ 4 400 000	≈ 3 400 000

Source: * FAOSTAT, total agricultural use and total imports of chemical fertilisers (Amount nutrient: N, P_2O_5, K_2O) in 2019 in the 12 African countries **Own calculation with population data from World Bank[18]; 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

[18] https://data.worldbank.org/indicator/SP.POP.TOTL?name_desc=false

Many regions in Africa lack proper sanitation facilities, leading to open defecation and contamination of water sources (e.g., Meinzinger et al., 2009). Even in cases where pit latrines or septic tanks are utilised, proper disposal remains inadequate and recycling is seldom practiced (Cofie et al., 2016). Recycling excreta through safe and controlled processes can contribute to improved sanitation and reduced waterborne diseases. Non-sewered faecal sludge from on-site facilities such as septic tanks and pit latrines as common in many low-income countries is favourable to sewage sludge due to low risks of chemical contamination (Nikiema & Cofie, 2014). Through composting or co-digestion a safe product for the application in agriculture can be derived (Castro-Herrera et al., 2022).

The co-composting of organic materials with human waste represents a cost-effective and low-tech approach for treating faecal sludge derived from on-site sanitation systems. This process enables the recovery of nutrients, enhances waste hygiene, and results in the creation of value-added products such as increased nutrient contents of composts for agriculture (Cofie et al., 2016; Meinzinger et al., 2009).

Anaerobic digestion of human waste (combined with food waste) can produce biogas, which can be used for cooking, heating, or electricity generation (Diener et al., 2014). This can help address energy poverty in certain regions. The ultimate utilisation and economic feasibility of treating and repurposing faecal sludge are contingent upon the specific local context. This can encompass a spectrum of possibilities, including its utilisation as a soil conditioner, as fuel for combustion or biogas source, its potential as a protein-rich animal feed derived from sludge processing, and even its incorporation as a constituent within building materials (Diener et al., 2014).

In many low- and middle-income countries the sanitation systems are not yet developed. Therefore, these areas may hold substantial potential for the adoption of urine separation and reuse, as well as composting or biosolid recovery, owing to the synergistic integration of innovative technologies with increasing advancements in sanitation coverage. In addition, the development of systems for recycling human waste could create employment opportunities in waste management, technology development and agricultural sectors.

The reuse of waste, and human waste specifically, can face social and cultural obstacles. The promotion of resource recovery from alternatives to pit latrines such as Ecological sanitation (Ecosan) have seen a limited uptake in various regions (Banamwana et al., 2022a; Banamwana et al., 2022b; Chunga et al., 2016). The various intricate factors affecting the adoption of Ecosan technology include the absence of sanitation policies, aversion towards utilising Ecosan by-products, limited technical support and concerns regarding safety. Furthermore, inadequate practical knowledge, illiteracy, substantial capital costs, repulsion towards human excreta, religious taboos and cultural limitations were identified as additional obstacles (Banamwana et al., 2022a). However, other authors such as Simha et al. (2021) conclude that consumer acceptance is not viewed a major social barrier for the recycling and reuse of human urine in agriculture. Notably, urine's substantial nutrient contribution underscores its promising potential, yet formidable technical obstacles continue to endure (Harder et al., 2019).

According to Cofie et al. (2014) major challenges for the recycling and reuse of human waste constitute sanitation facility types prevalent in developing nations, characteristics of faecal matter, predominant treatment technologies primarily oriented towards waste disposal rather than reutilisation, institutional and market influences, alongside adverse perceptions regarding the utilisation of excreta in agricultural practices.

Last but not least, a major obstacle impeding the broad-scale commercialisation of fertilisers derived from human excreta pertains to often unclear regulations. For instance, the utilisation of human waste is often inadequately defined or left ambiguous. Consequently, a grey area emerges, which exporting companies, in particular, aim to sidestep to prevent conflicts with certification schemes such as Global GAP (Moya et al., 2019).

In summary, recycling human waste presents a promising way to address sanitation and agricultural challenges and is hence also well aligning 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.

4.2 Biofertilisers

The terms “biofertilisers” and “biostimulants” are often used interchangeably in the (scientific) literature as currently no common definition for biofertilisers versus biostimulants exists. However, the term plant biostimulants has been defined by the EU (2019b, Article 47a): 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.”

Furthermore, EU (2019b) and du Jardin (2015) differentiate between microbial plant biostimulants and non-microbial plant biostimulants. Various authors use the term “biofertiliser” for microbial plant biostimulants such as arbuscular mycorrhizal fungi (AMF) and non-arbuscular mycorrhizal fungi (non-AMF) as well as beneficial bacteria, especially mutualistic, rhizospheric[19] plant growth promoting rhizobacteria (PGPR) such as phosphate (P) and potassium (K) solubilising bacteria and nitrogen-fixing bacteria (e.g., *Azotobacter, Azospirillum, Cyanobacteria/blue-green algae*), and nitrogen-fixing mutualistic endosymbionts of the type *Rhizobium* (e.g., Bamdad et al., 2022; du Jardin, 2015; Schütz et al., 2018). du Jardin (2015) proposes to use the term biofertilisers as a subcategory of biostimulants.[20]

4.2.1 Bacteria-based biofertilisers

Beneficial bacteria can occur “free-living” in the soil medium or in the rhizosphere, surrounding the plants roots, or they can be directly associated with the plants as endosymbionts[21] forming a direct symbiosis with a plant (du Jardin, 2015; R. K. Singh et al., 2020). The benefits provided to plants range from the supply of nutrients, increase in nutrient use efficiency, induction of disease resistance, enhancement of abiotic stress tolerance and the modulation of morphogenesis by plant growth regulators (Bamdad et al., 2022; du Jardin, 2015; Schütz et al., 2018) (see Table 9). Of particular interest are the supply and more efficient use of nutrients through the biological N_2-fixation (BNF) mechanism by nitrogen-fixing bacteria as well as P and K-solubilising bacteria and thus improved access to P and K from organic fertilisers and the soils nutrient stocks. The latter is of particular interest due to the increasing P demand, limited phosphorus reserves and the low availability of P specifically in soils with a low pH, which is particularly the case for many weathered tropical soils (Bejarano Herrera et al., 2016). Furthermore, merely about 15-30% of P applied to crops are eventually taken up by the crops during the growth cycle (Bejarano Herrera et al., 2016).

The evidence of positive agronomic effects of bacteria mixtures such as effective microorganisms (EM) is mixed or inconclusive with highly variable results across publications (Abdelkhalik et al., 2023; Mayer et al., 2010; Quiroz & Céspedes, 2019; Shin et al., 2017).

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[19] The rhizosphere is the layer of soil surrounding the roots that is influenced by them, e.g., by root exudates.

[20] Within this scoping study we will focus on microbial plant biostimulants und use the term “microorganism-based biofertilisers” or “biofertilisers” (see also glossary).

[21] “Endosymbionts are organisms that form a symbiotic relationship with another cell or organism. Some endosymbionts can be found either inside cells (intracellular), while others attach to the surface of cells (extracellular).” (Casem, 2016)

4.2.2 Fungal-based biofertilisers

Beneficial fungi comprise arbuscular mycorrhizal fungi (AMF) and non-AMF. AMF form a symbiotic relationship with plants, connect to their roots and form a system of branched structures in the plant cells. Thus, the AMF improves the supply of water and nutrients to the host plant and receives up to 20% of plant-fixed carbon (Parniske, 2008). AMF furthermore improve production of enzymes by plants and provide abiotic and biotic stress protection (Bamdad et al., 2022; du Jardin, 2015). Schütz et al. (2018) provided evidence by conducting a global meta-analysis on yield improvements of about 20% by applying AMF to crops. Such yield improvements were most pronounced in dry and tropical climates.

There are also non-AMF such as *Trichoderma spp*. (*Ascomycota*) and *Sebacinales* (*Basidiomycota*) that are not associated with a host plant throughout their life cycle, but also indicating even better performances in P/K-solubilisation, plant growth and yield compared to some beneficial bacteria (Bamdad et al., 2022). These non-AMF species have the advantage of being easier to propagate in vitro than AMF, where propagation for large-scale applications remains difficult (du Jardin, 2015).

Furthermore, the combination of inoculation of beneficial fungi and bacteria, the combination of nitrogen-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).

Table 9. Description of biofertiliser types[22]

Biofertiliser type		Advantages	Literature source
Beneficial bacteria-based			
Nitrogen fixer	Rhizobium Azotobacter Azospirillum	▪ Improve soil fertility, incl. N supply, soil aggregation ▪ Improve plant growth and yield ▪ Induce plant defence against bacterial, fungal and viral pathogens	Ahemad and Kibret (2014); Schütz et al. (2018); Thomas and Singh (2019); Vacheron et al. (2013)
		▪ N-fixing potential: 20-40 kg/ha/year (Azotobacter) 20-160 kg/ha/year (Azospirillum) 50-300 kg/ha/year (Rhizobium)	Kumar et al. (2022)
		▪ 70-250 kg/ha/year (Rhizobium)	Alves et al. (2003)
	Cyanobacteria (Blue-green algae)	▪ Improve crop growth, yield, soil formation, soil surface stabilisation, crust formation, enhance soil organic carbon, foster soil microbiota	Ammar et al. (2022)
		▪ N-fixing potential: 20-40 kg/ha/year	Kumar et al. (2022)
Phosphate and Potassium solubilising bacteria	e.g., Enterobacter sp.; Bacillus sp.	▪ Solubilise and make P available ▪ Significant improvements in plant growth, yield and P/K uptake (Limited yield effect when soil P is low)	Bamdad et al. (2022); Schütz et al. (2018)
N fixers and P solubilisers		▪ Positive effects are higher when N-fixers and P-solubilisers are combined	Schütz et al. (2018)
Beneficial fungal-based			

[22] The description of biofertilisers and respective microorganisms shall provide a rough overview, but can be considered incomplete and could be further differentiated.

Biofertiliser type		Advantages	Literature source
Arbuscular mycorrhizal fungi (AMF)	e.g., Glomus sp.	▪ Improved nutrition efficiency for macro- and micronutrients, water balance, and abiotic and biotic stress protection ▪ Yield improvements (specifically in dry and tropical climates)	du Jardin (2015); Schütz et al. (2018)
Non-arbuscular mycorrhizal fungi (non-AMF)	e.g., Aspergillus niger; Trichoderma sp.	▪ Improved nutrient uptake by crops (even better compared to bacteria) ▪ Biocontrol function ▪ Increased nutrient use efficiency, abiotic stress tolerance, organ growth and morphogenesis	Bamdad et al. (2022); du Jardin (2015)

4.2.3 Biofertiliser application and carrier materials

Biofertilisers can be applied to seed or soil and are applicable for various crop types (cereals, pulses, oilseeds, forage legumes, fruits and others). Carrier materials for biofertilisers can be in solid forms such as tablets, powders, granules – which can be of organic, inorganic or synthetic origin - or in liquid forms such as water, water-in-oil emulsions or organic oils (Raimi et al., 2021). Raw materials for carriers can range from peat and bagasse, to sterilised oxalic acid industrial waste, fly ash, charcoal, composted sawdust, kaolin, vermiculite, diatoms and wheat bran (Raimi et al., 2021; Thomas & Singh, 2019). Microbial contaminants are common issues influencing the quality of biofertilisers; hence the properties of carrier materials need to be well maintained to secure shelf-life and ultimately product quality.

4.2.4 Biofertiliser production and supply streams

The current production and use of biofertilisers in Africa is still low, although the first applications of biofertilisers in Africa such as AMF and especially nitrogen-fixing mutualistic endosymbionts such as *Rhizobium* date back decades (Raimi et al., 2021).[23] North America, followed by Europe are the largest markets for biofertilisers with about 50% of global revenue (2012), followed by Asia-Pacific and South America, while the global market share of biofertilisers in Africa is estimated at about 5% (BioFit, 2015; Raimi et al., 2021).[24]

Of the global production of biofertilisers, products with nitrogen-fixing properties account for about 80%, those with P-solubilising for 14% and others account for 6% (BioFit, 2015), hence this is expected to be more or less true for the African market as well.

Raimi et al. (2021) and Raimi et al. (2017) provide an overview of current inoculant production and associated (research) institutions, related challenges and proposed solutions: The most advanced market in Africa for biofertilisers and producers can be found in South Africa. Apart from South Africa, Kenya, Malawi and Zimbabwe, as well as Egypt in North Africa, appear to have some "advanced" level of production and usage (mainly rhizobia-based products), while Central and West Africa are the least

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[23] The UNESCO and others initiated the promotion of scientific cooperation among the Microbiological Resource Centres (MIRCENs) for biofertiliser production and other institutions in the 1980s (Raimi et al., 2021). Since 2013, the N2Africa project (https://n2africa.org/), a large scale, science-based "research-in-development" project, is active to explore and promote the use of legumes and identify new elite strains of *Rhizobium* and make them available to inoculant producers.

[24] 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).

developed countries in terms of production and usage. However, most of the biofertilisers marketed in SSA are imported and not adapted to local conditions (Masso et al., 2015).

4.2.5 Biofertiliser demand

In general, the market for biofertilisers is growing worldwide, with one of the main drivers being the need for more environmental friendly technologies and hence the aim to decrease agriculture's environmental footprint (e.g., du Jardin, 2015; Raimi et al., 2021).

The growth of the market for certified organic products worldwide is another driver as such products are promoted for organic farming (du Jardin, 2015). Several biocontrol agents and biostimulants are for example included in the list of authorised materials and substances for organic production (Regulation (EU) 2018/848). In 2019 the European Parliament laid down rules on the market of EU fertilising products (EU, 2019b), which came into force in 2021, thus increasing market transparency and possibly demand, also beyond the European market.[25] However, there is a need for a worldwide harmonised assessment of biofertilisers to increase efficacy and transparency (Feldmann et al., 2022).

Masso et al. (2013) reported that the absence of regulatory frameworks and thus missing assessment of biofertilisers leads to lacking quality and efficacy of related products in SSA. They found that 90% of tested products did not match in their composition with the product label or label claims. Similar quality constraints are reported by Herrmann et al. (2015) and Faye et al. (2013) for bacterial and arbuscular mycorrhizal fungi inoculants. The lack of product quality and regulatory frameworks is also confirmed by Raimi et al. (2021) for many African countries with corresponding effects on demand.

Masso et al. (2015) report on various possible constraints for the availability and adoption of biofertilisers in SSA, including:

- Agroclimatic constraints (e.g., poor understanding when and where to apply);
- Low soil pH (e.g., unfavourable for microorganism populations such as rhizobia[26]);
- Nutrient availability (e.g., P is necessary for BNF[27]);
- Drought and heat conditions (e.g., shelf-life and formulation of products);
- Low demand due to a lack of awareness and understanding of biofertilisers;
- Cost of production;
- Poor delivery mechanisms;
- Lacking regulatory frameworks and policies (e.g., quality control and regulation, difficulties in registering new products);
- Market opportunities.

The partially limited understanding and the resulting uncertainties and variable results in practice in the application of biofertilisers seem to be a general challenge. Some of the current limitations for agricultural use of beneficial bacteria are the still incomplete understanding of the multifunctionality and complexity of bacteria and their interactions in the soil medium and with other biotic and abiotic factors, and the associated variable responses of all factors involved (du Jardin, 2015; Masso et al., 2015; Shin et al., 2017). The technical challenges associated with the formulation of inoculants and respective variable results in practice pose another challenge (du Jardin, 2015). One of the difficulties

[25] In regard to the EU Regulation on fertilising products, Feldmann et al. (2022, p. 709) point out that there are some scientific and regulatory challenges e.g., due to multifunctionality and physiological effects of biostimulants and other abiotic and biotic factors.

[26] However, there are exceptions reported for example for AMF and Cyanobacteria (Masso et al., 2015), indicating the need for advancing research and our understanding of the matter.

[27] Rock phosphate can be applied together with P-solubilising bacteria to improve uptake (Masso et al., 2015).

in AMF application and use is the propagation of AMF on a large scale, "[…] and, more fundamentally, the lack of understanding of the determinants of the host specificities and population dynamics of mycorrhizal communities in agroecosystems" (du Jardin, 2015, p. 7).

In SSA, research on biofertilisers needs to be intensified to improve the agricultural application and use, e.g., adapted for low input systems, isolate, identify and examine the potential of local strains of beneficial fungi and bacteria (Masso et al., 2015; Raimi et al., 2021). Furthermore, knowledge among all stakeholders needs to be increased including governmental and research institutions, extension services, and farmers and farmer organisations (e.g., Masso et al., 2015; Mukhongo et al., 2016; Raimi et al., 2021). Government support and respective enabling policies have shown to be key enablers in selected developed and Asian countries as well as harmonised standards across countries are necessary to foster trade and create a favourable business environment (Masso et al., 2015). This includes, for example, clear administration processes and guidelines for the registration of biofertilisers, well-defined quality standards, periodic monitoring of products in the market, and enforcement of quality standards as well as human and technical capacity to enforce the former (Masso et al., 2015).

Therefore, policy strategies and actions are necessary that help foster the commercial production and marketing of biofertilisers. As with inorganic fertilisers, subsidy and credit schemes can be a way to be explored for the uptake of biofertilisers if quality standards and regulatory frameworks are secured to increase demand and use.

4.3 Policies, regulations and standards

4.3.1 Waste management and recycling policies, laws and regulations

For the recirculation of nutrients and organic matter from waste, waste management needs to be institutionalised with respective policies, laws and regulatory frameworks.

Muheirwe et al. (2022) found that for Sub-Saharan Africa global policies have not been fully integrated into national policies, while national policies have had mixed results, sometimes improving waste management but often in an unsustainable manner. Furthermore, the authors state that the weaknesses of policies, such as their insufficiency, lack of consistency and ambiguity, hinder effective implementation. Additionally, poor enforcement strategies, a lack of participatory mechanisms, inadequate awareness campaigns, the influence of power dynamics and politics, and weak political commitment further exacerbate the issue. The authors argue that to ensure the development of smart and clean cities while recycling materials, it is crucial for solid waste management initiatives to be legally supported, contextually relevant and co-generated. Effective policy implementation requires educating urban residents about the policies and fostering participatory strategies, while governments must demonstrate a strong commitment to waste management. 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 (Muheirwe et al., 2022).

Silpa Kaza et al. (2018) report as key challenges – among others – land scarcity for the establishment of (recycling) facilities, high urbanisation and sprawl, and difficulties of governments to coordinate services and investment. In terms of waste financing, many cities lack sustainable long-term planning as well as affording operational costs due to insufficient government finances and waste fees. Private-public partnerships have been challenging due to financial, institutional and political shortcomings (Silpa Kaza et al., 2018).

The water, sanitation and solid waste, as well as the agriculture sectors in low- and middle-income countries are largely isolated from each other and tend to work in silos but have a high potential for co-benefits. The cross-sector collaboration and service chains could maximise positive interactions and achieve complementary development goals by adopting an integrated approach, a holistic planning and implementation (Narayan et al., 2021).

The majority of African countries do not have established specific laws on municipal solid waste (MSW) management, but rather have general environment laws with sub-sections covering MSW (Shi et al., 2021). Policies in most countries do not prioritise organic waste recycling, policies do not even exist, the enforcement is lacking, or incentives are not favourable for recycling e.g., payment per weight of waste delivered to landfill (Silpa 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 (DEA, 2013), with some communities in South Africa already diverting up to 50% of organic waste from landfill (Chitaka & Schenck, 2023). Furthermore, various countries in SSA 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 (The-Republic-of-Kenya, 2022), Rwanda the Integrated Solid Waste Management Strategy (MoI, 2022), Ghana established organic fertiliser guidelines and a National Technical Team (NTT) on Organic Fertiliser Promotion, Senegal started organic fertiliser subsidies.[28,29] Table 10 provides an overview of the most relevant policies, legal/regulatory frameworks including strategies, programmes, acts, standards and guidelines on solid waste management and recycling in the 12 African countries as part of this scoping study.

Table 10. Solid waste management, recycling policies and legal frameworks in 12 African countries[30, 31]

Country	Solid waste management and recycling policy and legal frameworks	Comments	Source
1. Cameroon	**Law** No. 96/12 Environmental Management (1996)	Lays out waste management practices.	Albrecht et al. (2022)
	Urban Development and Housing signed **Order** No. 00072/MINAT/MINVILL (2000)	Defines hygiene/sanitation, collection and/or treatment of household waste. Poor implementation of existing laws and regulation, lacking infrastructure, awareness of laws and regulations among citizens, and source separation etc.	
	Decree no. 2012/2809/PM (2012)	Lays down the conditions for the sorting, collection, storage, recycling, treatment and final disposal of waste.	UNHABITAT (2018)
	Decree no. 001/MINEPDED (2012)	Sets out the conditions for obtaining an environmental permit for waste management.	
		There is no basic law on municipal solid waste management.	

[28] https://www.un.org/africarenewal/magazine/may-2023/ghana-goes-organic-build-resilient-food-systems

[29] https://euro.dayfr.com/local/221452.html; https://www.switchtogreen.eu/senegals-ce-path/

[30] Note: Waste management policy sets the overarching goals and principles, waste management regulations provide specific guidelines and standards for implementation, and waste management laws establish the legal framework and enforceable rules governing waste management. Together, these elements create a comprehensive approach to address waste-related issues in a jurisdiction.

[31] Note: Table 10 is intended to show the main policy and legal frameworks, but is not necessarily exhaustive.

Country	Solid waste management and recycling policy and legal frameworks	Comments	Source
2. Côte d'Ivoire	Government with World Bank elaborated the Urban Resilience and Solid Waste Management **Project** (USWMP) (2019-2020).	Aim is to improve SWM and services – among others. Until recently no legislation specific to SWM existed[32]; no specifics regarding recycling or composting provided in USWMP.	MoS (2020)
3. Egypt	Waste Management **Law** (2020)	Also established the Waste Management Regulatory Authority (WMRA) to oversee and enhance waste management and recycling, along with crafting a national strategy for better waste disposal and recycling.	MoFA (2023)
4. Ethiopia	Ethiopian Environmental **Policy** (1997), Public Health Protection **Proclamation** No 200/2000, Environmental Impact Assessment **Proclamation** No 299/2002, Environmental Pollution Control **Proclamation** 300/2002.	Well-developed set of policies and regulations on environmental management that include SWM, but no measures for enforcement, effectiveness unknown.	R. Singh and Singh (2022); Xie and Mito (2021)
	National Solid Waste Management **Proclamation** (No. 513/2007)	waste segregation at households' level is foreseen by it in Article 11.1.	Lenhart et al. (2022)
5. Ghana	Local Government **Act** (1993)	Lays the foundation for the formulation of by-laws for MSW	R. Singh and Singh (2022)
	Environmental Sanitation **Policy** (1999)	Provide specifications for MSW	
	The Ghana Environmental Sanitation **Policy** (2010) promotes resource recovery options. The National Environmental Sanitation **Strategy** and **Action Plan** (NESSAP), (2010) e.g., Awareness creation—change in sanitation behaviour.	Current challenges are low level of implementation of policies due to e.g., low political will, policy incoherence's, weak coordination, limited funding, inadequate logistics, expertise and infrastructure, growing population, negative attitudes of general public towards the environment.	Oteng-Ababio (2020); Williams et al. (2023)
	The National Solid Waste Management (SWM) **Strategy** for Ghana (2020).	Aims to enable effective waste recovery, reuse and recycling.	
6. Kenya	National Solid Waste Management **Strategy** (2015)	Platform for action between stakeholders, objectives are to reduce waste, waste segregation at source, resource recovery etc.	R. Singh and Singh (2022)
	The Sustainable Waste Management **Act**, no. 31 of 2022.	The act includes the promotion of a circular economy, including recycling and reuse. It covers organic and non-organic wastes.	The-Republic-of-Kenya (2022)

[32] https://unhabitat.org/sites/default/files/2022/07/abidjan_en.pdf

Country	Solid waste management and recycling policy and legal frameworks	Comments	Source
7. Malawi	National Environment **Action Plan**	Broadly framed, can be applied to MSW management.	GoM (2018)
	National Environmental **Policy** (2004)	Provides policy guidance incl. waste management.	
	Environment Management (Waste Management and Sanitation) **Regulations** (2008)	Includes waste separation at source and recycling.	
	Malawi Bureau of Standards **Act**	Establish and implement standards, incl. waste management.	
		Weaknesses are e.g., non-compliance, limited enforcement, poor waste segregation, inadequate infrastructure, poor public perceptions.	
8. Rwanda	**Law** No 04/2005 of 08/04/2005: Organic law	Provides the basis for all waste management activities.	R. Singh and Singh (2022)
	Regulations No 002/EWASTAN/ SW/RURA (2015) governing solid waste recycling in Rwanda	Regulatory framework: design, installation, operations that recycle, compost or convert solid wastes.	
	National Environment and Climate Change **Policy** 2019	Promotes circular economy	
	Rwanda Integrated Solid Waste Management **Strategy** (2022)	The strategy includes the promotion of a circular economy, including recycling and reuse. It covers organic and non-organic wastes. Ambitious targets by 2024: 40% solid waste collected and recycled; 50% of households sorting waste.	MoI (2022)
	Ministry of Agriculture **Strategic Plan** 2018-2024	Promotes an "integrated approach to soil fertility/nutrient management, which employs agroecology, resource recovery and reuse, and fertiliser enriched composts."[33]	MoAAR (2018)
9. Senegal	The Environment Code on the Waste Management and Recycling (**Law** No. 2001-01).	It states that disposal shall be environmentally sound or recycled.	RVO (2022); World-Bank (2019d)
	National Solid Waste Management **Programme** (2014), Integrated and Sustainable Solid Waste Management **Strategy** (2015).	Several policies existing, enforcement and finances are lacking, infrastructure & sorting practices under-developed, inefficient governance structure & collaboration	
10. South Africa	National Environmental Management: Waste **Act**, 2008	promotes integrated waste management based on the waste management. waste avoidance, reduction, reuse, recycling, recovery, treatment and safe disposal as a last resort.	RoSA (2009)

[33] Research on biofertilisers technologies such as organic fertiliser is a prioritised goal within Rwanda's Strategic Plan for Agriculture Transformation 2018-2024.

Country	Solid waste management and recycling policy and legal frameworks	Comments	Source
	National Waste Management **Strategy** (promotes composting)	50% of organic waste are recycled	DEA (2013); DEFF (2020); Ricci-Jürgensen et al. (2020)
		Coherent and integrated legislative framework, clear responsibilities, financing and enforcement mechanisms.	Shi et al. (2021)
11. Uganda	National Environment (Waste Management) **Regulations** (2020).	Section 18 foresees waste separation at source for sorting of recyclable, hazardous and/or nonbiodegradable waste.	NEMA (2020)
		Lacking awareness and enforcement – among others.	Muheirwe et al. (2023)
12. Zimbabwe	The Public Health **Act** (1996)	Deals with solid waste.	Shabani and Jerie (2023)
	The Environmental Management **Act** (2002)	Addresses solid waste management. Comprehensive legislation exists, but implementation and enforcement are lacking.	
	The Zimbabwe National Integrated Solid Waste Management **Plan** (ZNISWMP), (2010)	To address shortcomings, the Plan aimed to develop a decentralised MSW management, better stakeholder integration, waste reduction, source separation and recycling. However, many of proposed actions are not implemented.	Nhubu et al. (2021)

4.3.2 Organic and biofertiliser standards

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.[34]

In most African countries when a product such as compost is sold as an “organic fertiliser” laboratory testing (e.g., nutrient content) is obligatory for marketing the product as “fertiliser”. When a product is not marketed or labelled as “fertiliser” but as a soil amendment or soil improver, laboratory analysis is usually not required in most countries (see Table 11).

The African Organisation for Standardisation (ARSO) has developed an African Organic Fertiliser Standard in 2020 (ARS 1490:2020) with the aim to harmonise standards across African member countries.[35] The council of Ministers of ECOWAS adopted a regulatory framework in 2012 that laid down rules on the quality of fertilisers (including organic fertilisers) in the member states (ECOWAS-Comission, 2012). However, not all countries appear to have adopted or harmonised organic fertiliser standards yet (see Table 11).

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[34] Fertiliser standards typically cover various aspects of fertilisers, including their chemical composition, nutrient content, physical properties, labelling, packaging and handling.

[35] Currently only the draft version ARS 1490:2018 is online available.

Table 11. Organic and biofertiliser standards in 12 African countries

Country	Responsible institutions	Standards		Comment	Source
		Organic fertiliser (yes/no), (year)*	Bio-fertiliser (yes/no), (year)*		
1. Cameroon	Directorate for Regulation and Quality Control of Agricultural Inputs and Products	Yes (n/a)	n/a	OF: need to be tested on e.g., nutrient contents if marketed as organic fertiliser.	Interview CAM-1
2. Côte d'Ivoire	n/a	n/a	n/a	-	-
3. Egypt	Egyptian Organisation for Standardisation and Quality	Yes (2023)	Yes (2023)	Egyptian Standard ES 8079 "organic fertilisers-specifications"	[36]
4. Ethiopia	Ethiopian Standards Agency	Yes (2008)	Yes (2018)	OF: referring to soil conditioners	ESA (2021)
5. Ghana	Plant Protection and Regulatory Services Directorate (PPRSD)	Yes (2010/2022)	Yes (n/a)	More precise guidelines for OF developed in 2022	Masso et al. (2016); PPRSD (2022)
6. Kenya	Kenya Bureau of Standards-Secretariat	Yes (2023)	Yes (2011/2016)	BF: does not cover plant growth promoters	KEBS (2011, 2023)
7. Malawi	Malawi Bureau of Standards	no	no	OF: no registering demanded	MBS (2022); Simtowe (2015); World-Bank (2019b)
8. Rwanda	Rwanda Standards Board	Yes (2020)	Yes (2022)	BF: covers N-fixing bacteria, phosphate solubilising bacteria	RSB (2020, 2022a, 2022b)
9. Senegal	n/a	no	n/a	-	World-Bank (2019a)
10. South Africa	Department of Agriculture, Forestry and Fisheries	Yes (2017)	Yes (2019)	BF: Group 3 fertiliser	RoSA (2017)
11. Uganda	Uganda National Bureau of Standards	Yes (2023)	Yes (2023)	-	UNBS (2023)
12. Zimbabwe	Standards Association of Zimbabwe	no	no	OF: must be registered before being sold[37]	World-Bank (2019c)

*The year refers to the latest version of the standard

4.3.3 Organic and inorganic fertiliser subsidies

Fertiliser subsidies are financial incentives or support provided by governments to farmers or agricultural producers to help them purchase fertilisers at a reduced cost. The provision of subsidies

[36] https://www.eos.org.eg/ckfinder/userfiles/files/egy337.pdf

[37] Compost, manure, night soil must not be registered when being sold under its original name (not labelled as fertiliser) (GoZ, 2016)

for inorganic fertilisers is widespread in African countries, while this is less true for organic fertilisers (Table 12). Currently, Senegal and Ghana appear to provide subsidies for organic fertilisers. The Senegalese government initiated organic fertiliser subsidies in 2021, initially providing support for 3 000 tons. This allocation was later augmented to 10 000 tons in 2022. A substantial portion of the total cost for 1 ton of organic fertiliser, spanning from 80% to 90%, was covered by these subsidies.

Table 12. Organic and inorganic fertiliser subsidies in 12 African countries

Country	Subsidies (2023)		Comment	Source
	Inorganic fertiliser (yes/no)	Organic fertiliser (yes/no)		
1. Cameroon	yes	n/a	-	[38]
2. Côte d'Ivoire	yes	no	for specific crop (cotton) [39]	-
3. Egypt	yes	n/a	-	[40]
4. Ethiopia	yes	n/a	-	www.africafertiliser.org
5. Ghana	yes	yes	Fixed prices for organic fertilisers from specific companies[41, 42]	PPRSD (2022); www.africafertiliser.org
6. Kenya	yes	n/a	-	www.africafertiliser.org
7. Malawi	yes	n/a	Farm Input Subsidy Programme (FISP) since 2005/2006	
8. Rwanda	yes	n/a	-	
9. Senegal	yes	yes	OF subsidies since 2022; 10% of fertiliser subsidies for organic fertilisers[43]	
10. South Africa	n/a	n/a	-	-
11. Uganda	yes	n/a	-	www.africafertiliser.org
12. Zimbabwe	yes	n/a	-	World-Bank (2020)

The allocation of monetary resources to agricultural budgets for fertiliser subsidies varies significantly among countries and from year to year. For instance, in 2022, Rwanda allocated approximately USD 0.8 million for fertiliser subsidies, while in 2021, Malawi dedicated a substantial USD 150 million towards this purpose (see Table 13).

Table 13. Monetary value of inorganic fertiliser subsidies in 12 African countries

Country	Inorganic fertiliser subsidies		Source
	million USD	year(s)	

[38] https://www.afdb.org/en/news-and-events/press-releases/cameroon-african-development-fund-approves-eu63-million-loan-boost-food-security-53518

[39] https://www.gouv.ci/_actualite-article.php?recordID=13789#

[40] https://egyptssp.ifpri.info/2019/09/02/ifpri-egypt-seminar-fertiliser-policy-in-egypt-and-options-for-improvements-2/

[41] https://mofa.gov.gh/site/publications/68-pfj-publications/390-pfj-2022-general-implementation-guidelines-for-distribution-of-fertilisers

[42] https://mofa.gov.gh/site/media-centre/archived-info/40-media-center/latest-news/126-government-to-spend-gh-207m-on-fertiliser-subsidy

[43] https://cicodev.org/agriculture-fertiliser-subsidy-10-for-organic-fertilisers/?lang=en

1. Cameroon	41	2022	ADB (2022)
2. Côte d'Ivoire	n/a	n/a	-
3. Egypt	114	2018	Kurdi et al. (2020)
4. Ethiopia	43-62	2011-2014	Nhlengethwa et al. (2023)
5. Ghana	0-75	2011-2014	Nhlengethwa et al. (2023)
6. Kenya	6.7 40-77	2022 2011-2014	https://kilimo.go.ke/fertiliser-subsidy-2022/ Nhlengethwa et al. (2023)
7. Malawi	150 77-157	2011 2011-2014	De Weerdt and Duchoslav (2022) Nhlengethwa et al. (2023)
8. Rwanda	0.8	2022	https://allafrica.com/stories/202211080076.html
9. Senegal	30-47	2011-2014	Nhlengethwa et al. (2023)
10. South Africa	n/a	n/a	-
11. Uganda	n/a	n/a	-
12. Zimbabwe	100-900*	2016-2018	Pindiriri et al. (2021)

*Total agricultural input subsidies

5 Empirical study results

This section provides a summary of interviews conducted with 89 key informants actively engaged in the value chains of organic and biofertilisers (OFBF) across 12 African countries. Additionally, six interviews were conducted with experts who possess a broader perspective on the overall OFBF landscape. The findings presented here encompass a synthesis of key observations from all the countries, drawing on reference to the synthesis reports for the 12 countries. For more in-depth and country-specific information, readers can refer to the respective country synthesis reports (see Annex 8). For producer specific information, see the single interviews (separate report), and selected business case descriptions (Annex 8.3). Each section, i.e., sub-section, concludes with recommendations from the interviewees (see also the country specific recommendations).

5.1 Inorganic fertilisers

5.1.1 Overall status and use

Drawing from key informant interviews and supported by the literature review, it is evident that, apart from specific hotspots where exemplary extension services and research support innovative farmers, notably in Egypt and South Africa, along with occasional isolated initiatives, none of the 12 countries can be argued to possess a clearly defined overarching goal for the systemic enhancement of their fertiliser practices. Rather, it is more fitting to assert that a systematic approach to fertiliser usage must be created and executed, as it has never truly existed.

In countries where governmental fertiliser strategies do exist, its reach remains limited, primarily benefiting a minority of smallholder farmers. Those who gain access to its advantages are typically participants in specific training programmes, enjoy subsidy privileges, and engage in the market for agricultural inputs. These individuals have the means to procure and effectively utilise inorganic fertilisers. In contrast, the majority of smallholder farmers do not fully utilise inorganic fertilisers. They may occasionally use these fertilisers, deviate from the recommended application rates, or allocate the available quantity to different fields based on their financial constraints. Alternatively, if they benefit from subsidies, some may opt to purchase inorganic fertilisers and then resell them, redirecting the resulting income for purposes other than agricultural inputs. In cases where additional income is generated or through the sale of export products, it becomes a means to finance their inorganic fertiliser requirements. On the other hand, larger farm owners exhibit higher levels of education, greater financial independence, and the capacity to purchase and apply fertilisers in accordance with recommended guidelines.

"The situation is not very good in the sense that even before the Russian Ukraine crisis, the prices were not affordable to the smallholder farmers. You know, most of our farmers here are smallholders, and so the government had put in place a policy where they were subsidizing fertiliser for specific crops, what they call 'Planting for food and jobs policy', but the idea was over time to win the farmers via the subsidy to apply more fertiliser. So, if they could improve productivity, then they will consider agriculture as a business, but it does not seem to be working because of different reasons." (Interview-GHN-5; Researcher, Ghana)

All governments in the 12 countries to some extent provide subsidised inorganic fertilisers at a reasonable cost, whereas private dealers tend to sell the same product at significantly higher prices. Unfortunately, when faced with these elevated fertiliser prices, the governments generally do not provide any form of compensation, exacerbating the decrease in inorganic fertiliser utilisation. Moreover, there have been frequent reports of fertiliser manipulation, resulting in significantly lower nutrient content than what is indicated on the product label. Additionally, various interviewees have voiced concerns about unequal distribution of fertilisers within the country, which can be attributed to internal political conflicts.

While subsidies play a role in various countries their benefits are controversially discussed. A common theme among many interviewees is that they should be complemented by other inputs such as quality seeds, comprehensive information, and knowledge on optimising fertiliser utilisation and integrating it into crop rotational systems. Generally, it was agreed that an exclusive reliance on chemical fertilisers and subsidy schemes falls short of addressing the issue adequately. There is an increasing awareness of the necessity for supplementary measures.

"In the African context, the skewed public funds being allocated to fertiliser subsidy programs alone has also not helped. There needs to be a blended approach where fertiliser combined with soil health investments are promoted." (Interview-KEN-2; Researcher, Kenya)

5.1.2 Production, application techniques and impact on soils and crops

Production

The majority of the 12 countries do not dispose on an own inorganic fertiliser production apart from Egypt and South Africa. This dependency became critical since the Russian-Ukrainian war and the Covid-19 pandemic: less fertiliser available, higher prices and late delivery have been the consequences.

Countries primarily purchase and mix various types of fertilisers independently. However, the resulting spectrum is relatively limited and fails to adequately address the specific needs of crops, despite occasional existence of specific recommendations

Application techniques

Application techniques are lacking, often there is also oversupply as for example reported in Egypt due to knowledge gaps. In most countries only general fertiliser recommendations exist on the quantity independent of soil types.

Applying fertiliser to African soils poses several challenges. For instance, deep red soils can immobilise considerable quantities of phosphorus per hectare before reaching saturation. While overapplication of fertiliser is a potential approach, it does not directly address the underlying soil health concern; however, it can enhance efficiency. Furthermore, the storage and transport of nitrogen-based fertilisers, especially urea, result in significant nitrogen loss, further exacerbating the issue by causing substantial losses before the fertiliser even reaches the farm.

Impact on soils and crops

Acidification of soils was reported by all countries. Reasons are lack of organic matter, leaching processes and where constantly applied, inorganic fertilisers.

There is a scarcity of lime as a product, coupled with insufficient understanding of its significance and its intricate relationship with pH, the availability of inorganic fertilisers, and its impact on soil humus content. The various types, functionalities, and characteristics of lime, as well as methods for measurement and application, remain poorly known. Additionally, there is a notable surge in costs associated with both the product and its transportation. Consequently, the application of lime is currently limited. However, recognizing its potential, even small amounts applied in accordance with the stoichiometry of crops and in conjunction with organic manure could yield significant benefits.

When inorganic fertilisers are applied in accordance with guidelines and tailored to specific crops, the resulting impact on crop yield is positive, while environmental negative impacts are largely mitigated. Unfortunately, many interviewees noted that such successful practices are exceptions. This is mainly attributed to the absence of accompanying sustainable production practices, including diversified crop rotation, soil cover, application of organic matter, liming, and reduced-tillage interventions, which are not implemented for various reasons.

5.2 Environmental impact of current fertiliser and waste management practices

5.2.1 Nutrient loss by erosion

Interviewees mentioned, that one of the main factors contributing to nutrient loss in agriculture, along with weak cropping systems, is the widespread farming practice characterised by minimal investment in carbon. The predominance of maize-based farming systems highlights that almost all farming approaches, with only a few exceptions like the push-pull system, result in nutrient loss. From an economic standpoint, it is crucial to prioritise the production and recycling of biomass to offset the value of annual nutrient loss in carbon-poor soils.

5.2.2 Nutrient losses along the value chain

The current practice of storing organic matter, including household waste and human waste, in open dump sites or landfills results in significant and adverse environmental impacts. Any method that involves collecting this biomass and converting it into a liquid or solid product represents a highly pertinent effort to mitigate environmental harm and promote nutrient cycling.

The transformation of organic waste into organic fertiliser is frequently hindered by economic and political interests. Some argue that the economics of organic fertilisers are unfavourable. However, such an assessment overlooks various external costs of inorganic fertilisers and benefits of organic fertilisers.

5.2.3 Contamination of water bodies

Across countries various interviewee's report on open dumpsites or landfills, posing a grave threat to water bodies, leading to severe water quality issues. This contamination often renders the water unsuitable for drinking, necessitating costly purification processes. Furthermore, other contaminants present significant environmental and health risks, ultimately impacting society as a whole negatively. Additionally, the growing challenge of finding suitable dumpsites in mega-cities compounds the problem.

Another major source of groundwater and water body contamination results from inadequate human excreta collection practices and the application of inorganic fertilisers on bare soils. Some interviewees acknowledge the severe environmental damage caused by these practices and advocate for fundamental changes in both farming methods and waste management.

5.3 Production and technology of organic and biofertilisers

5.3.1 Origin of organic matter and microorganisms

5.3.1.1 Organic fertilisers

Smaller businesses gather animal manure and utilise local resources like crop residues, household waste, and wild plants (such as Tithonia) to produce compost, a common practice in several countries (e.g., Cameroon) and additionally enrich it with soft rock phosphate (Annex: Business Case 2: Biofertiliser Africa Ltd. - Uganda). The latter company conducted a regional assessment on availability of organic waste sources and concluded that these are plentiful available.

Alternatively, in places like Ethiopia, Zimbabwe (ZimEarthWorm Farms) or Uganda (VermiPro Ltd.), they may opt for vermicomposting. Some businesses enhance their products by adding mineral or inorganic fertilisers to ensure consistent nutrient content, sometimes combining them with biochar (Safi Organics Ltd., Kenya) or microorganisms (RADI Organics, Cameroon).

Larger companies focus on producing compost or bio-slurry. Several large compost producers can be met in Egypt such as Beni Suef the largest compost producer, who is constantly expanding production, uses farm residues and farmyard manure. Larger companies source their materials from various sources, including municipal household and green waste, market waste, slaughterhouse residues, and human waste from pit latrines or septic tanks. However, the use of human waste as dried sludge or co-composted with organic wastes is still a minority. Examples for the use of human waste are companies such as SAFISANA (Annex: Business Case 5: SAFISANA Ltd. - Ghana) who produce biogas and co-compost using faecal sludge and market wastes. The production of biogas is also not widespread or is faced with strong hurdles as for example in Ethiopia (see also section 4.1.1).

Additionally, these companies may use residues from food processing units (e.g., pineapple, coffee, rice, maize, coconut) (Annex: Case 1: Regen Organics - Kenya) and materials like water hyacinth (*Eichornia crassipes*)(Ethiopia) and slaughterhouse by-products. Such examples are found across all countries.

Across all countries one company was identified in Malawi that produces liquid organic fertilisers based on human urine (Environmental Industries Malawi).

The utilisation of Black Soldier Flies to create high-quality compost and animal feed is a specialised practice that requires specific waste materials. In this study, examples have shown the use of vegetable residues and food scraps for production (Annex: Case 1: Regen Organics - Kenya).

5.3.1.2 Biofertilisers

Biofertilisers, also known as biostimulants, encompass a range of products with minimal to no nutrient content. The boundaries between biofertilisers, organic fertilisers and biopesticides are not always clear, especially when small-scale producers mix various organic materials and microorganism-based products (e.g., Cameroon).

Some producers or initiatives produce liquids by soaking plants in water (also sometimes labelled as plant teas). They are primarily derived from plants like Tithonia (e.g., *Tithonia diversifolia*), Mucuna (e.g., *Mucuna pruriens*), or other cultivated forage legumes specifically grown for their properties when dissolved in liquids. They may also include weeds or wild plants collected from the farm environment, as seen in Ethiopia.

Some producers combine these liquids with microorganisms (MO), including effective microorganisms (EM) sourced from Japan and further processed and multiplied in Africa, either by a company or directly on the farm. This involves using a wide range of substrates, such as fermented plant extracts, fermented fish, bokashi, or fermented chicken manure (comprising ingredients like chicken manure, fish, garlic, chili, ginger, black pepper, alcohol, vinegar, wheat bran, molasses, etc.), as practiced in South Africa and Cameroon.

Bokashi, a Japanese technique, revolves around fermenting organic waste with beneficial microorganisms, converting it into a nutrient-rich soil conditioner and fertiliser. Interviewees predominantly utilised kitchen and market waste for this purpose (e.g., Senegal, South Africa).

Rhizobia (e.g., in Ethiopia, Kenya, and Malawi), mycorrhizal fungi (e.g., in Kenya, Egypt) or other nitrogen fixing bacteria strains or phosphate solubilising bacteria are sourced from domestic or international sources (e.g., India), such as companies, research units, or universities. Egypt appears to harbour relatively more activities with several companies being active in the field of biofertiliser production, development, and research (e.g., SEKEM Development Foundation, Royal Green Biotech, Chitosan) compared to countries in sub-Saharan Africa.

Additionally, Trichoderma (e.g., in Kenya, Ghana, and South Africa) and other biocontrol agents with pest and disease suppression properties, as well as biostimulants like seaweed extracts, or nutrient-rich rocks, are prepared but face multiple challenges, as observed in Kenya.

5.3.2 Product quality and laboratory equipment

Some companies operate their own laboratories (e.g., Royal Green Biotech, Egypt), collaborate with governmental, private, university or foreign labs (e.g., in Kenya: Cornell University, Nairobi University). However, various companies only conduct a product analysis for registering their product which is obligatory in most of the 12 countries when a product is sold as a "fertiliser" while products not labelled as "fertiliser" but solely as e.g., compost, do not need registration in most countries (see also section: 4.3.2 Organic and biofertiliser standards). Some key informants emphasised the importance of having laboratories that are accredited for specific types of analysis, methodologies, and tests.

There is generally a deficiency in establishing quality control for all products, with cases where product labels promise certain nutrient contents that are later found to be lower in actuality, as reported by scientists conducting further assessments. However, there is a lack of transparency regarding such procedures. In some instances, advisory services initially perceive products as promising, but they later observe limited impact on soils and yields. It was also reported that some governmental labs use outdated testing methodologies. When it comes to microorganism-based products (MO), information is even scarcer, and details about types and characteristics are often unknown. Producers and farmers typically assess quality based on visual characteristics of soils and crops.

Quality control regarding contaminations in compost is lacking. The content of heavy metals, critical organic substances, antibiotics, medical products, battery acids, pesticide residues, and plastics are primarily unknown due to the absence of separate household waste collection. Microplastic contaminants are also anticipated.

The nutrient content of organic fertilisers and soil amendments is often undisclosed or unknown, as reported by interviewees. Generally, non-source segregated waste composts tend to have nutrient contents below 1% for N, P, and K. Higher nutrient values are typically achieved through waste sorting, resulting in approximately 1-3% N, 1-2% P, and 1-3% K, or when household or agricultural waste is co-composted with human waste. However, it is important to note that these nutrient levels can vary due to several influencing factors. Additionally, some producers may enhance composts or organic fertilisers by incorporating undisclosed ingredients, including inorganic fertilisers, resulting in higher nutrient contents.

The nutrient content in certain liquid products (plant teas) is extremely low (e.g., Ethiopia), leading experts to argue that these products cannot be classified as nutrient fertilisers. It is expected that they may positively influence microorganism development, contain organic substances (such as phytohormones), which stimulate plant growth, fortify plants, or serve as plant protection against pests and diseases. Because these products are derived from diverse raw materials, standardisation is lacking, despite promises from producers. The varying quality can also be attributed to seasonal fluctuations in the availability and quality of raw materials.

The production of bacterial-based or mycorrhizal fungi-based biofertilisers generally plays a minor role. The use of Rhizobia strains, especially in soybeans, peas, and beans, is of significance and often quite successful (e.g., Agri Input Suppliers Ltd., Malawi). Other biofertilisers, like effective microorganisms (EM) or other microorganism-based products, have a limited role and are primarily utilised in the context of organic farming (e.g., South Africa). Around 90% of mycorrhizal products available on the market in Kenya and other African countries are counterfeit as reported by an interviewee from the International Institute of Tropical Agriculture (IITA) in Nairobi who has conducted research on biofertilisers.

"There are products containing things like Rhizobia for legumes, trichoderma, mycchorizal fungi etc. A lot of that is 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. Other

products contain extracts of sea weeds, or other extracts, all sorts of very weird stuff that's absolutely not working. 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." (Interview-KEN-1; Researcher 1, International Institute of Tropical Agriculture (IITA), Kenya)

5.3.3 Current status of on-farm produced solid and liquid fertiliser, and biochar

Farm internal compost production is currently limited due to a shortage of animal manure and biomass for composting. However, the potential for increased production exists, particularly if hedges and alley cropping systems are established. Organic manure and compost are often diverted for other purposes such as cooking or house construction, with proper compost management being the exception rather than the norm, often requiring external expertise.

It can be expected that the nutrient content of on-farm animal manure is generally lower than that of industrially offered organic fertilisers, except for chicken manure. Factors such as a limited number of animals, insufficient feed quantity, and lower feeding quality collectively result in lower overall production of animal manure and lower nutrient content. Biogas equipment, where available, is often of subpar quality. Generally, there is a lack of storage facilities, proper manure handling, and appropriate application technology, severely limiting the impact of on-farm organic fertilisers on soil fertility and crop yields.

Some farmers do collect biomass, animal manure, or wild plants to prepare compost for sale, but production remains limited. The same holds true for the production of plant teas and Bokashi, which are primarily driven by NGOs or, in exceptional cases, advisory services.

It is essential to recognise that on small farms, both the production and nutrient content of manure are exceedingly low. This is primarily because most farmers abstain from using inorganic fertilisers. These low-input methods contribute to a lower nutrient content in animal feed and consequently in the manure. Furthermore, very few small-scale farmers augment the nutrient content of manure by incorporating additional nutrients through animal feed. The exception to this practice is a minority who purchase concentrates for their chickens, but this contribution remains minimal. Additionally, in most cases, cow manure is allocated for alternative uses and not returned to the fields. Consequently, the liquid component is lost due to inadequate covering of compost heaps and loss of urine, leading to nutrient leaching.

It was also reported that farmers often favour fertilisers with an immediate impact on crop yields, such as inorganic fertilisers, particularly when applied correctly as liquid fertilisers, while compost with low immediate impact on crop yield, is not in the interest primarily of conventional farmers.

There is evidence suggesting that biochar can have multiple positive effects on soil fertility and, in the long term, contribute to crop yield improvement and more efficient nutrient utilisation, while reducing erosion. However, the adoption of biochar applications at the farm level is scarce, with most instances being facilitated by advisory services, NGOs, or university students (e.g., Kenya).

"Biochar is produced through the incentive of carbon credits mainly, there is now different programs. 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 USD 70 per ton of biochar, which is about a weeks' work. They say they're looking both at using invasive species, but also at excess residues, maize shanks, rice husk, and so on." (Researcher 2, International Institute of Tropical Agriculture (IITA), Kenya)

In summary, the majority of on-farm produced organic fertilisers currently fall short of meeting the nutrient demands and balancing the import-export nutrient ratio at the farm gate, despite relatively low levels of nutrient import. The loss of nutrients as a result of low management quality of organic fertilisers may be contributing significantly to the negative nutrient balance. In addition to optimised fertiliser management, integrating forage legumes and agroforestry, i.e., alley cropping to address nitrogen demands would be the next step to optimise nutrient cycles and soil fertility.

5.4 Agronomic characteristics

5.4.1 Type of farms applying off-farm organic and biofertilisers

In urban or semi-urban areas, off-farm produced organic fertilisers, usually in the form of compost, are mainly used in vegetable production. Users are small-scale producers as well as companies producing for export (e.g., Kenya). In rural regions, off-farm produced compost is predominantly used by commercial farms serving national or international markets. These farms encompass both organic and conventional operations, with a significant demand for nutrients to meet specific product standards. Examples can be found in flower, fruit, or coffee production, as observed in Kenya or Ethiopia.

Small farms, typically engaged in cultivating arable crops and maintaining a limited number of livestock (usually one to three cows, one ox, and some chickens), tend to engage in localised compost production (e.g., Interview CAM-3, Cameroon). However, these activities remain modest in scale.

Some small farms also apply liquid organic and biofertilisers, or other cost-effective agents that are suitable choices due to their affordability and ease of handling (e.g., Ethiopia, South Africa). Typically, farmers apply between 5 and 50 litres per hectare of liquid organic fertilisers, mixed with water up to a maximum of 1 000 litres per hectare, a quantity manageable with backpack sprayers. But these liquid organic fertilisers contain usually only very low nutrient concentrations. Instances of such practices have been identified, especially in organic farms in Ethiopia.

Furthermore, there are larger animal husbandry operations or poultry producing enterprises that supply a portion of their dung for compost preparation but do not reclaim the compost (e.g., Uganda).

5.4.2 Storage and application techniques for organic and biofertilisers

The interviews conducted did not yield extensive information regarding application techniques. Collection and adequate storage of solid and liquid animal manure is an exception. For compost products, there is a recommended application rate of 3 to 5 tons per hectare, which is a realistic figure in terms of transport and can also be managed by smallholder farmers. Nevertheless, certain producers recommended application rates ranging from 500 kg to 1 t/ha, particularly when these organic fertilisers were enhanced with additional ingredients like poultry manure, inorganic fertilisers, or rock phosphate. It is typically applied using animal traction and manual equipment. But it must be stated, that only some farmers apply the fertiliser properly. However, it is worth noting that transport capacity and labour remain limiting factors for applying organic fertilisers and compost. Also, abandoned field plots rarely receive any organic fertiliser.

Bio-slurry (bio-digestate from biogas production) is primarily distributed using buckets, watering cans, and hand-pulled or animal-drawn carts. Nevertheless, the information obtained from interviews on application techniques is limited. With such basic technology, significant ammonia losses can be expected. Furthermore, it is well-documented from bio-slurry surveys that storage and use of bio-slurry and biogas lack adequate technology and knowledge.

Scientifically valid information regarding the quantity of organic and biofertilisers (OFBF) that should be applied according to local contexts (e.g., soil type) is generally quite limited. Even when companies provide recommendations, it is important to note that most farmers lack the means to measure or accurately estimate their field sizes or the volume of liquid required. Scientific trials at research stations are also not widespread. Therefore, any data on the amounts of OFBF applied should be used cautiously. In most cases, relatively low application rates are expected due to factors like transport, cost, labour, and technological limitations.

5.4.3 Combination of organic, bio- and inorganic fertilisers

Many of the interviewed persons agreed that the new strategy involves a blend of organic and inorganic fertilisers. However, there is a notable absence of specific formulations or guidance regarding how this strategy should be structured and the respective roles of various fertilisers. Currently, practices involve adding inorganic fertilisers to compost or occasionally to liquid organic fertilisers in small quantities to maintain a specific nutrient content level and ensure product quality. It is important to consider that such mixtures could potentially disqualify the product for use in certified organic farming, as not all inorganic fertilisers are certified for organic agriculture.

5.4.4 Impact on soil and crops

Positive impacts of compost on soils and crop yields have been reported by various interviewees across countries, especially in organic farming, where there is greater knowledge and awareness of organic fertilisers. The likelihood of an immediate positive impact on crop yield is higher in soils dominated by a significant proportion of clay or sand, while soils with a higher loam content may have a less pronounced response. However, positive effects can still be observed depending on the often-weak soil structure. The delayed impact on yield is mentioned as one of the main challenges in applying compost. In contrast, the impact of bio-slurry on crops is highly valued.

"Farmers see an average of 30% yield increase when applying the compost in addition to mineral fertiliser applications." (Interview-KEN-4; OF Producer, Kenya)

The impact of liquid organic fertiliser formulations, classified as a product with extremely low nutrient content, is a subject of debate. Some argue that their positive effects are visible in the early stages of crop development, but later on, crop growth may stagnate if nitrogen fertilisers are not added (as seen in Ethiopia).

There is consensus that the application of Rhizobia has a very positive impact on the crop yield of grain legumes and nitrogen fixation.

"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." (Interview-MAL-8; Rhizobia Producer, Malawi)

However, there are cases where farmers have faced challenges, often due to issues with product quality or the presence of acidic soils that impede bacterial functionality. These factors have led to the abandonment of grain legume cultivation in some instances, and affected the further demand of Rhizobia products.

"According to our research, as well as by others, the yield of many crops increased by 16 - 52% when these crops received the recommended doses of biofertilisers (Azotin, Phosphatin, Potassiomag.)." (Interview-EG-4; Researcher, Egypt)

Furthermore, numerous interviewees have reported farmers' experiences with inorganic fertilisers (IF) resulting in a limited impact on crop yields. This observation encompasses a lack of nutrient adjustment in accordance with specific crop stoichiometry, soil acidity concerns, and instances of manipulated fertilisers, as mentioned in interviews conducted across all surveyed countries.

5.4.5 Application of organic and biofertilisers in organic farming

Organic farmers are at the forefront in the adoption of organic and biofertilisers (OFBF). This is primarily due to restrictions on the use of chemical nitrogen fertilisers, with only a limited selection of inorganic fertilisers permitted in organic farming (e.g., South Africa). Furthermore, some of the approved inorganic fertilisers are often not readily available in the market, a recurring issue in nearly all the countries surveyed.

However, despite their preference for OFBF, these farmers encounter challenges. The absence of quality control and certification standards for fertilisers tailored to organic farming means that not all OFBF products are readily accepted. It is worth noting that the many of OFBF users are organic farms with a focus on export markets.

5.5 Critical practices in organic and biofertiliser value chains

5.5.1 Use of crop residues and animal manure for the off-farm production

In certain instances, organic fertiliser producers gather crop residues and animal manure from farmers. However, this practice has detrimental effects on farm soils, as it diminishes on-farm biomass and reduces the carbon content that is essential for recycling within the farm's fields. This reduction in carbon has several negative consequences, such as diminishing water and nutrient holding capacity. While producers may compensate farmers for these residues, farmers ultimately have to purchase compost, which results in negative outcomes in terms of costs, labour, and crop yield, ultimately impacting income.

Conversely, in other cases, crop residues from fruit and coffee production are repurposed for off-farm organic fertiliser production (e.g., Uganda). The key distinction here is that the produced compost is reintroduced to the farm from which the biomass originated. The choice between the industrial processing model, a community-based approach, a company-based system, or a farmer-based method depends on the specific circumstances. However, it is crucial to consider that during biomass transport, pesticides may also be inadvertently transported, underscoring the importance of quality control to prevent further contamination.

In situations where there is a heavy reliance on inorganic fertilisers with limited organic matter production or implementation in the field, significant nutrient losses can occur, resulting in low efficiency. This approach also leads to a heightened dependence on the national and international inorganic fertiliser market.

As a recommendation, it is advisable to prioritise the retention of farm internal biomass, especially when financial resources are limited, transport costs are high, and there is no assurance of product quality when procuring external organic fertiliser or biofertiliser.

When farmers and advisers recognise the inefficiency of a particular organic or biofertiliser product, especially if it is too expensive or the farms are situated at a considerable distance, resulting in costly transport, and when advisory services are seldom available, it is advisable to encourage farmers to contemplate initiating their own production of OFBF. To pursue this, they should prioritise optimising internal biomass production, place emphasis on the proper collection of animal manure, and invest in the necessary technology for efficient product manufacturing and application, drawing inspiration from successful cases like ORDA in Ethiopia.

This approach is also highly recommended for farmers located far from the inorganic fertiliser market, who operate with limited income, but possess sufficient farm internal labour capacities.

5.5.2 Rural-urban nutrient balances

In cases where (organic) household waste, and sometimes even human waste, is collected in cities, it is typically processed into compost or slurry, and in some instances, biogas is produced. These products are primarily distributed to (peri)urban farms. This process underscores the movement of nutrients from rural areas to support urban agriculture. Transporting compost back to its rural origin can pose both logistical challenges and incur significant costs. Nevertheless, there are reports of sewage sludge being transported to more distant areas due to a high demand for nutrient sources, as mentioned by an interviewee in Uganda. Conversely, when these products are applied in urban and peri-urban areas, there is a continuous transfer of nutrients from rural to urban regions. It is of importance to establish nutrient balances to monitor this flow of nutrients and carbon.

5.6 Economy and markets of organic and biofertilisers

5.6.1 Current demand, use and type of crops

Demand primarily centres around compost, as it is the most familiar option among farmers. Many interviewees reported that since 2020, and in response to crises, the demand for alternatives to inorganic fertilisers like compost has been steadily increasing.

"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. Access to markets is less of an issue, but specific application rates is a major focus of ours this year! That said, the most common organic crops are nearly all export, which is likely an important aspect of the value chain. We are currently targeting to open 3 new sites for compost production. We aim also to expand to other African countries." (Interview-KEN-5; OF Producer, Kenya)

However, this trend is context-specific and interviewees from Cameroon and South Africa did not note a marked difference in demand. In countries or regions with low land tenure security or high land rental rates (e.g., Cameroon), long-term investments in land via organic fertilisers (or trees) can be inhibitive. Additionally, 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, insufficient advisory services and training, and delayed nutrient availability resulting in a lower impact on crop yield.

Limited access to materials, competition (e.g., from animal husbandry), market competition for residues, and transport costs can also restrict compost demand. Demand for compost derived from human excreta is sometimes limited due to social or cultural barriers, 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 as reported an interviewee from Uganda.

Compost is recommended for all types of cash 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). Due to the relatively high prices of most composts (ranging from EUR 0.72 to about EUR 30 per 50 kg), as well as challenges related to transport facilities and costs, application rates tend to be low, or small amounts are combined with inorganic fertiliser applications to enhance their efficiency. Typically, compost application rates are below 5 tons per hectare.

"I think commercial examples that show financial viability exist (Waste-based compost). Again, what is gonna immediately driving 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. (…) I'm almost sure it'll not be smallholder for large staple crop production." (Interview-KEN-2; Researcher 2, International Institute of Tropical Agriculture (IITA), Kenya)

Regarding composting, some interviewees stressed that it is relatively simple and achieves high temperatures, sanitising the waste, but it yields a voluminous product with limited nutrients, making it challenging to market. However, this depends on the region or country specific context, in Egypt for example, compost is demanded to improve the many sandy soils, but less for its nutrient contents.

Liquid organic fertilisers (bio-slurry) are in less demand, primarily because their transport is also 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, but adequate technology for spraying is limited.

Liquid organic fertilisers (e.g., plant / compost teas) are offered with varying quality, and there are mixed opinions about their relevance for soil fertility and crop yield. Demand is rising in cases where farmer groups apply them successfully, but in cases where farmers expected them to function as fertilisers, they have been disappointed, as they are not. Generally, knowledge about plant teas is very limited.

Biofertilisers cover a wide spectrum of plant types and are only crop-specific in some instances. Multiple products are available, but there is still a lack of a comprehensive overview and classification. Biofertilisers are not widely promoted by governments, and while some advisory services specialise in them, the majority do not value these products, except for Rhizobia, which is more widely recognised than other biofertilisers.

"We started 2014, we have seen more and more customers. We have 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 capacity possible." (Interview-MAL-8; Rhizobia Producer, Malawi)

The demand and use of mycorrhizal fungi are very 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 grain yield and nitrogen fixation, and serve as a high-value pre-crop for cereals. However, Rhizobia do not perform well under acidic soil conditions, leading to declines in demand. Additionally, the quality of Rhizobia can sometimes be insufficient (e.g., due to insufficient storage or transport conditions).

Other microorganism-based products, such as effective microorganisms (EM) and bokashi, are primarily used by organic farmers (South Africa), although demand is not very high. Some farmers also produce these products themselves.

For organic farmers, biofertilisers fit into their natural science understanding of strengthening soil and plant health by promoting the diversity and quantity of microorganisms. From the perspective of conventional farmers, the relevance of biofertilisers is low.

Future demand for OFBF depends on factors such as quality control, improved product descriptions, exclusion of contaminants, training, demonstration, and research to assess their impact on soil health and crop yield, as well as economic assessments. From a farmer's perspective, the most relevant economic factors are transport and distribution costs and technology (in the case of compost), as well as incentives such as subsidies similar to those offered for inorganic fertilisers.

5.6.2 Pricing

The prices for inorganic fertilisers have surged, doubling or even tripling in many African countries since 2018. A 50 kg bag of inorganic fertiliser now ranges from EUR 35 to 100, with an average of about EUR 54 (Table 14). However, price variations exist between countries, types of inorganic fertilisers, years, and within different regions of the participating countries. In some countries, prices have slightly decreased but still remain higher compared to the pre-2020 years. Ultimately, the price should be evaluated based on country-specific purchasing power.

As for organic fertilisers, observed prices exhibit significant variation across countries although different organic fertiliser qualities need to be considered among other factors (Table 14). Prices range from as low as EUR 0.72 for a 50 kg bag in South Africa to EUR 15 (EUR 0.75/50 kg) in Egypt. In both of these countries, some compost operations are highly mechanised, functioning on an industrial scale. Composts within this price range in these countries typically have nutrient contents below 1% and can thus be considered soil amendments rather than organic fertilisers.

In Senegal, one company sold a ton of organic fertiliser with NPK (1:1:1) for approximately EUR 213/ton, while another offered a phosphate-fortified compost with NPK (4:3:3) for EUR 300/ton.

In Ethiopia, a 100 kg bag of compost from source-separated household waste is sold for EUR 5, whereas a 50 kg bag of rock phosphate-fortified compost (including *Tithonia* and chicken manure) is priced at around EUR 38 in Uganda. The latter had three different nutrient compositions for different coffee plant growth stages (4.5:7:2; 7:3:3 and 2.4:3:9).

A phosphate fortified compost-biochar mixture (5:3:3) is sold at EUR 21 (50 kg) while a Black Soldier Fly (BSF) frass fertiliser with a nutrient value of 3:1:3 sells between EUR 9 and EUR 16 in Kenya.

A 50 kg vermicompost is sold for EUR 65 in Uganda, although specific nutrient compositions or quality parameters are not provided. In contrast, one of the interviewed companies in Zimbabwe sells a vermicompost (4:3:2) for EUR 12.20 (50 kg) and inorganic fertiliser fortified vermicomposts between EUR 23 and EUR 31.

Only a few liquid organic fertilisers were identified in this study, with costs ranging for 1 litre (l) from EUR 0.94 for a plant based liquid fertiliser (Ethiopia), EUR 3.30 and EUR 9.30 for a liquid fertiliser extracted from vermicompost in Uganda and Zimbabwe, respectively, EUR 17.50/l for a liquid fertiliser made from undisclosed plant ingredients (Cameroon), urine-based liquid fertiliser for EUR 1/l in Malawi, and about EUR 3/l in South Africa for an organic certified liquid fertiliser (4:1:6; 5:1:4; 7:1:2). Prices tend to decrease with larger quantities purchased. However, many organic fertiliser liquids lack information on nutrient contents, and sometimes nutrient contents can be very low, as observed in Ethiopia. Some imported products made from animal waste, such as hoofs, horns, and feathers, contain high nutrient contents, with a recommended application rate of 13 litres per hectare at a cost of EUR 25 per litre (Kenya).

The pricing of biofertiliser products varies widely, with costs ranging from EUR 1/l to as high as EUR 16. Notably, there can be significant disparities in prices, exemplified by the case of Rhizobia in Malawi, where it is sold for EUR 3.70 per 400 grams (for 1 ha), compared to EUR 4.70 per 100 grams in Zimbabwe. The recommended application rates for biofertilisers vary widely according to the product.

The breakdown of costs, gross margins, and profit margins was not disclosed by most interviewed companies, as these figures were considered proprietary information. Consequently, it is challenging to determine the reasons for the wide range of pricing across countries, although factors such as differences in labour costs and demand may contribute.

Producers from nearly all countries compared the price of 50 kg of inorganic fertiliser with 50 kg of organic fertiliser, generally asserting that organic fertiliser is the more economical choice. However, due to the lack of nutrient analysis in many cases, conducting an economic assessment of the nutrient market value of organic fertilisers remains challenging.

However, considering the case of Senegal, where one ton of NPK (15:15:15) fertiliser is priced at approximately EUR 800 to EUR 1 100. To match the nutrient values of the inorganic fertiliser, one would need about four to five times the amount of phosphate-fortified compost with NPK (4:3:3) priced at about EUR 300/ton, totalling about EUR 1 200 to EUR 1 500. However, conducting such a simplified calculation may not account for all relevant factors, such as potential improvements in soil fertility and responsiveness due to, e.g., increased organic matter content, among other considerations. Furthermore, evaluating the carbon value, which may be feasible in the future through mechanisms like carbon credits, waste costs, labour, transport, and processing costs, currently lacks comprehensive data. Therefore, it can be concluded that there is a substantial need for the verification of product effectiveness and economic viability. Nevertheless, various companies such as those in Kenya reported to be profitable.

Table 14. Overview on inorganic, organic and biofertiliser costs from interviewees

Country	Inorganic fertiliser costs (2023)	Organic fertiliser costs (2023)			Biofertiliser costs (2023)		
	EUR (50 kg)	Type (N:P:K)	Unit	EUR	Type	Unit	EUR
1. Cameroon	53-69 (DAP; Urea)	Compost with biofertiliser	50 kg	20.00	Plant tea	1 l	1.00
		Compost	50 kg	7.60 3.80			
		Liquid organic fertiliser	1 l	17.50			
2. Côte d'Ivoire	39-47 (n/a)	Compost	50 kg	15.00	n/a	-	-
		Poultry manure (not composted)	50 kg	0.76			
3. Egypt	35 (n/a)	Compost	1 t	15.00-24.00	Various	1 l	6-12.00
4. Ethiopia	60-100 (NPK; NPS)	Liquid fertiliser (<1:<1:<1)	1 l	0.94	n/a	-	-
		Compost	100 kg	5.00			
5. Ghana	25-37 (Urea; AS)	Co-compost (sewage sludge)	50 kg	7.00	n/a	-	-
6. Kenya	40-65 (DAP; NPK)	Compost (fortified) (1-3:>1:>1)	50 kg	15-25.00	Wondergro	n/a	16.00
		Fortified biochar-compost (5:3:3), fortified compost (3:5:3)	50 kg	21.00	Calcimax	1 l	8.00
		BSF Frass (3:1:3)	50 kg	9-16.00			
7. Malawi	54-67 (NPK)	Urine-based liquid fertiliser	1 l	1.00	Rhizobia	400 g (1ha)	3.70
		Liquid OF	1 l	1.60			
8. Rwanda	54-59 (DAP)	Compost	50 kg	3.80	n/a	-	-
		Compost (2:8:3,3)	50 kg	3.80			
9. Senegal	46-54 (DAP; Urea)	Fortified compost (4:3:3)	1 t	300.00	n/a	-	-
		Compost (1:1:1)	1 t	213.00			
10. South Africa	426 (t) (n/a)	Compost Compost	50 kg 50 kg	1.75 0.72	n/a	-	-
		Co-Compost (sewage sludge) (1.6:0.3:0.4)	1 t	28.00			
		Fortified compost* (2:3:2; 3:1:5; 5:1:5; 6:3:4; 8:1:1; 4:10:0)	1 t	580-782.00			
		Soil conditioner (vermicompost)*	35 kg	10.00			
		Liquid organic fertiliser* (4:1:6; 5:1:4; 7:1:2)	5 l	14.70-17.60			
		Liquid organic fertiliser* (4:1:6; 5:1:4; 7:1:2)	1 000 l	2 023-2 670			

Country	Inorganic fertiliser costs (2023)	Organic fertiliser costs (2023)			Biofertiliser costs (2023)		
	EUR (50 kg)	Type (N:P:K)	Unit	EUR	Type	Unit	EUR
11. Uganda	46-55 (Urea; DAP; NPK)	Fortified (4:7:2; 7:3:3; 2.4:3:9)	50 kg	38.00	Superagric	1 l	9.30
		Liquid (vermi tea)	1 l	3.30			
		Vermicompost	50 kg	65.00			
12. Zimbabwe	42-56 (n/a)	Fortified vermicompost: (7:7:7; 6:15:12; 25%N)	50 kg	23.00-31.00	Rhizobia	100 g	4.70
		Vermicompost (4:3:2)	50 kg	12.20			
		Vermi-foliar top dressing	20 kg	15.00			
		Vermi-tea	1 l	9.30			

Source: Key informant interviews; *certified organic

5.6.3 Economic performance and financial sustainability

Companies typically provide limited data, primarily related to production quantities, market prices, and employee numbers. Information on cost structure, revenues, gross margin is either not available or not provided as it is considered as company internal information. In many of the researched cases, the financial sustainability of companies remains fragile without financial or other support from either governments or private donors. Financial assistance for company development varies widely, with some companies receiving indirect subsidies from city authorities providing land and buildings, e.g., for compost production.

However, many of the companies who are existing for more than five years report to be profitable or at least to be financially stable (e.g., Annex: Case 1: Regen Organics - Kenya).

"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. We currently sell about 10,000 bags fertiliser a month (500 tons/month). 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)

High land costs especially in urban and semi-urban areas and a lack of incentives may discourage private enterprises from getting involved in waste management projects as reported by an interviewee from Kampala, Uganda. One interviewee highlighted the influence of fiscal dynamics in shaping economic priorities in waste management, using the example of faecal sludge management, which includes a dumping fee in its services, while solid waste disposal does not. This difference means that recycling and compost production ventures do not receive compensation from waste generators. This creates challenges in setting a selling price that covers production costs, including collection and transport expenses. Striking the right balance between these costs and the selling price is crucial for the success and competitiveness of composting initiatives in the market. (See Annex: Business cases) Most interviewed producers anticipate economic benefits with increased production and growing demand. Challenges they face include the expenses associated with modernising and mechanising processing technology, acquiring transport equipment and the need to import specific equipment, and implementing waste collection and sorting or biogas plants. However, nearly all interviewed producers emphasise the need for external financial support or improved investment conditions to further develop and expand their production.

Small companies initiated by individual farmers are typically self-financed. Raw materials are primarily sourced from the wild, the farmers' own land, or nearby farms. As production scales up, farmers hire additional personnel to assist with both production and product sales.

Subsidies or tax incentives for companies are non-existent or limited, yet the modernisation and expansion of these companies 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, interview participants from various countries underscored the considerable market potential, provided that specific challenges are effectively address.

Financial assistance for company development varies widely, ranging from no support to multiple funding sources from private entities, foreign governmental organisations (development cooperation), or international companies. These companies can be either profit-oriented or non-profit-oriented, with most of them having been established within the last decade (see Business cases in Annex 8.3). In some instances, companies are indirectly subsidised by city authorities providing land and buildings (e.g., Kampala, Uganda; Kenya). In the context of Ghana, the government procures as much as 80% of the compost production from certain companies, such as the Accra Compost and Recycling Plant. These compost products are then distributed directly to farmers through their national subsidy programme. Apart from Ghana, Senegal currently provides 10% of the total fertiliser subsidies for organic fertilisers. Out of the final price for 1 ton of organic fertilisers, between 80 to 90% of the price is subsidised. However, the challenge for the producer or organic fertiliser dealer is that the state pays the subsidies 12 to 24 month later. Therefore, the producers need to be able to have sufficient cash as waste raw material and waste transport etc. must be paid.

In some cases, it was mentioned that economic interests of companies who control waste disposal monopolies, coupled with policy makers involved in the industry, can hinder the establishment of new companies.

"Zoom Lion is the dominant waste management company in Ghana, probably due to very close political ties. And so, any other company which is trying even to collect waste has to work against this big brother, who is dominating the sector. So, we have big problems even getting waste. Keeping the land we have with our compost plant because, suddenly Zoom Lion said it is actually their land and they blocked other waste cars coming to our land. So, it's sometimes very difficult if there's one big company in already dominating the market to establish yourself." (Interview-GI-6; Researcher, Cross-country expert)

5.6.4 Organisational forms, type of actors, and value chains

Diverse organisational structures and associated actor groups are observed across the spectrum (Table 20). The spectrum of actors engaged in OFBF production is diverse and extensive. Producers hail from a multitude of backgrounds. This includes local entrepreneurs, including farmers who initially ventured into small-scale production, as well as public-private partnerships and entirely private entrepreneurial producers with backing from international donors.

In some instances, individual farmers have taken up informal production of organic fertilisers using their own raw materials and wild plant collections, such as *Tithonia diversifolia*. Alternatively, farmer groups have been established, with members contributing their labour and time to a collective effort, often initiated by an external organisation (e.g., cases in Uganda and Cameroon). These small-scale operations tend to be less mechanised and more reliant on manual labour.

Companies with mother companies in Europe or backing from international donors are for example Elephant Vert (Senegal, Côte d'Ivoire), Safisana (Ghana), Regen Organics (Kenya), and Biofertiliser Limited (Uganda). Some are embedded within a research context, providing access to technologies and extending financial support and expertise (e.g., Annex – Business case 4). Larger commercial companies producing at least 3 000 t/year of organic fertiliser can be found in Egypt, South Africa, in

Kenya, Ghana, Senegal, Côte d'Ivoire, Zimbabwe, Uganda, and Ethiopia (Full overview of companies Annex: Table 20).

The motivations for these actors exhibit a broad spectrum. Some are propelled by ethical or environmental concerns, responding to the inorganic fertiliser crisis, or pursuing scientific interests. Some operate within the framework of NGO programmes, while public companies often focus on reducing overall waste loads headed to landfills. There are also those deeply engaged in organic farming, acknowledging the significance of organic matter and microorganisms as crucial strategies.

Furthermore, certain individuals prioritise financial considerations, while others contemplate the potential of carbon credits to bolster farmers' independence or enhance local community resilience.

At the municipal level, various forms of organisation are present. 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., South Africa – see Annex: Business case 3). Furthermore, several private companies operate at a regional level, frequently utilising source-separated agro-processing and market wastes to produce organic fertilisers. These products may sometimes be supplemented with other inputs such as rock phosphate (e.g., Kenya – see Annex: Business case 1). In addition, in some cases where black soldier fly is used on source separated organic waste, two marketable products are produced in the form of animal feed from the BSF larvae and the compost in the form of frass (e.g., Annex: Case 1: Regen Organics - Kenya).

In Senegal, the biodigester programme is a crucial element of the organic fertiliser landscape, primarily centred on households. Private sector players in this industry recognise that producing organic fertiliser through household biodigesters can be more financially rewarding than focusing solely on biofuel or biogas production. The national programme, supported by the government and donors, has identified and certified six private sector biodigester companies operating at the household level. These firms supply households with biodigesters without upfront payment, and households compensate by providing the organic fertiliser (digestate) produced. This organic fertiliser, mainly derived from cow dung and vegetable waste, generates substantial income, approximately ten times more than biodigester sales. As a result, many producers are shifting toward larger-scale ventures, including collaborations with slaughterhouses. Nonetheless, their primary focus is on establishing their own organic fertiliser production units, given the promising profitability and growing demand for organic fertilisers in Senegal.

Biofertilisers are often sourced internationally by private companies (e.g., EM from Japan in South Africa), or they are manufactured by public research institutes (e.g., Rhizobia in Zimbabwe) or private companies (e.g., Rhizobia in Malawi, mycorrhizal fungi, and nitrogen-fixing bacteria in Egypt).

Table 15. Organisational forms, actor groups and value chains of off-farm organic and biofertiliser production

Organisational form	Actor / actor groups	Production size	Value-added products	Raw material source	Inter-viewed actors	Examples
Private (informal)	Single farmer	<10 t/year	Compost, biochar	Own: animal dung, crop residues, (Sekabira et al.) plant collections (Tithonia), Extern: fortified with IF	1	Observation by an interviewee from Malawi (Interview-MAL-8)
Private (informal), NGOs	Neighbourhood initiatives/farmer groups (village/community level), NGOs	<20 t/year	Compost, insect frass	Own/neighbourhood: animal dung, crop residues, (Sekabira et al.) plant collections (Tithonia), market wastes, Extern: fortified with IF or rock phosphate	3	Initiative by NGO Self Help Africa producing insect frass from household and market wastes (e.g., Uganda / Interview-UG-7)
						Initiative by Forum for Agricultural Advisory Services (CAMFAAS) and its local partner REA-Cameroon (Cameroon / Interview-CAM-3)
						PELUM's member organisations are establishing (bio)fertiliser units to educate farmers about crafting their own organic inputs (Uganda / Interview-UG-1)
Public, public informal[44], private-public partnerships (PPPs)	Municipality	>500 t/year	Compost	Agro-processing and market residues, human waste, slaughterhouse waste	3	Co-composting of human and other organic waste. Cooperation between private and public entity (South Africa - Business case 4, Ghana – Business case 5); Ghana - Accra Compost & Recycling Plant (ACARP)
Private (formal)	Private company (District/regional)	Ca. 20 – 120 000 t/year	(Fortified) Compost, biochar, liquid organic fertiliser	Agro-processing residues, market residues, rock phosphate, inorganic fertiliser, human waste, slaughterhouse waste, plant	19	Beni Suef (Egypt); Eco Green (Ethiopia); RegenOrganics (Kenya); SafiOrganics (Kenya); Elephant Verte, Biotech Services Senegal (Senegal); Glowish Agro Solutions, Rootzone Africa Ltd., Vermipro Ltd. (Uganda); Jaasgrow Ltd. (Ghana); Radi Organics, Family Green, Nang et Compagnie (Cameroon); Environmental Industries,

[44] 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.

				residues / wild plant collection (Tithonia)		Almena Organic Fertiliser, Green Finger Organic Fertiliser (Malawi); ZimEarthworm Farms, Flight Serve Enterprises Ltd. (Zimbabwe); Talborne Organics (South Africa); BioSolutions Ltd, Greencare Rwanda Ltd. (Rwanda)
Private (formal)	Private company (regional)	<10 000 litre/year	Biofertiliser	Various raw materials; imported biofertilisers mixed with organic materials; fermented plant juices	5	Vermipro Ltd. (Uganda); Radi Organics (Cameroon); Biotech Services Senegal (Senegal); Eco Index Agro Solutions Ltd. (Ghana); Lindros Whole Earth Consultancy (South Africa)
Private (formal)	Private company (national/international)	n.a.	Biofertiliser (powder/ liquid)	Nationally sourced bacteria strains	2	Royal Green Biotech (Egypt)
				n.a.		Elephant Verte (Senegal)
Public, private (formal)	Public research institutes, private company (national)	Ca. 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 interview

5.6.5 Distribution channels

Companies employ various distribution strategies, including working through their agents, cooperatives, or engaging in direct sales to farmers or large commercial enterprises (farms). Some have successfully partnered with retail shops, while others have even established their own retail outlets.

"Retailers are our most important selling point; they are in the communities." (Interview-KEN-4; OF Producer, Kenya)

"Our company serves 6 cooperatives with an average of 40-hectare farming land each. We sell on average 100 tons of Grekompost per cooperative. Our customers are smallholder farmers with a typical 0.5-hectare land or less." (Interview-RW-6; OF producer, Rwanda)

However, challenges arise when collaborating with shops that primarily focus on inorganic fertilisers rather than organic and biofertilisers (OFBF). In such cases, shop personnel require training on these products, which can be time-consuming and costly, especially when there is frequent staff turnover.

In cases where crop residues are collected from large enterprises involved in flower production, fruit crops, or coffee for export, the primary destination for organic fertiliser products is often the enterprises themselves. Some enterprises manage their own compost units.

Smaller companies tend to sell their products directly to neighbouring farmers or within their local communities. Some mentioned a maximum of 50 to 60 km for production and marketing of products to maintain profitability. Larger enterprises target peri-urban and urban farmers, with some maintaining a regional focus and others expanding their reach to export products to other African countries. Advisory services and NGOs often play a pivotal role in introducing OFBF but face limitations in knowledge. Training is essential, as they are typically experts in inorganic fertilisers and may not fully trust or advocate for OFBF, especially for farmers who prefer fertilisers with short-term impacts.

Overall, distribution channels for OFBF are underdeveloped in all countries studied, which is reflected in the lack of knowledge and awareness among farmers and other stakeholders on OFBF.

5.6.6 Marketing

Farmers exhibit reluctance to adopt OFBF primarily due to their familiarity with inorganic fertilisers, concerns 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.

Others utilise electronic media platforms such as WhatsApp, Facebook, SMS broadcasts, farmer organisations, advisory services, or NGOs to disseminate information and distribute their products. Moreover, farmers who are convinced by the products often become ambassadors for the companies' offerings.

Producers of OFBF target specific customer segments and tailor their advertising strategies accordingly. Some producers focus on small farmers, driven by ethical and environmental considerations, while others prioritise organic farmers with export products or larger commercial farmers with high value crops. Overall, advertising strategies are evolving, with further professionalisation expected.

Some interviewees emphasised that a lack of effective mechanisms for verifying the claims made about the organic and biofertilisers can lead to disappointment when these claims are not upheld. This lack of verification is identified as a primary barrier that could deter potential users. Moreover, the convenience of using organic and biofertilisers, when compared to mineral fertilisers, may pose another obstacle.

5.7 Scientific and educational environment

5.7.1 Research

Research on the impact of off-farm produced organic and biofertiliser (OFBF) on soil, the environment, and crops is still limited in most countries, primarily confined to specific universities or research institutes (e.g., CGIAR centres such as the International Institute for Tropical Agriculture (IITA), and the International Water Management Institute (IWMI). This research is even less common within state research institutions. As a result, OFBF producers often take it upon themselves to conduct research, albeit with limited resources. Some producers engage in collaborative efforts, receiving support from local and international universities or international donors (Table 16).

Table 16. Overview of selected institutions, research activities, challenges and gaps

Country	Selected institutions/partners	Overview of research and initiatives	Challenges and gaps
1. Cameroon	Universities in Douala, Buea, Yaoundé, Dschang	Lack of formalised research on OFBF; limited quantitative research; ongoing projects	Lack of quantitative data; need for collaboration and knowledge dissemination
2. Côte d'Ivoire	CSRS: Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, FIBL Switzerland	Limited research on organic fertilisers	Limited research resources; need for comprehensive documentation
3. Egypt	Individual researchers, Heliopolis University, SEKEM, University of Sadat City	Research focuses on practical solutions; lacks national research agenda; positive impact on soil and crops under specific conditions	Need for a national research agenda; transparency in trials; scaling up research
4. Ethiopia	Arba Minch University, NABU Germany, Bahir Dar University, Eco Green Ethiopia, ETH Zurich, DBFZ	Soil fertility map; research hotspots	Limited research activities; inadequate equipment and chemicals; limited public funding
5. Ghana	IWMI, IMANI Centre for Policy and Education, University of Cape Coast, University of Development Studies (Tamale)	Limited development of organic fertilisers; need for increased research and dissemination	Limited financial support; lack of awareness among farmers
6. Kenya	Cornell University, Nairobi University, Cranfield University, ICRAF, IITA, REGEN Organics	Collaboration with various institutions; research and development of organic fertilisers; focus on R&D	Knowledge transfer
7. Malawi	Department of Agricultural Research Services, Agriculture Research and Extension Trust, IITA	Trials testing organic fertilisers; collaboration with Japanese researchers and IITA on Rhizobia	Collaborative efforts needed; awareness among farmers
8. Rwanda	Rwanda Agriculture Board, ISAE	Government support for OFBF research	Lack of systematic programme; expensive services
9. Senegal	FENAB, ANCAR (Agence Nationale de Conseil Agricole et Rural), Agreco Afrique, Enda Tiers Monde	Training on use and application	Lack of official assessments; limited data availability
10. South Africa	Multiple researchers, universities	Significant research efforts on OFBF; collaborative projects on biostimulants/biofertilisers	Exploring molecular and biochemical pathways; using waste for composting and biochar production

Country	Selected institutions/partners	Overview of research and initiatives	Challenges and gaps
11. Uganda	Uganda Martyrs University, GULU University, Makerere University	Efforts to compile and document traditional knowledge	Lack of thorough documentation; limited funding
12. Zimbabwe	Research institutes, companies, Agriculture Extension Services	Limited literature; research by institutes and companies; need for better coordination	Coordination of research efforts; limited national-level funding

Source: Key informant interviews

Cameroon: Currently, there is a lack of formalised research on OFBF, lack of quantitative research assessing the impact of fertilisers on crop yields, with data being mostly observational rather than scientifically quantified. Some researchers who conducted research on organic fertiliser and/or biofertilizer are related to University of Douala (e.g., waste management policies), University of Buea (e.g., waste management policies), University of Yaoundé (e.g., economic and agronomic viability of waste-based organic fertiliser), and Dschang University (e.g., community waste-based composting projects).

While some product analyses have been conducted in France and the United States, comprehensive research on the outcomes is limited; there are efforts to collaborate with the International Institute for Tropical Agriculture (IITA) on the dissemination of knowledge related to OFBF, others mentioned collaboration with 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.

Côte d'Ivoire: Research on organic fertiliser from waste sources remains relatively limited. There is one ongoing study examining the impact of applying 10 tons per hectare of compost in comparison to inorganic fertiliser. Preliminary findings from this study suggest an increase in maize yield when using organic fertiliser, although these results have not been published yet. Funding opportunities for research in this area are available through government institutes and other mechanisms.

Egypt: Research on off-farm production of OFBF exists, but it is primarily focused on finding practical solutions for farmers rather than publication. While some individual researchers show interest in the topic, there is no established national research agenda. The trial concepts often lack transparency and detailed descriptions. Nevertheless, it is evident that these concepts have a positive impact on soil, crop yield, and quality, particularly in conditions characterised by low carbon content and soil salinity.

Ethiopia: 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). However, there is currently a lack of a comprehensive plan to enhance soil health. There are a few research hotspots, including Arba Minch University (in collaboration with ETH Zurich), the Lake Tana Water Hyacinth project by NABU Germany, and rhizobia research at Bahir Dar University. Nevertheless, research activities in general are quite limited. Some companies conduct their own research (Eco Green Ethiopia). University research on OFBF is often at a preliminary stage, hindered by inadequate laboratory equipment and chemicals.

based at Uganda Martyrs University in cooperation with the association PELUM, Gulu University (e.g., quality of municipal solid waste composts, waste bioenergy potential), and Makerere University (e.g., use of human waste, MSW composting, value addition of agricultural by-products).

Ghana: Organic fertiliser research is still in the early stages of development compared to mineral fertilisers, primarily due to limited research resources. There is a pressing need for increased research efforts, comprehensive documentation, and effective dissemination of research results. Despite the challenges posed by limited financial support, research remains a critical driver of future knowledge generation in this field.

The International Water Management Institute (IWMI), with a branch located in Ghana, has been actively involved in researching the potential for organic waste recycling over the past decade, including the reuse of faecal sludge. Other institutions conducting research on OF and/or BF are for example IMANI Centre for Policy and Education, Accra (e.g., policies for circular economy), University of Cape Coast (e.g., biochar production from agricultural by-products, use of human waste), Kwame Nkrumah University of Science and Technology, Kumasi, University of Ghana, and University for Development Studies, Tamale (e.g., MSW management and recycling). However, a significant issue persists – many farmers remain unaware of valuable research findings, underscoring the importance of extensive participatory research and dissemination.

Kenya: Some companies active in organic fertiliser production such as the case for Regen Organics (Annex: Business case 1) pursue collaborations with esteemed institutions like Cornell University, MIT, and Nairobi University. These collaborations have played a pivotal role in the research and development phase of their products. A collaboration with Cranfield University, funded by Pilot House, is dedicated to the development of an organo-mineral fertiliser and more concise recommendations for fertiliser application rates.

Malawi: The Department of Agricultural Research Services and the Department of Land Resources Conservation are organising trials to test organic fertilisers, such as Mbeya fertilisers, which are blends of organic materials.

Regarding Rhizobia, Japanese researchers from the University of Kyoto have played a pivotal role in ensuring product quality through their support. Additionally, Malawi’s Agriculture Research and Extension Trust has made substantial contributions to this effort. The valuable insights obtained from their research findings are integrated into product labels to provide essential information to users. Collaborative efforts with IITA have been concentrated on promoting the use of Rhizobia as legume inoculants. The difference in crop production between fields treated with inoculants and those without is reported to be substantial, underscoring the significant untapped potential in this area.

Rwanda: The government has initiated support for OFBF research (see Rwanda Strategic Plan for Agriculture Transformation 2018-2024). Researchers have conducted tests on products and run trials, but a systematic research programme is lacking. The high cost of soil and product analysis presents a barrier to developing an appropriate fertiliser strategy. Producers are connected with researchers to ensure compliance with all specified standards, and these researchers conduct tests on the product and carry out trials. In Rwanda, the Rwanda Agriculture Board (RAB) and the Institute of Agriculture, Animal Husbandry, and Environment Management (ISAE) are the main research institutions with expertise in soil and fertiliser analyses. However, their services can be expensive.

Senegal: At the farmer organisation level, there has not been an official assessment of organic fertiliser effectiveness. However, university-led research initiatives have undertaken such assessments, often with a bias toward mineral fertilisers. Some parameters suggest that organic fertilisers like Bokashi may lack certain essential nutrients. Limited research exists on different fertiliser types, but comparative tests have shown that plants receiving organic fertilisers exhibit enhanced resistance, longevity, production, quality, and resilience to pests and diseases. Official assessments comparing locally produced organic fertilisers and off-farm OFBF are lacking.

Quantifying the potential of organic waste remains complex, with specific figures elusive due to a lack of available data. Estimating waste for the ten largest crops would require a more comprehensive analysis not readily accessible at present.

South Africa: Significant research efforts are currently underway to explore the potential of OFBF in regenerating degraded land and restoring productivity. These initiatives include collaborative projects with partners in Sweden, spanning five years, aimed at developing biostimulants/biofertilisers. In addition to studying plant growth and soil health, this research delves into the molecular and biochemical pathways of plants. Scientists are investigating how genes are activated or suppressed following the application of these biofertilisers/biostimulants. Multiple researchers across South Africa are actively engaged in such projects, often in partnership with universities, with a specific focus on biofertilisers. Other research collaborations explore the use of human and household and green waste for co-composting and biochar production from human waste (e.g., RUNRES project).

Uganda: Concerted efforts are underway to compile literature and comprehensively document the knowledge pertaining to organic farming practices. While traditional practices have yielded a repository of knowledge, the absence of thorough documentation, particularly in a scientific framework, remains conspicuous. Researchers are addressing this gap, striving to synthesise scientific evidence with farmers' practices. It is worth noting that there is limited public funding available for research in the field of OFBF. Some research activities are for example

Zimbabwe: Research institutes and agricultural colleges play pivotal roles in conducting research trials and establishing demonstration plots. Additionally, companies such as the Tobacco Research Board, also play a role in assessing the impact of various fertilisers. However, there's a need for better coordination and consolidation of research efforts, as well as reporting and information dissemination.

To advance research in this field, collaboration with experts in agriculture entrepreneurship and economics is essential to conduct socioeconomic assessments of OFBF production. Universities often work with limited investment support. While some institutional-level support is occasionally received from companies seeking research on their products, national-level funding for research on OFBF is still a pending challenge.

Research on vermicompost serves as an illustrative example. The Tobacco Research Board conducted a four-year study on the suitability of vermicompost for tobacco, confirming its successful use in tobacco cultivation. The Marondera Horticulture Research Station has also demonstrated its effectiveness in various horticultural products. Zim Earthworm Farms secured a government tender and conducted experiments involving Water hyacinth and Hydrocleis to feed worms and produce vermicompost. Notably, the Agriculture Extension Services, a government department, engaged in seven years of research in collaboration with Zim Earthworm farms.

5.7.2 Awareness, knowledge, education and training

According to various interviewees, only a minority of farmers possess the knowledge and awareness required for effective organic fertiliser management. This knowledge is crucial for enhancing soil fertility, crop yield, and quality.

While some advisory services and non-governmental organisations specialise in organic fertiliser preparation, such as compost and bio-slurry, the majority still primarily focus on inorganic fertilisers (IF). This pattern is consistent across different countries, where extension services, farmers, and educational institutions tend to prioritise inorganic fertilisers. One common expectation is the immediate, visible impact on yields from using inorganic fertilisers.

However, the use and application of OFBF demand a different set of knowledge and skills. This includes understanding soil processes, fertility, and the appropriate application rates and timing. Additionally, combining organic and mineral fertilisers can be advantageous, but it requires specific skills, knowledge, and economic understanding that are often lacking.

Many interviewees stress the importance of awareness, education, and training for farmers, agricultural extension services, and agro-dealers regarding the utility, handling, and application of OFBF. This includes knowledge on key quality criteria such as for example organic matter content and C:N ratio in organic fertiliser. Effective promotion of these fertilisers also relies on raising awareness and outreach efforts. Nevertheless, challenges like resistance to change among farmers and the influence of agricultural industries are sometimes mentioned.

Certain OFBF enterprises provide demonstration trials and training programmes for extension workers and farmers. Notably, the adoption of OFBF practices remains relatively rare within governmental advisory services. This trend also extends to universities, with a few exceptions, such as Heliopolis University in Egypt and Mountain of the Moon University in Uganda, among others. Nevertheless, Universities and research institutions play a vital role in educating students and conducting research related to OFBF. In all countries, at least some universities or research institutes engage in research on various aspects of off-farm production of OFBF.

Across the board, it is mentioned that field demonstrations, workshops, and community-based trials play a central role in educating and promoting OFBF practices. However, many producers express that setting up demonstrations, educating and training farmers often exceeds their capacity in terms of both capital and time. Table 17 presents a summary of the varied insights shared by interviewees from different countries, particularly focusing on aspects related to knowledge, education, and training concerning both general fertiliser use and specific organic alternatives.

Table 17. Awareness, knowledge, education and training

Country	Key points from the key informant interviews
Cross-country experts	**Attitudes and perceptions** ▪ Public receptiveness to fertilisers derived from excreta is crucial, given diverse community attitudes. ▪ Addressing these perceptions is challenging, and surprises may arise. ▪ Education is needed to promote understanding and willingness to use such products. ▪ Farmers' resistance to embracing new approaches remains a significant challenge. **Organic matter in agriculture** ▪ Agricultural awareness is crucial for understanding the significance of organic matter. ▪ Organic matter is essential for long-term food production, and chemical fertilisers lack this vital component. ▪ Raising awareness about its value is of utmost importance. **Perception of organic fertilisers in Africa** ▪ Overcoming the perception that manure is the only organic fertiliser in Africa is a significant challenge. ▪ Workshops and seminars are needed for both farmers and extension services. ▪ Transforming animal waste into organic fertilisers contributes to environmental clean-up and promotes the circular economy. **Clear distinction and education** ▪ The absence of a clear distinction among organic fertiliser products based on crops is a barrier. ▪ Education plays a pivotal role in fostering understanding of standards, and the formulation of a certification scheme is emphasised to address this issue. **Knowledge sharing and collaboration** ▪ Knowledge-sharing and collaboration should be supported among entrepreneurs to avoid reinventing the wheel (e.g., BSF technology and handling). ▪ Entrepreneurs face similar challenges but often operate in isolation due to competition or a reluctance to share information.
1. Cameroon	**Challenges in educating farmers about OFBF** ▪ Educating farmers about OFBF often requires extensive awareness campaigns, especially in major agricultural hubs. ▪ Building trust and convincing farmers to buy unfamiliar products may involve providing samples to showcase quality. ▪ Digital technology can play a crucial role in reaching farmers and educating them about the quality and advantages (e.g., social media channels). ▪ Familiarity with granular fertilisers makes farmers hesitant to embrace OFBF. **Training on OFBF** ▪ While many NGOs offer training in compost production, there is limited focus on training in the production and application of off-farm produced OFBF.

<table>
<tr><th>Country</th><th>Key points from the key informant interviews</th></tr>
<tr><td></td><td>

Conventional farming methods dominate.
Small-scale farmers lack access to quality guidance for adopting new practices.
No dedicated courses or structured training programmes exist for off-farm fertiliser production.
NGOs work along the entire value chain, from production to marketing, offering diverse training programmes and facilitating exchanges between producers and farmers.

Community level approach

Conducting village-based workshops and demonstrations is effective in educating and marketing OFBF.
Collaboration with village chiefs, larger farms, and agricultural corporations can further promote OFBF.

The Cameroon Forum for Agricultural Advisory Services (CAMFAAS) introduced an innovative “tontine” system for organic fertiliser production involving community members; Efficient task division between younger and older women to produce fertiliser; Scalable and economically sustainable approach that helps farmers save money and energy; Requires voluntary involvement and cooperation of community members.
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<tr><td>2. Côte d’Ivoire</td><td>

Lack of knowledge about production techniques and regulations related to fertiliser use exists throughout the entire chain.
Absence of concrete data from experimental plots demonstrating the advantages of organic fertilisers over chemical ones hinders progress.

Farmers often prioritise short-term costs, which hampers the adoption of compost and other organic fertilisers.
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<tr><td>3. Egypt</td><td>
General challenges for OFBF adoption

Outdated information is a significant challenge.
Many farmers are unaware of suitable products for their crops and growth stages.
Disappointment occurs when farmers encounter low-quality products due to inadequate quality assurance measures; production methods contribute to the problem.

Knowledge gap

Some OFBF producers struggle to optimise products chemically and/or biologically.
Farmers lack a comprehensive understanding of product functioning. Some farmers mistakenly assume these products work like inorganic fertilisers.

Communication and knowledge dissemination challenges

Inadequate communication between researchers and government agencies.
Official extension service effectiveness is limited.
Lack of a structured private extension body.

Selected activities, e.g., Heliopolis University & SEKEM

Comprehensive education on OFBF production, technology, and variety.
Education of product use: Approach involves grouping farmers and conducting demonstration trials. 50% of trials showcase innovative plots, while the other 50% reflects farmers’ actual practices.
This approach allows farmers to witness the benefits firsthand.

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<tr><td>4. Ethiopia</td><td>

Insufficient awareness and acceptance of household waste recycling.
Severe constraints in advisory services for compost application.
Lack of university-level curricula addressing organic waste management.
Agricultural extension workers educating smallholder farmers about composting and compost preparation using crop residue and animal dung are the exception rather than the standard practice. However, the government recently initiated increased propagation of on-farm compost production.

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Country	Key points from the key informant interviews
5. Ghana	▪ Farmers often perceive that organic fertilisers do not provide immediate results like inorganic ones. ▪ Capacity building and education are crucial to change this perception and help farmers understand the long-term benefits of organic fertilisers. ▪ Some companies provide training for farmers and establish demo plots. ▪ Despite efforts, awareness and knowledge of using organic fertilisers remain relatively low among farmers, including educated ones. ▪ MoFA provides advisory services through extension agents to raise awareness among farmers about organic options. ▪ While many farmer organisations are dysfunctional, some operational groups play a significant role in spreading awareness about OFBF products. ▪ OFBF application: challenges include determining appropriate rates, timing, locations for compost and biochar production, and field application. ▪ Farmers prefer using their own organic fertilisers if they have the necessary knowledge and technical know-how.
6. Kenya	**Challenges for OFBF companies** ▪ Significant challenge in persuading and educating farmers about the importance and benefits of OFBF. ▪ Advisory services have limited awareness of alternative fertilisation approaches. ▪ Primary emphasis remains on Diammonium Phosphate (DAP). **Education and awareness efforts** ▪ Farmer field days, inviting other farmers, and conducting demo trials are crucial for implementing OFBF. ▪ Various activities are organised, but they are still limited in scope.
7. Malawi	▪ The government is actively promoting the use of organic manure and compost, such as Mbeya manure. ▪ Field demonstrations, radio advertisements, and flyers have proven to be the most effective means of promoting these initiatives, e.g., Rhizobia adoption. ▪ The University of Lilongwe plays a key role by providing demonstration plots to showcase technologies, e.g., Bio-nitrate fertiliser from human urine. ▪ Training of agro-dealers in OFBF is crucial, especially due to frequent personnel turnover.
8. Rwanda	**Farmers' awareness and training on organic fertilisers** ▪ Many farmers are aware of organic fertilisers and use them alongside mineral fertilisers. ▪ Some farmers market their on-farm produced organic fertilisers to larger companies. The government has launched an awareness campaign to educate smallholder farmers about using their composts instead of selling them. ▪ The government campaign also promotes compost-making cooperatives at the village level, especially targeting rural youths through grants. ▪ Rwanda Agriculture Board (RAB) provides soil analysis support, and Rwanda Standards Board handles testing and certification. ▪ Rwanda has been training smallholder farmers in compost production, resulting in certified compost producers in selected villages. ▪ Lack of knowledge remains a significant challenge, prompting government capacity-building programmes. ▪ Growing interest in organic agriculture has led to various organisations and the Ministry of Agriculture initiating training programmes. ▪ Rwanda Organic Agriculture Movement (ROAM): serves as the primary source of literature (dissemination material) on organic agriculture in Rwanda and provides training on organic fertilisers. **Knowledge dissemination** ▪ Radio Huguka (covers 60% of Rwanda) plays a crucial role in disseminating agricultural extension messages and promoting organic fertilisers.

Country	Key points from the key informant interviews
	▪ Radio Huguka collaborates closely with OFBF producers and farmers to share information.
9. Senegal	**Knowledge and awareness** ▪ Efforts are needed to educate, raise awareness, and train farmers about benefits of OFBF. Farmers become advocates of OFBF once they experience positive outcomes. ▪ Agronomists in Senegal are heavily trained in conventional agriculture and chemical fertilisers. Current agricultural education emphasises chemical fertilisers, hindering the transition to organic alternatives. ▪ Some farmers mistakenly believe that only increasing inorganic fertiliser application will double their yields (without considering soil fertility). ▪ Influence from well-funded inorganic fertiliser companies perpetuates this misconception. ▪ Comprehensive efforts in education and awareness are required at all levels of the agricultural sector. ▪ NGOs play a role in procuring and reselling organic fertilisers to farmers.
10. South Africa	▪ Agriculture faces challenges including limited support and knowledge. ▪ Knowledge gaps among agriculture extension agents and deficiencies in education curriculums. ▪ Combining organic and mineral fertilisers can be beneficial but requires specific skills, knowledge, and economic understanding. ▪ Measurement tools for OFBF, particularly assessing microbial life forms and their influence on crop growth, are lacking. ▪ Raising awareness and outreach efforts are essential for effective promotion of OFBF; ▪ Advisory services often receive training from conventional input industries, possibly discouraging the promotion of alternative methods. ▪ Younger farmers with internet access tend to be more open to new ideas and practices. ▪ Concerns about misinformation in the agricultural sector and "greenwashing" by some companies can create confusion among farmers.
11. Uganda	**Lack of government-led education and training** ▪ The public extension services do not directly offer education and training on OFBF use and application. ▪ Training opportunities are primarily provided by the private sector, especially NGOs. **Obstacles to OFBF adoption** ▪ Limited awareness among farmers about the benefits of organic fertilisers. ▪ Insufficient training in proper application techniques. ▪ Lack of established and reliable organic fertiliser products. ▪ Challenges in bridging the knowledge gap for product development and technology. ▪ Limited knowledge and expertise of agriculture extension services regarding OFBF. ▪ Absence of modern technology integration, hindering the detection of misuse and counterfeit products. ▪ Lack of standardised measures; traditional knowledge varies among regions and families. ▪ Many OFBF producers face challenges with support and awareness-raising, especially regarding farmer assistance organisations. ▪ Development agencies promote regenerative agriculture, but their approach does not always align with goals of OFBF producers. ▪ Challenges in setting up demonstration plots due to financial constraints. ▪ Limited influence of farmer organisations over farmers' decisions. **Positive developments** ▪ PELUM Uganda is actively involved in projects promoting organic fertiliser production, management, and application.

Country	Key points from the key informant interviews
	▪ The Organic Knowledge Hub for Eastern Africa (GIZ) seeks to enhance farmer capabilities. Farmers are actively involved in learning and experimenting with organic fertiliser production and application. ▪ Organisations like AWOLA and IMAGINE HER support small OFBF initiatives. ▪ PELUM Uganda utilises social media for promotion. ▪ Acceptance of OFBF among farmers is increasing. ▪ Manufacturers contribute expertise for more effective product development. ▪ Tooro Kingdom partners with organic farmers for training and knowledge transfer. ▪ NOGAMU collaborates with institutions like Uganda Martyr's University for OFBF development. The latter offers various programmes related to organic fertiliser production and sustainable agriculture.
12. Zimbabwe	▪ Department of Agriculture Extension Services plays a vital role in disseminating information and raising awareness about OFBF. They support on-ground demonstrations and assist farmers in adopting these fertilisers. ▪ Demonstration plots at agricultural colleges play a significant role in training prospective agricultural extension workers.

Source: Key informant interviews

5.8 Policies, regulations and certification

The common thread among the various countries is the shared challenge of developing and implementing comprehensive policies, regulations, and certification processes for OFBF. The absence of dedicated regulatory frameworks, coupled with varying degrees of support from governments as well as the lacking cross-sector collaboration in the case of organic fertilisers (agriculture, waste management, and sanitation), poses hurdles to the widespread adoption and production of OFBF. These challenges encompass issues such as the lack of clarity in policies, inadequate standardisation, complex registration procedures, and resource competition with mineral fertilisers. While some countries have taken positive steps to promote organic fertilisers (e.g., Senegal and Ghana), there is a collective need for clearer policies and streamlined regulatory processes to unlock the full potential of OFBF in agriculture (Table 18).

"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." (Interview-MAL-8; Rhizobia Producer, Malawi)

In most countries, government accreditation for products is mandatory, which can be a time-consuming process lasting up to three years and incurring significant costs. However, this situation does not deter producers from offering their products in the market. For exporters, especially larger producers, certification is a requirement, presenting additional challenges as both national and international standards must be met. The lack of organic certification hinders the distribution of OFBF in organic farming, even though organic farmers are among the most relevant customers.

Table 18 presents a summary of the varied insights shared by interviewees from different countries, particularly focusing on aspects related to policies, regulation and certification in general and for the different countries in specific.

Table 18. Policies, regulation and certification

Country	Key points on policies, regulation and certification
Cross-country experts	**Standards and regulations** ▪ Enforcement of existing local regulations is currently lacking in many countries but are essential for ensuring the quality and safety of organic fertilisers. ▪ Policies supporting organic soil inputs yield a larger return on investment, addressing both agricultural and public health benefits.

Country	Key points on policies, regulation and certification
	▪ Quantifying public health benefits is challenging, but holistic policies acknowledging broader societal benefits are crucial. **Policy-oriented approach and nutrient recovery** ▪ Policy initiatives play a pivotal role in nutrient recovery and reshaping the landscape. ▪ Clear policies are lacking which are needed to permit and guide the safe application of faecal sludge in agriculture, encouraging private sector and municipal involvement. ▪ Circular economy initiatives require a multi-stakeholder approach, involving various sectors like sanitation, agriculture, and energy. **Challenges in testing and corruption** ▪ Challenges in testing organic fertiliser products by local authorities, including deviations from prescribed procedures, pose currently significant hurdles. ▪ Corruption is pervasive in Africa and often leads to project delays, emphasising the importance of understanding and navigating these challenges. **Regulatory framework and certification** ▪ The development of clear regulatory frameworks, standards, and certification schemes is essential. ▪ Lack of distinction among products based on crops is currently a barrier that needs education and awareness for understanding standards. **Comprehensive waste management policies** ▪ Well-rounded policies should address waste segregation, financial support, and high-quality waste management products. ▪ Municipal collection services, diverse revenue sources, local food production independence, and education are crucial aspects of efficient waste management policies. ▪ Policies can adopt a combination of incentives and regulations for effective waste management, aligned with global initiatives. **Enabling environment for circular economy** ▪ Understanding the financial and regulatory environment is crucial for supporting the circular economy. ▪ Regulatory alignment with project goals is necessary to avoid hindrances in wastewater reuse projects. ▪ The financial environment, institutional capacities, regulatory framework, and public perception are key factors for successful initiatives. **Competing landscapes and policy environment** ▪ Competing landscapes, dominated by large waste management companies, can hinder the establishment of new initiatives (Example from Ghana). ▪ Clear policy environments are currently lacking which are needed to support initiatives like the reuse of faecal sludge as co-compost, attracting potential investors and addressing multiple challenges simultaneously. ▪ Policies promoting the use of faecal sludge as co-compost could attract green climate finance, making it a key policy area. **Social mobilisation** ▪ Social mobilisation and awareness-raising campaigns play an essential role in waste management. ▪ While entrepreneurs can manage the waste treatment process, policies need to drive waste segregation campaigns, promote awareness, and motivate public participation. ▪ These actions are typically beyond the scope of waste management entrepreneurs.

Country	Key points on policies, regulation and certification
1. Cameroon	▪ Cameroon lacks comprehensive policies and regulations to promote organic fertilisers, leading to the continued dominance of inorganic fertilisers. ▪ Competition for resources between organic and inorganic fertiliser initiatives is influenced by political interests and potential ties to the chemical fertiliser industry among government officials. ▪ Public authorities often lack practical knowledge of organic fertiliser production, hindering the development and implementation of effective policies. ▪ A subsidy programme provides up to 30% subsidies to the mineral fertiliser sector, but questions have been raised about its effectiveness, and the legal framework complicates its implementation. ▪ Waste sorting in Cameroon faces challenges due to complex and poorly enforced legal frameworks, hindering the diversion of waste to productive uses like organic fertiliser production. ▪ Inconsistent enforcement of fertiliser standards contributes to counterfeit products in the market, and the lack of specific laws promoting organic fertilisers hampers certification processes. ▪ The certification process for organic fertilisers is complex and expensive, discouraging production and expansion. ▪ Despite efforts to combat counterfeiting, effective enforcement remains a challenge, leaving farmers susceptible to fraudulent products. ▪ Challenges in obtaining organic certification include difficulties in verifying the organic status of inputs and high audit expenses. ▪ Municipalities in Cameroon often hesitate to invest in waste management, despite the negative impact of poor waste disposal, and public-private partnerships prioritise waste collection and landfill disposal over waste reuse. ▪ Empowering local councils to adopt waste management strategies can promote composting activities and enhance overall waste management practices.
2. Côte d'Ivoire	▪ Currently, in Côte d'Ivoire, there is limited policy focus on OFBF, and discussing environmental matters can be challenging.
3. Egypt	▪ Concerns exist in Egypt regarding the regulation of OFBF due to perceived product instability. ▪ Existing regulations in the OFBF sector are ambiguous, causing confusion for local producers and leading to issues like the spread of nematodes and fungal diseases from compost products. ▪ In 2020, the Egyptian parliament passed a law on organic agriculture, bringing significant improvements to the regulatory landscape but not resolving all issues. ▪ Many products in the market lack official government recognition, allowing almost anyone to produce and get approval from the Ministry of Industry without official sanction. ▪ Efforts are underway with the Egyptian Organisation for Standardisation and Quality to establish ISO-based standards, including seven standards for different OFBF products, e.g., biochar, vermicompost.
4. Ethiopia	▪ OFBF standards exist, but effective quality control is lacking. ▪ The crisis related to mineral fertilisers has led policy makers to consider OFBF as a potential solution. ▪ Positive developments in the Ethiopian government include the integration of composting into development plans and progress in the national biogas programme for larger-scale production plants (100 to 300 m3), which can provide energy for hospitals and schools. ▪ Ethiopian Solid Waste Management proclamation (Article 11.1) envisions household waste segregation, but lacks proper enforcement measures.
5. Ghana	▪ Ghana is making efforts to promote OFBF, with guidelines developed in 2022 and training programmes in progress, primarily supported by importers of these products.

Country	Key points on policies, regulation and certification
	▪ Stakeholder engagement within Ghana's ecological organic agriculture platform involves scientists, organic producers, and importers to establish acceptable practices, resulting in practical guidelines. ▪ During the fertiliser crisis, the Ghanaian government engaged compost producers and waste management experts to enhance local production. Recent developments include meetings, campaigns, and training programmes to support organic agriculture. ▪ Registering and testing organic fertilisers in Ghana is time-consuming, taking up to three years, which can be economically challenging, especially for small and medium-sized enterprises. ▪ Farmers who do not own land face challenges with organic fertilisers due to uncertain lease renewals and the slow release of benefits. ▪ The Accra Compost and Recycling Plant partners with the government in the Planting for Food and Jobs Fertiliser Subsidy Programme but faces challenges with continuous quality testing.
6. Kenya	▪ The development process lacks supportive measures for expediting progress, although the overall conditions were described as acceptable. ▪ Organic fertiliser registration takes approximately one and a half years, with room for improving and optimising the regulatory framework.
7. Malawi	▪ Malawi's National Fertiliser Policy of 2021 aims to promote the production, marketing, and use of high-quality inorganic and organic fertilisers. Organic agricultural value chain wastes and green waste are recommended as primary sources of organic fertilisers. ▪ The government advises the use of organic fertilisers without mixing them with mineral fertilisers, although there may be some lack of clarity regarding their purity. ▪ In response to various crises, such as Covid-19 and fertiliser shortages, the government has taken some measures, but there is no clear long-term strategy for addressing fertiliser shortages beyond subsidies. ▪ In 2023, Malawi introduced an organic fertiliser policy and established a regulatory framework for production standardisation, though there are no direct regulations on the importation of organic and biofertilisers. ▪ There are no subsidies for organic and biofertiliser producers or farmers, and support for industrial production of organic biofertilisers lacks clarity despite the National Fertiliser Policy's encouragement.
8. Rwanda	▪ Rwanda has established a national agriculture policy that covers both organic and mineral fertilisers, along with a strategic plan for agricultural transformation that includes both types. ▪ The absence of an organic agriculture policy in Rwanda leads to disparities in support for organic and mineral fertilisers. This lack of a supportive framework poses challenges for OFBF production and marketing. ▪ The government focuses on enhancing the quality of organic fertilisers through research and capacity-building for farmers. Discussions are ongoing about incorporating organic fertilisers into existing fertiliser subsidies. ▪ Tax exemptions on equipment and packaging materials are offered to support OFBF producers. However, Rwanda lacks waste sorting regulations or systems, limiting government support for organic fertiliser production. ▪ Importation of OFBF is less extensive than mineral fertilisers but still occurs, requiring import licenses and adherence to regulations, including safety testing and pilot runs. ▪ There are research inquiries into the potential production of organic fertilisers from human waste (Ecosan) in Rwanda, but government approval and regulations in this regard are unclear.
9. Senegal	▪ Since 2021, the Senegalese government has increased support for organic fertilisers, aiming to subsidise approximately 11 000 t by 2022-2023. ▪ Despite this shift, Senegal faces challenges, including the absence of standardised regulations for OFBF, which has led to the emergence of inexperienced companies, potentially jeopardising the industry's credibility.

Country	Key points on policies, regulation and certification
	▪ Senegal lacks established standards for organic fertiliser application, causing uncertainty about recommended application rates, ranging from 3 to 6 t/ha, creating a competitive but confusing market. ▪ Widespread adoption of organic fertilisers faces obstacles, and special attention is needed for regions, women, and young individuals seeking opportunities in rural areas. Sustainable financing mechanisms should replace last-minute fund allocation.
10. South Africa	▪ The Agriculture Research Council has successfully advocated for farmers' access to organic inputs, leading to government financial support for the purchase of organic fertilisers. ▪ Advocacy is crucial because policy makers often struggle to understand the realities of OFBF. While there is a positive shift in government recognition of OFBF, a clear strategy to promote them to the same level as mineral fertilisers is still lacking. ▪ The registration process for organic inputs in South Africa is cumbersome, as both off-farm OFBF must undergo the same screening process as mineral fertilisers. Efforts are underway to simplify the registration process for bio remedies, potentially incorporating OFBF. ▪ South Africa lacks a specific regulatory framework for OFBF, and regulatory bodies struggle to keep pace with industry advancements. Corruption and inefficiencies further delay the registration of new fertilisers, including organic ones.
11. Uganda	▪ Efforts are ongoing to involve farmers in policy discussions and integrate their ideas, notably in the development of the National Biotechnology Strategy, emphasising the potential of OFBF as a sustainable alternative to harmful chemicals. ▪ Uganda has a comprehensive organic agriculture policy that requires legislative backing for effective implementation. Supporting OFBF certification, possibly through subsidies, is crucial to boost the organic sector's growth. ▪ Existing policies emphasise on-farm and locally sourced materials in organic production, but the challenge is bridging the gap between policy content and practical execution.
12. Zimbabwe	▪ There is currently no specific policy or regulatory framework dedicated to organic fertilisers; existing regulations primarily focus on inorganic fertilisers. ▪ Regulatory authorities emphasise measuring nutrient levels like nitrogen, phosphorous, and potassium in fertilisers, neglecting factors associated with organic fertilisers such as biomass, microorganisms, and soil carbon content. ▪ The current policy framework strongly supports inorganic fertilisers, with development partners and sales outlets also favouring mineral fertilisers over organic alternatives. ▪ Shifting policies and engagements toward OFBF has the potential to increase their acceptance among farmers.

Source: Key informant interviews

5.9 Future prospects and recommendations

The subsequent section encapsulates the perspectives shared by interviewees regarding future prospects and their recommendations for the evolution of diverse fertiliser strategies, with a specific focus on off-farm produced OFBF.

5.9.1 Mineral fertilisers

There is a consensus among many of the interviewees on the need for a renewed mineral fertiliser strategy that considers farming systems and nutrient cycles beyond the farm. An integrated approach is seen as essential, emphasising both fertiliser use and investments in soil health. Some countries are planning to produce portions of their mineral fertilisers domestically.

To make mineral fertilisers more environmentally friendly, a decentralised green ammonia production approach was mentioned as a promising approach for the future. However, it necessitates significant capital investment for the production facilities as well as solar power installation. Further research focusing on assessing the feasibility and sustainability of this approach was recommended.

In the view of many interviewees although not all, the fertiliser crisis started to offer opportunities, as OFBF complement the availability of mineral fertilisers.

5.9.2 Farm internal organic fertilisers

Various interviewees mentioned that farmers, in general, should be well-informed about the benefits of compost and bio-slurry, and the need for training on producing and applying high-quality compost and bio-slurry using locally available resources. Encouraging the use of "internal" organic fertilisers sourced locally and integrating them with mineral fertilisers was viewed as an optimal approach, as it capitalises on their complementary characteristics. Some interviewees emphasized that the OFBF strategy should be harmonised with other agricultural practices, such as liming, alley cropping, incorporating forage legumes and animals.

5.9.3 Production and technology

Various experts noted the significant potential of nutrient recovery from waste and that respective technologies exist.

„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." (Interview-GI-2; International consultant)

A considerable amount of waste is generated in urban areas, yet the nutrients it contains are needed in rural regions. It is crucial to establish a mechanism for these nutrients to flow back to where they are required.

It was generally agreed that organic waste should be refrained from being discarded at dumpsites; instead, implementing source separation of waste would notably enhance the quality of raw materials. Gathering information about available feedstocks, their locations, quantities, and quality is essential for the production of organic fertiliser and soil amendments such as biochar and compost. The potential for using human excrement via biogas and slurry was emphasised by various interviewees, but this might require public demystification. Organic waste holds significant energy potential, particularly in the gasification process, which could be harnessed.

The majority of interviewed organic fertiliser producers regarded decentralising organic waste management as favourable due to the logistical, ecological, and economic constrains of transporting biomass to a central hub (<50 km radius). Decentralised systems can be established in collaboration with local farmers to tailor products to their needs. However, centralisation or decentralisation depends on the specific local context. The economies of scale can be favourable for centralised systems. Nevertheless, a systems-based approach can aid in finding appropriate systems considering various factors. Transport presents challenges, except when the producers directly deliver the materials. Nevertheless, transitioning to organic fertilisers may take time, mainly due to challenges like bulkiness and transport. Implementing effective sorting protocols for organic waste can reduce the time spent removing plastics and other debris.

"One of our big learnings from this first time around is the importance of being as close as possible to the waste streams. To reduce the transportation costs to a site, especially given the inefficiency of freight on the continent, really get, gets up pretty high, especially because you're trucking around a low value product. Government support in finding land in advantageous places would make a huge difference. Subsidizing the mechanization that's used (e.g., windrow turner) would incentivise proliferation. Basic mechanization or the shredding of the material on the way in makes a huge difference on the time it takes to compost and the quality of the compost in the end. Improved upstream

sorting, if there was sorting of organic waste from, you know, we spent a lot of time picking plastics and different debris and t-shirts." (Interview-KEN-4; OF Producer, Kenya)

Several interviewees emphasised the possibility of pelletising organic fertilisers as a strategy to reduce bulkiness, enhance ease of handling, and enable the mechanical spreading of the pelletised fertiliser for streamlined mechanised operations. However, pelletisation increases electricity and machinery costs, requiring careful consideration of economic feasibility. Scrutiny of packaging, storage conditions, and the enduring quality of products over time is warranted. Promoting waste separation awareness is crucial to fully tap into the potential of organic fertilisers. While blending techniques and catalysts used are known for their quality, it was mentioned that upscaling production has proven challenging because the entire process is often manual. Investment in front loaders and general mechanisation, is therefore seen as imperative. Refining the packaging and accessibility of organic fertilisers on a smaller scale was deemed essential.

The persistent issue of power cuts was emphasized to be an issue in various countries as it disrupts production schedules, sometimes necessitating night-time operations. In this regard, transitioning the production unit to solar power or establishing a subsidiary factory, where power cuts are less frequent, was viewed as a possible solution.

It was emphasised that organic fertiliser companies should develop crop-specific products tailored to the individual nutrient requirements of different crops. Rather than offering one-size-fits-all products, it was emphasized that the focus should be on meeting the specific needs of each crop. To maintain up-to-date fertiliser recommendations and address soil acidity concerns, conducting comprehensive soil sampling was considered pivotal.

"We recently received a grant from Pilot House which is giving us the money we need to test 150 different treatments to give farmers across a variety of crops (9 different crops including for example maize, potatoes, cabbage, coffee, avocado, sugar cane) and geographies the most specific application recommendations for the blending of organic fertiliser (compost) and synthetic mineral fertiliser. More grant money like this would allow for a more exact suite of recommendations." (Interview-KEN-4; OF producer, Kenya)

Increased competition may eventually reduce the prices of mineral fertilisers before considering their replacement. For effective organic fertiliser distribution at the farm level, the adoption of appropriate technology was deemed crucial. Innovation and financial support were seen as indispensable across all sectors.

The key difference in producing high-quality compost often lies in the level of municipal support. Subsidies, provision of land, and equipment are essential forms of support to facilitate the composting process. In South Africa, for instance, in one case the municipality covers the cost of the sewage sludge that is utilised, reducing expenses for the project. It was acknowledged that finding cost-effective solutions is critical, especially since compost production can be a challenging business, particularly when considering the costs of waste transport. Transport, both for waste and the final product, is a significant logistical factor. Restructuring a city's waste management is often vital.

Innovations such as container-based sanitation (Annex: Business case 2) is viewed as another interesting option and should be further explored. Such systems can also include for example the treatment of separated urine (alkaline dehydration) and faeces to create a promising fertiliser.

The Black Soldier Fly (BSF) technology was mentioned as promising by various interviewees. In comparison to traditional drying beds, which have space limitations, BSF can process waste more rapidly. However, comprehensive research is needed to determine the economic advantages of using BSF over other methods.

"I think the one that I feel has now, at the moment, the most revenue potential is black soldier fly. But it also has to be clear that black soldier fly can treat a certain fraction of the waste. It's mostly the food

waste, things that are easy digestible. Garden waste, woody waste doesn't really work well. But it's not seasonal, because that's an operation, it's a biological cycle, so you need to make sure that you can always operate it in a regular way (get waste regularly). Of course, you can vary in terms of the size, but of course if you're investing in a facility, you have a certain design size and ideally you want to operate it at the design level, otherwise you're kind of, it's over capacity or under capacity, and that's economically not ideal." (Interview-GI-5; Researcher, Switzerland)

While some older technologies like sludge composting and co-composting have limitations, there is potential for improvement to make them viable. Co-composting can be effective in sanitising faecal sludge (Annex: Business cases 4 and 5). This also ties into the sanitation systems, emphasising the need to view these systems holistically to ensure a sufficient supply of sludge and compost. The nutrients in faecal sludge can enhance the overall nutrient content of composts, although this depends on the composting process quality (e.g., nitrogen losses). It was emphasised to use septage from on-site sanitation rather than sewage sludge, which has different applications such as landscaping. One interviewee highlighted the relative cleanliness of septage, with microbial risks that can be mitigated through co-composting with carbon-rich municipal organic waste.

"(…) there's lots of the faecal sludge. And in the countries where we work, 95% of all the faecal sludge comes from onsite 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 onsite sanitation, about septage tanks and the septage is rather clean. It has microbial risk, but we can eliminate those. And co-composting nitrogen rich faecal sludge with carbon rich municipal organic waste, can produce quite a good product." (Interview-GI-6, Research coordinator, IWMI)

Biochar, including the combination with compost or human waste such as urine, was viewed positive by many interviewees due to its potential for supporting soil health. Another interviewee mentioned the possibility of turning faecal sludge into biochar, citing its potential to alleviate concerns associated with using untreated sludge. Nevertheless, a considerable number of respondents acknowledged the challenge of making these operations and products economically viable. Despite this, the potential avenue of acquiring carbon finance was highlighted as a viable option. For sole biochar one interviewee noted that few farmers are willing to pay for a product like biochar that does not show an immediate effect.

"Organic fertilisers and soil amendments like biochar are very good for us for the simple reason that our soils are quite acidic and the use of lime is not common. But the biochar is alkaline by nature. And all our tests have proven that once we incorporate the biochar, the first thing it does is to improve the soil pH. The other thing is also that it improves the soil water holding capacity. If you have a smallholder farmer growing vegetables, water management comes at a cost. Therefore, if they have biochar in there, that will store the water for a relatively longer period of time. Apart from that, the biochar also retains some nutrients to soil. So, biochar is very good and we have a lot of different feed stock such as coconut husk, which is a waste turning to biochar. There is maize stalks and rice husks after the milling. So, it's a lot of organic feed stock available." (Interview-GHN-5; Researcher, Ghana)

The production of biogas is controversially discussed. Some interviewees pointed to the viability and failure of many biogas projects in low- and middle-income countries. Furthermore, anaerobic digestion does not provide sanitation due to its lower temperature. The resulting digestate, especially if it contains faecal sludge, requires careful consideration for its intended use. Moreover, it was highlighted that most anaerobic digesters in low and middle-income countries use wet systems, leading to a wet digestate, necessitating additional processing to remove excess moisture. This added complexity is balanced by the production of biogas as a valuable by-product as well as the slurry with its nutrient contents. One interviewee expressed scepticism about biogas being the optimal solution, particularly in tropical regions like where they are located. They noted the limited need for heat in the tropics and highlighted electricity problems as a more pressing concern. Converting biogas to electricity was deemed complex on a large scale. The interviewee advocated for composting as a preferable alternative, suggesting it as a more practical and efficient approach, especially in tropical climates. Nevertheless, biogas can also be utilized as a cooking fuel, offering an alternative to other sources such as charcoal. The latter, in addition to contributing to deforestation, poses health risks to users due to the emission of smoke.

To promote increased OFBF application, it was emphasized that organic and biofertiliser providers should provide farmers with precise application rates for diverse crops and guidance on optimal timing. Such support is vital for farmers to harness OFBF to their full potential. The development of granulated formulations for organic fertilisers simplifies farmers' ability to regulate application rates. Additionally, diversifying fertiliser acquisition methods can enhance their widespread utilisation.

Some interviewees highlighted the expanding adoption of organic farming as a possible driver for an increase in demand, potentially prompting an upsurge in production of OFBF. Despite challenges, certified organic production is on the rise, driven by growing consumer interest and potential export opportunities. Organic farming emerges as a viable alternative to mainstream agriculture, particularly when combined with complementary practices like fallowing, crop rotation, intercropping, and mixed farming. Indigenous knowledge becomes pivotal in this context, emphasising the significance of reviving historically prevalent crop associations. This practice involves pairing nitrogen-producing crops like cowpeas with maize or other companion crops, enriching both agricultural practices and local consumption traditions.

5.9.4 Economy and markets

According to various interviewees, there is potential for organic and biofertilisers (OFBF) to gradually replace inorganic fertilisers, although many emphasised the need for both fertiliser types. However, substantial financial support for OFBF is currently limited. Demonstrating the proof of concept is crucial before attracting more significant financial backing. Funding should be localised, particularly in institutions lacking sufficient resources. Some interviewees argued that demonstrating the economic feasibility of OFBF is crucial for attracting investments from companies, without additional support.

With special emphasis on waste recycling some interviewees argue that cost recovery cannot be the main aim as it should be a public service which is paid for by taxpayers. One interviewee noted the challenge of making organic waste management financially sustainable, as stakeholders often expect these processes to be profitable. They observed that it is challenging for these technologies to be cost recovering, and some form of financial support or subsidy is often necessary, which differs from the approach taken for landfilling. A different approach can be taken, by treating it as waste management, where 60% of the costs are covered by public money for waste management (e.g., by the municipality), making the compost more attractive to farmers. This shift in pricing dynamics can increase the utility of compost. Public sector support is vital for marketing compost products, involving proximity to purchasing farmers. This may require restructuring rural-urban areas to establish more efficient systems. To create an effective biowaste management stream, it was deemed essential for the entire waste management system to be designed with biowaste in mind.

Some technologies such as animal feed innovations using black soldier flies and cassava peels have been reported to be highly profitable. Nevertheless, for such operations respective "clean" organic wastes are needed. In contrast, innovations related to soil inputs are noted for their narrower profit margins and higher associated risks.

One interviewee emphasised the challenge of sourcing high-quality organic waste for all technologies. Accessing clean, organic waste is crucial, as sorting mixed waste afterward is less economically favourable and results in lower quality. Commercial waste with a clean waste stream is often captured for use as animal feed. However, household organic waste, although significant in volume, is dispersed and mixed with other materials, making it difficult to capture. Therefore, the interviewee suggested focusing on easily accessible waste, such as market and commercial waste, as a starting point.

Currently, some initiatives rely on donor funding and are tied to specific programmes, which can lead to sustainability challenges once the programme concludes. Some argue, to promote OFBF, it is essential for the private sector to take proactive initiatives in producing off-farm OFBF while ensuring sustainable financing. Private sector financing, with affordable capital and equitable subsidies compared to inorganic fertilisers, can promote sustainable growth of OFBF.

One interviewee proposed an onsite business model for food processing factories, such as those involved in coffee or juice manufacturing. This model involves setting up fertiliser units at the processing facility, with a focus on financing the fertiliser from application until increased yield. The suggested approach is to bridge the financial gap for farmers during the period from applying fertiliser to harvesting, enabling them to repay the investment with the proceeds from their harvest. This model aims to kickstart the process. The interviewee emphasized the importance of processing companies, or in cooperation with other donors, pre-financing fertilisers for farmers at the beginning, creating a stronger connection to their supply chain.

"It is actually a question of financing the fertiliser from the use until the increased yield (of smallholder farmers). So, if there could be a model, how to finance these six, eight months until the fertilisers show an impact on yield, then this could make a difference." (Interview-UG-10; OF producer, Uganda/Denmark)

Challenges include unsustainable price increases in some raw materials, driven by inflationary pressures, making significant cost reductions beyond around 10% unlikely. To expand the market for these products both locally and internationally, securing the necessary capital for raw material procurement and operational expenses is seen as imperative. Before considering imports, evaluating a country's internal capacity for producing OFBF is necessary. Different sources of raw materials necessitate various processing equipment, impacting financial resources.

Sufficient funding is crucial for improving production, particularly as machinery purchases may require financial support. Addressing challenges related to energy costs and subsidies, along with increased grant funding, is seen essential by various interviewees. Delays in state subsidy payments can impact cash flow and timely bank payments, requiring optimisation measures. Increasing the quantities of state-subsidised organic fertilisers, recognising their vital but non-long-term support to farmers, is advised by various interviewees. Subsidies for technologies should extend to organic fertilisers where applicable to biofertilisers, similar to those for mineral fertilisers. Organic fertiliser production can qualify for payments for ecosystem services (e.g., carbon credits), promoting sustainability and contributing to environmental conservation by encouraging the use of low-energy and renewable energy sources in the production process. Greenhouse gas emission calculations should be part of the strategy including the GHG mitigation from landfills.

"Biochar is produced through the incentive of carbon credits mainly, there is now different programs. 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 USD 70 per ton of biochar, which is about a weeks' work. They say they're looking both at using invasive species, but also at excess residues, maize shanks, rice husk, and so on." (Interview-KEN-1; Researcher 2, International Institute of Tropical Agriculture (IITA), Kenya)

Seeking partnerships with NGOs that provide funding to support community-focused initiatives is another way to promote OFBF. These partnerships can address soil and consumer health concerns while fostering sustainable agricultural practices. A significant challenge lies in the insufficient financial resources allocated to technology and laboratories required for quality control. This includes nutrient analysis, carbon content evaluation, monitoring of organochlorides from plastic remnants, detection of heavy metals (e.g., from batteries), identification of drug residues, and pathogen assessment. Without financial support, the production of OFBF may not succeed.

Investors also require financial support for establishing compost units in communities, and it was highlighted that subsidies that alleviate importation taxes are needed. Increasing importation taxes on mineral fertilisers can stimulate the production and adoption of OFBF, incentivising farmers to transition towards more sustainable options.

Attracting manufacturers and technology providers from Europe and the United States is seen as essential by some interviewees. Effective governance and a strategic marketing approach are crucial to draw heightened attention from substantial investors. While local investors presently play a pivotal role, framing compost production to highlight its importance will attract more substantial investments.

The introduction of more efficient production methods through new plants may contribute to cost reductions and, subsequently, affect pricing positively. Efforts are underway to optimise household waste for organic fertiliser production, focusing on cleaner and better-sorted green/organic waste. The potential establishment of composting units in select cities, with hopes of securing donor funding, is a key strategy for some interviewees. Initial targets for organic waste collection include major markets, hotels, agro-processors and gastronomy establishments for efficient waste sorting. Alternative sourcing options like wastewater treatment should be explored. All these activities should be further developed. Some interviewees recommended to fortify produced composts (e.g., organo-mineral fertilisers) the products to effectively compete with mineral fertilisers. Managing the bulkiness of compost material requires minimising transport distances, underscoring the significance of establishing regional and decentralised waste management systems.

One interviewee emphasised the need for increased "business thinking". Many compost stations operated without a business mindset, with staff primarily focused on producing compost. Limited incentives existed for selling compost, resulting in a static salary for employees regardless of sales. The interviewee argued that introducing business thinking into the waste and sanitation sector was crucial.

Regarding the willingness to pay and market acceptance of various organic fertilisers was controversially discussed among interviewees. Some emphasised the challenge of enhancing the market appeal of co-composted faecal sludge. From practical experience of one interviewee, enriching the co-compost by adding inorganic nitrogen and phosphorus, to make it more attractive to farmers, did not fundamentally change the problem of product acceptance. Others reported pelletisation as a possible solution. However, farmers often prioritise rapid nutrient accessibility for their crops, favouring immediate benefits over long-term soil nutrient improvement. Therefore, the market's perception of value and the willingness of customers to pay for the product can be ongoing challenges, whether the co-compost contains faecal sludge or is made from regular compost or organic waste.

The principle of the polluter paying for waste management holds true, signifying that those generating waste are accountable for its disposal. Nonetheless, the approach of using incentives might also warrant consideration, as it tends to be more appealing and less restrictive than outright bans. Furthermore, the economic assessment should internalise the costs associated with water contamination, the adverse health effects of improper waste disposal, and the impacts on climate change and food security.

It was expressed that the future of OFBF involves stabilising the domestic market, with export as an option, provided that high standards of quality are maintained. However, exporting organic fertiliser products across borders requires compliance with phytosanitary requirements. The constraints for market development of the diverse OFBF are primarily related to the absence of a well-defined marketing strategy and the lack of adequate support resources. In most retail shops, mineral fertilisers and their related inputs dominate the market, overshadowing organic fertilisers and biofertilisers. Shifting the focus of these market engagements towards organic fertilisers and biofertilisers could significantly enhance their adoption among farmers.

Some interviewees pointed out that the market exhibits a dynamic nature, emphasising the necessity for a verification mechanism for the biofertilisers and organic fertilisers introduced to the market.

Verified products with a constant quality and reliability are needed to gain consumer trust and hence foster market growth.

Some recommended biowaste management to be carried out on a smaller scale by targeting specific waste generators, such as vegetable markets, beer breweries, food processing industries, and fruit juice companies. These entities produce a consistent type of waste in manageable quantities, making planning and product quality more stable. This approach also simplifies marketing and sales since customers can rely on consistent product specifications.

Some companies have future plans for expanding to other African countries and beyond, with a focus on becoming leading producers of organic fertilisers. Upgrading and expanding the production unit is aimed at capitalising on economies of scale, leading to reduced production costs. While licensing requirements have limited competition in the organic fertiliser market, competition is expected to increase over time as demand grows.

Organic farming presents potential according to various interviewees, particularly for high-value crops and greenhouse products. The awareness and demand for organic products in Africa mirror those in Europe, creating a timely opportunity to cultivate a thriving organic market in the region's urban consumer classes with higher budgets. The ongoing crisis and challenges faced by farmers in affording chemical fertilisers could accelerate the transition to organic agriculture. To further organic farming development, it was seen as crucial to support Participatory Guarantee Systems (PGS), especially considering that one of the main customers of OFBF is organic agriculture. Promoting local organic guarantee schemes could boost the utilisation of organic and biofertilisers, even within the local market, as (urban) consumers exhibit a strong preference for locally-produced organic products. To finance "organic" approaches, alongside subsidies, connecting carbon credits with organic farming was mentioned.

"The organic production is growing, for example, pineapple and cocoa. And that can provide an opportunity for the increase in demand of organic fertilisers." (Interview-CAM-5; Researcher, Cameroon)

Lastly, it was highlighted that the production and use of OFBF have the potential to generate employment opportunities in a country with high unemployment rates. By promoting organic fertilisers, efforts can be directed towards creating jobs in various communities, with the goal of establishing at least one job opportunity in each community. This not only benefits the agricultural sector but also contributes to overall economic development. Therefore, it was acknowledged that policies should be established to ensure that biodegradable waste is not disposed of in dumpsites but made available to fertiliser manufacturing companies for conversion into organic fertiliser. Institutions generating waste should adopt climate-smart waste management policies and regulatory frameworks. City councils and similar institutions should invest in waste management technology to unlock the potential of organic waste.

5.9.5 Research

Interviewees emphasised the need for increased investment in research and development for OFBF. Much existing research originates from outside of Africa, highlighting the necessity for localised expertise and technology tailored to the region's unique conditions.

To address OFBF effectively, a comprehensive and multidisciplinary approach to fertilisation is recommended. This approach should validate the impact of these fertilisers on crop behaviour, yield, and production quality across a diverse array of crops.

Enhanced communication and collaboration between individual researchers and policy makers are seen as crucial to ensure the seamless integration of OFBF practices into official research agendas and policies. Moreover, when contemplating the integration of mineral fertilisers, externally sourced organic fertilisers, biofertilisers, and farm internal organic fertilisers, it is vital to consider cost considerations and adapt assessment parameters accordingly.

It was highlighted that the environmental impacts of OFBF need to be assessed. This research should encompass effects on soil quality, water resources, and ecosystems, considering both positive and negative aspects. Developing standardised assessment frameworks is essential. Assessing environmental sustainability through performance indicators, emissions tests, and lifecycle assessments is seen as crucial, particularly as environmental engineering expands due to climate change concerns. This also includes the emissions from waste disposal sides, particularly the methane emissions associated with waste. One interviewee highlighted the research need on specific technologies such as Black Soldier Flies (BSF). Some research suggests that BSF can be more efficient than composting in terms of overall GHG emissions, more specific life cycle assessments are needed to provide a more comprehensive understanding.

The use of human excreta through biogas and slurry as raw materials in organic fertilisers is a viable but was considered a potentially misunderstood option. Public education and demystification may be necessary to gain acceptance. Considering the source of raw materials, including their type, origin, and sustainability within the supply chain, is crucial. It is akin to mining from a single location and transporting it to the factory for processing and sale. However, this approach warrants careful consideration due to potential negative environmental impacts at the source. Further research is necessary on how to make biogas plants and operations in low and middle-income countries viable and lasting.

Addressing the demand for effective organic waste sorting systems in urban areas is a pressing concern. Research should also focus on optimising the composting process and elevating the quality of the final compost product. Exploring strategies to enhance essential nutrient levels, especially in the context of sewage sludge utilisation in agriculture, remains a significant research priority, involving the optimisation of nutrient recovery from diverse waste streams.

In this regard, one interviewee highlighted the importance of waste segregation and how to motivate people to separate their organic waste. Research efforts are underway, utilising social psychology models to identify factors that drive or hinder waste segregation behaviours. Understanding these aspects, whether related to the availability of bins, time constraints, or social pressure from neighbours, is crucial for designing effective campaigns and interventions that target the specific barriers to behaviour change. The interviewee stressed the importance of capturing waste close to the source of generation, requiring the active participation of waste generators, and research is ongoing to determine how to make this participation effective.

Looking beyond immediate adoption, the primary concern is whether there is a sufficient supply of organic fertilisers and biofertilisers to meet the needs of farmers. The rate of replacement of mineral fertilisers with organic and biofertilisers hinges on the support provided for these sustainable options. This support should encompass intensified research initiatives, awareness campaigns, and the delivery of effective extension messages that directly reach farmers. The establishment of dedicated demonstration centres can facilitate this process, serving as living proof of the benefits of these alternatives.

To effectively utilise off-farm organic fertilisers, thorough analysis of the organic materials for each purchased unit is crucial, considering that batch quality can vary. Proper batching of compost is essential, even if it incurs higher costs. Ensuring organic fertiliser quality requires assisting producers in documenting product contents and displaying them on labels. Random sample testing conducted by research stations can further guarantee product quality. Enhanced collaboration between researchers and OFBF companies is necessary to collectively address challenges and propose methods for quality improvement. Unfortunately, a lack of dedicated funding for research in this field poses a significant obstacle.

Establishing monitoring systems to assess the efficacy and quality of these fertilisers is vital. Community capacity should be built to evaluate fertiliser quality comprehensively. To bolster confidence in these products, it is crucial to assess their quality, including toxicity levels and potential adverse effects on humans. The quality of most OFBF remains untested. Moreover, potential toxins within these products and their long-term implications need further observations. Research should encompass a broader spectrum of plants, as farmers frequently employ various organic resources without a clear understanding of their composition and their soil impact. Regulators within the fertiliser sector should rigorously approve and certify these products, ensuring their authorisation before they are released to the market. This process guarantees that these products meet the necessary quality and safety standards.

It is imperative to establish a rigorous classification system for these products and conduct thorough market research. Rigorous testing across various agro-ecological zones is essential to ascertain informed application rates for organic fertilisers.

Collaborative efforts between research and industry partners can help in scaling up OFBF. Establishing an association or umbrella organisation that brings together organic fertiliser and biofertiliser companies would create a platform for collaboration and shared initiatives. Moreover, forging strong partnerships with farmers and vegetable growers is essential to determine the optimal compost quantity and its potential combination with mineral fertilisers. These studies should comprehensively address both agronomical and economical aspects. Furthermore, encouraging farmer participatory research and promoting knowledge dissemination regarding the proper application and utilisation of organic fertilisers and biofertilisers are vital steps towards achieving sustainable adoption.

The analysis of organic fertilisers should take a comprehensive approach. Rather than solely focusing on assessing nitrogen, phosphorous, and potassium levels, it is imperative to consider the broader impact on soil health and ecosystem services. Additionally, exploring combinations of both fertiliser types – mineral fertilisers and organic and biofertilisers - should be considered. When discussing productivity, it is crucial to consider not only yield but also the chemical, biological, and physical improvements these fertilisers bring to the soil.

Encouraging research and development of diverse biofertiliser types is crucial, given the limited variety in the market. Research should focus on developing biofertilisers using locally available resources to reduce dependence on imported materials (e.g., Rhizobia). The Rhizobia technology requires comprehensive support to address various challenges. According to some interviewees, unscrupulous dealers have been selling expired products and, in some instances, repackaging them. Therefore, the development of a regulatory framework to govern the use of inoculants is essential. Furthermore, it is necessary to establish a legal framework to facilitate privatisation in this context. To revitalise Rhizobia technology, substantial support is needed to reconfigure the entire process. This includes investments in demonstration plots, research initiatives, advisory services, and the development of a robust marketing strategy and regulatory framework. A comprehensive approach, involving laboratory assessments and certification, is imperative to ensure the highest quality.

Expanding the number of demonstration plots and allocating more funding for such projects is essential to showcase the tangible benefits of sustainable fertiliser practices. Implementing agricultural demonstrations at the farm level is a powerful catalyst for change, allowing farmers to witness the tangible benefits of OFBF compared to mineral fertilisers. Research should yield precise recommendations on application rates for organic and biofertilisers, ensuring their effective and efficient use. Importantly, it is worth noting that many farmers use organic fertilisers without awareness of the nutritional content of the materials they employ. Therefore, promoting education on this aspect is crucial.

Researchers supporting farmer organisations in procuring organic and biofertilisers and operating demonstration plots can significantly promote the adoption of organic manures and increase the utilisation of these fertilisers in agriculture. This requires investments in demonstrations, research initiatives, advisory services, the development of a marketing strategy, and the establishment of a regulatory framework – where not existent. Research on OFBF should increasingly focus on practical applications, encouraging collaboration among researchers to address agricultural challenges. Researchers should invest in creating educational materials to inform farmers about the use and impact of organic fertilisers and biofertilisers. Enhancing fertiliser packaging, particularly by local entrepreneurs, is crucial for improving attractiveness, traceability, and user-friendliness.

Additionally, integrating OFBF into university curricula, emphasising advocacy, and aligning with government support are essential for expanding the research framework. In the short to medium term, effectively transferring technology to farmers through farmer participatory trials is vital for the adoption of OFBF.

Some highlighted the importance of intersectoral collaboration between waste management experts and agricultural and animal husbandry researchers to explore these aspects further and promote the value of waste-derived products in various sectors.

5.9.6 Knowledge, education and training

"The biggest challenge was to convince and educate farmers on the importance and usefulness of the product." (Interview-KEN-5; OF Producer, Kenya)

"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." (Interview-EG-4; Researcher, Egypt)

Government support, including the establishment of dedicated units for education, training and pedagogy, plays a pivotal role in disseminating knowledge about OFBF. To achieve that, advisory services must bolster their capabilities. In this context, supporting technical staff of farmer organisations is vital. Collaborative efforts with government extension services are essential for educating farmers about the proper application of OFBF. Capacity building at all levels, covering aspects such as microbiology and micro-nutrients, holds significant importance. Also reshaping the perceptions of agricultural professionals is essential.

Training programmes for farmers and input dealers, including soil testing services, are crucial for advancing the OFBF industry. Introducing extra services like soil testing aims to enhance farmers' understanding of their soil, based on past feasibility phase experiences. Soil analysis helps farmers understand their soil's specific needs and challenges, guiding their fertiliser choices by providing soil and crop-specific advice. These programmes should encompass both theoretical knowledge and practical techniques, emphasising product characteristics, such as nutrient and carbon content. Additionally, guidance is necessary on optimising fertiliser use and integrating it into rotational systems. This education also includes raising awareness about the detrimental effects of synthetic fertilisers on soil and the environment while highlighting the benefits of OFBF in improving soil fertility. Efforts should also concentrate on understanding and integrating indigenous knowledge systems into organic fertiliser practices, complementing historical mineral fertiliser use.

Creating awareness about OFBF characteristics is fundamental, with an initial focus on increasing awareness to drive demand. Enhancing awareness and education can be achieved through community radio, social media, local language advertising, and leveraging social networks. Maintaining constant communication with farmers and addressing funding challenges for awareness campaigns is crucial. Involving extension services, NGOs, and technology dissemination experts is essential for effective awareness-raising and training. Special attention should be paid to involving young people and women, recognising their potential contributions to the agricultural sector.

Multistakeholder engagement and synergies are essential, particularly in managing organic waste and validating the effectiveness of technologies like inoculants. Transdisciplinary innovation platforms, e.g., exemplified by the RUNRES project, encourage collaboration and innovation to address sustainability challenges in agriculture. Bridging the gap between research and extension services is imperative to ensure research findings effectively reach farmers. Encouraging business participation in the production and distribution of OFBF is crucial for long-term sustainability. Collaboration is vital at various levels, involving farmers, companies producing OFBF, and collaborative research efforts aimed at developing crop-specific organic fertilisers or, e.g., promoting Rhizobia.

Motivating households to engage in waste separation and involving schools in educational initiatives, with children as messengers, are key components. Harnessing the potential of household waste requires inclusive consumer training for proper waste separation. Promoting composting at the household level continues to be a focal point. Promoting community-based initiatives is crucial. Promoting composting at the household level and establishing demonstration projects in villages are key strategies. Initially, the focus should be on increasing awareness, which naturally stimulates demand.

Overcoming information barriers represents a significant challenge. Access to a comprehensive information database including product quality of OFBF, market information and prices, and application procedures is vital. Providing farmers with essential information and boosting their confidence in using these fertilisers can lead to greater acceptance.

Documenting compositions of locally produced organic fertilisers at the village level is essential for transparency and informed decision making. Tailoring educational materials to local dialects ensures accessibility and engagement. Familiarity with various fertiliser formulations allows farmers to complement mineral fertilisers effectively with compost or other organic fertilisers. To optimise the benefits of organic fertilisers, it is crucial to focus on proper dosage to prevent over-application, especially for solid or liquid fertilisers. Transitioning to a granulated format can improve accuracy, usability and efficiency in application. Advocacy and capacity building are vital for raising awareness, avoiding progress delays caused by operating in isolation. Familiarity with various fertiliser formulations is essential for effective complementation of mineral fertilisers with compost or other organic fertilisers. This includes handling, using, and identifying certified OFBF in the market while distinguishing them from counterfeits.

Addressing concerns related to human excreta-based fertilisers is paramount for their successful adoption. This involves comprehensive education and awareness campaigns. Additionally, it is crucial to document the compositions of locally produced organic fertilisers at the village level to ensure transparency and informed decision making. This knowledge documentation should draw from practical experience and existing literature. To enhance the acceptance and utilisation of these fertilisers, it is vital to address genuine health concerns and perceived risks associated with human excreta-based fertilisers. Providing essential information and boosting farmers' confidence in using these fertilisers can significantly contribute to their greater adoption. Furthermore, harnessing the potential of household waste necessitates inclusive consumer training for proper waste separation.

Creating long-term demonstration projects in villages and technical support in collaboration with farmer organisations and raising awareness among farmers are key elements. This educational process involves various methods, including field visits, workshops, farmer-to-farmer extension and training sessions.

"The key for success is education, which we had to do on our own, which we mainly do by demo-trials, showing in the field how it works." (Interview-KEN-4; OF producer, Kenya)

Establishing a robust linkage between science, policy, and practical implementation is imperative. Collaborative efforts involving universities, research institutes, the private sector, and farmers are essential to prevent delays in progress resulting from isolated operations. The creation of facilitator roles in remote villages not only provides employment opportunities but also helps extend the reach of organic fertiliser consumption beyond urban areas. Collaborations with international organisations, which work closely with producers, can yield substantial benefits. Encouraging business engagement in the production and distribution of organic fertilisers remains essential.

The educational system should incorporate organic farming principles and practices. The integration of organic farming principles into agricultural education is essential to prepare the next generation for OFBF integration.

5.9.7 Policy, regulation and certification

To promote the adoption and growth of OFBF in African nations, a comprehensive approach is emphasised as vital by numerous key informants. This approach involves integrating OFBF into existing agricultural policies alongside inorganic fertilisers and pesticides, ensuring a cohesive policy landscape. Simultaneously, a dedicated OFBF policy framework should be developed, addressing gaps in current agricultural policies. This framework should encompass regulations, quality control measures, certification processes, research initiatives, and incentives such as subsidies and tax breaks, covering the entire organic waste value chain, from households to farmers.

Some interviewees have highlighted the expenses linked to inadequate sanitation and solid waste management. Therefore, policies supporting the production of organic soil inputs yield a much larger return on investment, as they contribute to improved public health outcomes in addition to agricultural benefits. This underscores the importance of adopting policies that encompass a broader perspective and acknowledge the broader societal benefits beyond agriculture.

One interviewee highlighted that market challenges are frequently mentioned for the currently limited scaling of nutrient recovery although reasons are multifaceted, however, emphasising that policy measures play a pivotal role in reshaping the landscape. A valuable lesson learned from a project in Ghana, which focused on nutrient recovery from faecal sludge, was the absence of guidelines in agricultural policies regarding nutrient usage. This aspect is often overlooked, and it is essential to establish clear policies that not only permit the use of faecal sludge in agriculture but also provide guidelines for its safe and effective application. Such policies not only incentivise the private sector to engage but also encourage municipalities involved in waste treatment to participate in nutrient recovery, given their role in waste treatment. A comprehensive national strategy for waste management, emphasising reduction, reuse, and recycling (Triple R), can provide the necessary framework for local authorities to implement programmes.

Substantial government support is crucial for facilitating the transition towards an increasing use of OFBF. This support should include guidance for farmers and comprehensive initiatives that encompass quality control, regulations, standards, laboratory equipment, accredited labs, market regulations, and product standards. Addressing climate change is an essential component of the transition. Implementation of on-farm soil fertility management systems alongside OFBF to bridge gaps and accelerate uptake, increases the efficacy of the OFBF approach.

“Even just an official recommendation by policies or the Kenya fertiliser board to use organic fertilisers could help increase the demand further.” (Interview-KEN-4; OF Producer, Kenya)

Streamlining bureaucracy and ensuring political stability are prerequisites for advancing waste collection and management. Strengthening approval processes for OFBF products is necessary to ensure quality and reliability. Rigorous certification and authorisation should be mandated before OFBF products enter the market. Enforcing strict regulations on chemical inputs can drive the adoption of OFBF. To establish a well-structured regulatory framework enforced through policy measures to facilitate marketing endeavours, expand the product’s market reach, and ensure quality, is mandatory. Scaling up composting projects can introduce quality control challenges. Policies should consider the need for quality control mechanisms when scaling waste management initiatives to ensure consistent product quality.

Integration with international policies is vital, with international efforts complementing national ones to promote OFBF use. Collaboration with the African Union is crucial, fostering openness to innovative ideas from within Africa regarding OFBF development. This may include the establishment of an association or umbrella organisation to guide production and research in the sector.

To standardise production processes and enhance cost-effectiveness, government should support waste management as a public service and foster collaborative efforts between research institutions, governmental bodies, and private enterprises. Furthermore, to make resource recovery economically viable, multiple revenue sources should be considered. While revenue from selling products is one income stream, it often may not cover all treatment costs. Policies should support additional revenue sources. For instance, fees for waste collection, as paid by households, may cover the cost of collection but not treatment. This underscores the need for diverse income streams. Policies should explore mechanisms to balance costs and income. Municipal collection services should be responsible for waste collection. This reduces the burden on treatment entrepreneurs and allows them to focus on the core waste management processes. Moreover, municipalities should consider providing gate fees to treatment facilities for their services, just as they do for landfill management, to support waste management and ensure cost coverage for the treatment facility.

Extending financial and logistical support through policy initiatives for awareness campaigns and dissemination activities is crucial for successful adoption. Supporting infrastructure development is vital, involving government efforts to identify suitable land strategically for processing organic biomass and provide incentives such as subsidies for mechanisation tools like windrow turners. Mechanisation can play a crucial role in improving composting processes, e.g., especially for aeration during thermophilic composting. Hand-turning compost can also be cost-prohibitive due to labour expenses. Mechanisation not only enhances efficiency but also improves the quality of compost. Quality remains a significant concern, requiring clean substrate and skilled personnel, but it is attainable with the right approach.

Local municipalities may provide land for free or at reduced rates, especially in urban and semi-urban areas where land prices are rising. Such incentives can significantly boost the adoption and proliferation of OFBF.

Policy support can play a crucial role in promoting source segregation by designing awareness campaigns and providing necessary infrastructure such as bins. Some projects or initiatives faced challenges related to barriers like the cost of purchasing bins, making it important for policies to address these barriers. Social mobilisation and awareness-raising campaigns play an essential role in waste management. While entrepreneurs can manage the waste treatment process, policies need to drive waste segregation campaigns, promote awareness, and motivate public participation. These actions are typically beyond the scope of waste management entrepreneurs.

An efficient fertiliser application strategy based on improving soil fertility, monitored through soil testing, should be implemented. Quality assurance through policy support for quality assessment, standards, and import regulation is essential. Authentication of products through research and standardisation guarantees efficacy and eliminates ambiguity.

Resolving land tenure issues is crucial, potentially requiring land reform policies to encourage farmers to invest in organic fertiliser production and application.

Community empowerment is key, aiming to empower communities to generate organic matter at a reduced cost, ensuring sustainability practices beyond state subsidies. Encouraging local and regional initiatives is crucial, where policies can promote waste separation and community composting. This should include training programmes and adapting municipal waste management systems.

The institutional environment was identified as the most significant component by various interviewees. They noted the importance of cross-sector collaboration and communication and the breaking down silos between the waste, sanitation and agricultural sectors. They emphasised the need for institutional capacities that can facilitate collaboration and integrate nutrients back into the agricultural cycle.

National policies can align with global initiatives and movements, such as the “Sanitation for All” and “Swachh Bharat Abhiyan” (Clean India Mission) in India. These movements have created momentum around cleaning the environment, improving sanitation, and waste management. Policies can ensure that the momentum translates into effective waste treatment solutions and resource recovery.

Recognising the significant influence of government policies and actions on farmers’ practices underscores the need for decisive government policies to promote and facilitate the adoption of organic fertilisers, aligning these efforts with policies on organic farming. The development of concepts and strategies at various levels, including households, districts, zones, and regional geographical units, can foster organic farming practices.

6 Author perspectives: conclusions and recommendations

Based on a review of existing literature and 89 qualitative interviews spanning the entire organic and biofertiliser (OFBF) value chain across 12 African nations, this report explores the current state of off-farm OFBF production and its future perspectives in Africa. From these investigations, the authors draw the following conclusions and recommendations.

While acknowledging variations in OFBF production, economic landscapes, market dynamics, practical implementation, research activities, extension services, training initiatives, policies, regulations, product quality standards, and certification schemes among different African countries, it is important to emphasise that the findings reveal various commonalities. These shared aspects allow us to formulate general conclusions and recommendations applicable within the diverse African context.

This report offers valuable insights, although it does not claim to provide an exhaustive overview of OFBF in the selected countries. Nonetheless, it furnishes comprehensive information that can support overall assessments and the development of policies related to off-farm produced OFBF, as well as strategies and programme formulations for research, the economy, markets, education, and training aspects.

6.1 Conclusions

Organic fertilisers and biofertilisers, with their distinct types, are diverse products that require separate assessments on various fronts. Common challenges in the implementation of OFBF include a complex of infrastructure deficits, such as inadequacies in collection and distribution systems, road construction, availability of land in urban areas, transport and storage. Additionally, financial challenges like the cost and availability of waste materials, management costs, taxation, and transport costs contribute to these difficulties.

Organic fertilisers and biofertilisers should not be viewed as direct substitutes for mineral fertilisers but rather as complementary. Integrating them with mineral fertilisers offers benefits to farmers by reducing the cost of mineral fertilisers and improving soil health. For instance, in sandy soils, mineral fertilisers can be ineffective without the incorporation of organic materials due to mineral leaching.

Shifting the focus towards improving soil health is crucial. Poor and degraded soils reduce the effectiveness of mineral fertilisers, decreasing demand for them. Introducing compost in these areas can lead to noticeable yield improvements, potentially increasing demand for compost.

Organic fertiliser production and technology

Overall, it can be affirmed that there is a substantial untapped potential for recycling organic waste, a significant portion of which remains underutilised. This holds true for the three main waste streams of food and green waste from households, human waste, and agricultural processing by-products, including market wastes.

Investing in the recycling and reuse of organic waste through products such as compost, bio-slurry or even the use of black soldier flies offers various benefits. It addresses multiple pressing issues, including the accessibility, cost, scarcity, quality, and dependence on mineral fertilisers. Simultaneously, it addresses environmental and health concerns, such as water contamination and greenhouse gas emissions from open dumpsites and landfills, environmental pollution, and nutrient and soil carbon deficiencies in agriculture. Collectively, these factors exert pressure to reshape the approach to organic waste management, presenting a substantial win-win opportunity. Hence, there is a need for systems-based approaches to waste management. Opportunities for establishing context-specific solutions are abundant, particularly where conventional waste management systems, such as incineration-based systems, have not been implemented.

The organic fertiliser production landscape varies across countries, with smaller businesses producing <50 t/year, while larger companies producing up to 120 000 t/year. Some companies incorporate mineral or inorganic fertilisers, biochar, or biofertilisers to enhance their products. Notably, the use of human waste in production remains a minority practice, with examples like SAFISANA in Ghana. Specialized practices, such as utilizing black soldier flies for compost and animal feed, are also observed. Overall, the organic fertiliser industry exhibits diverse approaches and faces various obstacles across the examined countries.

Composting is a less technologically intensive process compared to bio-slurry production from anaerobic digestion. The primary bottleneck lies in household waste separation, hindered by factors like insufficient education, motivation, and a lack of incentives for consumer participation. The management of organic residue collection often suffers due to inadequate or lacking technical equipment, leading to operational weaknesses. Transport is an important factor with many actors emphasising the decentralised production.

A high potential for the recycling of nutrients from human waste exists. However, questions remain open when it comes to using human waste for OF production, and information regarding the quality of humus fractions and nutrient content is limited for both types.

In the ongoing discourse, there exists limited awareness of the potential of bio-slurry, when correctly applied, to significantly contribute to fulfilling a portion of crop nitrogen requirements. Technical and economic challenges, along with knowledge gaps, hinder the realisation of this potential.

Biofertiliser production and technology

When it comes to biofertilisers, which encompass a wide range of products varying in both quality and quantity, their production remains limited in most of the 12 countries. Biofertilisers are highly sensitive during production, storage, transport, and application, requiring a greater depth of knowledge for their proper and successful utilisation. Microbial contaminants are common issues influencing the quality of biofertilisers; hence the properties of carrier materials need to be well maintained to secure shelf-life and ultimately product quality.

Regarding plant teas, their impact on soils, plant growth, and overall plant health is not yet fully understood and critically discussed.

While there are positive outcomes associated with the production and application of rhizobia, the field lacks access to modern technology to support these efforts. However, successful producers exist such as in Malawi. Furthermore, low soil pH levels are inhibiting rhizobia infection, meaning that rhizobia, necessary for nitrogen fixation, are not present in the soil. Consequently, the contribution of legumes to the nitrogen budget is minimal. Additionally, crops like forage legumes are absent from the farming system, along with their multiple functions. This also holds true for leguminous alley crops, which currently have a limited presence and therefore make insignificant contributions to both the carbon and nitrogen balance, resulting in a negligible positive impact on crop yield.

Biofertilisers based on arbuscular mycorrhizal fungi (AMF) are currently primarily applied in research settings, with limited practical application in broader contexts.

Further challenges in biofertiliser application include limited understanding, resulting in uncertainties and variable outcomes. Issues stem from incomplete knowledge of bacterial multifunctionality, complex interactions in soil, and varying responses to biotic and abiotic factors. Technical challenges in formulation and inconsistent practical results are further important obstacles. Additionally, difficulties in large-scale propagation of AMF and a lack of understanding of host specificities and population dynamics pose further challenges.

Potential supply of organic matter and macronutrients to produce organic fertilisers

The brief analysis of potential organic waste streams, namely household and human waste, and agricultural processing by-products, indicates great potential for a (re)circulation of organic matter and its nutrients (resource). However, the nutrients from such wastes will not be sufficient to provide the needed amounts in agricultural crop production. Additions of inorganic fertilisers may be necessary in conjunction with a holistic fertiliser strategy.

Economy and markets

The OFBF landscape in the 12 African countries under investigation reveals diverse organisational structures and actor groups. This encompasses a range of actors, from individual farmers involved in informal organic fertiliser production using local resources to farmer groups engaged in collective efforts. Additionally, various municipal-level arrangements, including public-private partnerships, contribute to this landscape. Private companies also play a substantial role in regional OFBF production, frequently making use of locally sourced organic materials. Some entrepreneurs have received support from international donors and/or NGOs.

In terms of waste financing, many cities lack sustainable long-term planning as well as affording operational costs due to insufficient government finances and waste fees. Private-public partnerships have been challenging due to financial, institutional, and political shortcomings.

Further challenges persist, including high land costs, and the need for external financial support to modernise and expand operations. Small-scale ventures often begin with self-financing and locally sourced materials, gradually expanding with additional personnel as production scales up. Financial support for OFBF companies varies, with some receiving indirect subsidies such as free waste provision by the municipality, while others rely on private funding sources. Some government initiatives, such as those in Ghana and Senegal, actively procure and subsidise organic fertilisers to support farmers.

However, in many of the researched cases, the economies of companies are fragile, and the sustainability of these businesses is at risk without financial or other support from either governments or private donors. Nonetheless, various companies reported to be profitable, specifically those that have been operating for more than five years. Additionally, the economies of OFBF face challenges such as corruption, counterfeit products, and other activities that undermine product quality and erode consumer trust.

Pricing

The pricing of fertilisers, both inorganic and organic, varies significantly across the 12 countries and is influenced by various factors, including nutrient content, production methods, and local market dynamics. The surge in prices of inorganic fertilisers in many African countries for the last years has prompted farmers to explore alternative options. Organic fertilisers, while presenting a more economical choice in some cases, face challenges related to the disclosure of nutrient content, making it difficult to conduct an accurate economic assessment of their value. Farmers also hesitate to apply organic fertilisers, as long as land tenure is insecure.

Furthermore, the wide range of pricing across countries is influenced by factors such as labour costs and demand, but a lack of cost breakdowns and gross margins from interviewed companies makes it challenging to pinpoint specific reasons for these disparities.

It is essential to consider not only the economic value but also the potential benefits of organic fertilisers in terms of soil fertility improvement and long-term sustainability. As the fertiliser landscape continues to evolve, there is a need for comprehensive data and verification of product effectiveness and economic viability.

While challenges persist, some companies have reported profitability in the organic fertiliser sector, indicating opportunities for growth and development in this field.

Market demand

In general, interview participants in most countries reported an increasing demand for OF and acknowledge the significant market potential for organic fertilisers, contingent on addressing specific challenges and fostering an enabling environment for investment and growth. Biofertilisers are not widely promoted by governments and related advisory services. In the case of rhizobia, increasing demand has been reported.

However, a well-organised market, i.e., distribution networks for OFBF does not exist. Critical is the lack of quality standards, lack of laboratories for product classification, and scientific evidence of the impact on soil quality and crop yield of specific products. This deficit is in line with the lack of soil analysis, as well as crop specific recommendations for inorganic fertilisers and a differentiation of these fertilisers according to the crop demand. All these factors hinder market demand.

Marketing

The adoption of OFBF by farmers is partly met with resistance primarily due to their familiarity with inorganic fertilisers, concerns about increased workload, and the perception of lower short-term impacts on crop yields, especially in cases where farmers cultivate rented land.

One key approach involves offering OFBF products for free as part of advertising campaigns and providing crucial training and field demonstrations. Field demonstrations have proven to be particularly effective, as reported by many OFBF producers. Additionally, electronic media platforms, including WhatsApp, Facebook, SMS broadcasts, as well as farmer organisations, advisory services, and NGOs, play a significant role in disseminating information and distributing OFBF products.

OFBF producers are increasingly tailoring their advertising strategies to target specific customer segments. Some prioritise small farmers, while others focus on organic farmers with export-oriented products or larger commercial farmers. Larger farms, especially those involved in organic agriculture or serving export markets, are the primary consumers of OFBF due to economic considerations. On the other hand, small-scale farmers often prefer locally produced products from their immediate communities. While it is widely acknowledged that OF cannot fully replace inorganic fertilisers, they play a crucial role in addressing specific soil deficiencies, particularly in terms of increasing humus content. They offer a valuable contribution to the overall nutrient balance, enhance the efficiency of inorganic fertilisers by improving crop uptake, and provide other positive effects (as outlined below). Notably, there is a prevailing issue of trace element or micronutrient deficiencies in soils, and there is limited awareness of the potential of organic fertilisers to address these deficiencies.

Distribution channels

The distribution strategies employed by companies in the OFBF sector exhibit a range of approaches, from collaborating with agents and cooperatives to direct sales and even establishing retail outlets. However, these strategies come with their own set of challenges, particularly when working with shops primarily focused on inorganic fertilisers, necessitating time-consuming and costly training efforts.

Large enterprises involved in various agricultural sectors, such as flower production, fruit crops, or coffee for export, often serve as the primary destination for organic fertiliser products, with some managing their own compost units. Smaller companies typically engage in direct sales within local communities, while larger enterprises target peri-urban and urban farmers, with varying degrees of regional or international reach.

Advisory services and NGOs play a vital role in introducing OFBF but face limitations in knowledge and training. Their expertise often leans towards inorganic fertilisers, which can influence their level of trust and advocacy for OFBF, especially for farmers seeking short-term impact fertilisers.

However, it is important to note that distribution channels for OFBF remain underdeveloped across the countries studied, leading to a lack of knowledge and awareness among farmers and other stakeholders regarding the potential benefits of these products. Further efforts and investments in distribution and education are needed to unlock the full potential of OFBF in sustainable agriculture across Africa.

- **Science, knowledge and education**

Across all levels of the OFBF value chains, knowledge, training, and education are often limited, with most initiatives organised by companies themselves or relying on experiential learning, and university engagement remains relatively rare. Financial support or other incentives are insufficient at all stages of the process. A similar situation prevails in the field of research on off-farm produced OFBF.

Many interviewees stress the critical role of awareness, education and training for farmers, extension services and agro-dealers. Effective promotion also relies on increasing awareness and outreach, though challenges like farmer resistance to change and the influence of established agricultural industries persist.

The prevailing lack of knowledge and awareness surrounding OFBF aligns with the advisory services' predominant emphasis on inorganic fertilisers in most countries, but also the fragmented discourse in science. This knowledge and awareness are however pivotal for enhancing soil fertility, crop yields, and quality. It also mirrors the limited utilisation of organic fertilisers sourced directly from within farms. In both cases (on-farm and off-farm produced OFBF), common challenges emerge, such as labour requirements, the need for suitable technology for collecting, processing, storing, and applying OFBF, knowledge gaps, and the financial constraints necessary to cover technical investments. Furthermore, effectively combining organic and mineral fertilisers for optimal results requires specific skills, knowledge, and economic understanding, which are frequently lacking.

Regardless of the critical assessment of the current practices involving off-farm produced OFBF there exist several remarkable examples of OFBF production on a small, medium, and large scale. These examples can serve as exemplary cases and valuable learning experiences for the future advancement of OFBF. The same holds true for the utilisation and application of OFBF, which play a crucial role in the future dissemination of off-farm produced OFBF.

- **Policies, regulations and certification**

In many cases, policies, initial regulations and standards or certification schemes are established, but their implementation tends to be fragmented or inadequate. Many policies or regulatory frameworks suffer from weaknesses such as insufficiency, lack of consistency, and ambiguity, which hinder effective implementation. A significant gap exists in terms of robust monitoring and control systems for OFBF. Moreover, OFBF are often not included in current agricultural policies alongside inorganic fertilisers and pesticides.

Organic fertiliser

The majority of countries do not have established specific laws on municipal solid waste (MSW) management, but rather have general environment laws with sub-sections covering MSW. Policies in most countries do not prioritise organic waste recycling, policies do not even exist, the enforcement is lacking, or incentives are not favourable for recycling.

Furthermore, poor enforcement strategies, a lack of participatory mechanisms, inadequate awareness campaigns, the influence of power dynamics and politics, and weak political commitment further exacerbate the issue. 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.

The broad-scale commercialisation of fertilisers derived from human excreta pertains to the ambiguous regulations governing their application. The recycling and reuse of wastes such as human waste, requires strong regulatory frameworks to ensure that the benefits are maximised while minimising potential risks.

The water, sanitation, and solid waste as well as the agriculture sectors in many of the studied countries are largely isolated from each other and tend to work in silos but have a high potential for co-benefits. The cross-sector collaboration and service chains could maximise positive interactions and achieve complementary development goals by adopting an integrated approach, a holistic planning and implementation which could be supported by respective policies.

Apart from the multi-fold challenges, various countries in SSA have recently started to establish agendas with regard to fostering increased organic waste recycling towards organic fertiliser production and use.

Biofertiliser

There is a need for a (worldwide) harmonised assessment of biofertilisers to increase efficacy and transparency. The lack of product quality and regulatory frameworks has impeding effects on the demand for biofertilisers.

Government support and respective enabling policies have shown to be key enablers in selected developed and Asian countries. Harmonised standards across countries are necessary to foster trade and create a favourable business environment for biofertilisers.

6.2 Recommendations

Drawing upon a literature review, interview findings, country syntheses, and field experiences, these recommendations offer diverse strategies to support the implementation of off-farm produced OFBF in respective countries and beyond. The recommendations are organised based on categories derived from the empirical results section, interviews, country syntheses, and a value chain perspective (Table 19).

Although certain countries may already have implemented some of these recommendations, this scoping study underscores a significant gap in the effective action needed to ensure the successful and efficient adoption of OFBF. We have also incorporated a column to evaluate the suggested timeframes for implementing specific activities, allowing for adaptation to meet country-specific demands.

To effectively apply these recommendations in various countries, it is essential to engage in further discussions and make necessary adjustments to align with the current state, planning activities, and priorities within each specific country. These recommendations span across diverse sectors and are interconnected, emphasising the importance of implementing them collectively for ultimate success. Additionally, these recommendations can function as a valuable checklist for monitoring and evaluating country-specific planning steps and development processes. To facilitate the successful integration of OFBF into agricultural practices, a comprehensive and multifaceted approach is emphasised.

Table 19. Overall recommendations

Policy subjects	Recommendations	Time frame*
	Value chains	
General recommendations	▪ Develop a comprehensive policy framework for OFBF considering environmental, urban, rural, and agronomic contexts. Include OFBF processing, marketing, distribution, and on-farm application and the related educational and scientific environment, public relations and dissemination. ▪ Consider the specific conditions of organic farming.	MLT
	▪ Encourage coordinated policy efforts that integrate OFBF into existing agricultural policies alongside inorganic fertilisers and pesticides. ▪ Ensure that policies are consistent, well-enforced, gender sensitive, small- and large-scale sensitive, and adapted to changing urban and rural environments.	ST
	▪ Address land tenure issues through land reform policies to encourage farmers to long-term investments.	MLT

Policy subjects	Recommendations	Time frame*
	▪ Coordinate the policy framework across Africa and align it with international standards and regulations.	MLT
	▪ Support the establishment of collaboration platforms, including all stakeholders (industry, policy, research, farmer organisations etc.)	ST
Promote organic waste recycling	▪ Treat waste management as a public service. ▪ Encourage and support comprehensive policies and regulations that prioritise organic waste recycling, particularly municipal solid waste (MSW) management and respective restructuring of MSW. ▪ Municipal collection services should be responsible for waste collection.	MLT
	▪ Municipalities should consider providing gate fees to treatment facilities for their services, just as they do for landfill management, to support waste management and ensure cost coverage for the treatment facility.	ST
	▪ Focus on regionalised/decentralised systems for waste collection, processing, and distribution to keep transport costs low.	MLT
	▪ Develop clear and unambiguous policies to permit and guide the safe application of faecal sludge (e.g., as co-compost) in agriculture, encouraging private sector and municipal involvement.	ST & MLT
	▪ Foster and support „business thinking" in the waste and sanitation sector vs. the mere goal of waste reduction.	MLT
	▪ Invest in awareness campaigns, participatory mechanisms, and enforcement strategies to incentivise recycling and reduce environmental pollution.	ST
	▪ Implement source separation of organic waste to enhance raw material quality for organic fertiliser production. ▪ Collaborate with local farmers to tailor products to their needs, reducing transport burdens.	ST & MLT
Enhance cross-sector collaboration	▪ Ensure cross-sector collaboration, coordination, and alignment of policies between sanitation, waste management and the agriculture sector. ▪ Foster a systematic approach to establish a circular (economy) system that considers the entire waste value chain.	ST & MLT
	▪ Collect regionalised data for monitoring raw material quantities and qualities. Provide data access to relevant stakeholders.	ST
	▪ Evaluate the nutrient transfer from rural via urban areas (consumers).	ST
	▪ Tailor policies to municipalities and rural communities based on their access to raw materials and quantities.	MLT
	▪ Government channels already used for distributing chemical fertilisers could also accommodate organic fertilisers, ensuring a wider reach.	ST
Develop integrated fertiliser strategy	▪ Promote integrated fertiliser management and develop respective strategies with the aim of enhancing soil health as the central goal. ▪ Establish a framework for an integrated understanding of organic (on and off-farm) and inorganic fertilisers, as outlined in the fertiliser strategy (see annex 8.1). ▪ Support the development of crop-specific guidelines (e.g., fertiliser types, timing)	ST & MLT
Harness energy potential	▪ Explore the feasibility of decentralised green ammonia production powered by renewable energy sources. ▪ Consider financial mechanisms or partnerships to support capital investment in green ammonia production facilities.	MLT
	▪ Explore the (regional) energy potential of organic waste, particularly in the gasification process, and promote its utilisation as well as the by-product bio-slurry.	ST

Policy subjects	Recommendations	Time frame*
Develop standards and establish quality control systems	▪ Establish accreditation and certification processes sensitive to small and large-scale companies' economic conditions. ▪ Develop and implement robust quality standards and regulatory frameworks for OFBF to ensure product quality, efficacy and transparency. ▪ Promote the establishment of laboratories and testing facilities. ▪ Coordinate with international standards and control mechanisms.	ST
	▪ Foster harmonised standards across countries to facilitate trade and create a favourable business environment for biofertilisers.	MLT
	▪ Establish robust monitoring and control systems for OFBF to ensure compliance with regulations and standards. ▪ Implement mechanisms for tracking the environmental and agronomic impacts.	ST & MLT
	▪ Encourage organic fertiliser companies to develop crop-specific products that meet the unique nutrient requirements of different crops, moving away from one-size-fits-all approaches.	ST
	▪ Encourage local entrepreneurs to enhance fertiliser packaging for better attractiveness, traceability, and user-friendliness.	ST
Encourage private sector initiatives and enhance financial support and incentives	▪ Encourage proactive initiatives from the private sector in off-farm produced OFBF with sustainable financing. ▪ Consider especially small-scale ventures, to modernise and expand their operations. ▪ Private sector financing should offer affordable capital and equitable subsidies compared to mineral fertilisers. ▪ Increase quantities of state-subsidised organic fertilisers. ▪ Explore public-private partnerships and government initiatives to procure and subsidise organic fertilisers to support farmers.	ST & MLT
	▪ Explore payments for ecosystem services (e.g., carbon credits) as incentives for the collection and processing of various organic waste types for farm application. ▪ Policies promoting the use of faecal sludge as co-compost could attract green climate finance, making it a key policy area.	ST & MLT
	▪ Increase the ease of doing business by reducing costs for companies and start-ups.	ST & MLT
	▪ Invest in general mechanisation to upscale organic fertiliser production and streamline manual processes. ▪ Provide financial support for machinery purchases and address challenges related to energy costs and subsidy delays.	ST
	▪ Explore incentives for waste management and internalise costs associated with water contamination, health effects, climate change, and food security.	ST
	▪ Support public land provision for organic waste recycling initiatives especially in urban/peri-urban areas where land prices are increasing.	ST & MLT
	▪ Ensure viable business plans adapted to the customer base.	ST
	▪ Support the development of granulated formulations for organic fertilisers to simplify application rates and mechanised application.	ST
Develop a marketing strategy	▪ Develop a well-defined marketing strategy for OFBF to shift market focus toward organic and biofertilisers and enhance adoption. ▪ Explore the use of existing mineral fertiliser distribution channels of governments for OFBF.	ST
Stimulate organic farming	▪ Support the expansion of organic farming practices, including fallowing, crop rotation, intercropping, and mixed farming. ▪ Revive indigenous knowledge and crop associations to enrich agricultural practices.	MLT

Policy subjects	Recommendations	Time frame*
Community empowerment	▪ Empower communities to generate organic matter at a reduced cost through local and regional initiatives, including waste separation and community composting.	MLT
	Research	
Research programmes	▪ Invest in research and development efforts to assess the potential benefits of off-farm produced OFBF comprehensively. ▪ Direct research activities toward a holistic farming approach (as outlined in the fertiliser strategy), incorporating biodiverse land-use systems, agronomic practices, and types of fertilisers.	ST & MLT
	▪ Coordinate an African-wide research programme covering raw material collection, processing, product analysis, application, and economic aspects within the socio-cultural, climatic, and geographic context. Seek support from organisations like the African Union, EU, and other funding bodies.	ST & MLT
	▪ Encourage research and development of diverse organic, organo-mineral and biofertiliser types/products (e.g., pelletisation) and the combination of these, using locally available resources incl. human waste. ▪ Explore how to increase willingness to pay and market acceptance.	ST & MLT
	▪ Explore the feasibility of decentralised green ammonia production powered by renewable energy sources.	MLT
	▪ Conduct nationwide soil sampling to maintain up-to-date fertiliser recommendations and address soil acidity concerns.	MLT
	▪ Conduct comprehensive research to assess the environmental impacts of OFBF use, including effects on soil quality, water resources, and ecosystems.	MLT
	▪ Assess greenhouse gas emissions from open waste dumping and landfills and conduct environmental accounting.	ST
	▪ Intensify research on biofertilisers e.g., adapted for low input systems, isolate, identify and examine the potential of local strains of beneficial fungi and bacteria.	MLT
Research platform	▪ Develop research platforms including all relevant stakeholders (nationally and transnational) to conduct studies that inform sustainable practices and improve product quality. ▪ Enhance communication and collaboration between researchers and policy makers to ensure the seamless integration of OFBF practices into official research agendas and policies.	ST & MLT
	Knowledge, training and education	
Education and training	▪ Incorporate the teaching and training of OFBF within the framework of a holistic farming approach, as outlined in the fertiliser strategy. ▪ Provide education and training programmes for farmers, extension services, and agro-dealers regarding the utility, handling, and application of OFBF. ▪ Systematically foster integrated approaches to soil fertility and related technologies into educational programmes at all levels. ▪ Emphasise the importance of soil health and sustainable agriculture practices. ▪ Establish a programme for training of trainers. ▪ Differentiate between small and large scale. ▪ Address different climatic regions, farm types, infrastructures, and organic farming conditions. ▪ Promote the adoption of appropriate technology for organic fertiliser distribution at the farm level, ensuring precise application rates and optimal timing guidance.	ST & MLT

Policy subjects	Recommendations	Time frame*
	▪ Seek partnerships with NGOs to support community-focused initiatives that address soil and consumer health concerns and promote sustainable agricultural practices.	ST & MLT
Interface research – advisory services - producers	▪ Coordinate research, advisory services, and producer activities. ▪ Establish regionalised field demonstrations and farmer-to-farmer extension in cooperation with partners from research and production of OFBF. ▪ Provide the respective infrastructure and finances.	ST & MLT
	▪ Establish regionalised pilot farm systems integrating local knowledge and experiences. ▪ Support farmer organisations in procuring and operating demonstration plots.	ST & MLT
	▪ Establish and support community-based initiatives and demonstration projects in villages to increase awareness and stimulate demand.	ST & MLT
Awareness campaigns	▪ Create awareness about OFBF characteristics through community radio, social media, local language advertising, and social networks. ▪ Involve extension services, NGOs, and technology dissemination experts. ▪ Focus on involving young people and women in agricultural education. ▪ Policies need to drive waste segregation campaigns, promote awareness, and motivate public participation ▪ Educate the public about the benefits of utilising human excrement via biogas and slurry to gain acceptance. ▪ Allocate finances for awareness campaigns	ST & MLT
Job creation	▪ Recognise the employment potential of OFBF production and use it to generate job opportunities in various communities, contributing to economic development.	MLT
	▪ Evaluate the demand for education and training programmes to create jobs and develop specific qualifications.	ST

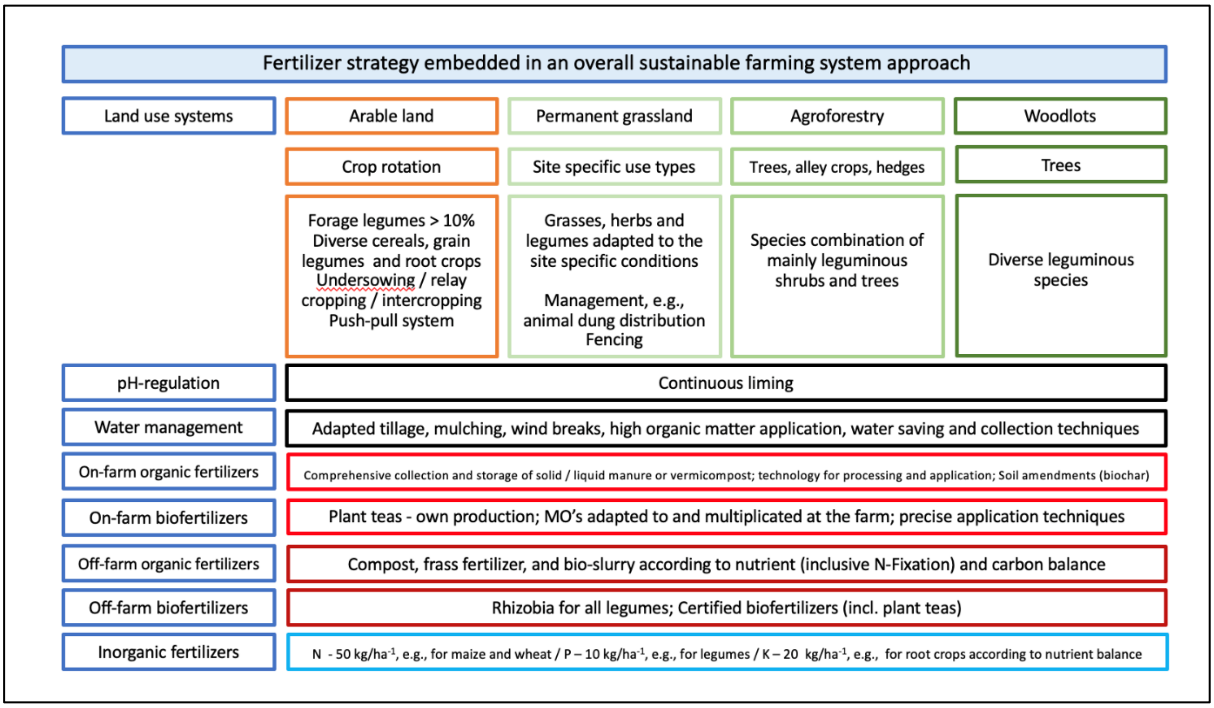
*Time horizon: ST=short-term; MLT=mid to long-term

6.3 Fertiliser strategy embedded in an overall sustainable farming system approach - overview

The off-farm production and utilisation of OFBF should not be seen as an isolated activity but rather as an integral part of an overarching fertiliser strategy. The diagram below provides a concise overview of the key components within a farming system that must be harmonised to ensure a systematic and efficient implementation of OFBF.

All fertiliser applications are influenced by various factors, including site-specific soil and climate conditions, the specific demands of the crops in terms of intended yield and quality, previous crop residues, and other relevant considerations. A nutrient and carbon balance serves as orientation for the application of fertilisers. Additionally, the mineralisation processes of different organic matter types and nutrient availability are crucial factors that inform the fertilisation strategy.

For a more detailed explanation and description, please see annex 8.1.



Source: own

Figure 4. Fertiliser strategy embedded in an overall sustainable farming system approach

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8 Annex

8.1 Fertiliser strategy embedded in an overall sustainable farming system approach – detailed description

This section is not based on interviews but has been included to underscore the potential for on-farm contributions to nitrogen and carbon balance, such as soil fertility and crop yield, in addition to the application of various off-farm sources, which are part of the strategy. Various on-farm strategies can be employed to improve nutrient and carbon balance. It's noteworthy that, currently, aside from nitrogen, all nutrients present in animal manure mainly originate from the existing nutrient soil reservoir. This holds true for the majority of smallholder farms, as the input of mineral fertilisers and nutrient input via feed is still very low or non-existent. Nitrogen is the only nutrient that represents a genuine addition, primarily occurring when collected by legumes through rhizobia.

8.1.1 Introduction

Agroecological principles indeed emphasise the reduction of farm external inputs in agriculture. However, it is important to recognise that off-farm produced OFBF can align with these principles by promoting the principles of recycling and reuse, particularly when implemented on a regional scale. These fertilisers can serve as valuable tools for enhancing soil fertility and sustainability while minimising the need for external synthetic farm inputs. Therefore, the production and use of off-farm produced OFBF should be integral to the ongoing discourse on agroecology.

To effectively address the declining soil fertility in African soils and bolster a climate-resilient farming system with significantly improved productivity, OFBF must be part of a comprehensive land use and fertiliser strategy. In the subsequent discussion, we will delve into this strategy with a primary focus on agronomy, while socio-economic, educational, scientific, cultural, and political aspects will be explored separately.

It is widely acknowledged that a majority of African soils suffer from nutrient depletion, soil erosion, low pH, insufficient nutrient and carbon content, resulting in meagre yields and often subpar product quality. Consequently, animal productivity remains low as well. Naturally, regional variations in soil and climate types exist, and there are various best practices in place.

In this discourse, agroecology is defined primarily from a natural science perspective, alongside various farming approaches such as conservation agriculture, regenerative agriculture, climate-smart agriculture, and others. These approaches offer diverse farming practices with the potential to rectify soil fertility deficits, mitigate climate change effects, and substantially enhance farm productivity. However, a significant challenge lies in the selective application of these farming approaches, with some practices receiving undue attention, while others are overlooked. This approach undermines their overall efficiency and, in some cases, proves counterproductive.

Consequently, a comprehensive approach is needed that encompasses all sectors of production—arable land, permanent grassland, agroforestry, animal husbandry, and woodlots—in addition to the integration of OFBF into farming systems. It is self-evident that this approach should prioritise climate resilience.

The chronological sequence of the subsequent discussions serves as a comprehensive guide for planning and monitoring the sustainability and productivity of a farming system. The implementation of specific land use systems aligns with distinct objectives, including sustainability, resilience, ecosystem services, climate resilience, and productivity. Our recommendations are rooted in these overarching goals. While each farm will necessitate specific adaptations based on factors such as available labour, site conditions, economic constraints, specific food demands, traditions, and cultural considerations, it is essential to avoid the exclusion of any key agroecological practices. These practices are inherently interconnected and collectively contribute to a more sustainable and productive farming system.

While there may be additional components impacting the sustainability and productivity of a farming system, such as breeding technologies, pest and disease management, tillage systems, and others, they are indeed relevant. However, their integration would lead to the exploration of new topics and discussions that extend beyond the scope of this study, i.e., intention of this study.

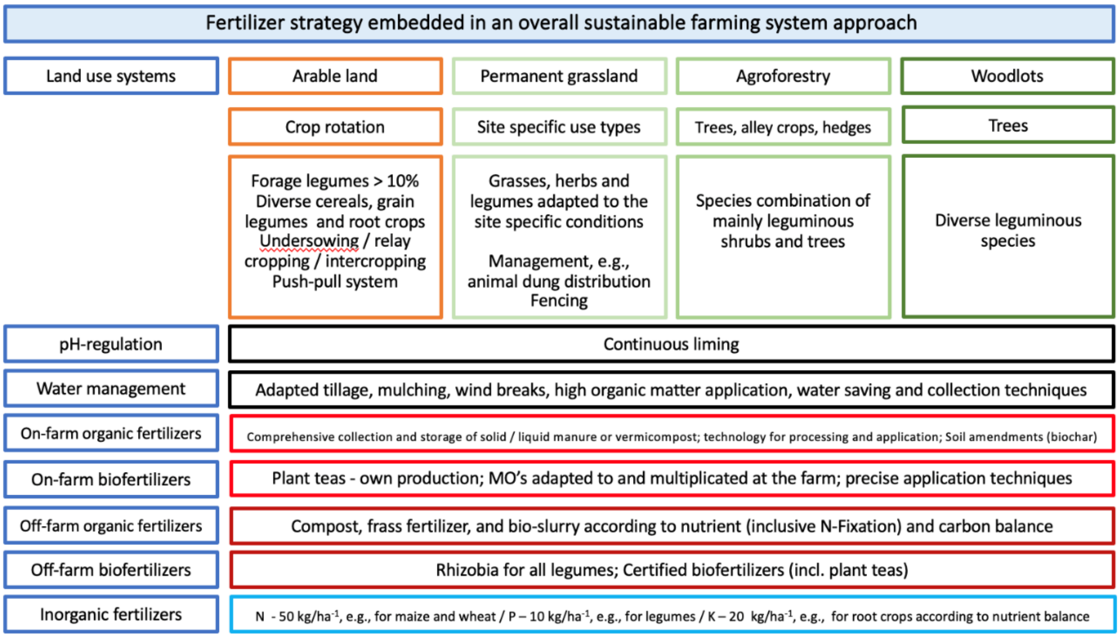

Figure 5. Fertiliser strategy embedded in an overall sustainable farming system approach

8.1.2 Components of an overall sustainable farming system approach and current limitations

Land use systems

Land use systems should be diverse, encompassing practices such as crop rotation, tailored permanent grassland utilisation based on topography and soil characteristics, and responsive animal husbandry strategies, along with the integration of agroforestry and woodlots.

Current limitations*:* Knowledge and expertise related to biodiverse land use systems are noticeably absent from both advisory services and academic curricula and research agendas. However, it is worth noting that there are isolated exceptions to this trend.

Crop rotation

Crop rotation diversity entails the incorporation of a variety of components, including forage legumes such as desmodium, lucerne, clover, sainfoin, and others, as well as grain legumes characterised by a substantial biomass production in addition to their grain yield (GLB), encompassing cowpea, lablab, mucuna, mung bean, vicia and others. Grain legumes (Addae et al.), such as peas, beans, chickpeas, lentils, and others (Addae et al.), typically yield significantly less biomass compared to green leafy leguminous biomass (GLB). Therefore, they are categorised separately within the legume group. In the crop rotation, forage legumes and GLB should collectively constitute 20% of the cultivated crops. The remaining 80% of the rotation can consist of cereals, with a preference for a minimum of three different cereal varieties, oil crops and grain legumes. Where feasible, intercropping with grain legumes is encouraged. The proportion of maize should be restricted to no more than 50%. Root crops should constitute no more than 30% of the rotation, and to mitigate soil erosion, Root crops should be undersown with slow-growing forage legumes or intercropped with grain legumes. In cases where adequate water resources are available, maize cultivation should involve undersowing with slow-growing desmodium or white clover, or alternatively, intercropped with alley trees.

One significant deficiency in cropping systems is the absence of forage legumes, with the exception of the push-pull system primarily driven by undersown desmodium in maize, and surrounded by napier grass. Forage legumes do not only fulfil the protein needs of livestock but also contribute to food production by providing protein rich feed and thus increase the meat and dairy production. Additionally, they significantly enhance crop yields and quality in subsequent crops. Moreover, forage legumes possess deep root systems that can absorb depleted nutrients, and the substantial root biomass they generate enhances soil fertility. The nitrogen fixation rate of forage legumes is estimated to range from 80 to 250 kg of N per hectare. Their nitrogen contribution is valuable in both the short and long term (spanning three crop sequences), and their carbon sequestration capability is among the highest in cropping systems, particularly through their robust root biomass.

The nitrogen fixing rate of grain legumes is estimated to range from 30 to 120 kg of N per hectare. While their nitrogen availability is short to medium-term (spanning two crop sequences), their role in carbon fixation is not as significant as forage legumes, yet they still maintain a positive carbon balance.

Catch crops, which are primarily legumes or a combination of legumes and non-legumes, play a crucial role in nitrogen and carbon fixation. However, their significance under tropical and subtropical conditions is relatively limited compared to temperate climates. In these regions, catch crops often serve as short-term cultivated crop mixtures due to the necessity of utilising all available land for food or forage production. These crops are typically established during the short rainy season.

The fertiliser value of catch crops is estimated to range from 30 to 80 kg of N per hectare. Nitrogen availability is short-term, and their contribution to carbon fixation falls between that of grain legumes and forage legumes.

Undersown crops primarily consist of forage legumes and are established within maize or, more commonly, wheat, shortly after the main crops (approximately 2 weeks following planting). These undersown crops continue to develop biomass after the main crop's harvest and can be utilised for forage or seed production over several months.

Relay cropping involves undersowing primarily in maize, potato, or sorghum towards the end of the main crop's growing season. This allows the remaining water resources to be efficiently used and often involves grain legumes like cowpeas, peas, lentils, and others.

Current limitations: The challenges include a general shortage of seeds, specifically of (forage) leguminous crops, limited knowledge and expertise on utilising forage for animal feeding, and frequently, the absence of rhizobia in the soil. The availability and functionality of rhizobia are compromised in instances of low soil pH (as indicated below). Furthermore, a prevailing misconception that "people cannot consume forage", leads to concerns about sacrificing land for food production.

Addressing these challenges necessitates the acquisition of more comprehensive knowledge about various aspects of forage legumes. This includes a deeper understanding of the diverse forage legume varieties, their harvest yield potential, nitrogen fixation capabilities, mineralisation attributes, pH sensitivity, productivity rates, and overall forage quality. Such insights are crucial for devising effective strategies to overcome the identified constraints and optimise the incorporation of leguminous components within agricultural systems.

Agroforestry

Agroforestry, along with its various subtypes, including alley cropping in diverse configurations, silvo-pastoral systems, and hedgerows, constitutes fundamental components of land use systems. Their incorporation should ideally account for approximately 10% or more of the overall land use, while promoting a high degree of species diversity within these systems.

Primarily, leguminous alley trees and shrubs are planted to serve multiple purposes, including windbreaks, erosion control, as a forage source, among other functions. The stems of these trees can be harvested and utilised as a sustainable source of firewood, while also being utilised as mulch or compost material to enhance soil fertility. These trees and shrubs typically yield around 5 tons of dry matter per hectare in above-ground biomass annually. Nitrogen fixation by crops varies, ranging from 50 to 200 kg per hectare, with nitrogen availability spanning from the short term (leaves) to the long term (lignified branches). As a result, they represent a valuable resource for enhancing both the nitrogen and carbon balance in the agroecosystem.

Current limitations: Without technologies for agroforestry management and lacking transport options can be burdensome, leading to increased workloads. Additionally, limited knowledge on the AF management, access to seedlings and the risk of damage by animals can pose obstacles to the establishment of these practices. The issue of limited space is often raised as a potential hindrance, even though it is evident that many farms still have substantial fallow land, often amounting to as much as 20%. However, insecure land tenure or rented land arrangements can be inhibitive for long-term investments such as agroforestry.

Permanent Grassland

Whenever feasible, it is advisable to establish permanent grassland within a silvo-pastoral framework or integrate them into alley cropping systems (e.g., utilising tree lucerne) as well as the use of natural fencing, e.g., Euphorbiaceae family. Furthermore, livestock density should be adjusted to suit the specific conditions, and seed materials should be chosen to match soil characteristics, especially in areas with open soils. This includes the consideration of protein-rich grasses like Brachiaria spp. or tropical forage legumes in the seed mixtures.

Current limitations: In many regions permanent grasslands are overused and eroded. Productivity in these areas is significantly hampered by the absence of adequate fencing and proper management practices, leading to persistent and irreversible land degradation. The situation is exacerbated by the lack of consistent management and protective measures for grasslands, the failure to reseed overused land due to a shortage of suitable seed materials, coupled with the impacts of droughts and flooding events. Moreover, the limited knowledge and experience, particularly regarding the intricate relationship between feed quality, livestock productivity, and the effective utilisation of animal manure, contribute to the predicament in managing grasslands effectively.

Woodlots

The utilisation of leguminous tree species, such as *Acacia mangium*, presents a promising alternative to traditional monoculture practices like eucalyptus cultivation. These leguminous trees not only offer comparable or even superior productivity but also exhibit the unique advantage of permitting concurrent cultivation with food crops during the initial two years. Following the harvest of these trees, the nitrogen and carbon residues they leave behind can be leveraged to sustain subsequent food crop production. It is crucial to refrain from monocropping and, instead, promote diversity by incorporating other tree species into the mix. This approach not only enhances overall ecosystem resilience but also contributes to more sustainable and resilient agricultural practices.

Current limitations: Presently, Eucalyptus species dominate the landscape, leading to detrimental consequences for soil fertility. Generally, information regarding more suitable alternatives that align with the sustainability of land use systems (Yeo et al.) is not widely disseminated.

Nutrient and carbon balances

Nutrient and carbon balances serve as invaluable tools for planning and monitoring the comprehensive utilisation of both organic and inorganic fertilisers, thereby facilitating the optimisation of fertiliser strategies.

Current limitations: Currently, the implementation of nutrient and carbon balances is infrequent. There is a notable scarcity of data concerning the nutrient content of all relevant inputs and outputs necessary for calculating nutrient balances accurately. Furthermore, there is a significant deficit in knowledge and practical experience in the field, with nutrient balancing rarely incorporated into fertiliser strategies developed by advisory services and seldom prioritised as a subject of research.

pH – balancing

The increasing acidification of soils is adversely affecting crop yields, particularly for grain legumes, as rhizobia, which play a vital role in these crops, are sensitive to low pH values. Consequently, farmers are abandoning the cultivation of this essential crop group, which has significant implications for human nutrition, soil fertility, and the sustainability of cropping systems. Moreover, the positive contributions of grain legumes, such as their use as forage (e.g., mucuna, lablab, or cowpea) and their ability to suppress weeds, are lost within crop rotation systems. These functions are valuable in reducing the reliance on external inputs and associated costs.

The practice of liming, in conjunction with the application of organic fertilisers that contribute to both an increase in soil pH and compensate for potential humus depletion, should be considered a standard procedure in soil management. Incentives such as subsidies should be strategically directed to support the production and application of these recommended practices. To ensure accessibility and relevance, it is important to make lime of various qualities available on a regional basis. Furthermore, organising the application techniques through producers, farmers' organisations, or communities can streamline the process and enhance its efficiency. It is worth noting that liming not only serves to balance soil pH but also enhances aggregate stability and nutrient availability. These benefits, in turn, promote the activity of rhizobia and contribute to overall soil health and agricultural productivity.

Current limitations: Transporting lime to farms located in remote areas presents a notable challenge, as does the distribution within the fields, especially considering the recommended application rate of 1-2 tons per hectare. This logistical hurdle can hinder the adoption of effective liming practices in these regions. Moreover, there is a noteworthy limitation in terms of knowledge and education about lime and its benefits, research efforts related to lime application are insufficient, which, in turn, affects its availability and affordability in the market.

Water management

Water is indispensable for crop yield, making it a critical factor in agricultural production. Consequently, it is crucial that all farming activities, particularly those related to land use systems, encompass a holistic approach to water management. This approach should include the incorporation of organic matter from various sources to improve soil water retention, the cultivation of drought-resistant crop varieties, the implementation of tillage systems that facilitate water storage and efficient utilisation, the establishment of water collection systems, and the adoption of water-saving irrigation practices.

Current limitations: Water management is a complex and knowledge-intensive field, often requiring the expertise of multiple specialists and substantial technological investments. In many areas, there is a lack of incentives such as subsidies and comprehensive technology and advisory support for water management practices.

Organic matter management

To regenerate soil fertility and fortify soils against the effects of climate change, it is important to establish a comprehensive range of strategies for enriching soils with organic matter. Organic matter, regardless of whether it originates from on-farm or off-farm sources, plays a multifaceted role in soil improvement. Organic matter serves as a conduit for the transfer of macro- and micronutrients, contributes to bolstering the soil's resistance against pathogens, enhances soil aggregate stability, augments water-holding capacity and infiltration rates, facilitates increased nutrient uptake by plants, and provides protection against soil erosion. Leguminous crops are particularly noteworthy in this regard, as they not only fix nitrogen through symbiosis but also, as demonstrated by various studies, forage legumes and leguminous alley crops actively redistribute leached nutrients from deeper soil layers to the upper layers. The pivotal roles of organic fertilisers and biofertilisers in this context are elaborated upon below.

Current limitations: Investments in organic matter management are less emphasised but a highly beneficial means of enhancing crop yields. Research efforts in this area are limited, with a predominant focus on mineral fertilisers and pesticide applications. Additionally, farmers often encounter obstacles in the form of increased workload and associated costs when considering investments in organic matter management.

On-farm organic and biofertilisers

Organic fertilisers: Effective management of livestock fertilisers is crucial, and this involves the collection, proper storage, and responsible application of these resources to soils and crops. Technologies should be employed to facilitate organic matter management, including the production of compost from a variety of crop residues.

A dual approach should be adopted: one focused on compost production with an emphasis on enhancing soil fertility, and the other involving the application of bio-slurry as a flexible nitrogen fertiliser that can have a significant positive impact on crop yields when managed correctly. Vermicompost, as a subvariant of compost, is also noteworthy for its additional contributions to soil fertility. Implementing these strategies can greatly benefit agricultural systems by optimising nutrient cycling and enhancing soil health.

Biochar, when used as a soil amendment, contributes to improved water-holding capacity, serves as a nutrient reservoir, and provides a hospitable environment for microorganisms. As such, it represents a valuable addition to enhance soil fertility and overall soil health.

Current limitations: The management of dung poses significant challenges as it is frequently not collected, often washed out due to open storage, or repurposed for uses like cooking. Additionally, the nutrient content and overall quantity of dung per animal are quite low, which limits its potential for nutrient and carbon transfer and, consequently, its impact on crop yield and quality. Compounding these challenges, there is a notable absence of adequate technology for dung management, and the existing solutions are often of low quality. Furthermore, there is a lack of comprehensive knowledge and practical experience in the successful management of organic fertilisers. Organic fertiliser does not receive the necessary attention from advisory services, universities, and research institutions, which further hinders its effective utilisation in agriculture.

In the case of biochar, there is a need for further development of farm-adapted production technology to ensure quality and consistency. Additionally, more research and data are required to determine optimal application rates and methods.

Biofertilisers: The inclusion of liquid biofertilisers, derived from various plant materials and serving as biostimulants for microorganisms while strengthening plants, is a valuable complement to organic fertilisers. However, it is important to note that our understanding of their functions and efficiency in soil-crop systems is still limited, indicating the need for further research and exploration in this area.

Current limitations: The impact of liquid biofertilisers is a topic of ongoing discussion within the agricultural community. Due to variations in their composition, which can differ from one farm to another and over the course of the year, achieving standardisation is a significant challenge. Efforts to establish consistent quality and application rates for these liquids based biofertilisers are essential to their effective use.

Off-farm organic and biofertilisers

Organic fertilisers: Off-farm produced compost, including frass-based fertilisers, co-composted sewage sludge etc., sourced from various origins, represents a valuable addition to address the soil carbon deficit in soils and bolster soil fertility. While they contribute significantly to the nutrient balance in some instances, it is important to note that their impact may vary. Similarly, off-farm produced bio-slurry is a valuable fertiliser, as discussed earlier. Both of these fertilisers play a crucial role in improving the efficiency of inorganic fertilisers when integrated into farming practices. To fully harness the benefits of these fertilisers, it is imperative that they are well-defined and free of any contamination. Subsidising the production and utilisation of these fertilisers is recommended to incentivise their adoption and promote sustainable agricultural practices.

Current limitations: Some of the major limitations comprise varying quality, costs and effectiveness, transport costs, lacking knowledge on application rates and soil nutrient status, as well as perception of farmers. Furthermore, insecure land tenure or rented land arrangements can often lead farmers to prioritise short-term results and quick returns on their investments.

Biofertilisers: Biofertilisers can significantly contribute to crop health and crop yield, especially in dry areas. The application of rhizobia is essential wherever legumes are cultivated, particularly in the majority of soils where it is necessary until the establishment of rhizobia colonies. To enhance their activity, liming and minor additions of inorganic phosphorus (P) can be applied. Additionally, mycorrhizal fungi play a valuable role in enhancing soil fertility and improving nutrient and water uptake by plants. They are especially effective when pesticides are excluded, and the use of inorganic fertilisers is limited.

Current limitations: Some of the major limitations include lacking quality of marketed products, knowledge on application rates, a lack of well-defined products, leading to uncertainty among customers. Additionally, the availability of rhizobia is often limited, and their functionality may not always be guaranteed.

Inorganic fertilisers

In accordance with nutrient balances, the determination of the intended crop yield should take into account various factors such as agro-ecological conditions, the preceding crop, potential nutrient residues from previous years, and the application of organic fertilisers (both off-farm and on-farm sources). Based on these considerations, the supplementation of macro and micro elements through inorganic fertilisers can be determined. It is advantageous to select inorganic fertilisers that are sensitive to the stoichiometry of the specific crops being cultivated.

Current limitations: Some of the major limitations for inorganic fertilisers are lacking accessibility, and often unfavourable cost-benefit ratios, for example, due to low agronomic efficiency and low farmgate prices of harvested crops.

The synergistic combination of organic and inorganic fertilisers, along with nitrogen contributions from legumes, represents a valuable approach to nutrient management in agriculture. However, it is important to acknowledge that this integrated approach is not widely recognised or promoted. It is not commonly included in advisory services or university curricula, although there are exceptions to this trend. Additionally, research in this area is relatively limited. Furthermore, the fertiliser industry may not prioritise the development or promotion of integrated fertiliser strategies.

Animal husbandry

Animal husbandry plays an important role as an intermediate element in the fertiliser system. When the feed provided to animals is enriched with higher nutrient content, and the animals efficiently consume forage, this leads to increased production and enhanced nutrient content in the resulting animal manure. Consequently, the nutrient-rich manure becomes a valuable resource that can be effectively redistributed in the field where it is needed, promoting improved soil fertility and sustainable agricultural practices.

Current limitation: The productivity of animal husbandry is often constrained by factors such as limited feed supply and low feed quality. In many cases, there is a prevailing belief among farmers, advisers, and researchers that forage legumes compete with food crops for limited land resources. However, it is important to recognise that under optimised conditions (including pH regulation, the incorporation of organic fertilisers, and additional inorganic phosphorus), the integration of forage legumes into farming systems can yield several significant benefits:

a) Enrichment of feed with protein, leading to higher animal productivity and improved product quality. b) Utilisation of nitrogen from forage legumes to increase the yield and quality of subsequent crops, thereby compensating for the reduced production area for food crops. c) Contribution to overall soil fertility, plant health, weed suppression, and enhanced organic fertiliser production. d) Enhancement of the quantity and quality of organic fertilisers, promoting soil health and sustainability. e) Mitigation of the irreversible loss of land through erosion processes.

This systemic and integrated thinking is not always well-represented in advisory services, university curricula, and research discussions, although there are notable exceptions.

The role of "traditional" systems

Traditional systems were established during periods when population rates were often significantly lower, and the proportion of forested land was much higher than it is today. Therefore, it is essential to acknowledge that these traditional systems may not be directly applicable to contemporary agricultural challenges.

However, traditional knowledge can still play a valuable role in informing the revision and adaptation of current farming systems toward a more systemic and sustainable approach. To do so effectively, a comprehensive analysis and assessment of the existing farming systems, incorporating traditional wisdom, is necessary. By merging traditional practices with modern insights, it is possible to develop farming systems that are better suited to the evolving needs of both agriculture and the environment.

8.1.3 Conclusions

OFBF can be viewed as integral components of an overarching systemic farming approach. Their multifaceted functions underscore the importance of integrating them into farming systems as a primary strategy for achieving carbon and nutrient balance.

The question should not revolve around whether on-farm OFBF, off-farm OFBF, or inorganic fertilisers are to be preferred, but rather how they can complement each other within a biodiverse land use system. In this context, the optimisation of on-farm OFBF should take precedence, followed by the incorporation of off-farm OFBF to facilitate the recirculation of carbon and nutrients and stimulate biological processes. Inorganic fertilisers should be used selectively to address specific nutrient imbalances.

This approach necessitates a fundamental shift in agronomic practices, moving away from a conventional mindset and embracing a more holistic and integrated approach to farming that prioritises sustainability, soil health, and nutrient management. The formulation of well-defined policies is crucial as a backbone for guiding and supporting such a holistic and integrated approach. Effective policies can provide the necessary framework, incentives, and regulations to encourage the adoption of environmentally sound and socially responsible agricultural approaches, ensuring long-term food security, ecological resilience, and economic viability.

8.2 Country reports – a synthesis of all country interviews

8.2.1 Cross-country experts

I Status quo

Mineral fertiliser

Interviewee-1: The interviewee stated that farmers, as well as local governments, are acutely aware of their position at the tail end of intricate and lengthy supply chains, making them vulnerable to fluctuations in prices. For example, in Ethiopia, the local government is transitioning toward organic banana cultivation in Arba Minch, influenced by shifts in fertiliser prices and a growing recognition of the vulnerability associated with relying solely on imported nutrients. This evolving awareness is driving the need for change, with farmers seeking organic inputs, and countries considering policy adjustments to bolster organic production.

Interviewee-3: The interviewee stated that the current situation with traditional chemical fertilisers is highly unstable. Following the onset of the Covid-19 pandemic, there was a disruption in the logistical chain for fertiliser production. Additionally, the interviewee mentioned that the conflict between Russia and Ukraine led to the imposition of several sanctions, causing a significant increase in the cost of natural gas, a crucial resource for urea production. Natural gas is closely linked to electricity production, and the soaring electricity prices affected the costs of ammonia-based fertilisers. This situation posed challenges not only for European countries but also for developing countries, such as various African nations, which heavily relied on fertiliser imports from Europe, Russia, or Ukraine.

Furthermore, the interviewee shared a specific example involving the country of Gambia. Government officials in Gambia approached the interviewee, explaining that ongoing contracts had faced challenges. During the contract negotiation process, a supplier had initially agreed to provide fertilisers but later refused due to the low contract price. This occurred in 2020, and the situation subsequently worsened.

The interviewee suggested that every crisis presents opportunities for various industries. For instance, the rising costs and reduced accessibility of traditional chemical fertilisers encouraged farmers to consider alternatives like organic fertilisers. Farmers began to change their mindset as they realised that organic fertilisers could be obtained at similar or even lower prices than chemical ones. They also observed impressive results in their fields, with some organic fertilisers proving as effective as inorganic ones. This shift in perspective extended not only to farmers but also to Sub-Saharan governments.

The interviewee explained that their African business operations primarily focused on countries like Kenya, Tanzania, Rwanda, Nigeria, Ghana, and Cameroon. They also cooperated with different countries, such as Uganda, South Africa, Gambia, and Ethiopia, to pursue certification.

Drawing from their experience working with these countries, the interviewee highlighted Kenya as a notable example. The Kenyan government had been actively striving to achieve some level of food security through local fertiliser production.

Interviewee-6: The interviewee did not observe any change in the current situation compared to the period before Covid-19 or any economic crisis. They considered the challenges at the interface between the waste and agricultural sectors more fundamental than the current challenges addressed by various projects. While acknowledging that these projects draw attention to the issue, the interviewee expressed the need to address more foundational challenges.

Off-farm organic and biofertilisers

Production and technology

Interviewee-1: The primary objective of the RUNRES project (partner countries: Ethiopia, Rwanda, Democratic Republic Congo, South Africa) is to identify methods for capturing and processing organic waste streams that accumulate in urban areas. The goal is to transform these waste streams into valuable products that can reintroduce nutrients into the soil, ultimately promoting long-term soil health and fertility to support sustainable food production. The innovations supported by the project fall into three distinct clusters:

1. Soil Inputs: These innovations focus on providing soil nutrients derived from recycled products.
2. Animal Feed: Organic waste streams, such as those from black soldier flies and cassava waste, are used to produce animal feed.
3. Municipal Composting: In South Africa, for instance, an innovative approach involves collecting sewage sludge from a treatment facility and collaborating with the municipality to restructure solid waste management. This includes chipping green waste from the entire city, resulting in the production of compost that is sold to commercial growers in the area. Various soil inputs, including stored urine and vermicompost from human excreta, are produced, and quality assurance measures are in place to assess nutrient concentrations.

The project has encountered challenges, including pathogen reduction and heavy metal contamination. There is also a collaboration with experts from ETH Zurich to address pharmaceutical concerns. In the Democratic Republic of Congo, there have been issues with heavy metal contamination, particularly chromium levels exceeding regulatory limits, compared to South African regulations, which are less stringent.

One of the project's innovation leaders in Ethiopia excels in municipal compost production, achieving high quality by effectively separating waste streams at the household level. The support and involvement of municipalities have been instrumental in restructuring solid waste management and ensuring the production of a high-quality compost. It's important to note that the quality of municipal compost can vary significantly.

The key difference in producing high-quality compost often lies in the level of municipal support. Subsidies, provision of land, and equipment are essential forms of support to facilitate the composting process. In South Africa, for instance, the municipality covers the cost of the sewage sludge that's utilised, reducing expenses for the project. Finding cost-effective solutions is critical, especially since compost production can be a challenging business, particularly when considering the costs of waste transport. Transport, both for waste and the final product, is a significant logistical factor.

Container-based sanitation is viewed as another interesting option, which includes the treatment of separated urine (alkaline dehydration) and faeces to create a promising fertiliser (urine enriched biochar). The nitrogen in this fertiliser is primarily in the form of urea (about 5%), making it readily available for plants. Initial trials indicate that this approach is as effective as standard chemical fertilisers, significantly increasing maize productivity. The project is now exploring this approach in South Africa.

Interviewee-2: There is significant potential for nutrient recovery from waste, which is closely linked to both urban and rural systems, playing a vital role in the circular economy. Rather than solely focusing on the benefits to the agricultural sector, we must consider the broader impact, particularly in addressing climate concerns and strengthening the connections between urban and rural areas. This is an important point for policy makers to recognise.

A considerable amount of waste is generated in urban areas, yet the nutrients it contains are needed in rural regions. It is crucial to establish a mechanism for these nutrients to flow back to where they are required. The economic aspect is also significant because depleted soils can negatively affect food production and water usage. Investment in nutrient recovery is essential given its multifaceted benefits encompassing economic, environmental, and social dimensions.

The Black Soldier Fly (BSF) technology shows promise, but its economic feasibility needs further evaluation. In comparison to traditional drying beds, which have space limitations, BSF can process waste more rapidly. However, comprehensive research is needed to determine the economic advantages of using BSF over other methods.

While some older technologies like sludge composting and co-composting have limitations, there is potential for improvement to make them viable. This also ties into our sanitation systems, emphasising the need to view these systems holistically to ensure a sufficient supply of sludge and compost.

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.

The interviewee emphasised: *"In some places they put up an amazing plant for treating faecal sludge, but the waste doesn't even get there because we might not have private empties to collect and transfer the waste, or they collect the waste, and they dump it somewhere."*

Interviewee-3: The company of the interviewee produces organic fertilisers from using by-products from livestock slaughter such as hoofs, horn, feathers. They aim to set-up production plants in various African countries, currently they are importing all their products from Europe to Africa. However, they also have contingency plans in place. As part of their strategy, they are planning to build a factory in Kenya. Simultaneously, they aim to establish collection points in major livestock areas to reduce the distance that farmers need to transport materials.

For specific materials like hoofs, the interviewee explained that they would collect them, subject them to a cooking process to eliminate pathogens, followed by drying and crushing to prepare them for transport. These processed hoofs would then be ready for shipment. However, when dealing with materials like poultry feathers, extended storage is not possible, as they are highly susceptible to disintegration. The interviewee emphasised that there is only a 24-hour window to process feathers effectively.

To address the time-sensitive nature of poultry feathers, the interviewee indicated that they collaborate with poultry slaughtering houses and rendering plants. In cases where a farmer in a remote area has a small quantity of materials, like two chickens, collecting the materials in time may not be feasible. However, materials such as hooves, horns, and wool are considered excellent options because they do not degrade, even after years of storage.

Interviewee-4: The interviewee noted that raw materials for organic and biofertilisers exhibit significant variability.

Regarding barriers for OFBF, the interviewee identified several key challenges. Firstly, accessing the necessary raw materials represents a significant hurdle. Additionally, a lack of effective mechanisms for verifying the claims made about the organic and biofertilisers can lead to disappointment when these claims are not upheld. This lack of verification is identified as a primary barrier that could deter potential users. Moreover, the convenience of using organic and biofertilisers, when compared to mineral fertilisers, may pose another obstacle.

In terms of the application of organic and biofertiliser standards, the interviewee outlined the opportunities that arise from current issues such as climate change, environmental degradation, and deteriorating soil health. These issues have created a growing demand for organic food and related products, including clothing. Consequently, there is a pressing need for the verification of inputs used, particularly fertilisers, to meet this increasing demand. Moreover, the recent increase in mineral fertiliser prices due to geopolitical factors, such as the conflict in Ukraine, has created further opportunities for organic and biofertilisers in the market.

Interviewee-5: The interviewee focused on technologies for treating organic waste or biowaste, including sludge and faecal sludge, which are distinct from solid waste. Faecal sludge poses additional challenges due to its higher pathogenicity, necessitating proper sanitation measures when using it as fertiliser to avoid health problems. The interviewee's expertise lies in solid waste management, specifically organic solid waste or biowaste, such as food and garden waste in urban or residential settings. However, they mentioned that they haven't extensively explored the management of agricultural waste.

Regarding waste treatment options, the interviewee acknowledged that there are various options, each with its strengths and weaknesses. They emphasised the importance of considering the trade-offs in the specific local context to determine the most suitable approach.

The interviewee discussed their work over the years, which included composting, anaerobic digestion for biogas production, carbonisation (e.g., biochar), and more recent work on black soldier flies, all aimed at reducing organic waste. They highlighted that organic waste constitutes a significant portion of total waste, ranging from 50% to 80%, and effective treatment methods could reduce landfill usage and greenhouse gas emissions.

To make a significant impact on organic waste management, the interviewee stressed the need for source segregation and separate collection or delivery methods, applicable to all technologies. Each technology has its advantages and disadvantages. Composting is relatively simple and achieves high temperatures, sanitising the waste, but it yields a voluminous product with limited nutrients, making it challenging to market. However, this depends on the region or country specific context:

"Egypt for instance, is a very good case. But there, the customers are not interested in the nutrients. They're interested in the organic matter because they have very bad soils. it's mostly sandy soils, except for the delta, but in other areas of Egypt. So, of course, depending on what your soil conditions are, suddenly it may become quite interesting, but then it has to be clear that it's the driving force is actually now for compost is not nutrients, is then organic matter, because of bad soil quality. So Soil improvement is the objective not soil nutrition."

In contrast, anaerobic digestion does not provide sanitation due to its lower temperature. The resulting digestate, especially if it contains faecal sludge, requires careful consideration for its intended use. Moreover, most anaerobic digesters in low and middle-income countries use wet systems, leading to a wet digestate, necessitating additional processing to remove excess moisture. This added complexity is balanced by the production of biogas as a valuable byproduct.

Black Soldier Fly (BSF) technology is similar in this regard, yielding both protein and a digestate (referred to as "frass"), which can be used as a compost after some post-composting treatment. Entrepreneurs often prioritise the protein value over the fertiliser value, but there is potential to explore the fertilising value of the residue. Research on using black soldier fly residue as a fertiliser has shown promise, though it has yet to reach the implementation phase. The primary challenge with BSF and biowaste is sourcing. Labour, they pointed out, is not a significant obstacle, particularly in developing countries or low- and middle-income countries, where manual labour can handle substantial quantities. In some instances, highly industrialised and automated approaches have failed, as seen in South Africa, where they adopted concepts similar to those in the Netherlands. The interviewee highlighted that labour can be viewed as an opportunity to create jobs rather than a cost barrier, especially in lower-income countries.

The interviewee stressed the challenge of waste sourcing, explaining that while there is an abundance of waste, it may not be in the desired form for processing. Achieving the required waste form can be difficult and may necessitate source separation or segregation, which adds complexity. They advised those seeking support to ensure they can obtain a reliable and consistent supply of waste, avoiding seasonality issues that can disrupt the biological cycle of BSF. It's also essential to operate at or near the design capacity of the facility to maximise economic efficiency.

The interviewee mentioned a successful BSF project in Indonesia where a pilot plant was handed over to a private company. They supported approximately 12 partners in building BSF plants, and most of them continued to operate even two years after the project's conclusion. While these operations were relatively small in scale, the interviewee highlighted the sustainability of these initiatives beyond the project period. They also noted the establishment of a network or professional association of BSF entrepreneurs who could exchange information and support each other.

The interviewee discussed the importance of knowledge-sharing and collaboration among BSF entrepreneurs, particularly in the context of Uganda, to avoid reinventing the wheel. They emphasised that many entrepreneurs face similar challenges but often operate in isolation due to competition or a reluctance to share information. The interviewee recognised the need to create a community of practice in Uganda to facilitate sharing equipment design, approaches, and problem-solving. They pointed out that local expertise and context-specific knowledge are crucial, as outsiders may not fully understand the local context, which can act as a barrier to progress.

Carbonisation

Regarding carbonisation, the interviewee noted its limitations, primarily applicable to specific waste fractions, such as dry and woody materials. Carbonisation has potential applications as a product or fuel. Using it as fuel is a logical choice, and it can be considered as an option. However, when thinking about carbon storage for soils, like biochar, the interviewee highlighted challenges with customer acceptance. Biochar faces more significant obstacles than compost because it is not a fertiliser but rather a soil amendment. Few farmers are willing to pay for a product like biochar that would improve soil quality over an extended period.

While carbon briquettes for energy as fuel could be interesting, the trend is shifting toward cleaner fuels like gas, as traditional charcoal briquettes and stoves may produce harmful smoke leading to respiratory diseases. However, the interviewee believed that carbonisation might find its place in industrial applications, where the constant quality and storability of the product make it advantageous compared to biogas, which is not easily stored.

Combining biochar with sanitation, particularly urine-enriched biochar, piqued the interviewee's interest as a means to enhance its market appeal. However, the process has associated costs, leading to discussions about whether it needs to be cost-recovering. The interviewee expressed frustration with the concept of strict cost recovery, emphasising the importance of making such technologies economically viable. They suggested that, like Black Soldier Fly (BSF), not every aspect of waste management needs to be strictly cost-recovering or profitable, as these technologies offer other valuable benefits beyond financial returns.

Co-composting of faecal sludge (and inorganic fertiliser addition)

The interviewee discussed a project involving the co-composting of faecal sludge in Ghana, specifically in Kumasi. In this project, faecal sludge and market waste were co-composted, focusing on pathogen reduction and worm egg control. The results indicated that co-composting was effective in sanitising faecal sludge, but nutrient levels in the final product did not significantly increase.

The primary reason for this limited nutrient enhancement was the high-water content of faecal sludge, which is typically around 98 to 99%. Such high-water content makes it challenging to incorporate faecal sludge into compost in its original form, as it could make the compost too wet. Therefore, a dewatering step was necessary to reduce the water content. However, this process resulted in the loss of nutrients contained in the liquid fraction of faecal sludge. Additionally, during composting, ammonia volatilisation occurred, particularly with higher temperatures, which further contributed to nutrient losses. As a result, the co-composting process did not significantly boost nutrient values in the final product (compared to compost from organic wastes only).

The interviewee emphasised that, from a waste management perspective, the co-composting of faecal sludge was still valuable, as it effectively treated the faecal sludge. However, the challenge remained in enhancing the market appeal of the product. To address this issue, the project involved enriching the co-compost by adding inorganic nitrogen and phosphorus, making it more attractive to farmers. Nevertheless, the fundamental problem of product acceptance persisted.

Farmers often prioritise rapid nutrient accessibility for their crops, favouring immediate benefits over long-term soil nutrient improvement. Therefore, the market's perception of value and the willingness of customers to pay for the product were ongoing challenges, whether the co-compost contained faecal sludge or was made from regular compost or organic waste. The interviewee underscored that these challenges in value perception and market acceptance remained largely unchanged, irrespective of the specific composting process or ingredients used.

Interviewee-6: The interviewee discussed incineration as another waste management perspective gaining popularity in many areas. Incineration is seen as a method to dispose of waste, potentially producing energy for the grid or generating biogas. However, the interviewee shared insights from a global review of biogas projects, expressing concerns about the generally negative reviews of such projects in various regions, including Africa, Ghana, and Asia.

The interviewee mentioned a local example of a school with a biogas project, highlighting the limitation of not being able to use the biogas in the canteen due to the considerable distance between the plant and the canteen. They acknowledged the simplicity of the technology but questioned its scalability, emphasising the need to wait for the outcomes of the ongoing global review of biogas projects.

The interviewee expressed scepticism about biogas being the optimal solution, particularly in tropical regions like where they are located. They noted the limited need for heat in the tropics and highlighted electricity problems as a more pressing concern. Converting biogas to electricity was deemed complex on a large scale. The interviewee advocated for composting as a preferable alternative, suggesting it as a more practical and efficient approach, especially in tropical climates.

Waste sources

With regard to organic waste sources the interviewee emphasised households as the largest contributors, followed by markets, restaurants, and some industries. While acknowledging the vast quantity of organic waste, they noted that it may not be inherently rich in nutrients.

Quality and nutrient content

To enhance the compost for potential sale, the interviewee proposed enriching it with faecal sludge, a prevalent waste source in the countries they work in, primarily from on-site sanitation systems. They clarified that they focused on septage from on-site sanitation rather than sewage sludge, which has different applications such as landscaping. The interviewee highlighted the relative cleanliness of septage, with microbial risks that can be mitigated through co-composting with carbon-rich municipal organic waste.

"And so now you have to think if you really want to sell this compost, you have to enrich it. And then you look around and then you see, there's lots of the faecal sludge. And in the countries where we work, 95% of all the faecal sludge comes from onsite 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 onsite sanitation, about septage tanks and the septage is rather clean. It has microbial risk, but we can eliminate those. And co-composting nitrogen rich faecal sludge with carbon rich municipal organic waste, can produce quite a good product."

The interviewee acknowledged the challenge of maintaining a constant product due to the varying nutrient values of different organic wastes. They emphasised that the nutrient value of co-compost is significantly lower than that of inorganic fertilisers, making them distinct in terms of volume and characteristics. While industrial fertilisers are concentrated and efficient, co-compost requires larger quantities for the same nutrient supply.

“Of course, the nutrient value of the residing compost is still much, much lower than of any industrial fertiliser. you cannot compare a co-compost, with let’s say 3% nitrogen with UREA which has 46% nitrogen. And so for farmers to use now the compost, we would’ve to carry, 15 times the amount of compost compared to as he would’ve to carry 15 tons compared to one ton. So it’s just a huge volume. It’s a totally different process. it needs different infrastructure, different machinery to transport it and et cetera. So it’s never really comparable, one is a fertiliser and the other is a soil amendment.”

Despite the differences, the interviewee emphasised the valuable contribution of organic fertilisers, particularly in reducing the reliance on chemical fertilisers. They highlighted the additional benefits of organic fertilisers, including greenhouse gas emission reduction and waste volume reduction, making them environmentally beneficial.

Pelletisation of compost was discussed as a strategy to improve the product for farmers. The interviewee explained that farmers might find loose compost messy and challenging to distribute. Pelletisation, compressing the compost into pellets, reduces the transport volume, making it more manageable and resembling industrial fertilisers. However, they acknowledged that pelletisation increases electricity and machinery costs, requiring careful consideration of economic feasibility.

Carbonisation (Biochar)

The interviewee emphasised that not all biochar is the same, as it varies based on the source material, such as cocoa husks or maize residues. Different biochars exhibit distinct characteristics, leading to varied results in crop trials. While some trials showed increased yields, others demonstrated no significant impact.

They mentioned a project involving six German universities conducting biochar trials in Ghana and Burkina Faso. The overall outcome was positive, but the interviewee stressed that it was not a revolutionary change. They highlighted instances where seemingly lifeless soil produced remarkable yields after the application of biochar. However, they urged caution in interpreting such results, emphasising the need for careful comparison.

While acknowledging the benefits of biochar, the interviewee urged consideration of alternatives such as compost. They suggested comparing biochar to compost and manure in terms of carbon sequestration and nutrient binding. The interviewee expressed a preference for prioritising the use of manure as manure, stating reservations about turning manure into biochar.

Despite not being an absolute biochar advocate, the interviewee expressed a positive stance on its application to faecal sludge, citing its potential to alleviate concerns associated with using untreated sludge.

“Some people want to make biochar out of manure. that’s totally crazy. I’m not a total Biochar fan. but I love it for faecal sludge because there are many people still have concerns and if you transform it into biochar the concerns are gone.”

When asked for the potential of biochar soaked with urine, highlighting their potential benefits in field trials with maize, where they showed comparable yields to inorganic fertiliser use, the interviewee pointed to possible technical and logistical challenges in scaling up such practices, particularly in terms of urine collection, storage, and condensation, emphasising the practical considerations that often hinder theoretical ideas.

The interviewee provided a specific example of a noteworthy biochar project in Sri Lanka, where a German couple is harvesting water hyacinths from lakes and transforming them into biochar. This initiative aims to address the overgrowth of water hyacinths, which can negatively impact lakes. The couple collaborates with a German NGO that organises carbon finance for the project, highlighting the financial sustainability aspect of transforming biomass into biochar.

The interviewee noted that they secured carbon finance for such a project which was viewed as a positive potential. They noted the farmers' involvement in water hyacinth removal, explaining that the shift towards biochar is driven by the potential for carbon finance, adding an economic incentive to the business model.

Research

Interviewee-1: Within the project a comprehensive material flow analysis was undertaken to assess the potential of waste streams to meet the agricultural community's requirements. In collaboration with a researcher at AVAC, a material flow analysis model was developed, focusing on a case study in Msunduzi, South Africa. This analysis involved mapping the area, determining the amount of agricultural land needed, making assumptions about the number of people fed per hectare, and estimating the nitrogen and phosphorus capture potential of organic waste streams within the case study area.

The project employed both current and scenario models to consider potential restructuring of the waste management system. By redirecting phosphorus flows that would otherwise end up in landfills, it was estimated that between 20% and 40% of the nutrient requirements for an agricultural system within a specific boundary could be met. This estimate is subject to contextual variations but serves as a rough guideline.

In general, in most cases approximately a quarter of nutrient needs could potentially be fulfilled through recycled nutrients. Depending on the specific nutrient and the methods used, this percentage could vary. For example, it can be assumed higher nitrogen losses occur during composting but smaller phosphate losses. Nonetheless, the range of 20% to 40% remains a feasible estimate. It's essential to note that this analysis specifically addresses plant nutrients and does not account for carbon, which is a fundamental component often lacking in chemical fertilisers.

Interviewee-2: One aspect that lacks sufficient understanding is the long-term impact of using organic fertilisers, particularly in the tropics and subtropics. It is not enough for governments to promote the market and encourage farmers to adopt these products; they must also allocate resources to research. This research should focus on assessing the potential effects of resource recovery on soil and the broader ecosystem, as these impacts are currently unknown. It is challenging to predict the consequences on soil and groundwater resulting from five or ten years of utilising faecal sludge-based fertiliser. This uncertainty should be acknowledged.

The promotion of the circular economy is valuable, but it is equally important to stress the necessity of concurrent research efforts to monitor and comprehend the long-term environmental consequences. Therefore, while advocating for the circular economy, it is crucial to emphasise the importance of implementing measures for ongoing assessment and understanding of its impacts.

Interviewee-3: In Kenya, there is an existing stock of products, and the interviewee mentioned ongoing collaboration with the government for specific field trials. They are striving to establish a stronger presence in the country and are planning to construct a factory in Kenya. The interviewee primarily focuses on their fertilisers derived from animal waste, including poultry feathers, livestock hoofs, horns, and sheep wool.

When introducing their products to a new country, it is essential for them to conduct local testing to meet specific requirements. The crops grown in these countries, such as maize, vegetables, coffee, tea, and cotton, are generally similar. Research activities are often coordinated through organisations chosen by the Ministry of Agriculture. While some countries have their laboratories and institutes, others rely on established institutions, like Sokoine Agricultural University in Tanzania and the Rwanda

Agricultural Board in Rwanda. In Kenya, various institutions, particularly agricultural universities, play a significant role in these endeavours.

Typically, testing focuses on basic parameters, primarily assessing crop yields. However, a notable challenge with local institutes is their lack of advanced laboratory equipment. They can perform basic tests, like pH analysis, but are unable to conduct more detailed analyses of organic matter or specific nutrients. This gap has prompted some private companies, such as OCP, to establish their mobile laboratories. For instance, in Kenya, these companies offer soil testing services directly to farmers. The interviewee mentioned that the adoption of new technology, such as soil sensors, drones, and GPS, could significantly aid in soil mapping efforts across Africa.

Interviewee-4: The interviewee acknowledged that there has been a lack of research regarding the availability, uptake, and impact of OFBF. The interviewee emphasised that adhering to standards necessitates the ability to verify any claims made. Subsequently, the interviewee emphasised that addressing this verification aspect is the next point of focus.

Interviewee-5: The interviewee mentioned their current work on quantifying emissions related to Black Soldier Flies (BSF) and its potential as a leverage point for policies aiming to reduce emissions and achieve net-zero goals. They highlighted the significance of addressing emissions from the disposal side, particularly the methane emissions associated with waste. The primary focus is to determine the emissions reduction achieved through BSF and how this reduction can be quantified. While there are limited studies on this topic, including one “rough” paper that suggested BSF is four times more efficient than composting, more specific life cycle assessments are needed to provide a more comprehensive understanding.

The interviewee also discussed the importance of waste segregation and how to motivate people to separate their organic waste. Research efforts are underway, utilising social psychology models to identify factors that drive or hinder waste segregation behaviours. Understanding these aspects, whether related to the availability of bins, time constraints, or social pressure from neighbours, is crucial for designing effective campaigns and interventions that target the specific barriers to behaviour change.

“Seeing what makes people actually do certain behaviours or separate their waste? What is the barrier? Is it really not having a bin? Or is it more, they don’t have the time or they feel that they would be looked at strangely by their neighbours. That’s more like the social pressure aspects. people think they are weird if they do it, and things like that. trying to understand what those aspects are, because once you know that, once you understand that, then you can design your campaign or your awareness raising or your intervention to target exactly those factors.”

Regarding the sustainability of waste segregation over time, multiple studies are ongoing to determine what motivates people and how to ensure that waste separation remains a consistent practice, not limited to project durations. The aim is to provide support to municipalities and stakeholders in achieving sustained waste separation efforts. This approach is not limited to organic waste but also extends to addressing the plastic recycling problem. The interviewee stressed the importance of capturing waste close to the source of generation, requiring the active participation of waste generators, and research is ongoing to determine how to make this participation effective.

The interviewee acknowledged that they do not conduct extensive research on the value of the products generated from waste management. However, they recognised the potential value in raising awareness among farmers about the benefits of compost, digestate, or BSF larvae. They highlighted the importance of intersectoral collaboration between waste management experts and agricultural and animal husbandry researchers to explore these aspects further and promote the value of waste-derived products in various sectors.

Interviewee-6: The interviewee had been working on closing the rural-urban nutrient cycle in Sub-Saharan Africa for the past 20 years. They emphasised that the focus was not limited to a specific country, as they consistently worked across countries. The majority of their experience and data had been generated in Ghana, where they were based.

However, they highlighted a study conducted in Sri Lanka in response to the president's declaration two years ago to transition the country to complete organic farming by banning the import of inorganic fertiliser.

Reflecting on the situation, the interviewee acknowledged the challenges in attempting to close the nutrient cycle without inorganic fertiliser. They considered various sources of organic matter, such as water hyacinths, faecal sludge, manure, and domestic waste. The interviewee explored the possibility of using these sources to meet the nutrient demands of specific commodities, like paddy rice.

Examining different scenarios, including utilising existing infrastructure and investing in additional resources, the interviewee found a substantial gap. They revealed that the existing resources of the country would not suffice to meet the nutrient requirements for paddy rice, necessitating the import of large quantities of organic fertilisers. Importing organic fertilisers, however, would be economically impractical and cumbersome for farmers due to the low nutrient value.

In assessing the possibility of transitioning to organic farming and eliminating inorganic support, the interviewee asserted that a balanced approach was essential. They emphasised the advantages of both organic and inorganic methods, stating that there was no practical way to completely eliminate inorganic support at the current level of production. The interviewee underscored the need for a gradual transition, highlighting the catastrophic consequences of the sudden import ban on inorganic fertiliser, leading to a significant drop in yields and a food crisis.

Economy and markets

Interviewee-1: In Ethiopia, the introduction of mechanisation played a crucial role in improving composting processes. Initially done manually, the project imported a compost turner to mechanise the process, especially for aeration during thermophilic composting. Hand-turning compost was cost-prohibitive due to labour expenses. Mechanisation not only enhanced efficiency but also improved the quality of compost. Quality remains a significant concern, requiring a clean substrate and skilled personnel, but it is attainable with the right approach.

However, acquiring the compost turner posed a challenge as it had to be imported from China. The cost of such equipment is approximately USD 25 000, making it feasible for municipal-scale compost production (Note by the interviewee: Such a compost turner could serve a city of about 250 000 inhabitants). The project collaborated with the municipality to restructure a quarter of the city's waste management, with plans to extend this approach city-wide.

Economists were an integral part of the project, assessing the economic viability of innovations. Compost production is characterised by thin profit margins, with certain innovations unable to generate profits. Farmers often prioritise NPK (nitrogen, phosphorus, potassium) when assessing nutrient needs. Compost, with its lower nitrogen content (around 1%), is less economically competitive compared to urea, which has 46% nitrogen. Explaining the benefits of compost and organic matter to farmers remains a challenge.

Public sector support is vital for marketing compost products, involving proximity to purchasing farmers. This may require restructuring rural-urban areas to establish more efficient systems. For this reason, the project mentions the so called Rural-Urban-Nexus as one is looking at city region food systems. The project has focused on identifying sustainable innovations that will persist after project funding ends.

Animal feed innovations using black soldier flies and cassava peels have been highly profitable, and their continued success is anticipated beyond the project's duration. In contrast, soil input innovations have narrower profit margins and are riskier. Public sector commitment to subsidies and support is essential for the viability of these innovations.

The notion that a circular economy can fully replace the role of the state in waste management and environmental responsibility is unrealistic. While a circular economy offers economic development opportunities, it still relies on government support and involvement. Circular economy initiatives alone cannot replace the need for government support in addressing environmental challenges.

Interviewee-2: In certain contexts, cultural factors can influence the acceptance of faecal sludge in agriculture. Farmers may be hesitant to use it in its raw form due to issues like odour, flies, and concerns about potential health hazards. However, when faecal sludge is treated and presented as a refined product, there is limited evidence to suggest that farmers are unwilling to use it.

Farmers are generally aware of the value of faecal sludge as a means to improve soil health, particularly when combined with chemical fertilisers, especially for those who own land for the long term. The challenge lies in the economic evaluation for farmers, who must weigh the benefits of investing in organic nutrients versus synthetic fertilisers. The decision depends on factors such as land ownership, where leased land may not incentivise soil improvement through organic fertiliser.

To address this challenge, it is crucial to establish incentives for organic fertilisers, ensuring that their prices are competitive with or lower than synthetic fertilisers. Governments can play a role in this by providing market support and subsidies, similar to those offered for chemical fertilisers. One example is Sri Lanka, where farmers qualified for subsidies on chemical fertilisers only if they also purchased an equivalent amount of organic fertiliser.

Incentives should extend to producers of these products as well. For example, manufacturers investing in composting technology may be influenced by import restrictions, affecting their interest in such investments. These market structures can reshape both the demand and supply sides of the equation, from waste sourcing to resource distribution.

Transport can be a challenge, especially when delivering organic fertilisers to rural areas. Government channels already used for distributing chemical fertilisers could also accommodate organic fertilisers, ensuring a wider reach. Governments play a significant role in influencing change and supporting the circular economy.

Quality is another critical factor, primarily concerning pathogen reduction and the overall quality of the product. Ensuring a high-quality product is essential for market acceptance. Governments should understand the importance of subsidies and financial support in the short term to encourage investment in nutrient recovery and circular economy initiatives.

To drive the adoption of circular economy practices, governments should not solely rely on the private sector but take a more active role. Promising technologies include composting faecal sludge, which addresses two major waste streams and produces a high-quality product with elevated nutrient levels compared to regular compost from municipal solid waste. Additionally, Black Soldier Fly technology shows great potential, although further research is necessary. Biochar is a "novel" technology requiring more extensive research - especially on economic viable models and according to respective local contexts - before making definitive statements about its potential.

Interviewee-3: Rwanda appeared to be a promising country for the interviewee to initiate production due to its reputation as the "Switzerland of Africa" and its strong support programmes for farmers. However, they encountered challenges related to the insufficient availability of raw materials necessary for establishing a larger production plant in the country. As a result, the interviewee adjusted their plans.

The initial focus was on obtaining certification for their products, imported from Slovakia to Rwanda. This certification process took approximately two years to validate that their products met the local conditions in Rwanda. During this period, a marketing campaign was launched, and products were distributed to local farmers. The interviewee emphasised the importance of collecting feedback to determine the demand for their fertiliser. Based on the feedback, they would assess the need for a production plant in Rwanda, considering the country's relatively small size and purchasing power.

The interviewee also discussed the strategic priorities in other countries, highlighting Kenya's advantageous position due to its access to the sea and established railroads. The interviewee observed that Kenya had a more receptive attitude toward private-public partnerships, leading to a more efficient introduction of their products. In Kenya, they have conducted trials in collaboration with various Kenyan agricultural institutes and organisations under the Ministry of Agriculture.

The interviewee noted that doing business in Tanzania presented certain cultural challenges, with a perception of lower workforce motivation compared to other East African countries. However, it was mentioned that the priority for constructing a factory would likely be Kenya.

The interviewee shared observations regarding the presence of China, Russia, and India in Africa, with these nations enjoying advantages due to their physical presence and numerous incentives for engagement in various sectors, including agriculture and infrastructure development: *"There are a lot of Indians conducting the business systematically because for example, in Kenya, business with distribution of the agro-inputs is controlled by an Indian company. And because of their main power and because of their systematic approach, they were able to create a monopole because they have shops everywhere in every small village. And by this, they can control what product will get to the market or not get to the market. And if they will have some overproduction of fertilisers or pesticides and so on in India, which they are not able to sell, what they are doing is that they are proposing it to the Ministry of Agriculture as a gift because it's not costing them much. It cost them maybe just for the transport, but it's giving them a huge PR and it's giving them also opportunity to get in the minds of the farmers. And this is the same with the Russian fertilisers."*

The interviewee indicated that their target audience includes both cash crop and traditional crop farmers, with an emphasis on the latter. They expressed that their products can offer a real alternative to traditional chemical fertilisers, with potential cost savings of 20% to 30% while maintaining comparable efficiency. Over 15 years of research led to achieving yields on par with chemical fertilisers while being cost-effective.

The interviewee described their product pricing in Africa, acknowledging that costs are influenced by the complex supply chain and import-related expenses, which could add extra costs, making the imported product around EUR 25 per litre which translates into costs of about EUR 800 per hectare (32 litres per hectare). They also highlighted the positive reception of investments in African countries and their offers of tax incentives and exemptions.

Interviewee-4: The interviewee pointed out that the market exhibits a dynamic nature, emphasising the necessity for a verification mechanism for the biofertilisers and organic fertilisers introduced to the market.

Interviewee-5: The interviewee noted the challenge of making organic waste management financially sustainable, as stakeholders often expect these processes to be profitable. They observed that it's challenging for these technologies to be cost-recovering, and some form of financial support or subsidy is often necessary, which differs from the approach taken for landfilling.

"It's something the taxpayer pays through the municipalities, through the municipal budget of the waste management. But then suddenly for the organic waste, everybody kind of switches to, this has to make money and it shouldn't cost anything or all the costs should be recovered. And I think that's one of the big challenges because my experience is that all these technologies, it's very difficult to be cost recovering."

In Switzerland, the interviewee mentioned that compost production is supported by municipalities, with compost being distributed for free due to a lack of a market and limited willingness to pay for it.

This approach helps recover organics effectively and prevent them from ending up in undesirable places.

The interviewee expressed their belief that BSF technology currently has the most revenue potential, primarily for processing food waste. This technology has a high-value protein component (animal feed) and produces valuable fertiliser residues. In contrast, composting faces challenges because the compost itself has lower perceived value compared to inorganic fertilisers, which contain more nutrients concentrated in a smaller volume or mass. This makes it less appealing to users who prefer easily accessible NPK fertilisers.

The interviewee discussed the cost factor associated with compost production, highlighting that when aiming to cover all costs, the compost price tends to be relatively high. They noted that compost offers lower nutrient values compared to inorganic fertilisers. However, a different approach can be taken, treating it as waste management, where 60% of the costs are covered by public money for waste management (e.g., by the municipality), making the compost more attractive to farmers. This shift in pricing dynamics can increase the utility of compost.

"Then the costs, it seems like, okay, it's not competitive enough, but that's only because you try to recover all the costs of the process of the composting, right?

If you take another approach and say, it's waste management, let's say 60% of those costs are covered and only 40% of the costs of making compost need to be recovered, then suddenly the whole price system changes, and then it becomes much more attractive to use this material for the farmers."

The interviewee emphasised the challenge of sourcing high-quality organic waste for all technologies. Accessing clean, organic waste is crucial, as sorting mixed waste afterward is less economically favourable and results in lower quality. Commercial waste with a clean waste stream is often captured for use as animal feed. However, household organic waste, although significant in volume, is dispersed and mixed with other materials, making it difficult to capture. Therefore, the interviewee suggested focusing on easily accessible waste, such as market and commercial waste, as a starting point.

Marketing organic fertiliser from organic and human waste

The interviewee emphasised that, the challenge remained in enhancing the market appeal of co-composted faecal sludge. To address this issue, the project involved enriching the co-compost by adding inorganic nitrogen and phosphorus, making it more attractive to farmers. Nevertheless, the fundamental problem of product acceptance persisted.

Farmers often prioritise rapid nutrient accessibility for their crops, favouring immediate benefits over long-term soil nutrient improvement. Therefore, the market's perception of value and the willingness of customers to pay for the product were ongoing challenges, whether the co-compost contained faecal sludge or was made from regular compost or organic waste. The interviewee underscored that these challenges in value perception and market acceptance remained largely unchanged, irrespective of the specific composting process or ingredients used.

Farmers, particularly those in urban areas, were discussed in the interview. The compost from urban waste was deemed to have the highest market in such areas. This is due to its proximity to the city, making transport more convenient. However, these farmers tend to prioritise immediate crop yield over long-term soil benefits. The uncertainty of land tenure, especially in urban plots, where land may not be owned but used informally, means that investing in long-term soil quality is not their primary concern. Consequently, inorganic fertilisers are favoured over organic ones like compost in these scenarios.

In India, the practice of separating wet waste and dry waste using two bins is common and socially accepted. This separation not only enhances access to the organic fraction but also creates opportunities for the recycling of plastics and other recyclables. Keeping these waste streams separate from the start ensures that plastics and paper, for instance, remain of higher quality for recycling. Such separation can be an effective approach, and there are many examples where it works successfully.

The interviewee emphasised the need to understand the psychological drivers for waste separation. In Austria, for example, there may be limited motivation to promote waste separation because the existing system is designed around incineration plants with composting as a secondary consideration. To create an effective biowaste management stream, it is essential for the entire waste management system to be designed with biowaste in mind.

Furthermore, the interviewee mentioned that biowaste management can be carried out on a smaller scale by targeting specific waste generators, such as vegetable markets, beer breweries, food processing industries, and fruit juice companies. These entities produce a consistent type of waste in manageable quantities, making planning and product quality more stable. This approach also simplifies marketing and sales since customers can rely on consistent product specifications.

"If you're substrate, if your incoming waste is stable, is similar, then your outcoming is also similar and your outgoing product. That's important because that's a marketing aspect, a sales aspect. If the customer doesn't know what they're getting, because it always changes, then it's much more difficult to sell. if they know, this is what I get, it always has 1% nitrogen, et cetera, et cetera, then they know what they get. And so you can make a specification sheet for your product. And that's of course if your input varies, then also your output varies. And then you, you don't really know what you're selling."

The interviewee shared challenges they encountered in Indonesia, where the variability in waste composition from season to season made it challenging to convince animal feed companies to accept black soldier fly larvae. Additionally, the feed producers' demand for large quantities posed logistical challenges for scaling up quickly and finding a suitable market, illustrating two major hurdles in this context.

Interviewee-6: The interviewee highlighted that most projects, including those from their institution (IWMI), were initiated by the waste and sanitation sectors, which owned the waste. Municipalities and waste companies, rather than agricultural or fertiliser companies, played a significant role in waste-to-agriculture initiatives. Despite running large-scale public-private partnerships in Ghana, the interviewee noted that only waste companies, not agricultural or fertiliser companies, applied to run compost stations.

They elaborated on the challenges faced by compost stations, emphasising that many were driven by a primary goal of waste volume reduction and cost savings rather than generating revenue from compost sales. Municipalities viewed compost stations as a means to reduce waste volume and associated costs, leading to a limited emphasis on sales. The interviewee highlighted the need for expertise from the agricultural sector to close the loop effectively.

"…but most of all we are reducing the waste volume and they're tracking with the waste volumes. They're struggling with finding landfill sites, they're struggling with the transport costs. So getting the waste volume down, that is a total priority and I fully understand it. but then the challenge is we are never closing the loop. Because to close the loop, you need this expertise. You need actually not a public-private partnership where the public sector is providing the waste. And then the private sector is again, a waste management company. In transforming it, you need another partner and a partner who is coming from the agricultural sector and is interested, knows the market, knows what kind of compost actually the market wants, because the normal agricultural market is very sceptical when it comes to municipal solid waste compost. They don't like it. Carbon is very high, nitrogen is very low. There might be plastic and et cetera. but if they have very particular requirements, so a compost, which really should appear to them, needs some valorisation, needs some value, you need some blending. that's what we do when we are, for instance, co-composting."

In regard to co-composting the interviewee stated the use of faecal sludge to possibly increase the nitrogen content in the final compost product. The production and use of biochar were also highlighted as a possible avenue. Furthermore, he mentioned the pelletisation of organic fertiliser in order to make it more attractive to farmers.

The interviewee identified a second major challenge – a lack of business thinking. Many compost stations operated without a business mindset, with staff primarily focused on producing compost. Limited incentives existed for selling compost, resulting in a static salary for employees regardless of sales. The interviewee argued that introducing business thinking into the waste and sanitation sector was crucial.

"We saw so many compost stations, which were set up with good intentions by various research projects, NGOs, initiatives, which had enough money to go two years, three years, and as soon as the support ceased, they collapsed and they died because they didn't get enough revenues and they never thought enough about actually considering this as a business."

Knowledge, education and training

Interviewee-1: Attitudes and perceptions play a pivotal role, particularly when discussing fertilisers derived from excreta. It's essential to ensure that there is receptiveness and willingness among people to use such products and consume food grown with them. This aspect becomes a significant and challenging issue because different communities hold diverse attitudes toward fertilisers derived from human excreta. It can be unpredictable, and surprises may arise in this regard.

From an agricultural perspective, it is crucial to educate and build knowledge about the significance of organic matter. Organic matter is essential for long-term food production, and chemical fertilisers do not provide this vital component. Raising awareness about the value of organic matter in agriculture is of utmost importance.

Interviewee-3: The production of organic fertilisers in Africa is associated with a common perception that manure is the only type of organic fertiliser. Overcoming this mindset presents a significant challenge, requiring extensive workshops and seminars aimed at both farmers and extension services.

The interviewee emphasised that their approach contributes to environmental cleanup by transforming hazardous animal waste into organic liquid fertilisers. They expressed the importance of promoting the circular economy, wherein farmers are encouraged to increase their livestock and poultry production. By doing so, farmers can recognise the value in not only selling meat and eggs but also in selling waste materials.

However, the primary hurdle they face is addressing the prevailing mindset among farmers, which continues to be a significant point of contention.

Interviewee-4: Regarding the barrier, the interviewee highlighted the absence of a clear distinction among products based on crops and stressed the pivotal role of education. They emphasised the importance of raising awareness to foster understanding of the standards and the formulation of a certification scheme.

Policy, regulations and certification

Interviewee-1: Standards for these processes can significantly vary depending on the location. In this case, the project opted to adhere to Rwandese regulations due to their stringent regulatory requirements. These regulations provided a robust framework for ensuring the quality and safety of the products.

Moreover, there are externalities associated with fertiliser production that extend beyond their economic value. For instance, inadequate solid waste management and sanitation systems result in substantial public health burdens, which impose significant costs on African countries. Numerous public health studies have highlighted the expenses linked to inadequate sanitation and solid waste management. Therefore, policies supporting the production of organic soil inputs yield a much larger return on investment, as they contribute to improved public health outcomes in addition to agricultural benefits.

Quantifying the exact value of these public health benefits can be challenging, but the overall return for communities is significantly higher when policies take this holistic approach, considering both agricultural and public health benefits. This underscores the importance of adopting policies that encompass a broader perspective and acknowledge the broader societal benefits beyond agriculture.

Interviewee-2: The reasons for the limited scaling of nutrient recovery are multifaceted. Our research has delved into these issues, and it's encouraging to see a policy-oriented approach because we need policy initiatives to instigate real change. While market challenges are frequently mentioned, our research suggests that policy measures play a pivotal role in reshaping the landscape.

We've observed some progress in countries like India and Sri Lanka, where policy adjustments have been made. This presents a significant opportunity for advancing nutrient recovery.

One valuable lesson from our project in Ghana, which focused on nutrient recovery from faecal sludge, was the absence of guidelines in agricultural policies regarding nutrient usage. This aspect is often overlooked, and it's essential to establish clear policies that not only permit the use of faecal sludge in agriculture but also provide guidelines for its safe and effective application. Such policies not only incentivise the private sector to engage but also encourage municipalities involved in waste treatment to participate in nutrient recovery, given their role in waste treatment.

The interconnectedness of circular economy is a notable feature. It spans multiple sectors, encompassing sanitation, agriculture, energy, and more. It is vital to recognise that circular economy cannot function in isolation, and policy making should involve various stakeholders to ensure its success. A multi-stakeholder approach is essential, and it underscores the collaborative nature of circular economy initiatives.

Interviewee-3: When introducing new organic fertiliser products to countries, they must undergo testing by local authorities. A significant challenge often encountered is related to the methodologies employed by these laboratories and local authorities in their field tests. In many instances, these institutes do not adhere to the provided instructions. For example, if they are instructed to use 10 litres at the beginning of the season before planting, they might only use two and a half litres after planting, leading to test failures. When questioned about the deviation from the prescribed procedures, the response might be that they forgot, necessitating a restart of the process. Similar issues have arisen in several countries, including Tanzania, Cameroon, Kenya, and Uganda. These unforeseen factors require a great deal of patience and constitute one of the most significant challenges.

The interviewee noted that corruption is a pervasive issue in Africa, and while it exists globally, it is particularly prevalent on the continent. They emphasised that it is essential to consider the role of corruption in project delays. Even minor bureaucratic obstacles, such as an officer refusing to sign a document, can lead to significant delays that can last for multiple seasons. This aspect of corruption is seen as deeply cultural and challenging to change, with the expectation of payment in various situations.

Overall, the interviewee underlines the importance of understanding and navigating these challenges in the African context.

Interviewee-4: The interviewee expressed that the development of standards itself forms a regulatory framework. However, once these standards are in place, recommendations can be provided. Currently, the regulatory landscape is not well-defined, and there is a need for a regulatory environment that promotes equitable practices. At present, it seems that each entity is devising its own standards without a cohesive framework. Farmers lack a reliable means to verify various claims.

The interviewee pointed out that there are committees dedicated to regulations, but their role is to produce usage guidelines, not to create regulations. They have established model regulations that countries can consider adopting.

Interviewee-5: The interviewee discussed various aspects related to policy and support in the context of waste management and resource recovery. Overall, the interviewee emphasised the need for well-rounded policies that encompass education, waste segregation, financial support, and a focus on high-quality waste management products to create a sustainable and efficient waste management system:

1. **Campaigns for source segregation:** Policy support can play a crucial role in promoting source segregation by designing awareness campaigns and providing necessary infrastructure such as bins. Some projects or initiatives faced challenges related to barriers like the cost of purchasing bins, making it important for policies to address these barriers.
2. **Municipal collection services:** The interviewee emphasised that municipal collection services should be responsible for waste collection. This reduces the burden on treatment entrepreneurs and allows them to focus on the core waste management processes. Moreover, municipalities should consider providing gate fees to treatment facilities for their services, just as they do for landfill management, to support waste management and ensure cost coverage for the treatment facility.
3. **Revenue sources:** To make resource recovery economically viable, multiple revenue sources should be considered. While revenue from selling products is one income stream, it often may not cover all treatment costs. Policies should support additional revenue sources. For instance, fees for waste collection, as paid by households, may cover the cost of collection but not treatment. This underscores the need for diverse income streams. Policies should explore mechanisms to balance costs and income.
4. **Local food production independence:** The interviewee highlighted the value of local food production independence. Developing the capacity to produce animal feed within the country can reduce dependence on imports, which may become unreliable during events like the Covid-19 pandemic or supply chain disruptions. Policies should incentivise and support local food production to enhance food security.
5. **Education and awareness through policy:** Policies can promote education and awareness among farmers and other stakeholders. The interviewee cited an example from Bangladesh where a composting project received certification from the Ministry of Agriculture. This certification enhanced the perception of the compost's quality and enabled the project to sell compost to fertiliser companies. By partnering with these companies, the project extended its reach throughout the country, demonstrating the impact of supportive policies and official certifications in promoting organic fertiliser.
6. **Quality control and scaling:** Scaling up composting projects can introduce quality control challenges. Policies should consider the need for quality control mechanisms when scaling waste management initiatives to ensure consistent product quality.
7. **Policy measures (Sticks and Carrots):** Policies can adopt a combination of incentives (carrots) and regulations (sticks). These measures can include tax exemptions, tax relaxation, local laws promoting waste segregation, and penalties for non-compliance. A comprehensive national strategy for waste management, emphasising reduction, reuse, and recycling (Triple R), can provide the necessary framework for local authorities to implement programmes.
8. **Social mobilisation:** Social mobilisation and awareness-raising campaigns play an essential role in waste management. While entrepreneurs can manage the waste treatment process, policies need to drive waste segregation campaigns, promote awareness, and motivate public participation. These actions are typically beyond the scope of waste management entrepreneurs.

9. **Global initiatives and movements:** National policies can align with global initiatives and movements, such as the "Sanitation for All" and "Swachh Bharat Abhiyan" (Clean India Mission) in India. These movements have created momentum around cleaning the environment, improving sanitation, and waste management. Policies can ensure that the momentum translates into effective waste treatment solutions and resource recovery.
10. **Focus on energy from biogas:** In some countries like India, the primary focus may be on biogas as an energy source, with incentives and grants supporting its development. However, the challenge is that the digestate (the byproduct of biogas production) is often overlooked, despite its high nutrient content. Policies should consider ways to utilise this valuable resource effectively.
11. **Development of methodologies:** Policies can support the development of methodologies and standards. For example, the UNFCC (United Nations Framework Convention on Climate Change) methodologies for quantifying emission reductions are critical for projects like composting. Developing such methodologies can provide a foundation for measuring the impact of waste management projects and facilitating their inclusion in climate mitigation efforts.

Interviewee-6: The interviewee emphasised the importance of understanding the enabling environment, including financial and regulatory aspects, to support the circular economy. Training efforts aimed to enhance compost stations' understanding of the agricultural market and market penetration strategies. However, the interviewee underscored the need for a broader understanding of the financial and regulatory environment to ensure sustainable circular economies in the global south.

"So another branch of what is missing is to understand the enabling environment, to understand the financial and the regulatory environment for supporting the circular economy in these countries. Like in the case of India, there was this fantastic example, which in the meantime was changed again for certain reasons where everyone who wanted to sell industrial fertiliser, had a ratio of organic fertiliser, I think it was two to one. So, if you sell, let's say two tons of industrial fertiliser, you have to add one ton of organic fertiliser. So suddenly the industrial fertiliser companies, if they wanted to sell something, they're running around from compost station to compost station, trying to get organic fertiliser."

The interviewee noted that the European context, providing an example from Germany, where they had experience with diverting toilets, such as the ones in the GIZ building (German Development Cooperation Headquarters). However, despite the existence of advanced toilets, the regulations in Germany and other places prohibited the use of urine on agricultural fields. The interviewee highlighted the challenge of closing the nutrient loop and harvesting these valuable nutrients when regulations do not align.

In many countries, particularly in Sub-Saharan Africa (SSA), the use of treated wastewater is in a regulatory grey area. This ambiguity causes donors to hesitate, fearing that they might invest in initiatives that regulations do not support. The interviewee emphasised the importance of working in parallel with regulatory development to instil confidence in donors. They cited an example of an investment in Ghana, where they contributed to the development of an irrigation policy supporting wastewater reuse, even if not fully treated, based on WHO 2006 guidelines. This policy provided donors with a justification to invest in wastewater reuse.

In contrast, the interviewee shared a case from Burkina Faso where the lack of local legislation led a French donor to base their wastewater reuse project on French regulations. This decision significantly limited the project's scope, preventing farmers from using treated wastewater for vegetables due to French regulations. Despite having a treatment plant, farmers were forced to continue using highly polluted water for vegetables, as the treated water could only be used on flowers according to French regulations.

The interviewee stressed the critical role of the regulatory environment, noting that it can significantly impact the success and scope of projects related to wastewater reuse. The need for regulations that align with project goals was underscored to avoid situations where investments are hindered by conflicting or restrictive regulatory frameworks.

The interviewee emphasised the importance of the financial environment, regulatory framework, institutional capacities, and public perception as key factors.

Regarding the financial environment, the interviewee highlighted the significance of tax incentives, especially for importing necessary equipment. They stressed that tax exemptions could support smaller startups, making it feasible for them to invest in nutrient recovery projects.

The institutional environment was identified as the most significant component. The interviewee noted the importance of breaking down silos between the waste and agricultural sectors. They emphasised the need for institutional capacities that can facilitate collaboration and integrate nutrients back into the agricultural cycle.

Public perception was acknowledged as a vital factor influencing project success. Despite the potential overvaluation of public perception in the global North, the interviewee stressed its relevance, especially in regions where consciousness and education are increasing. They provided examples from Singapore and Namibia to illustrate the varying degrees of public acceptance of treated wastewater in drinking water.

The interviewee listed these four components - financial, regulatory, institutional capacity, and public perception - as the most important enabling environmental factors for successful initiatives. They also highlighted the challenges posed by the regulatory environment, such as the need for official approval before selling compost and the impact of dominant waste management companies on the market.

Competing landscapes were identified as a critical factor, particularly in regions where a dominant waste management company, like Zoom Lion in Ghana, could hinder the establishment of new initiatives. The interviewee also highlighted the humorous yet practical example of competing feasibility studies for utilising organic waste in Accra, where different donors had conflicting objectives of producing energy and compost from the same waste stream.

The interviewee discussed a policy aspect related to the use of waste-derived products, drawing a parallel with European discussions. The main concern raised was the clash between regulations when considering waste products as soil inputs, especially when exporting them between countries. The interviewee noted that this issue hasn’t been a significant problem in sub-Saharan Africa due to the lack of regulations in this regard, creating a somewhat undefined or grey area.

They emphasised the importance of creating a clear policy environment to support initiatives like the reuse of faecal sludge as co-compost. The lack of such policies might discourage donors from investing in these projects. The interviewee highlighted the need to open doors for potential investors and farmers by demonstrating the value of co-composting faecal sludge as a nitrogen-rich source. This approach could address both sanitation and waste issues while supporting agriculture.

Additionally, the interviewee suggested that policies promoting the use of faecal sludge as co-compost could potentially attract green climate finance, positioning it as a key policy area for addressing multiple challenges simultaneously.

II Future perspectives and recommendations

Research

Interviewee-3: According to the interviewee: If Europe aims to establish a strong foothold in African countries and avoid being overshadowed by Chinese and Russian companies, it should consider investing in research initiatives, field testing, and farmer seminars. The interviewee believes that a more comprehensive and up-to-date research on livestock populations is essential, as some existing data is outdated or inaccurate. In Rwanda, they encountered discrepancies between government documents claiming high cattle production rates and the actual reality of nearly empty slaughterhouses. Therefore, the interviewee emphasises the need for accurate data collection to facilitate proper calculations.

Another vital area for research is soil quality and any changes in soil composition resulting from fertiliser use. During their visit to Rwanda, the interviewee discovered concerning practices at companies producing organic composts. They found that bio waste was mixed with microplastics, including plastic bags and bottles, and then sold as organic fertiliser. This led to the reintroduction of microplastics into the soil and products. Hence, the interviewee suggests that research could address microplastics both in the soil and in imported products, presenting opportunities for new research endeavours.

Interviewee-4: ARSO intends to conduct research to verify manufacturers' claims. Quality research is instrumental in establishing a conformity assessment process. One aspect that has not received comprehensive analysis is the origin of microorganisms. An essential question to answer is whether these microorganisms are naturally present in the local environment. If they are indeed found locally, the next step would be to determine how they can be isolated and cultivated within the region. The implications of importing microorganisms remain uncertain. This matter requires in-depth discussion within the committee.

Economy and market

Interviewee-3: From the interviewee's perspective, as a small to medium-sized company from Eastern Europe, they are actively seeking partnerships with governments to support their initiatives. They are in the process of negotiating a Memorandum of Understanding with the Kenyan Ministry of Agriculture for knowledge exchange, field testing, and seminars. However, the interviewee underscores the challenges faced by small to medium-sized enterprises in achieving these goals. They advocate for support from European institutions to facilitate these endeavours, pointing out the significant opportunities for various industries in Africa, including seeds, animal feed, probiotics, agro-processing equipment and organic fertilisers.

The interviewee expects that within the next five years, there will be more and more interest among farmers toward considering organic farming as a viable alternative to traditional methods. They see a window of opportunity for this shift before inorganic fertilisers regain their previous position, which was impacted by conflicts and the Covid-19 pandemic. They emphasise the importance of knowledge transfer and local presence for market establishment and envision the opening of several factories in Africa in the coming years.

Furthermore, the interviewee hopes to see the development of a robust research system in Africa and envisions offering joint solutions that address employment and migration challenges while strengthening the cooperation between Europe and Africa. They highlight the need for integrated solutions, acknowledging that organic fertilisers can replace some inorganic fertilisers in certain cases: "*I would say integrated solution is needed. But of course, in some cases, organic fertilisers can replace inorganic fertilisers. But looking at the whole sector, organic fertilisers can be derived from biogas plants. It can be compost, it can be manure, it can be many things. So, when we look at the combination of all of it, it can become, very sustainable replacement of maybe 50% of fertilisation needs globally."*

The interviewee does not advocate for the elimination of the chemical fertiliser industry but suggests opportunities for collaboration, such as creating semi-organic products or combining reduced NPK usage with organic matter to promote sustainable agricultural practices. Ultimately, they stress the importance of utilising the available resources on the ground and integrating organic alternatives into the existing agricultural landscape.

Interviewee-4: A potential barrier to the adoption of organic and biofertilisers could be the elevated prices associated with these products. Additionally, limited market demand for organic and biofertilisers in certain countries may impact the development of relevant standards.

Knowledge, education and training

Interviewee-3: Regarding incentives, the interviewee suggests the possibility of European programmes that provide financing for various activities such as workshops and field trials. They believe that such programmes could play a crucial role in creating awareness and supporting their initiatives.

Interviewee-4: A certification scheme is currently in development to facilitate systematic evaluations and audits in support of organic agriculture. Following the establishment of this certification scheme, ARSO intends to promote awareness of OFBF standards among stakeholders and enhance the capacity of individuals who will be involved in training farmers in this domain. These comprehensive efforts are aimed at providing full support to the system.

Policy, regulations and certification

Interviewee-1: The interviewee emphasised that their position is that integrated soil fertility management (ISFM) is the way forward: *"And the limiting factor here is organic matter, which means that we have to find ways to bring organic material back to soils in sub-Saharan African agro-ecosystems."*

Interviewee-3: From the interviewee's perspective, they propose several measures that could support not only their company, but also other European companies interested in organic fertilisers and organic farming. These proposed measures aim to foster closer cooperation and mutually beneficial relationships between Europe and Africa, particularly in the context of organic farming and agriculture:

1. **Educational programmes for farmers**: The EU could provide incentives for educational programmes aimed at farmers, focusing on organic and sustainable farming practices, and transitioning from subsistence to profitable farming.
2. **Alignment of standards and regulations**: The interviewee suggests that the EU could work with local African governments to align standards and regulations, including CE certification, across countries, reducing the need for testing in each respective country.
3. **Incentives for exporting organic products**: European companies could receive incentives to export organic products or support organic farming initiatives in Africa, which would create a two-way relationship beneficial to both regions.
4. **Bartering system**: The EU could establish a bartering system where European companies provide products such as fertiliser, biopesticides, etc., in return for African agricultural commodities. This could motivate African farmers to use European products and support the European industry.
5. **Regional contracts to prevent double taxation**: The interviewee suggests signing regional contracts to prevent double taxation, which would help protect investments made by European companies in African countries.
6. **Agreements for investment protection**: Policies that encourage African countries to sign agreements protecting the investments of European companies, ensuring legal protection in case of changing laws and adverse actions by host governments.

Interviewee-4: It is noteworthy that there is a growing interest in acquiring biofertilisers and organic fertilisers with well-documented information and substantiated claims. There is also a strong desire for comprehensive research on biofertilisers derived from plant by-products.

ARSO is planning to conduct quality research on BSF frass and collaborate with the International Centre for Insect Physiology and Ecology (ICIPE) to validate the quality claims associated with it. Until a conformity assessment mechanism has been established, there may still be some uncertainty in this regard. These are essential aspects that ARSO is eager to address.

8.2.2 Cameroon

I Status quo

Mineral fertiliser

The crisis in Cameroon has caused a significant slowdown in mineral fertiliser imports. This, in turn, has led to a surge in energy and fertiliser prices. The application of synthetic chemicals in agriculture has become a topic of concern and discussion among consumers in local markets.

50 kg bags of fertiliser that were once affordable at CFA 18 000 (EUR 27) now range from CFA 38 000 (EUR 58) to CFA 42 000 (EUR 64). The repercussions of this price increase are felt in essential food items, such as ground nuts, which have seen a 100% rise in cost. Additionally, potash prices have doubled, impacting production costs and consumers' daily lives. This surge in fertiliser prices has resulted in a cascading effect on food prices, with some products experiencing a staggering 100% increase. For instance, ground nuts, previously priced at CFA 100 (EUR 0.15), now sell for CFA 200 (EUR 0.30). This rise in costs affects various food items, including vegetables, crops, and even basics like bread. While transport costs have contributed to this trend, fertiliser costs are a significant driving factor, accounting for approximately 50% to 75% of the overall price increase. Proximity to Nigeria has created a fertile ground for contraband and questionable mineral fertiliser quality in Cameroon. The cost of imported fertilisers has also driven many players, including traders and retailers, out of the sector.

Manufacturers have been found falsifying formulas. The responsibility of verifying mineral fertiliser quality falls on the National Norm Agency. Cameroon's national agency, known as the Norm agency, is tasked with quality verification. However, ensuring quality remains challenging, and verification lapses are not uncommon. Quality concerns persist in mineral fertilisers. Manufacturers may falsify formulas, but it remains unclear whether this occurs before or after mineral fertilisers enter Cameroon.

Most smallholder farmers have reduced or abandoned inorganic fertiliser use due to high prices. Many smallholder farmers lack access to mineral fertilisers. Additionally, a significant portion of farmers faces literacy challenges, impacting their ability to read and correctly apply fertilisers, including following recommended dosages. Farmers often use less fertiliser than recommended standards, varying by crop type and intensity. Small producers are struggling to adapt due to increased poverty levels. Some farmers have formed collectives to purchase fertilisers more efficiently. Insufficient fertiliser supply sometimes leads to non-compliance with recommended dosages. For instance, a recommended 20 kg application may be reduced to 10 kg due to limited availability. In terms of fertiliser application, urban and peri-urban farmers predominantly use synthetic fertilisers, with only about 20% opting for organic alternatives such as chicken manure. Recommendations for various crops vary: a mixture of 50 kg NPK and 50 kg urea per hectare for tomatoes, cucumbers, carrots, lettuce, and other leafy vegetables. For maize, cocoyams, plantains, potatoes, and similar food crops, the recommended dosage is around 30 kg per hectare. In contrast, cash crops like cocoa and rubber require approximately 80 kg per hectare.

While subsidies exist, the specific amount is uncertain. Many farmers lack knowledge about correct fertiliser usage, either due to illiteracy or lack of training. Some farmers with limited land resources overapply chemical fertilisers to intensify production.

It is crucial to have comprehensive knowledge about the consequences of introducing synthetic elements into the soil. Misunderstanding these interactions often leads farmers to believe that their soil's fertility is the problem, leading them to invest in more synthetic fertilisers. In reality, the soil's structure has deteriorated, and the solution lies in improving organic matter content rather than relying solely on chemical fertilisers. The detrimental effects of chemical fertilisers on agriculture and the ecosystem are becoming increasingly apparent. These fertilisers are gradually undermining the foundations of sustainable farming, raising concerns about food security and the risk of potential famine.

Farm internal organic fertilisers

A small number of farmers produce their own organic fertilisers by recycling household and local organic waste. This practice, adopted by approximately 5% of farmers, significantly enhances crop yields, especially for horticultural and staple crops such as maize and sorghum. However, there is currently no established formal management system for organic fertilisers produced on farms. Consequently, many farmers rely on external sources like chicken manure for their agricultural needs.

Off-farm organic and biofertilisers

Production and technology

Organic-minded and environmentally conscious farmers are generally more open to using organic fertilisers, while the majority (95%) still prefer chemical fertilisers due to their faster nutrient absorption by plants and roughly 20% of them incorporate farm and agricultural waste into their farming practices. The preference for mineral fertilisers is driven by its rapid nutrient assimilation. However, organic fertilisers have demonstrated positive effects on crop yields, especially for horticultural and staple crops like maize and sorghum. The success of OFBF hinges on product authenticity, as counterfeit products remain a concern.

High-quality organic fertilisers, often sourced from animal husbandry or agricultural by-products, offer significant benefits to agriculture. While the presence of free-roaming cows can pose challenges, it also presents opportunities for farmers. These farmers collect the valuable manure left by these cows, which serves as a natural source of organic fertiliser. Additionally, manure from chickens and other livestock is considered a viable alternative for organic fertiliser.

To address the high costs associated with chemical fertilisers, some farmers are exploring the possibility of combining them with organic fertilisers, given the nascent state of organic fertiliser development in Cameroon. The choice of fertiliser depends on the type of crop being cultivated, whether it's horticultural, cereal, export, or perennial. Farmers employ a variety of strategies when it comes to fertilising their crops.

Some farmers are encouraged to take the initiative to create their own fertilisers using unused household waste and can expand their efforts by collecting waste from their surroundings. Despite the potential for abundant compostable waste at the household level, constraints like inadequate dustbins, limited kitchen space, and institutional limitations impede effective waste sorting and composting practices. This results in a surplus of compost with limited interest and utilisation.

The shift towards organic fertiliser usage goes beyond profitability, aiming to safeguard soil health. Compost, in particular, has proven effective for tubers like Irish potatoes but may not yield the same results for maize. As a potential solution, the discussion includes the addition of 25% chicken manure to the compost when used for maize cultivation.

Urban composting in Cameroon faces substantial hurdles, mainly due to the absence of organised treatment processes. This practice carries potential health risks and the risk of contaminants like heavy metals. Nevertheless, farmers working in partnership with NGOs have shared positive feedback regarding organic fertilisers. While some communities have established waste collection systems, the quality of the resulting compost may be compromised, often containing unwanted elements like glass bottle fragments. Waste management remains a pressing issue in many municipalities, marked by insufficient sorting methods and composting facilities.

OFBF are mainly produced at the community level, although quantities remain limited. There are small-scale producers, some of whom have registered companies and developed innovative products, such as biofertilisers that stimulate plant growth by enhancing nutrient uptake:

Fermented Crop Residues: This includes dried and ground crop residues, mucuna, and cow dung, enriched with beneficial microorganisms (MO) and mixed with water.

Plant Growth Hormone: A novel OFBF derived from wood vinegar and fermented plant juice, although still in the testing phase, has shown promise in boosting yields, particularly in rice cultivation.

Tithonia-based Formula: Comprising Tithonia leaves, dried cow dung, ashes, Bokashi (featuring sugarcane molasses, yeast, photosynthesising bacteria, actinomycetes, and mould fungi), EM (Effective Microorganisms), and water. This concoction is stored for 21 days in bags and has demonstrated its ability to enhance vegetable production.

Resourceful Ingredients: Some produce organic fertilisers from a combination of resources, including chicken droppings and various unused domestic sources, such as sorted household waste and agricultural waste from agro-based industries like breweries, sawmills, and palm oil processing.

Plant and Neem Mix: A versatile mixture of diverse plants and neem extract in water serves multiple purposes, acting as a fertiliser, soil amendment, insecticide, and fungicide.

Examples of commercially produced OFBF are:

- Super Limax is an organic fertiliser created by mixing various organic materials, such as corn stalks, rice straw, plant-based materials (like Sambu or Mucuna), and livestock manure. Notably, the livestock manure undergoes a month-long fermentation process followed by drying. Instead of traditional composting, the material is dried and finely ground and added with a biofertiliser imported from India.
- Winox, a product that belongs to the category of foliar liquid biofertiliser (biostimulants). Its formulation consists of fermented plant juice and fermented fruit juice, both fermented over a span of approximately 60 days. Key ingredients include water, Mucuna, and components from the Neem tree. Winox is applied every two weeks and has proven effective for crops like tomatoes and various vegetables. According to lab analysis the product contains per litre: N=0.58%; $P2O5$=7.5%; $K2O$=3.24%; S=2.0%; CaO=3.8%; Mg=0.523%.
- "Garden Fresh" is a product-based plant growth hormones generated from a blend of wood vinegar and fermented plant juice. Currently in the testing phase, this product is not yet available in the market. Its potential benefits and applications are under evaluation.

Example of community-based production (non-commercial):

- A specialised mixture is crafted to boost soil fertility and crop growth. This concoction includes 60 kg of Tithonia leaves, 100 kg of dried cow dung, 40 kg of ashes, 10 kg of Bokashi (comprising sugarcane molasses, yeast, photosynthesising bacteria, actinomycetes, and mould fungi), 1 litre of Effective Microorganisms (EM) mixed with water, and approximately 50 litres of water. The mixture is stored for 21 days in bags to optimise its effectiveness.

OFBF are often utilised in organic farming practices. Nevertheless, the expansion of organic agriculture encounters several significant challenges:

1. **Lack of Government Support:** Securing support from government ministries and institutions has proven to be a complex and arduous process, impeding progress in the organic farming sector.
2. **Consumer Mindset Rebuilding:** Altering consumer habits and perceptions regarding organic products has presented a formidable challenge. Many individuals still associate organic with higher costs, necessitating comprehensive efforts to reshape these attitudes.
3. **Fraud and Adulteration:** Addressing fraudulent practices and product adulteration remains an ongoing struggle. Effectively enforcing penalties against offenders is often challenging.

4. **Distribution Hurdles:** The presence of restrictions within distribution channels further complicates the organic fertiliser market landscape.

Despite these challenges, some interviewee's claim that farmers using OFBF have the potential to achieve yields comparable to or even surpassing those achieved with chemical fertilisers. However, they also note that the task of convincing and educating farmers about the benefits of organic fertilisers demands substantial effort and resources.

Research

Currently, there is a lack of formalised research on OFBF, lack of quantitative research assessing the impact of fertilisers on crop yields, with data being mostly observational rather than scientifically quantified.

While some product analyses have been conducted in France and the United States, comprehensive research on the outcomes is limited; there are efforts to collaborate with the International Institute for Tropical Agriculture (IITA) on the dissemination of knowledge related to OFBF, others mentioned collaboration with 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. In some cases, students contribute to research on various products, and with researchers and doctoral students, but in general such collaborations are limited. Companies engaged in the production of OFBF often conduct their own field trials to assess product effectiveness. Research and literature reviews may help in devising new strategies.

Economy and markets

The current crisis on the mineral fertiliser market has presented market opportunities for start-ups in OFBF production, despite the challenges. However, unlike Europe, a well-established market for OFBF is lacking in Cameroon. Many farmers prioritise immediate financial gains over concerns about soil degradation and long-term sustainability.

Limited equipment and capital pose significant barriers for companies looking to enter the OFBF production sector. External support from international organisations like USAID can aid in OFBF development, especially in terms of equipment and capital. Remote and isolated areas face logistical hurdles in fertiliser delivery, relying on old vehicles or motorcycles. Remote tracking through digital platforms helps bridge geographical gaps.

One significant issue faced by waste management companies is the perceived high cost of composting organic waste. According one interviewee, HYSACAM, for instance, has reported that compost production might not be financeable viable compared to synthetic fertilisers.

Energy costs for compost processing and other composting-related activities can also pose challenges. Therefore, considering energy sources for composting facilities becomes crucial.

The market landscape lacks significant competition, presenting opportunities for producers. Companies employ door-to-door demonstrations, direct consumer engagement, and collaborations with distributors to showcase their product quality.

Efforts to manage organic raw material costs involve collecting materials from farms and nearby areas. Many processing steps, from transport to bottling or packaging, are done by hand, limiting production capacity. Encouraging farmers to produce their own organic fertiliser using local resources reduces costs, promotes self-sufficiency, and protects the environment.

Pricing of organic composts remains volatile. OFBF remains competitively priced compared to chemical fertilisers. Widespread production could further lower costs. Counterfeit products pose a significant challenge in the OFBF market, harming its reputation and authenticity (e.g., weight and nutrient content do not correspond to the pack description).

OFBF customers range from small-scale farmers to large-scale agricultural associations. Producers aim to support communities in environmental and agricultural practices while making farmers more independent from imported chemical fertilisers and reducing costs. Creating job opportunities at the community level through extension workers helps consumers and boosts local economies.

OFBF certification is often seen as costly and complex procedure that companies may struggle to pursue, and hinders them to offer the products for organic farmers (e.g., organic cocoa farmers). Young start-ups face difficulties securing essential documents, like organic certification, due to lack of support and high associated costs.

Knowledge, education and training

Environmental protection may not be the top priority for most farmers, but some do show genuine interest in the environmental and health benefits of organic fertilisers. However, educating farmers about OFBF is a significant undertaking that often requires extensive awareness campaigns, especially in major agricultural hubs. Building trust and convincing farmers to buy unfamiliar local products often involves providing samples to showcase their quality. Digital technology can play a crucial role in reaching farmers and educating them about the quality and advantages of locally-produced goods.

While many NGOs offer training in compost production, there is limited focus on training in the production and/or application of OFBF. 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 agroecological practices.

Small-scale farmers need access to quality guidance for adopting new practices. Currently, there are no dedicated courses or structured training programmes specifically designed for off-farm fertiliser production. There is also a significant lack of awareness among farmers regarding the benefits and appropriate application rates of mineral fertilisers. Familiarity with granular fertilisers often makes farmers hesitant to embrace OFBF which are available in bulk or as liquid formulation. Bridging this knowledge gap should encompass not only OFBF but also environmental aspects.

Training farmers in producing their own organic fertiliser is crucial, even though large-scale production may present challenges. Video documentation can be a useful tool for sharing and promoting successful OFBF projects.

Conducting village-based workshops and demonstrations incurs costs but proves effective in educating and marketing OFBF. Collaboration with village chiefs, larger farms, and agricultural corporations can further promote OFBF. These initiatives bring communities together, strengthening social bonds and fostering collective thinking.

NGOs work along the entire value chain, from production to marketing, offering diverse training programmes and facilitating exchanges between producers and farmers. Initiatives such as household compost bins generate interest among the population. Partnering with organisations like the Youth Professional for Agricultural Development Network in Cameroon can help identify and promote sustainable agricultural solutions.

The Cameroon Forum for Agricultural Advisory Services (CAMFAAS) and its local partner, REA-Cameroun, have introduced an innovative "tontine" system tailored to the needs of farmers. This system involves weekly gatherings of women from the Common Initiative Group in Koupa-Kagnam, Koutaba district. Together, they collectively produce 130 kg of organic fertiliser, which is made from a blend of *Tithonia diversifolia* leaves, ash, animal waste (such as chicken droppings and cow manure), bokashi (well-fermented organic matter), and a microorganism inoculum (EM5). This fertiliser becomes ready for use after 21 days of mixing. What makes this community-level approach different is its efficient task division between younger, physically stronger women, and older women. This ensures the efficient production of fertiliser. Moreover, it allows each member to access the required fertiliser for their farms, demonstrating its scalability and untapped potential. Implementing this model in different regions could foster innovation, as communities contribute unique insights that could enhance the process. Economically, this approach is sustainable as it helps farmers save money and energy, especially considering the rising costs of fertilisers. However, it needs the voluntary involvement and cooperation of community members. The participating farmers are predominantly small-scale, with many cultivating crops such as sweet potatoes, potatoes, vegetables, and maize.

Policy, regulations and certification

Cameroon currently lacks a comprehensive policy framework and regulations that incentivise the adoption of organic fertilisers in agriculture, which has resulted in the continued predominance of chemical fertilisers. While the government is considering strategies to promote organic fertilisers, there is competition for resources between organic and chemical fertiliser initiatives. This competition is influenced by various factors, including the interests of individuals in politics and government who may have ties to the chemical fertiliser industry, potentially impacting the formulation of organic fertiliser policies.

One of the challenges faced is that public authorities often lack a deep understanding of the practical aspects of organic fertiliser production. This knowledge gap can hinder the development and implementation of effective policies to support organic fertilisers in the agricultural sector.

A subsidy programme has been launched, providing up to 30% subsidies to all players in the mineral fertiliser sector, including importers, traders, and retailers, aiming to alleviate the impact of the crisis. These subsidies are primarily targeted at farmer groups. Questions have been raised about the effectiveness of government subsidy programmes, with some suggesting that the methodology for granting subsidies may not be optimal at the grassroots level. Implementing cash accounts with state support for price reduction is challenging due to complexities in the legal framework and the organisation's uncertain recognition by the state.

Cameroon faces difficulties related to waste sorting due to a complex and ambiguous legal framework with poor enforcement. The new Law on Decentralisation empowers local councils to adopt waste management strategies. Some areas have implemented solutions that suit their specific circumstances. In some cities, waste management is in public-private partnerships where management entities are paid based on waste load. This system lacks incentives for diverting waste to other productive uses like organic fertiliser production.

The current state of the fertiliser market in Cameroon faces several challenges due to the absence of comprehensive regulation. Fertiliser standards are inconsistently enforced, contributing to the presence of counterfeit products in the market. Cameroon lacks specific laws that promote the use of organic fertilisers, and the certification process is hindered by financial requirements and evolving legislation.

According to one interviewee who produces a liquid organic fertiliser, the certification processes has grown increasingly complex, involving time-consuming and expensive steps: The introduction of the 2023 Finance Act has added further intricacies to the approval of organic fertilisers, placing additional constraints on production. Meeting ISO quality standards and navigating ANOR (National Standards Authority) procedures present significant challenges, acting as obstacles to the expansion of organic fertiliser production. Compliance with ISO regulations related to quality processes is impeded by intricate and costly procedures, discouraging the production of OFBF.

Government policies may not effectively encourage soil protection practices, primarily due to a lack of robust enforcement mechanisms. Despite efforts to combat counterfeiting, effective enforcement remains a challenge, leaving farmers susceptible to fraudulent products. Some organisations, such as GIZ, operate programmes aimed at promoting organic agriculture and assisting farmers in gradually reducing their reliance on chemical fertilisers.

Transitioning entirely from chemical to organic fertilisers overnight is challenging. A gradual approach, such as implementing a law or regulatory framework mandating a specific percentage of organic fertiliser use, could facilitate the transition. A significant portion of farmers in Cameroon do not own the land they cultivate, which poses a hindrance to the adoption of organic fertilisers. Smallholders face issues of insecure land tenure, discouraging long-term investments in farming. The focus is often on quick returns, leading to unsustainable agricultural practices. Organic compost typically shows its benefits gradually over time, making it less appealing. Implementing a law that requires a certain percentage (e.g., 10%) of fertiliser use in agriculture to be organic could promote the adoption of organic fertilisers. Over time, this percentage could be increased.

While there are policies in place to promote organic agriculture, challenges primarily lie in their practical application obtaining organic certification is hindered by difficulties in verifying the organic status of inputs like poultry droppings used in the product. The expenses associated with certification audits, including travel and accommodation for auditors, make the certification process prohibitively expensive for some producers or producer organisations.

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.

Effective waste sorting at the source can significantly reduce processing costs for composting. The new Law on Decentralisation empowers local councils in Cameroon to adopt their waste management strategies, opening up opportunities for municipalities to explore waste conversion methods like composting. Some urban areas, such as Yaoundé, have already started adopting alternative waste management strategies, including composting. This shift in national policy can promote composting activities and enhance overall waste management practices.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology

Organic fertilisers are highly relevant for peri-urban poor farmers due to their proximity to production sites, which reduces transport costs. These farmers are also aware of the issues related to poor waste disposal in their areas and the need for sustainable alternatives. The use of organic fertilisers can potentially lead to increased local food production.

Transitioning to organic fertilisers may take time due to challenges such as bulkiness and transport. Despite these challenges, organic production is growing, particularly in crops like pineapple and cocoa. The rise of interest in organic production and potential export opportunities could gradually increase trust and demand for organic fertilisers. It is likely that organic fertilisers may partially substitute mineral fertilisers in the future as trust and demand grow.

Research

Further development of research in the field of organic fertilisers is essential. To determine the optimal composition of organic fertilisers, particularly in the case of liquid fertilisers, more knowledge and research are needed. Collaborative efforts between universities and municipalities can play a pivotal role in advancing research and initiatives related to organic fertilisers. Consumer concerns about the safety of crops grown with organic fertilisers should be addressed, particularly regarding potential pathogen transmission. Municipalities need funding to enable research about OFBFG quality.

It is crucial to conduct research into potential pathogens present in organic fertilisers. Concerns about disease transmission through waste use in crop cultivation should be tackled. Psychological and cultural beliefs surrounding the use of waste products, like manure, need to be addressed.

The establishment of soil testing facilities is of paramount importance. These facilities serve as invaluable resources for gathering crucial insights and data that can significantly enhance our understanding and safe utilisation of organic fertilisers. To further promote sustainable agricultural practices, it is imperative to also enhance the monitoring and evaluation of soil properties. This enables us to fine-tune compost composition and application, ensuring that they align with the specific soil requirements and crop demands. The promotion of composting should include provisions for soil testing facilities to prevent over-application and ensure nutrient balance.

Economy and market

Increasing importation taxes on inorganic fertilisers has the potential to stimulate the production and adoption of OFBF. This policy change can incentivise farmers to transition towards more sustainable fertiliser options.

Furthermore, redirecting organic waste towards compost production can have dual benefits. It not only helps reduce the cost of urban waste management but can also serve as a potential source of subsidies for fertiliser plants, making OFBF more economically viable. However, addressing existing logistical challenges is crucial, and additional support and resources can facilitate wider market penetration of organic fertilisers.

Moreover, organic fertiliser production can qualify for carbon credits, encouraging the use of low-energy and renewable energy sources in the production process. This not only promotes sustainability but also contributes to environmental conservation efforts.

Actively seeking partnerships with NGOs that can provide funding to support community-focused initiatives is another avenue for promoting organic fertilisers. These partnerships can address soil and consumer health concerns while fostering sustainable agricultural practices.

Lastly, it's important to recognise that the production and use of organic fertilisers have the potential to generate employment opportunities in a country with high unemployment rates. By promoting organic fertilisers, efforts can be directed towards creating jobs in various communities, with the goal of establishing at least one job opportunity in each community. This not only benefits the agricultural sector but also contributes to overall economic development.

Knowledge, education and training

A multi-pronged approach is imperative to drive the adoption of organic fertilisers effectively. These strategies encompass empowering farmers to engage in local fertiliser production, promoting community-based initiatives, and encouraging business participation.

The promotion of composting at the household level has sparked considerable interest among the population, and it should continue to be a focal point. Establishing demonstration projects in villages, collaborating with village chiefs, and raising awareness among farmers all play pivotal roles in this process.

Advisory services must bolster their capabilities to disseminate information and provide necessary resources. Furthermore, there is a need to tailor educational materials, such as videos, to local dialects, ensuring accessibility and engagement with interested groups.

It's crucial to recognise the diversity of approaches among farmers, with some adopting individualistic methods while others thrive on collaboration. Flexible advisory services that accommodate both these dynamics are vital. Collaborative problem-solving can foster a sense of community and social contribution among members, often driven by a common issue that farmers are eager to address collectively.

To facilitate the shift from chemical to organic fertilisers, it is essential to reshape the perceptions of agricultural professionals. Emphasis should be placed on reducing chemical fertiliser usage and increasing the adoption of organic alternatives. Awareness campaigns targeting both farmers and consumers are necessary to educate them about the detrimental effects of synthetic fertilisers on soil and the environment. Simultaneously, they should be informed about the benefits of organic fertilisers in enhancing soil fertility.

The educational system should evolve to incorporate organic farming principles and practices, preparing the next generation for sustainable agriculture. Additionally, documenting the compositions of locally produced organic fertilisers at the village level is crucial for transparency and informed decision making.

Creating facilitator roles in remote villages is essential for generating employment opportunities and expanding the reach of organic fertiliser consumption beyond urban areas. Collaboration with organisations like GIZ, which closely work with producers, can yield significant benefits.

Policy, regulations and certification

Initiating the shift towards organic fertilisers should commence with decisive government policies and actions aimed at actively promoting and facilitating their adoption. This proactive governmental role will significantly influence farmers' perceptions and practices in the agricultural sector.

Addressing land tenure issues is crucial to encourage farmers to invest in organic fertiliser production. In some cases, land reform policies may be necessary to tackle this challenge effectively.

International policies should complement national efforts in promoting organic fertiliser use. Achieving this requires a coordinated approach to align both national and international policies for a harmonious and impactful outcome.

Policy initiatives play a pivotal role in driving change and should extend support, both financial and logistical, for awareness campaigns and dissemination activities. Policy alterations must prioritise reducing subsidies for chemical fertilisers while reallocating comparable support for organic alternatives.

Furthermore, policy makers should reevaluate the actual requirement for chemical fertilisers and ensure that imports align with these genuine needs, leaving ample room for the utilisation of organic fertilisers. Sensitising high-level national policy makers, including those in the Ministry of Agriculture, is crucial. Their active promotion of organic fertiliser usage and initiation of the transition process will underline the significance of government involvement in these early stages of change.

Promoting research tailored to local circumstances and fostering the adoption of organic fertilisers are crucial policy objectives. Policy makers should actively champion grassroots-level initiatives that utilise local and organic materials in organic fertiliser production. This endeavour should commence with national policies designed to raise awareness about the numerous benefits of compost production and usage.

Effective policies should strive to reduce costs, rendering organic fertiliser production and adoption economically viable. Legislation should encourage the utilisation of local resources and provide support to local producers and consumers. Policies should serve as catalysts for local potential, offering financial and other forms of backing to organic fertiliser initiatives. The active engagement of public authorities in supporting economic endeavours such as organic fertiliser production is paramount to their success.

Subsidy policies need to be adaptable and responsive to fluctuations in the international fertiliser market. Subsidies should extend to organic fertilisers in addition to chemical variants, with a keen focus on emerging market dynamics. Taxation can be leveraged to influence on-ground activities, coupled with procurement policies that prioritise organic production for government initiatives. Tax incentives can effectively steer activities toward organic production, while procurement policies can elevate organic products' status for government and public programmes. The amalgamation of organic fertiliser production with carbon credits holds the potential to create new employment opportunities in regions plagued by high unemployment rates.

Currently, the organic fertiliser production sector lacks comprehensive regulation and robust quality control systems, setting it apart from the more structured chemical fertiliser industry. The absence of systematic state oversight regarding fertiliser quality requires correction, aligning laws and regulations with practical implementation.

Policies should actively promote the use of organic fertilisers in large-scale agricultural practices and government-owned plantations. National-level policies for soil protection measures should be vigorously implemented to encourage organic fertiliser utilisation.

Strategies should be developed to address the issue of fertiliser smuggling from unregulated countries, with the state taking responsibility for resolution.

Regular and systematic quality testing of organic fertilisers is imperative to ensure consistency and reliability. Therefore, policies must integrate quality assurance and monitoring applications to uphold composting standards. While some effective laws and quality tests already exist, systematic quality control measures need adaptation and robust enforcement. However, some producers among the interviewee's mention that the approval and quality control procedures should be simplified to save time and resources.

While policies may have a secondary role compared to awareness, they can gradually promote waste separation at the source and the development of community composting initiatives. These policies should endorse training programmes on compost production to educate communities about waste separation and composting. Municipal waste management systems should adapt to include organic waste recovery and recycling, thus contributing to the availability of organic fertilisers. Stricter regulations regarding landfills and waste dumps are essential to support the availability of organic fertilisers. Municipalities should be mandated by policy to reduce the quantity of waste directed to landfills, focusing on waste separation and recycling. Similar to regulations concerning plastics, producers of compostable products can be compelled to implement take-back policies and promote recycling. Municipal contracts with waste service providers should be modified and updated to align with new waste management practices.

Companies involved in composting should receive support, including waivers and access to public land for their activities.

Encouraging community involvement through the principle of "shared problems, shared solutions" can motivate people to embrace organic fertilisers.

The transition towards organic fertilisers should be gradual. For example, policies can encourage a 50% reduction in chemical fertiliser use while simultaneously promoting a corresponding 50% increase in organic fertiliser use. Advisory services require support, both in terms of capacity building and resources, to effectively disseminate the idea of organic fertiliser use. Policies should provide increased support to advisory services engaged in awareness-building and dissemination projects.

8.2.3 Côte d'Ivoire

I Status quo

Mineral fertilisers

The various crises have resulted in a rise in mineral fertiliser prices, consequently driving up the cost of food items. Currently, the price of nitrogen has experienced a slight decline. Overall, the utilisation of mineral fertilisers remains low. Farmers face limitations in terms of accessibility, untimely deliveries, disruptions in supply chains, and an inability to afford mineral fertilisers.

Before Covid-19, mineral fertilisers cost were below CFA 500 (EUR 0.76) for 1 kg of NPK or for urea, now it costs CFA 1 000 – 2 000 (EUR 1.52-3.05) depending on the region. Compost costs CFA 200 (EUR 0.3) per kg in comparison.

Cotton companies provide mineral fertilisers for free, although farmers are still required to cover some of the costs. Some of the mineral fertilisers they receive is often used for other crops such as rice or maize. While the government recommends using 200 kg of mineral fertilisers per hectare for rice cultivation, most farmers do not adhere to this guideline. Those cultivating rice as part of a larger area may receive some support.

Farmers who have 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.

Farm internal organic fertilisers

Composting, and even the utilisation of compost, remains relatively rare. 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’s important to note that they primarily use raw manure rather than composted manure. Poultry droppings are readily available, with prices ranging from CFA 500 (EUR 0.76) for a 50 kg bag to CFA 1 000 (EUR 1.52) for a 100 kg bag.

Off-farm produced organic fertilisers

Production and technology

The majority of organic waste ends up in landfills, which has adverse environmental consequences. The presence of illegal dumps in towns underscores the deficiencies in waste management services, which can lead to water table contamination. Certain communities rely on this water source for their drinking water supply.

- In Côte d’Ivoire, there are likely three main companies engaged in organic fertiliser production: Elephant Vert (formerly Biofertil), Lonoci, and Green Countries. Some agro-industrial companies may also operate small-scale compost production units. Elephant Vert produces approximately 50 000 tons per year. Meanwhile, Green Countries production is estimated to be less than 2 000 tons per year. Lonoci, although recently established, produces an estimated 2 000 tons. The latter uses a small container for turning organic wastes into compost within four weeks, producing about 150 kg of compost from 400 kg of organic wastes.
- A project, funded by a Swiss oil palm producer, collects oil palm and coconut residues, converting them into compost for use in plantations. Prominent farmers employing organic practices, such as 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 added with inputs like urine for nutrient enrichment.
- Aerobic digestion is another possibility, but its complex technology and the economic challenges associated with repairs make it less favourable. However, companies such as Lonoci test small biogas container units of approximately 2 to 3 m^3.

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.

While blending organic and mineral fertilisers is feasible, it has yet to gain widespread popularity. Some market gardening companies employ a blend of droppings and mineral fertilisers, such as urea, for their operations.

The development of decentralised composting of organic waste could significantly support the growth of organic farming. Many manufacturers are committed to sustainable/organic cocoa, leading to reduced use of mineral fertilisers and increased utilisation of organic alternatives.

Composting municipal solid waste is considered more challenging due to the need to collect unsorted waste from households, sort it, and then compost it. This process is labour-intensive and often yields lower-quality compost. Currently, there is no sorting at the source.

The potential for compost production using agro-business waste, municipal waste, and sawdust from sawmills is generally considered to be very high. However, it's important to note that these fertilisers may not entirely replace mineral fertilisers, with both organic and mineral fertilisers viewed as necessary in agriculture.

Research

Research on organic fertiliser from bio-waste remains relatively limited. There is one ongoing study examining the impact of applying 10 tons per hectare of compost in comparison to mineral fertiliser. Preliminary findings from this study suggest an increase in maize yield when using organic fertiliser, although these results have not been published yet. Funding opportunities for research in this area are available through government institutes and other mechanisms.

Economy and market

Producers of organic fertilisers should bear the costs of acquiring raw materials, and the composting facility should be compensated for processing green waste. Subsequently, producers can sell the final product. Presently, there is a higher demand for compost than the production capacity can meet. Therefore, compost production is regarded as a profitable sector.

An estimate was conducted to compare the costs of fertilisers, specifically mineral fertiliser versus compost. The results indicated that organic fertiliser production is approximately five times more costly. This poses a challenge for smallholder farmers, as the majority cannot afford to purchase compost. One potential solution could involve farmers contributing a portion of the raw material as a form of payment. As of now, only export-oriented sustainable or organic producers can manage the expense of compost.

Knowledge, education and training

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.

Throughout the entire fertiliser production and distribution chain, there is a notable lack of knowledge regarding production techniques and regulations related to fertiliser use. The absence of concrete data from experimental plots that could clearly demonstrate the advantages of organic fertilisers over chemical ones is a significant impediment to further progress. The benefits of using compost, for instance, can persist for two, three, or even four years. However, farmers often only consider the short-term costs, which hampers the adoption of compost among smallholders, among other contributing factors.

Policy, regulations and certification

Currently, in Côte d'Ivoire, there is limited policy focus on OFBF, and discussing environmental matters can be challenging.

II Future perspectives and recommendations

Production and technology

There is a growing demand to enhance soil organic matter levels through organic inputs. 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.

Research

In the realm of fertilisers and their applications, there is an urgent need for scientific research that examines both the positive and negative environmental impacts. Additionally, there is a growing demand for studies focused on implementing organic waste sorting systems at the source in urban areas, enhancing the composting process, and raising the quality of the final compost product. It is also crucial to explore methods for increasing the levels of essential nutrients, particularly in the context of sewage sludge utilisation in agriculture, which represents a significant area of research interest. Moreover, conducting demonstrations and scientific experiments, including collaborations with vegetable growers to determine the optimal compost quantity and its potential combination with mineral fertilisers, is essential. These studies should encompass both agronomical and economical aspects to provide comprehensive insights into the field.

Economy and market

Currently the prices of the compost product are already too high, hindering the establishment of such fertilisers value chains. All compost types should be affordable for both smallholders and industrial farms, currently its only for the latter.

Entrepreneurs looking to invest in this sector could benefit from incentives such as subsidies or municipal support. The initial setup of composting units requires substantial investment, and government or municipal assistance can facilitate the successful launch of such initiatives.

Knowledge, education and training

Most of the work is to educate the people first of the basically things, always in a combination of theory and practical work on the composting. The impulse of any project should come from the people of the country. There is need to find ways to motivate households through formation (education) for waste separation and also to work with the schools because the children are the best multiplicators.

Farmers need training on how to make and apply good quality compost because that’s still a big problem on many farms. The farmers need to be aware of the compost and the benefits. Farmers should be trained about the characteristics of the product, including figures on nutrient and carbon content. This would dispel any doubts about nutrient content and heavy metals, for example. The advisory services need to be aware and provide the right advice to farmers. The people along the value chain need to have that knowledge too.

Policies, regulations and certification

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, it’s imperative that the government provides financial support for the implementation of OFBF, possibly through mechanisms like CO_2 certificates and regulatory frameworks. The composting sector, in particular, holds promise in aiding the government’s efforts, as composting effectively reduces greenhouse gas emissions in the organic waste sector. Standardisation of all types of compost is essential, and pricing should be based on quality. Regulatory measures should also be put in place to govern the application of various OFBF products.

8.2.4 Egypt

I Status quo

Mineral fertiliser

Egypt is largely self-sufficient in the production of mineral fertilisers, with 8 manufacturing plants contributing to the production of 22.5 million tons of fertilisers. The majority of these are produced domestically, including around 15% of nitrogenous fertilisers. While some specific fertilisers or blends are imported, the domestic production meets a significant portion of the country's needs.

Fertiliser prices have experienced notable increases since the onset of the Covid-19 pandemic and the conflict in Ukraine. This price surge has affected both mineral and organic fertilisers. Organic fertilisers, including compost, are not exempt from this trend, as their production also requires energy and incurs transport costs. The affordability of fertilisers is a pressing concern, especially for larger farms that have been impacted by export losses during the pandemic. Fluctuations in exchange rates have further compounded the price issue, with a 50 kg bag currently costing around 1 200 Egyptian pounds (approximately EUR 35).

As a response to these challenges, farmers are seeking alternatives to traditional mineral fertilisation. Some turn to compost or innovative options like spirulina algal fertilisers, which provide a nitrogen source. However, the affordability factor remains a significant consideration in this shift. It's worth noting that lower-priced fertilisers often contain elevated levels of chloride. Additionally, instances of insoluble fertilisers are not uncommon, and there is a notable absence of quality control in the market.

Certain subsidies for mineral fertilisers exist, albeit primarily for staple crops like wheat. Previous practices of applying 120 kilograms of nitrogen per Feddan (equivalent to 4 200 square meters or 286 kg N/ha) based on textbooks or recommendations from national institutions have been questioned and adapted due to the changing circumstances.

There are drawbacks of excessive application of nitrogen, phosphorus, and potassium (NPK). In the particular context of Egypt's oxidised soils, the overuse of nitrogen has alarming consequences. The excessive nitrogen accumulates as nitrate, which the plants struggle to manage effectively. This accumulation, unfortunately, acts as a beacon for pests like aphids and fungi, compelling farmers to apply pesticides shortly after fertilisation. This practice brings about costs in four distinct ways:

1. Financial losses: The excessive application of nitrogen incurs unnecessary financial burdens.
2. Pesticide dependency: Elevated nitrate levels in plants attract pests, necessitating the use of pesticides.
3. Nitrogen loss: The surplus nitrogen is lost through both emissions and leaching.
4. Reduced yield and quality: Imbalanced nutrient levels result in decreased crop yield and compromised quality.

To address these challenges, the government has implemented a new distribution system for major fertilisers to farmers. This system ensures that farmers receive the appropriate types and quantities of fertilisers based on the cultivated area and specific crops. While a shift towards more judicious use of inorganic fertilisers is encouraged, it is acknowledged that small, strategic applications can still be effective and applied as needed.

Farming practices

The primary challenge lies in the declining levels of soil organic carbon. Even farms that integrate organic materials like compost or manure witness diminishing organic carbon content. This trend emphasises the critical importance of addressing the depletion of soil organic carbon.

There are reference laboratories available for soil testing. These analyses provide recommendations for the appropriate product quantities to be added, as well as subsequent testing to assess their impact on the soil. Many soils are affected by salinity, particularly with the presence of calcium carbonate and calcium bicarbonate. OFBF do not directly introduce nutrients into the soil; rather, they enhance the availability of existing nutrients. Micronutrient deficiency is a prevalent issue in soils. Farmers are recognising the importance of applying micronutrients, but some may perceive it as an additional or complementary practice. However, it's crucial to understand that plants require varying amounts of different elements, and maintaining a proper balance is essential.

Off-farm produced organic and biofertilisers

Production and technology

There exists an ample amount of waste that can be repurposed into organic fertilisers or soil enhancements. The prevalent soils are largely of mineral origin, with organic matter content averaging below 1% across most parts of Egypt. To sustain a thriving microbiological ecosystem in the soil, the imperative is to build up organic carbon.

The bio-based products sector and associated companies are experiencing significant growth in Egypt. A UNIDO project actively supports small and medium enterprises engaged in green businesses. Notably, there are approximately 16 to 20 recognised companies involved in the production of compost and other organic fertiliser (OF) products. Well-known entities include SEKEM, Agriculture Research Centre (ARC), Miegos and Beni Suef. The largest producer, Beni Suef, generates approximately 100 000 t/year of compost. Remarkably, demand continues to outstrip production capacities.

The domain of biofertilisers is represented by roughly 40 companies, although this segment functions more within an informal market structure. Notable participants include SEKEM, Chietosan, Royal Green Biotech, National Research Centre (NRC), ARC, Evergro, Organic Biotech, AgroTech, Bio Egypt, and Gaara Trade. For example, Royal Green Biotech sells two liquid products: Bio Nova Key, which serves as a foliar spray, and Nova Plus Bio Fertiliser, a liquid biofertiliser. The liquid formulations are derived from animal manure, sourced from cows, buffalos, and chickens.

Moreover, bacteria-based products have been derived from local fields, amassed over a span of more than 35 years, encompassing regions such as upper Egypt, the western part of Egypt, and Sudan. These products are activated on-site to efficiently stimulate plant defences and enhance crop yields. According to Royal Green Biotech, leveraging this technology can yield approximately 50% lower costs when compared to exclusive reliance on chemical fertilisers. However, the widespread implementation of this technology is hindered by several challenges, including concerns related to the shelf-life and transport of biofertilisers, especially when production occurs in remote areas. The successful adoption of this approach necessitates specialised knowledge and equipment for producing biofertilisers like rhizobia, as well as ensuring proper quality control and storage procedures.

Of particular interest is the MO-product, which centres on bacteria strains. The innovative approach by Royal Green Technologies involves harnessing naturally occurring microbes discovered in local fields. These microbes are activated on-site to more effectively stimulate plant defences and amplify crop yield. Over more than 35 years, numerous strains from diverse regions, including Upper Egypt, the western part of Egypt, and Sudan, have been cultivated.

Millions of tons of agricultural waste remain untapped, awaiting utilisation (UNIDO study results undisclosed). The primary constituents for organic fertiliser production are sourced from agricultural byproducts (such as residues from rice and wheat cultivation, banana production, sugar cane, and biogas digestates), alongside animal manure. Notably, a company specialises in generating biogas from an array of waste materials. While the on-farm production of bioslurry poses challenges, off-farm production proves more economically viable. Bioslurry are derived from animal manure, encompassing cows, buffalos, and chickens. The ensuing impacts on soil health, plant vitality, and the environment exhibit a range of effects.

Cairo employs two distinct waste collection systems, with one established by the municipality and the other being informal in nature. While there are locations that facilitate the sorting and segregation of organic matter from plastic or metal materials, such facilities are limited in number. 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 substances like polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs) PAHs. However, ongoing initiatives are working towards establishing standards that govern production facilities, aiming to address and mitigate such concerns.

The recommended dosage of compost and biofertiliser varies depending on factors like the crop, season, and soil condition. For instance, a productive palm tree may receive 50 kg of compost, while an olive tree could benefit from 15-25 kg based on its age. Cotton fields typically require 10 tons per acre (24 tons per hectare). As for biofertiliser, a recommended dosage of 15-20 litres per acre is suggested, comprising a mixture of free N2-fixer, P-solubiliser, and K-solubiliser. This dosage is especially relevant for short-duration crops like vegetables. For longer-term crops such as fruits, it's advised to apply the recommended dosage every three months.

Research

Research on off-farm production of OFBF exists, but it is primarily focused on finding practical solutions for farmers rather than publication. While some individual researchers show interest in the topic, there is no established national research agenda. The trial concepts often lack transparency and detailed descriptions. Nevertheless, it's evident that these concepts have a positive impact on soil, crop yield, and quality, particularly in conditions characterised by low carbon content and soil salinity.

There are reference laboratories available for soil testing. These analyses provide recommendations for the appropriate product quantities to be applied, as well as subsequent testing to assess their impact on the soil. Many soils are affected by salinity, particularly with the presence of calcium carbonate and calcium bicarbonate.

Economy and markets

Currently, the market for commercial organic fertilisers primarily offers compost, with vermicompost being available to a lesser extent. Despite the rise in mineral fertiliser prices, most interviewees do not report a significant increase in the adoption of organic fertilisers by farmers. However, it is noted that farmers generally recognise the benefits of using compost. The largest compost producer in Egypt, namely Beni Suef, primarily supplies its compost to both large-scale organic and conventional farms.

When small-scale farmers initially adopt OFBF, they often add organic fertiliser alongside their existing practices, which can strain their economic situation due to added costs. 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 chemical fertilisers. Moreover, they contribute to improved soil fertility and crop quality, thereby amplifying profits. This economic benefit extends to the production process of organic fertilisers like compost and compost tea. Furthermore, the production of OFBF presents an opportunity for job creation.

In addition to the local market, certain products are also exported to countries like Saudi Arabia, Bahrain, Morocco, Tunisia, and Sudan. In recent years, there has been an introduction of new biofertilisers into the market. However, the successful adoption of these products depends on farmers having knowledge and understanding of what biofertilisers are and how to use them effectively. This includes understanding whether the product contains bacteria, beneficial fungi, or other components.

The current primary economic challenges include the fluctuating conversion rates between the Egyptian pound and currencies like the euro. This creates difficulties in purchasing equipment, especially since a significant portion of the equipment comes from countries like Germany, South

Korea, and Japan. Additionally, expanding operations or acquiring another company has become much more costly compared to a decade ago.

Knowledge, education and training

OFBF still face numerous challenges, including issues stemming from outdated information. Many farmers remain unaware of suitable products for their crops and their respective growth stages. Disappointment arises when farmers try these products and encounter low quality products due to inadequate quality assurance measures. Quality encompasses not only nutrient composition but also biological aspects. This is further compounded by the production methods employed.

A gap in knowledge exists on both ends: producers struggle to optimise products chemically and biologically, while farmers lack a comprehensive understanding of product functioning. Some farmers mistakenly assume that these products operate similarly to conventional urea or ammonia nitrate fertilisers, leading to unrealistic expectations. Furthermore, inadequate communication and knowledge dissemination between individual researchers and government agencies exacerbates these challenges. Although an official extension service exists, its effectiveness is limited, and there is no structured private extension body. For instance, there is a dearth of companies offering extension services or production on behalf of investors, resulting in a disorganised and haphazard approach.

University courses, specifically at Heliopolis University/SEKEM, offer comprehensive education on the production, technology, and variety of OFBF. These courses are available at both undergraduate and graduate levels, with SEKEM being involved in offering them. The approach involves grouping farmers together and conducting demonstration trials, with 50% dedicated to showcasing innovative plots and the other 50% reflecting farmers' actual practices. This approach allows farmers to witness the benefits firsthand.

Policy, regulations and certification

Efforts are also underway in collaboration with the Egyptian Organisation for Standardisation and Quality to establish standards in accordance with ISO guidelines. There are currently seven standards being developed, focusing on various aspects such as organic fertiliser, biofertiliser, biochar, vermicompost, and vinasse products. The registration of products has presented its own set of challenges.

A significant number of products currently available in the market lack official recognition from the government. Presently, anyone can produce a product on their farm, gain approval from the Ministry of Industry for production, but the product itself may not be officially sanctioned. This situation understandably raises doubts about product legitimacy.

Regulatory authorities are currently concerned about the perceived lack of stability in the products from OFBF. The regulations governing this area are not entirely clear, and this ambiguity extends to local producers as well. Consequently, the sale of compost, for instance, has led to the inadvertent spread of nematodes and fungal diseases to farmers' fields.

Two years ago, the Egyptian parliament enacted a law focused on organic agriculture, which has notably improved the situation. While it has not resolved all issues entirely, it has significantly enhanced various aspects of the landscape.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology

It is crucial to shift a focus towards improving soil health. Tackling this challenge involves not only sharing insights from individual cases but also ensuring their integration into policy making and ministry decisions.

Given the significant proportion of agricultural land facing challenges like low carbon content, salinisation, and desertification, Egypt presents a unique scenario. There exists substantial potential for waste utilisation through OFBF across small, medium, and even industrial enterprises.

Research

Despite yielding positive scientific results, the ministry often perceives OFBF practices as supplementary, similar to an optional dessert following a meal. To bridge this gap, there is a need for enhanced communication and collaboration between individual researchers and policy makers.

The integration of OFBF into the official research agenda/the research bodies of the ministry is key. There is high potential, to substitute mineral fertilisers at least for 80 to 90%.

Economy and market

Various promising methods in OFBF production have emerged, necessitating additional financial backing. Moreover, effective management of organic fertilisers within farms is essential, though the limited land availability poses challenges for allocating space for biomass production.

Subsidies for technologies should extend to OFBF similar to those for mineral fertilisers. Integrating OFBF into official research agendas, both within the ministry and universities, is essential.

Knowledge, education and training

Capacity-building should encompass all levels, including biological aspects and micro-nutrients. Demonstrations are vital for persuading farmers about new practices and products, while technical staff of farmer organisations should be supported. Alongside agricultural residues, the vast potential of household waste must be harnessed, requiring inclusive consumer training for proper waste separation. An awareness campaign spanning the entire value chain, orchestrated by the government, is vital to drive transformative change.

Policy, regulation and certification

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.

8.2.5 Ethiopia

I Status quo

Mineral fertilisers

The utilisation of mineral fertilisers in Ethiopia faces various limitations due to external and internal factors. Smallholder farmers generally apply low rates of mineral fertilisers, and recommendations mainly focus on maize farming. The ongoing crisis has worsened this scenario, leading to less than 50% of fertilisers being accessible in the market. Challenges like delivery delays and quality concerns are prevalent. Inefficient utilisation of mineral fertilisers is observed, including leaching, untimely application, substantial ammonia losses from urea use in high temperatures, partial oversupply, soil acidification, and insufficient humus content.

Farm internal organic fertilisers

Farmers primarily depend on cow dung for cooking fuel, leading to minimal use of organic fertilisers. The prevalence of maize cultivation contributes to soil erosion, and the limited cultivation of grain legumes restricts nitrogen fixation due to acidic soils. While some farmers have initiated the production of liquid biofertilisers using plant material and organic residues as a cost-effective approach, its impact on yield remains limited, and nutrient deficiencies persist. The inadequate nutrient content in agricultural soils, coupled with the scarcity of nutrient-rich forage and limited access to forage legume seeds, further undermines the quality and quantity of organic manures.

Off-farm produced organic and biofertilisers

Production and technology

Environmental damage occurs as waste is dumped in open sites, often leading to human waste from household pits seeping into these areas. Despite the presence of collection systems, they are not widespread, and the absence of organic waste separation presents a challenge.

The emergence of smaller companies producing compost from high-quality market waste is a niche that will likely persist and grow. However, in the broader context of waste management, this contribution remains relatively small. Additionally, there is a 2019 report by SNV regarding the feasibility and farmers' perceptions of biogas digesters, offering insights into the associated challenges. (https://snv.org/assets/explore/download/eth_bus_2019_report.pdf).

At the national level, the Ministry of Agriculture is advocating for small-scale composting, with a particular emphasis on vermicomposting, for smallholder farmers. However, despite these efforts, the adoption of such practices by purchasing and applying compost remains uncommon and confined to specific farms.

In specific regions, a type of liquid organic fertiliser (organic liquid eco green Ethiopia) made from legumes and farmer residues is accessible. Yet, its nutrient content is minimal, preventing its classification as a fertiliser. While this product offers some benefits to crops and soil, it cannot fully substitute industrial nitrogen fertilisers. In certain instances, mineral fertilisers are added to maintain a desired level of quality.

Various companies provide rhizobia products, which differ in their effectiveness. Some have demonstrated success and led to significant crop yield improvements, particularly in crops like peas. However, others fall short in delivering results, often due to the prevalence of acidic soils that impede the bacteria's activity. Biochar production occurs sporadically at the farm level, but production has faced challenges throughout the entire production chain due to technical issues.

An international research project has effectively implemented waste separation using compost technology and transport trucks (e.g., Arba Minch). Furthermore, efforts to motivate local agro-processors to create value-added goods from raw agricultural materials, such as bananas, have yielded positive results. However, the recycling of human waste through the production of struvite from source-separated human urine has not progressed as intended. As a result, it has not been chosen for scaling due to various factors. Nonetheless, both composting and agro-processing have been selected for scaling in Phase II of the project period.

The Nature and Biodiversity Conservation Union (NABU), Germany, is actively engaged in harvesting water hyacinths from Lake Tana and converting them into biogas (slurry), compost, or biochar. They conduct field trials to test these products and provide training to farmers for implementing these processes. This project is ongoing until 2027.

Recently, an avocado oil-producing farm in Jimma has secured a contract with Saudi Arabia to export compost. This business model might seem unconventional in terms of circularity, but it's interesting to note the emergence of such a market, which was previously non-existent.

Individuals from BASF Ethiopia are contemplating entering the compost market through waste collection initiatives in East Africa. They are particularly interested in managing single-variety plastic waste, given that a significant portion (50-80%) of household waste in Ethiopia comprises organic matter. This move would also align with their larger-scale efforts in plastic pyrolysis. Notably, in

Ethiopia, there is a growing number of companies engaged in composting and selling compost at competitive prices, ranging between USD 150 to 300 per ton.

The Urban NAMA COMPOST project in Ethiopia aims to encourage the use of Integrated Solid Waste Management (ISWM) and Urban Green Infrastructure (UGI) strategies in cities and towns. Its goal is to support the Ethiopian government's Growth and Transformation Plan (GTP II) by enhancing coordination between regulations and institutions related to ISWM and UGI. The project focuses on creating a financially sustainable system for producing and using compost, involving micro and small enterprises.[45]

Research

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). However, there is currently a lack of a comprehensive plan to enhance soil health.

There are a few research hotspots, including Arba Minch University (in collaboration with ETH Zurich), the Lake Tana Water Hyacinth project by NABU Germany, and rhizobia research at Bahir Dar University. Nevertheless, research activities in general are quite limited. Some companies, like the organic liquid fertiliser producer (organic liquid eco green Ethiopia), conduct their own research. University research on OFBF is often at a preliminary stage, hindered by inadequate laboratory equipment and chemicals.

Economy and market

In the current market, there is a predominant offering of a single liquid organic fertiliser and a handful of rhizobia products, although their availability is confined to specific regions. Various strategies for distribution and advertising are employed, but the presence of black markets is notable. To avoid counterfeit products, producers prefer to rely on their own distribution networks. The profitability of OFBF producers remains relatively low.

The main obstacles to broader distribution of existing organic fertilisers are the substantial costs related to investment, transport, and household waste separation. Additionally, the absence of incentives for waste separation at the household level poses a significant hurdle. While these products are reasonably priced for farmers, there is ongoing debate about their effectiveness in improving crop yields.

Knowledge, education and training

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. It is important to highlight that farmers continue to primarily depend on cow dung as a fuel source for cooking.

Policy, regulations and certification

Waste segregation at households' level is foreseen by Ethiopian Solid Waste Management proclamation in Article 11.1, however, there are no measures in place for the proper enforcement. Quality control, regulations, laws, and standards for OFBF are currently either absent or in the early stages of development, with effective implementation still a challenge. However, the ongoing crisis related to mineral fertilisers has prompted policy makers to be more receptive to addressing the OFBF issue. They are increasingly considering the inclusion of OFBF on their agenda as a potential solution

[45] https://www.undp.org/ethiopia/projects/urban-nama-compost

to mitigate the mineral fertiliser crisis. Positive developments are also observed within the Ethiopian government. Composting is now integrated into development plans. Notably, the national biogas programme is taking strides towards larger-scale production plants (100 to 300 m3), a significant move that can provide energy for hospitals and schools, thus enhancing economic viability.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser

The OFBF strategy must be coordinated with other agricultural practices, such as liming, alley cropping, integrating forage legumes and animals, as well as the use of mineral fertilisers.

Production and economy

There are several promising initiatives in the production of OFBF, often in an experimental phase and self-financed, with partial support from international donors. While liquid biofertilisers have established a presence in the market, their efficiency remains uncertain, and is controversially discussed. Rhizobia products require accompanying soil management, specifically pH adjustment. Further investment is needed for effective human waste management, and the bottleneck in compost production lies in household waste separation.

In some cases, the lack of testing capabilities hampers problem detection. The availability of such testing facilities is imperative, as process management enhancement hinges on the ability to conduct comprehensive assessments.

In another project, pyrolysis is studied to decrease volume and potentially yield a marketable end product with favourable pricing, although this remains an open question requiring further exploration. To ensure effective organic fertiliser distribution at the farm level, the adoption of appropriate technology is crucial. Innovation and financial support are indispensable across all sectors.

Decentralising organic waste management is imperative. The logistical, ecological, and economic infeasibility of transporting biomass to a central hub necessitates local solutions.

Research: -

Economy and market

A significant challenge revolves around the insufficient financial resources allocated to technology and laboratories needed for quality control. This encompasses nutrient analysis, carbon content evaluation, monitoring of organochlorides from plastic remnants, detection of heavy metals (e.g., from batteries), identification of drug residues, and pathogen assessment. Managing the bulkiness of compost material requires minimising transport distances, underscoring the significance of establishing regional and decentralised waste management systems.

There is a project studying additional generate income for farmers through carbon finance via CO_2 certificates. Nonetheless, establishing a financially sustainable business can be challenging. However, a feasibility study is expected to be completed by the end of 2023, exploring different potential business models.

The principle of the polluter paying for waste management holds true, signifying that those generating waste are accountable for its disposal. This principle could be applied in Ethiopia as well. Nonetheless, the approach of using incentives might also warrant consideration, as it tends to be more appealing and less restrictive than outright bans.

Furthermore, the economic assessment should internalise the costs associated with water contamination, the adverse health effects of improper waste disposal, and the impacts on climate change and food security.

Knowledge, education and training

Essential qualifications for the future encompass several factors. Knowledge transfer emerges as a pivotal aspect. Proficiency in process management, especially concerning compost and biogas facilities, holds significant weight. The ability to identify challenges is vital.

Policies, regulation and certification

It is 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.

8.2.6 Ghana

I Status quo

Mineral fertilisers

The ongoing conflict between Russia and Ukraine has sent shockwaves through the fertiliser market, causing a dramatic surge in fertiliser prices in Ghana. This price hike has made fertilisers unaffordable for larger-scale farmers who traditionally relied on purchasing from the market. While government programmes do offer subsidies for mineral fertiliser production, the country's heavy reliance on imports remains a significant concern. Despite the presence of an external investor ready to establish a mineral fertiliser manufacturing plant, doubts persist regarding whether this endeavour will be sufficient to reduce dependency on external sources.

Extensive market research and feasibility studies conducted with farmers have illuminated the challenges they face in achieving satisfactory crop yields due to fertiliser unavailability.

Currently, local manufacturing of fertilisers in Ghana is limited to blending and packaging, with ambitious plans for future expansion. Interestingly, the government of Ghana is the largest purchaser of fertilisers within the country. However, despite these efforts, significant challenges persist in delivering fertilisers to individual farmers when and where they are needed, especially in the right combinations.

In preparation for the future, the government is taking proactive steps by planning to establish a fertiliser manufacturing plant. This strategic initiative aims to enhance the accessibility and affordability of fertilisers, ultimately contributing to the advancement of the agricultural landscape in Ghana. Addressing these multifaceted challenges, the Ghanaian government has also rolled out fertiliser subsidy initiatives, notably the "Planting for food and jobs" programme. Nevertheless, these efforts encounter ongoing hurdles in ensuring an equitable distribution of these subsidies and broad accessibility among farmers.

The government is committed to supporting farmers through subsidy programmes like the "Planting for food and jobs policy." However, accessing these subsidies is complex, with smallholder farmers owning over two hectares ineligible. Ironically, subsidised fertilisers, meant to help farmers, have become costlier, prompting some to sell them on. Quality concerns arise as these fertilisers are sometimes left exposed during transport, causing leaching and doubts about mineral content. A 50 kg bag of fertiliser still costs around EUR 40. Subsidised mineral fertilisers require a 15% contribution from farmers, but confusion exists about their distribution, potentially favouring (peri) urban areas.

The supply of mineral fertilisers is unreliable, and smallholder farmers faced issues related to technical knowledge and affordability even before the Russia-Ukraine crisis. Limited mineral fertiliser availability, worsened by the Covid-19 pandemic and the conflict, has raised fertiliser prices. Farmers see the benefits of using more fertilisers but struggle with affordability due to the quality and accessibility of local products.

The fertiliser sector in Ghana is marred by concerns about ingredient quality, volume accuracy, and product authenticity, worsened by misleading labelling practices. Counterfeit agricultural products have inundated the market, challenging the agricultural sector. Corruption within the sector is often cited as the reason for the government's inability to control these subpar items effectively. To safeguard against formula replication and potential business losses, Ghana sometimes receives agricultural products 15 years after their patent life has expired. Although research on some products has been conducted, the results remain undisclosed due to fears of replication.

The fertiliser industry in Ghana predominantly relies on compound fertilisers like NPK, but farmers may not be familiar with specific compositions such as NPK 15:15:15, NPK 20:20:0, or NPK 20:8:10. The sector faces developmental challenges, impacting the availability of fertilisers like Triple Superphosphate (TSP) and Muriate of Potash (MoP). Farmers typically receive general fertiliser application recommendations, often involving two bags of NPK and one bag of urea per acre. Educational initiatives and demonstrations are employed to ensure correct fertiliser application. Follow-ups and advisory support are provided to ensure proper usage. However, agricultural efficiency faces significant challenges. Manual measurements on the soil surface result in substantial volatilisation due to weather conditions, impacting crop yields, human health, and the environment. The absence of soil testing exacerbates the problem, leading to suboptimal fertiliser application. Farmers often rely solely on fertiliser companies' recommendations due to a lack of education in best practices.

While efforts have been made to engage farmers, establish supportive policies, and invest in fertiliser-related research and development, more policy support is required. Demonstrations and trials aim to encourage effective fertiliser use, but cost constraints and logistical challenges hinder individual farmers from utilising fertilisers to their full potential. Even when farmers receive limited mineral fertiliser quantities, they tend to spread it thinly across their entire land, limiting its effectiveness. Proper training on fertiliser use, including quantity, timing, and application methods, is essential to address these challenges.

The high cost of inorganic fertilisers, both in the short term and long term, is partly attributed to their detrimental effects on soil health when not used judiciously. This underscores the importance of transitioning towards more sustainable and balanced fertiliser practices. The mineral fertiliser crisis acted as a catalyst for farmers to explore organic alternatives, marking a positive trend for the industry.

The demand for organic fertilisers has surged, particularly since the onset of the Covid-19 pandemic and disruptions in inorganic fertiliser supplies. This shift was already in motion before the crisis due to the rising awareness of the environmental and soil health impacts of inorganic fertilisers. To convince farmers who have historically managed without heavy fertiliser use, advocacy and research results are crucial. Many believe that farming without substantial reliance on fertilisers is still possible, even if it leads to lower yields. Demonstrations and evidence-based approaches play a key role in changing these perspectives. Continuous reliance on mineral fertilisers like urea and sulphate of ammonia can lead to soil acidity and reduced productivity. Research suggests that a combination of mineral and organic fertilisers is preferable to promote soil health and agricultural productivity.

Farm internal organic fertilisers

Farmers prefer hands-on control as it adds authenticity to their work. They are well-acquainted with the content and quality, enabling full responsibility. In contrast, off-farm options often raise doubts due to questionable claims. Given the choice and tools, most farmers would opt to produce their own fertilisers on the farm.

Off-farm produced organic and biofertilisers

Production and technology

The mineral fertiliser crisis has underscored Ghana's heavy reliance on a single source for our food supply. While compost production surpasses that of biofertilisers, overall production remains limited. Organic fertilisers gain favour due to their eco-friendliness, unlike mineral counterparts. An intriguing case is a company marketing wood vinegar as a bowel stimulant rather than a fertiliser. The transition to organic fertilisers by many farmers faces a crucial challenge - the correct application of biofertilisers and organic alternatives.

Using compost consistently and in the right quantities significantly enhances soil quality and yields, an approach already yielding success for some farmers. However, a common issue is mixing synthetic and organic fertilisers, allowed for oil farm-produced organic fertilisers but restricted for organic farmers. Embracing a holistic approach is key, focusing on healthier alternatives beyond fertilisation. Organic composting methods gain traction as a mineral fertiliser substitute, employing products like wood vinegar, market waste, and human excrement. Unfortunately, specific data on this shift remains unavailable. Off-farm OFBF prove beneficial, especially for resource-limited smallholder farmers lacking sufficient cattle for manure.

Combining mineral fertilisers with OFBF has proven particularly effective, producing synergistic results. Farmers continually receive education on enhancing soil fertility through organic techniques, leading to the establishment of organic desks.

Since 2017, government subsidy programmes have incorporated organic fertilisers such as composts and liquid organic variants, including some imports, except for locally produced compost. Farmers' understanding of the impact of chemical and organic fertilisers evolves. In regions with varying seasons, organic farming can face challenges as crops die during the winter, necessitating a fresh start each rainy season. In such cases, a combination of mineral and organic fertilisers, including off-farm produced ones, can be highly effective. Exclusive adoption of organic farming can be challenging in such circumstances. Initially, they may favour chemicals for quick short-term effects. However, as they grasp organic fertilisers' comparable efficacy and positive soil impacts, organic choices become apparent. Organic fertilisers release nutrients slowly, delaying benefits and adoption rates. However, the armyworm invasion showcased the effectiveness of organic control methods, motivating some farmers to embrace these practices. Off-farm producers sometimes exploit farmers, capitalising on perceived industry ignorance. However, once farmers discern inauthentic claims, they cease purchases.

The mineral fertiliser situation is not a crisis, as some farmers had already shifted towards organic fertilisers before the Covid-19 pandemic and the Russian war against Ukraine. The trend towards organics is driven by health concerns among consumers.

Organic fertilisers require larger quantities and provide slower results, leading to combinations with inorganic fertilisers. However, a gradual shift towards sole organic fertiliser use is observed due to soil damage concerns. Large farms and smallholders are adopting organic fertilisers, often combined with mineral fertilisers for early yields. Some farmers have achieved remarkable success using exclusively organic fertilisers, resulting in impressive yields. Notably, successful black American farmers have adopted organic fertilisers, and there's a steady increase in the number of individuals, including those in conventional farming, turning to organic options.

OFBF products offer diversity, but they come with production challenges, as outlined below:

- A prominent waste collector and other firms manufacture compost. Black soldier flies are promoted for composting, but waste collection remains problematic with materials not adequately separated.
- Biochar use is growing, but incentives may be needed. Coconut husks, maize stalks, and rice husks, pineapple and palm oil residues, and market waste (around 60%) offer environmentally friendly soil amendment sources for biochar production.

- Safisana, established in the Netherlands, deals with faecal and organic waste, aiming to be self-sustainable while promoting a healthy environment. Raw materials come from industries and markets. Faecal and industrial food waste undergo anaerobic biogas digestion, producing electricity. A proactive waste recycling approach is taken.
- Accra Compost and Recycling Plant, established in 2012, collaborates with Ghana's municipalities and focuses on waste utilisation and value addition. Their composting offers two forms: granular and liquid.
- Cocoa farmers leave pods on the farm for future use as manure. Companies buying cocoa husks from farmers are criticised for undermining farmers' interests. Wood vinegar has been successfully used in nurseries and other crops.

Organic fertilisers find applications in a wide range of crops, spanning vegetables, pineapples, tubers, cereals, and even cash crops like cocoa. The increasing popularity of organic fertilisers reflects the growing awareness of their benefits for both agricultural practices and the environment.

Research

Organic fertilisers are still in the early stages of development compared to mineral fertilisers, primarily due to limited research resources. There is a pressing need for increased research efforts, comprehensive documentation, and effective dissemination of research results. Despite the challenges posed by limited financial support, research remains a critical driver of future knowledge generation in this field.

The International Water Management Institute (IWMI), with a branch located in Ghana, has been actively involved in researching the potential for organic waste recycling over the past decade, including the reuse of faecal sludge.

OFBF producers have garnered recognition from researchers at the University of Cape Coast, School of Agriculture. These companies have also established robust relationships with the Ministry of Food and Agriculture and key industry stakeholders. However, a significant issue persists – many farmers remain unaware of valuable research findings, underscoring the importance of extensive participatory research and dissemination. Research endeavours are strongly influenced by the experiences of farmers, and they validate concerns regarding the prevalence of adulterated fertilisers in the Ghanaian market.

To ensure product quality, some OFBF companies employ in-house laboratory testing procedures that adhere to Ghana's established standards. The monitoring and evaluation departments of OFBF companies rigorously assess outreach efforts, impact measurement methods, and beneficiary assessments to align with global standards. Current research primarily centres on composts crafted from diverse raw materials, but it is imperative to explore biofertilisers and other potential sources of organic fertiliser extracts. Research is at the core of these companies' operations, serving as the driving force behind enhanced product quality. This includes investigations into feedstock materials for biodigesters and experiments with raw materials. Research findings emphasise the advantages of organic fertilisers, particularly in regions characterised by low rainfall, in promoting soil health and moisture retention.

Some PhD students are actively engaged in research influenced by these companies. Scientists seek knowledge from these producers, and students benefit from robust support for their project research skills. While extensive engagement with advisers and researchers is limited, there is a willingness among these companies to welcome students conducting related studies. Additionally, the presence of an in-house agronomist plays a pivotal role in ensuring product quality and delivering valuable advisory services.

Furthermore, other companies operating in this sector conduct extensive research, including comprehensive testing. They foster close scientific collaboration between their researchers and various laboratories. Universities and scientists indirectly contribute through the purchase of products and providing feedback. Independent research initiatives are also prevalent, drawing insights from experts in the fertiliser sector. Challenges persist, such as the need to reduce production time and identify less contaminated sources of raw materials.

Economy and market

One of the key challenges facing Ghana's organic fertiliser sector is the limited production capacity of compost-producing companies. This limitation severely impacts their ability to meet the surging demand. A potential solution could involve injecting capital directly, either through resource acquisition or technology enhancements, to ramp up production.

Ghana heavily relies on importing organic fertiliser products for example from Europe (specifically for certified organic production for export). While these imports often assure quality, they also contribute to higher prices compared to locally produced alternatives. Despite local production efforts, a significant portion of organic fertilisers and biofertilisers are still imported from Europe. This overreliance on imports leads to pricing issues and a lack of product differentiation in the market. The importation also introduces foreign microorganisms, raising ecological concerns.

Additionally, the bulkiness of organic fertilisers poses a barrier for some conventional farmers considering a switch to organic fertilisation options. Furthermore, the concentration of production centres in urban areas creates accessibility challenges for rural farmers. When comparing these costs to mineral fertilisers, the economics are relative, as organic fertilisers often require larger quantities for effective use.

There's been a gradual increase in demand, strongly correlated with growing awareness among farmers. Heightened awareness about climate change and the necessity for mitigation measures has also contributed to this upswing. This preference stems from the ready availability of organic materials for composting, making organic options economically advantageous over the long term.

In recent years, indirect subsidies have played a role through farmer fertiliser subsidies, which include support for organic fertilisers and biofertilisers. This subsidy has effectively created a market for producers in this sector. However, accessibility remains a challenge due to centralised production and stocking. While subsidies can serve as a short-term measure to support farmers, the long-term focus should shift toward training farmers to view their agricultural activities as businesses. Encouraging cost and revenue analysis empowers farmers to accurately calculate their profits. Nevertheless, the presence of free handouts can sometimes inadvertently discourage farmers from giving their full effort, as they may become overly reliant on external aid.

Pricing often plays a decisive role in farmers' choices. In some cases, the cost of organic fertilisers is more affordable than chemical alternatives, making them an attractive option. Farmers may consider supplementing their own production with off-farm alternatives. Interestingly, when farmers receive organic fertiliser for free, they may choose to sell it to generate additional income. This reflects their primary concern: balancing yields and costs while striving to achieve the highest soil fertility possible. Cost considerations often lead to resistance when there's a financial element involved in recommendations. Assessing the economic feasibility of organic fertiliser involves a careful evaluation of the labour required. While it may seem economically attractive in principle, practical implementation can present challenges that need to be considered.

Working directly with farmers and farmer associations has been instrumental in the success of companies operating in this sector. In some instances, a significant portion of total organic fertiliser production, around 80%, is procured by the government through its national programme. The remaining production is distributed through retail outlets, catering to farmers outside the government scheme or those needing additional fertiliser. Farmer organisations also play a crucial role in product distribution. Even with substantial government procurement, companies continue their advertising efforts to explore untapped markets. 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.

To expand market reach, a distributor scheme has been devised, and plans are in place to initiate broader media advertising. Presently, radio advertisements are being actively used, and distributors conduct their advertising campaigns. Direct farmer outreach through visits and participation in farmer programmes is also actively pursued.

To overcome the challenge of limited outlets in areas beyond Greater Accra and Kumasi, efforts are being made to expand. Utilising online platforms and social media allows potential customers to connect with producers. Educating input dealers and sales agents about product usage enables them to effectively reach end consumers.

Many companies in this sector often rely on donors for sustainability. 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.

Knowledge, education and training

A primary challenge faced is the perception among farmers that organic fertilisers do not deliver immediate results similar to inorganic fertilisers. Capacity building is therefore a critical component. Education is the key to overcoming this challenge, enabling farmers to comprehend the long-term benefits and sustainability of organic fertilisers. Comprehensive farmer training covering various subjects, including organic farming techniques, research methodologies, trade in organic food produced by farmers, and advocacy services aimed at preserving biodiversity and ecosystem health is offered from some companies.

To address significant education gaps among farmers, particularly those influenced by negative perceptions, there is need for a mindset shift. Rather than merely advising farmers on organic fertilisers, actively engage producers of these fertilisers to provide training and support for their products. This approach is designed to enhance farmer understanding and confidence in the effective use of organic fertilisers.

To equip farmers with practical knowledge, certain companies have made substantial investments in research and demonstration plots for their products. Demonstrations play a pivotal role in showcasing proper application methods to optimise production. Furthermore, we provide comprehensive application manuals tailored to different crops.

Efforts are being made to educate farmers on the use of locally available resources for compost production. Special programmes teach farmers how to transform household waste into compost, emphasising sustainable practices. Farmer training on the application of OFBF, coupled with the establishment of demonstration plots, plays a pivotal role in encouraging the adoption of these fertilisers. Farmers often base their decisions on the evidence observed from these plots.

Despite several efforts, the awareness and knowledge of using organic fertilisers among farmers, including educated ones, remain relatively low. Awareness-raising about soil quality and its impact on crop selection can be challenging, as some farmers underestimate the importance of soil fertility.

A relevant advisory service is provided by the Ministry of Food and Agriculture (MoFA) through their extension agents. While these agents are not directly involved in markets or distribution channels, they play a crucial role in raising awareness among farmers about the benefits of organic options. However, their scope is limited, as the type of fertiliser provided to farmers is determined at the national level. It is essential to highlight that advisory services in this sector are entirely independent and free from external influence. The impact and influence of NGOs have been limited in the operations of these companies.

Lectures on organic fertilisers are available at universities. Consumer education has played a pivotal role in improving the market. Previous reservations about using human excrement for food production have diminished as consumers gain a better understanding of the thorough sanitisation process, assuring them of the cleanliness and usability of organic fertiliser. Agronomists provide education alongside visual testimonies through demonstration greenhouses and plots.

While the role of farmer organisations has been somewhat limited due to the dysfunctionality of many such groups, a few operational organisations have played a significant role in spreading awareness about OFBF products.

To promote OFBF, documentation through participatory guarantee systems (PGS) and the creation of an acceptable inputs magazine have been introduced. The magazine serves as a valuable guide for PGS farmers, helping them identify and locate acceptable organic inputs available in the country.

While many companies provide educational newsletters to support their products, comprehensive industrial documentation is often lacking. This gap sometimes leads farmers to opt for mineral fertilisers due to concerns about timely crop responses. Furthermore, some organic soil amendments remain underutilised due to challenges in determining appropriate rates, timing of application, suitable locations for compost and biochar production, and field application. However, given the choice, many farmers express a preference for using their own organic fertilisers if they possess the necessary knowledge and technical know-how.

Policy, regulations and certification

Ghana has made strides in promoting organic fertilisers and biofertilisers despite challenges. Guidelines for their production have been developed (in 2022), and training and extension programmes on their usage are underway. These initiatives are primarily supported by OFBF importers. Stakeholder engagement within the Ecological Organic Agriculture platform of Ghana involves scientists, organic producers, and OFBF importers to agree on acceptable practices. A guideline resulting from this stakeholder engagement has been disseminated for practical application.

During the fertiliser crisis, the Ghanaian government engaged various stakeholders, including compost producers and waste management experts, to devise strategies to enhance local production. Despite the initial slow adoption rate, the government continued to encourage farmers through trials and demonstrations. Recent developments, such as meetings, campaigns, and training programmes to promote organic agriculture, demonstrate government support. The government actively seeks to intensify organic fertiliser production and availability, remaining flexible about the types of biodegradable raw materials used. However, a comprehensive waste collection strategy appears to be lacking.

Assessing the quality of fertilisers in Ghana is a complex and time-consuming process, often taking up to three years before research results are released. This prolonged evaluation period incurs significant costs, and obtaining a license for organic fertilisers and biofertilisers after such a lengthy assessment may not always be economically viable, especially for small and medium-sized enterprises. Regulatory Services Directorate (PPRSD) and the Ghana Standards Authority have to approve the quality of the product (lab analysis required).

Farmers who do not own land face difficulties in appreciating organic fertilisers and biofertilisers because they often rely on one-year leases, and lease renewals are uncertain. The slow release of organic fertilisers and the time it takes for soil response make it challenging for these farmers to observe immediate benefits.

Accra Compost and Recycling Plant has forged a partnership with the government through the Planting for Food and Jobs Fertiliser Subsidy Programme. This programme involves the supply of organic fertiliser. However, the existing regulatory framework mandates continuous quality testing, which presents a notable challenge for the company.

Currently, there are no established legal conditions for distribution. As a result, Accra Compost and Recycling Plant has improvised certain conditions, such as the buyer assuming responsibility for any bottle breakage during transport. They also advise against exposing the product to direct sunlight, and transport logistics are the buyer's responsibility. Fortunately, their product is available throughout the country, making distribution manageable.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology

Looking ahead, there is anticipation that the demand for organic fertilisers will more than double the current level. Implementation of a regulatory framework will enhance the outlook for organic fertilisers and boost consumer and investor confidence in organic products. Expansion of the product range and maintaining high-quality standards aims to contribute to the growth and success of organic agriculture in Ghana.

The Ghanaian government is expanding its waste collection model across various cities. Transitioning from synthetic to organic compost fertiliser must be a gradual process to prevent crop loss. When dealing with virgin land, it's advisable to use compost right from the beginning.

Regarding raw materials, there are no foreseen challenges, as the main sources are abundant human waste, agro-industrial waste, and market waste within the country. However, quantifying the current and future amount of organic waste may pose a challenge. Gathering information about available feedstocks, their locations, quantities, and understanding their quality is crucial. Once this information is obtained, the focus can shift to the processes involved in biochar and compost production.

Trials on compressed gas for cooking are ongoing. However, challenges related to transport distance and delays might impede progress. Ensuring the quality of raw materials, especially if they are not separated at the source, poses an additional risk. Despite these obstacles, there are plans to expand and develop another plant in another city, like Kumasi, with the goal of increasing production and participating in the government agriculture support programme. The aim is to increase nutrient levels significantly.

Accra Compost and Recycling Plant has garnered attention from several West African countries interested in setting up similar plants and seeking advice. Improved compost quality is essential. Future plans include expanding production to other parts of the country, with a current pilot plant in Kumasi focusing solely on compost production. The goal is to address waste issues in Ghana and anticipate an increasing demand for organic fertilisers.

As the market for organic products continues to grow, there are considerations also of other companies to expand the production line to include other products like (natural) pesticides. Plans include further diversification within the organic agriculture market by offering organic inputs, starting with knapsack sprayers and introducing additional inputs in the future. Ensuring the quality of these fertilisers is crucial, focusing on high-quality materials in their production.

Research

Research and certification are essential steps before introducing products to the market. Farmers can act as researchers themselves, collaborating with researchers to assess product effectiveness through participatory research. Policies supporting organic fertiliser research in higher education should be in place, with outcomes shared with companies looking to scale up production. Further research should explore the potential of using local resources without the need for imported materials, given the abundance of productive weeds and waste materials

Justifying the efficacy of products is crucial. Additional funding is required to conduct further research on product effectiveness in addressing existing problems.

In terms of biofertilisers, the raw material base is expected to remain secure in the future, as long as respective plant species and microorganisms are available. Investments in research allow for the cultivation and harvest of these organisms.

Conducting a value chain analysis of the organic sector will be beneficial in improving the contributions of all actors to the sector's development.

Organic agriculture is rapidly growing, and organic fertiliser production levels are expected to surpass inorganic fertilisers. Price is a significant factor in this shift, but it's important to develop organic fertilisers that can boost crop yields at a faster rate to compete with inorganic alternatives. This requires more research to professionalise local production. Plans include expanding research and product range into other areas of organic production, such as liquid pesticides and organic inputs.

Economy and market

Anticipated demand growth is driven by the Russia-Ukraine war's effects and the increasing popularity of the product. But also, primarily due to cost considerations. The growing market for organic fertiliser is also attributed to increasing awareness of the negative effects of inorganic fertilisers, both on the product and the production process.

Organic fertilisers are also expected to gradually reduce farmers' reliance on mineral fertilisers, although they may still be used side by side on farms. Plans include introducing granule organic fertiliser to meet diverse farmer needs, with challenges related to predicting its level of patronage.

There is a need to increase production by 1.5 times, but challenges might be material availability and the cost of obtaining additional materials. Plans involve securing financial support to develop three product lines and hiring qualified personnel to enhance product quality. Sourcing raw materials from different sources necessitates various processing equipment, impacting financial resources. Sufficient funding is crucial for improving production, as machinery purchases require financial support.

Current marketing strategies, built on strong farmer relationships through visits and demonstrations, have been effective.

Some companies have future plans for expanding to other African countries and beyond, with a focus on becoming leading producers of liquid organic fertilisers. Upgrading and expanding the production unit is aimed at capitalising on economies of scale, leading to reduced production costs. While licensing requirements have limited competition in the organic fertiliser market, competition is expected to increase over time as demand grows.

Continued innovation and improvement in offerings, coupled with increasing awareness and positive farmer attitudes towards organic products, are expected to drive demand for fertilisers and contribute to the growth of a sustainable organic agriculture industry.

Knowledge, education and training

The impact of organic fertiliser takes time, so creating awareness about their characteristics is essential. Initially, the focus should be on increasing awareness, which will naturally drive demand. Afterward, investments in distribution channels and demand management can be considered.

Information barriers pose a significant challenge. Access to a comprehensive information database is crucial. Farmers need proper education to ensure a clear understanding of their tasks and execution methods. Shared knowledge should be thoroughly tested and supported by factual evidence, even when facing differing opinions or debates.

There is a pressing need for soil and crop-specific advice on fertiliser requirements. Knowledge documentation from practical experience and literature plays a crucial role. Farmers should have familiarity with various fertiliser formulations, not just one, to effectively complement mineral fertilisers with their compost or other OF. It's essential for farmers to possess a clear understanding of the components they are adding to the soil.

Advocacy and capacity building are vital for raising awareness, which is currently limited or non-existent. Ensuring a strong connection between science, policy, and practice is crucial. Collaboration between universities, research institutes, the private sector, and farmers is necessary to avoid progress delays caused by operating in isolation.

The demand for training programmes to educate farmers and input dealers on handling, using, and identifying certified organic products in the market, while distinguishing them from counterfeits, is essential for the sector's growth. Education through demonstrations, field visits, workshops, and training sessions will play a pivotal role in advancing the organic agriculture industry. The establishment of designated best practice areas, where long-term demonstrations are conducted and thoroughly documented, is essential.

Additional services like soil testing to assist farmers in analysing their soil before using products are necessary. This approach aims to better understand farmers' challenges and needs based on past feasibility phase experiences.

Policies, regulations and certification

The existing regulatory framework presents significant challenges for emerging businesses, primarily due to high costs and intricate procedures. A potential solution to consider, particularly for initial setup, is the waiver of registration costs while maintaining essential quality assurance processes. This adjustment could create a more conducive environment for new ventures to flourish.

Policy support is essential, especially in establishing a regulatory framework for quality assessment of OFBF. Well-planned initiatives indicate a promising future where OFBF can successfully replace mineral fertilisers. Policies should regulate the import of such fertilisers, especially regarding quality. Demonstrations and farmer field schools effectively highlight the benefits at the community level, leading to replication in farmers' fields.

There's a pressing need to authenticate products through research and standardisation to prevent misleading claims. These standards provide confidence to farmers by ensuring proven efficacy.

Ghana's objective should be self-sufficiency in fertiliser production, encompassing both mineral and organic fertilisers. Successful implementation of this policy direction remains a challenge that needs to be addressed.

While specific figures are unavailable, there is a general trend of increasing demand for OFBF due to several factors, where further engagement is recommended:

- Collaboration between the Ministry of Agriculture and stakeholders of the Ecological Organic Agriculture Initiative has raised awareness.
- Government initiatives promoting household kitchen gardens for food self-sufficiency contribute to rising demand.
- Growing preference for organic food due to food safety concerns.
- Concerns about children's safety and chemical input misuse have also spurred demand. Meeting this growing demand requires capacity building among local producers.
- Climate change is a real concern, and the use of OFBF helps create a conducive environment for mitigation and adaptation.

The government's organic fertiliser subsidy programme is pivotal, and farmers increasingly recognise the value of organic fertilisers. This recognition is making competition in the organic fertiliser market inevitable.

In the case of organic farming, current legal conditions are under development. A comprehensive policy framework regulating all aspects of organic agriculture is essential. Local certification reduces product costs, while regulations ensure quality. Government policies can influence sales and demand for organic products. With government support at the district level, Ghana has the potential to transition to organic agriculture. Co-designing organic projects with funding partners and farmers ensures farmer involvement in soil fertility management practices, increasing technology adoption. To promote organic agriculture, policies should transform education from primary to tertiary levels, focusing on organic soil fertility management. Encouraging youth participation in organic fertiliser and biofertiliser production at the district level is vital.

8.2.7 Kenya

I Status quo

Mineral fertiliser

According to a World Bank report, the recent surge in fertiliser prices can partly be attributed to the conflict in Ukraine. However, fertiliser prices have been on a consistent rise since 2008 and are unlikely to see a decrease in the foreseeable future. Developing domestic fertiliser production capabilities in Kenya will take time, leaving price reduction as the primary solution to prevent an impending food crisis.

Mineral fertiliser prices have experienced a 100% increase in recent years, rising from USD 30 to 35 per 50 kg to USD 60-70. Although the price of DAP, a key fertiliser, has recently slightly decreased, price adjustments on the continent tend to lag behind global shifts by about six months. The government has advised discontinuing the use of DAP due to its soil acidification effects. DAP is typically used as a basal fertiliser, while urea is applied as a top-dressing. Information on NPS application is not readily available.

While the recommended application rate for mineral fertiliser is 50 kg per hectare, this may not always be necessary. For instance, forested areas in Congo do not require the same amount. On the other hand, countries such as Ethiopia, Rwanda, and Malawi are closer to achieving the 50 kg target.

There is an ongoing debate about potentially increasing the recommended application rate of mineral fertilisers. The target for mineral fertiliser application, as set by the Abuja declaration, aimed at 50 kg of nutrients per hectare. The current usage has doubled from eight to 16 kg/ha, with projections indicating slightly higher figures. Despite this increase, 20 kg remains significantly below the 50 kg target. However, the question arises: why is 50 kg the standard? For example, in forested areas of Congo, applying 50 kg of fertiliser is unnecessary. Conversely, countries like Ethiopia, Rwanda, and Malawi are already approaching the 50 kg target. Discussions are also underway to potentially raise the recommended 50 kg/ha rate.

In response to the escalating costs of mineral fertilisers, organic fertiliser producers have also raised their prices. For instance, a 50 kg bag of compost can range from 2000 to 3500 Kenyan Shillings (approximately EUR 15 to EUR 25). In contrast, locally (on-farm) produced organic fertilisers have remained more affordable and consistently accessible.

While subsidies play a crucial role and offer benefits, they should be complemented by other inputs such as quality seeds, comprehensive information, and knowledge on optimising fertiliser utilisation and integrating it into rotational systems. Recognising that relying solely on fertilisers and subsidy schemes is inadequate, there is a growing understanding of the need for supplementary measures.

Applying fertiliser to African soils poses several challenges. For instance, deep red soils can immobilise considerable quantities of phosphorus per hectare before reaching saturation. While overapplication of fertiliser is a potential approach, it does not directly address the underlying soil health concern; however, it can enhance efficiency. Furthermore, the storage and transport of nitrogen-based fertilisers, especially urea, result in significant nitrogen loss, further exacerbating the issue by causing substantial losses before the fertiliser even reaches the farm.

Farm internal organic fertiliser

Livestock densities in smallholder settings tend to be low. A survey conducted in Eastern Uganda, which can be considered representative of Western Kenya and many other regions, highlighted the scarcity of straw and stover. Although these materials are used as cattle feed, there are other residues like maize shanks that might not be abundant but still hold significance. Even with modest smallholder farming productivity, approximately one ton of maize shank is produced. The shank, containing maize grains, is usually discarded due to its unsuitability as animal fodder. However, even after shank removal, a substantial amount of residue remains. Comment by the interviewee: "It's worth noting that I don't advocate for complete residue removal from fields; retaining some residues is vital for mulching purposes. As these residues decompose, they release carbon into the soil, enhancing fertility. Moreover, leaving residues on the fields preserves soil aggregation and prevents soil destabilisation."

Off-farm produced organic and biofertilisers

Production and technology

The efficacy of off-farm produced organic fertilisers is constrained by their low nutrient concentrations. Studies claiming positive yield outcomes from these fertilisers are often met with scepticism due to their omission of nutrient application rates per hectare, relying solely on quantity measurements (litres, tons per hectare). Such publications are predominantly found in non-peer-reviewed journals.

Regrettably, the Kenyan market is plagued by a notable presence of counterfeit biofertilisers, resulting in financial losses for consumers.

- Compost from horticulture residues: Horticulture plays a pivotal role in Kenya's economy, marked by a multitude of greenhouses dedicated to cultivating green beans, flowers, and vegetables. These endeavours produce substantial waste that holds potential for composting, thereby generating a valuable resource. The close proximity of greenhouses to waste origins and their link to urban horticulture position them as prime candidates for compost production. Numerous Kenyan enterprises, including Dudutech located in Nairobi, are actively involved in large-scale compost production utilising greenhouse residues. It's plausible that numerous other companies are also adopting comparable approaches similar to those of Dudutech.
- Compost: Several specialised companies are dedicated to collecting green and other organic waste and converting it into compost, which is subsequently sold directly to farmers or supplied to input providers. Despite these initiatives, a considerable portion of solid organic waste continues to find its way into landfills. 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. Developing sustainable approaches for managing solid organic waste is imperative. While composting remains a viable option, its practicality can vary. Incineration could present a viable alternative, but it's crucial to ensure the proper capture and treatment of emissions resulting from the process. Roadside pruning offers another potential biomass source for biochar production. As an illustration, "my former research assistant established their biochar production enterprise by securing a concession from the municipality to collect roadside trimmings and hedges that would otherwise be burned. Numerous other instances of utilising such biomass sources can be found."
- Biogas: In smallholder settings, such as the dock pit, can be used to produce energy from crop residue. This energy can be used to offset energy needs, which is something that people struggle with every day. Developing utility models that allow farmers to feed their crop residue to these systems would be a valuable way to improve energy access in smallholder settings. Biodigestion is

a superior solution as gasification can result in the loss of nitrogen. When it comes to biochar, my guiding principle is to use fibrous, high lignin, and cellulosic materials, guided by the carbon to nitrogen ratio. There tends to be an excess of high carbon residue compared to high nitrogen residue. Gasification systems often struggle with human waste due to its high inorganic carbon content. The faecal sludge sitting in pits for extended periods leads to the breakdown of organic carbon into inorganic forms. As a result, the quality of the final faecal sludge is compromised. The main challenge of organic waste transformation into organic fertiliser lies in ensuring a year-round supply of biomass. Existing combined heat and power units can generate one kilowatt of electricity from approximately 1.5 kilograms of properly densified biomass.

- Biochar: Numerous programmes are now incentivising biochar production through carbon credits. A notable example is Plant Village, backed by USAID, which sets up carbon cubes to train farmers in artisanal biochar production techniques. The resulting biochar is certified by Biochar for Life, a company involved in purchasing and trading carbon credits. Farmers can earn around USD 70 per ton of biochar, approximately a week's worth of work. Plant Village primarily focuses on using invasive species and surplus residues like maize shanks and rice husks to create biochar. Additionally, new companies have emerged recently, producing biochar-enriched organic fertiliser mixed with black soldier fly excrement. One such example is Safi Organics, located in a rice-growing region, using rice husks as feedstock for their batch processing. However, the drying process incurs high costs, making widespread biochar use economically challenging.

Research indicates that applying one ton of biochar per field can boost grain yields by 0.5 to 0.7 tons per hectare (authors assume that it is about coffee yield), potentially enhancing coffee farm productivity by up to 70%. The most effective strategy combines biochar and manure use. Biochar-enriched fertiliser, a blend of biochar and mineral fertiliser, shows promise as a promising fertiliser formulation.

A study suggests that applying biochar to a field could potentially increase root growth by up to 50%, leading to a potential 50% increase in crop yields. Biochar can also enhance steep pruning quality in specific scenarios by aiding in the decomposition of pruning materials, making them more digestible for microorganisms. Setting sustainable removal rates for steep pruning is essential for economic viability, as not all pruning material offers the same energy density or utility.

Biochar production from human waste holds potential as a technology, but it's important to acknowledge the associated challenges. Implementing biodigestion and promptly collecting faecal sludge can yield high-quality biochar from human waste. Biochar can also effectively mitigate the odour of chicken manure.

Black soldier fly manure (BSFM): Derived from the waste of black soldier flies, BSFM offers a sustainable and environmentally friendly alternative to chemical fertilisers. Its cost is on par with mineral fertilisers, making it mainly suitable for higher-value crops such as horticulture. Nevertheless, its adoption among smallholder farmers for staple crop production remains limited due to the associated costs of these fertilisers and a general lack of awareness about their benefits among smallholder farmers.

Rhizobia (R): Certain R strains have been found to lack efficiency. Exploring the development of crop-specific rhizobia strains could be promising. However, the production of grain legumes, which could potentially serve as a nitrogen fertiliser, depends on market demand and the economic feasibility of these crops. This often makes them an unpredictable factor for fertilisation. Forage legumes such as Desmodium encounter seed shortages, and seeds for alfalfa and red clover are practically inaccessible.

Mycorrhiza (M): M, although more prevalent, tends to be less specific in its action. Regrettably, around 90% of mycorrhiza products available on the market in Kenya and other African countries are counterfeit. In cases where mycorrhiza populations naturally exist in the soil, they can readily establish symbiotic associations with plants that require mycorrhiza support. There are certain applications, such as employing tissue culture methods to inoculate plants and trees with mycorrhiza during the hardening phase, which can enhance survival rates. Nevertheless, these treatments come at a considerable cost and cater to a specialised market segment.

Trichoderma (T): Trichoderma and other biocontrol agents that possess pest and disease suppression properties encounter significant challenges among the array of available products. Bio-stimulants like seaweed extracts, while valuable, do not serve as fertilisers in their own right. Nutrient-rich rocks, when applied in substantial quantities (several hundred kilograms), might have an impact, but their effectiveness diminishes with small-scale applications. An intriguing approach is enhanced rock weathering, a technique that liberates nutrients from rocks by exposing them to air, water, or introducing acids or bases. This method has the potential to curtail the need for excessive fertilisers and concurrently enhance soil quality.

Research

Some companies active in organic fertiliser production such as the case for Regen Organics (Annex: Business case 1) pursue collaborations with esteemed 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-mineral fertiliser and more concise recommendations for fertiliser application rates.

Economy and market

The domestic market faces a shortage of high-quality equipment that meets specific requirements, leading to the need for imports to achieve optimal functionality. This situation also extends to spare parts. Vehicles assembled outside the country are subject to a minimum import tax of 30%. In certain cases, foreign organisations cover investment costs. Observing the expenses at each stage of the production process, which includes waste collection, sorting, lack of tipping fees, and exclusion from government fertiliser recommendation and subsidy programmes, is essential. While efforts sponsored by cities and improved financing terms have proven beneficial, companies still heavily rely on their own resources. 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.

Knowledge, education and training

One of the significant challenges encountered by OFBF companies is persuading and educating farmers about the significance and benefits of organic fertilisers. Presently, advisory services have limited awareness about alternative fertilisation approaches. The primary emphasis remains on Diammonium Phosphate (DAP). Education through farmer field days, inviting other farmers, and conducting demo trials are considered crucial for implementing OFBF. While various activities are organised, they are still quite limited in scope.

Policy, regulations and certification

There is a deficiency of supportive measures that could expedite development. The registration process for organic fertilisers usually spans about one and a half years, and although the overall condition is acceptable, there is potential for enhancing and optimising the regulatory framework.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Off-farm produced organic and biofertilisers

Production and technology

Fertiliser application must be adapted to incorporate alternative amendments. It is crucial to efficiently recycle locally accessible materials whenever possible, extending beyond fertiliser strategies to encompass practices like Brachiaria seed utilisation. 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. Organic waste harbours significant energy potential, especially in the gasification process, which should be harnessed.

Research

Decentralised green ammonia production offers promise for the future but demands substantial capital investment and the use of renewable energy sources like solar power. Basic research must be better linked with industry to ensure that resource recovery and regenerative models are implemented correctly and receive more prominence in discussions. More demo plots, more funding for demo plots, better knowledge on more exact application rates for the different locations are necessary.

Economy and market

Energy prices must be reduced, and subsidies as well as increased grant funding are imperative. Otherwise, a food crisis could emerge. Attracting manufacturers and technology providers from Europe and the United States is essential, along with establishing effective governance and a strategic marketing approach. Support or subsidies that lower equipment import costs and alleviate importation taxes are needed.

Looking ahead to the medium term, a promising avenue lies in the production of green ammonia. This entails establishing smaller production facilities exclusively powered by renewable energy sources. Linking carbon credits with organic farming could offer progress in this realm. Advancements and experiments in this direction hold potential for numerous African countries, as the capital investments needed for such plants are lower. With multiple production facilities spread across the continent, transport costs could be significantly minimised. Green ammonia production relies on sustainable energy sources like solar power, aligning with eco-friendly practices. However, the widespread adoption of this technology will require time to materialise. Policy improvements are imperative; having a stronger voice in this industry would be highly beneficial. Organising to advocate for our interests and enhance policies, such as regulating the organic market, would be advantageous. The current lack of market regulation poses a substantial challenge.

Knowledge, education and training

Knowledge about optimising fertiliser 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.

Policy, regulations and certification

In the African context, the allocation of public funds to fertiliser subsidy programmes has proven ineffective. The disruptions in global fertiliser supply chains have compounded the issue, and it will be a gradual process for Kenya to establish domestic fertiliser production capabilities. Consequently, the risk of food shortages in Africa looms. A fresh mineral fertiliser strategy is essential, one that takes into account farming systems and nutrient cycles beyond the farm. A more integrated approach is required, emphasising the simultaneous use of fertiliser and investments in soil health. Introducing tax incentives or waivers for companies engaged in processing and treating urban waste to produce biochar and other OFBF could yield positive outcomes.

OFBF should be included in government subsidy programmes similar to those that subsidise mineral fertilisers. Policies should be put in place to encourage the production and use of OFBF. Government assistance in locating suitable land for processing organic biomass in strategic locations would have a significant impact. Subsidising the mechanisation tools employed, such as windrow turners, would serve as an incentive for wider adoption and proliferation.

8.2.8 Malawi

I Status quo

Mineral fertilisers

Malawi does not produce its own mineral fertilisers; instead, it has only two blending factories with a combined annual production capacity of 284 000 tons. YARA Company donated fertilisers to the Malawian government in response to Covid-19 to support smallholder farmers in the country. The two blending factories, Optichem in Blantyre and Malawi Fertiliser Company (MFC) in Lilongwe, currently have production capacities of 50 tons per hour and 62 tons per hour, respectively (totalling 284 000 tons per year). Collaboration between the Ministries of Agriculture and Mining is essential to facilitate access to resources, such as Rock phosphate deposits.

The prices of mineral fertilisers have risen by over 100% since the start of the Ukraine-Russia conflict. Import challenges, including the absence of a domestic harbour, high transport costs, and suboptimal international relations, have compounded the issue. There have been significant price fluctuations in subsidised fertilisers. For instance, two years ago, a 50-kilogram bag was priced at MK 4 595, but today it stands at MK 15 000, roughly equivalent to USD 60 for NPK, with regional variations. However, due to subsidies on inorganic fertilisers, farmers are only required to contribute USD 15.

Before the crisis, the government recommended using 300 to 400 kilograms of NPK per hectare. Presently, the government offers a maximum of 50 kilograms per farmer at a subsidised rate of USD 1 per kilogram (as per the fertiliser bill). This programme benefits 2.5 million farmers. In the open market, the same fertiliser is priced at USD 1.50 to 1.60 per kilogram.

Indeed, there is now a fertiliser bill in place. In general, the country has regulations governing the exploitation of mineral resources, and this extends to fertilisers, not exclusively.

The government of Malawi is executing an Affordable Inputs Programme that targets smallholder farmers, providing them with subsidies. During the Covid-19 pandemic, YARA Company generously donated fertilisers to the Malawian government to support smallholder farmers in the country. However, it's essential to note that this programme reaches only 2.5 million smallholder farmers out of the 3.1 million smallholder farming families in Malawi. Additionally, the subsidies provided cover only one 50-kilogram bag per farmer. The levels of fertiliser subsidies have been significantly reduced due to the increased prices of fertilisers resulting from the fertiliser crises triggered by the conflict in Russia and Ukraine. Subsidies are only provided to a limited number of smallholder farmers (2.5 million) through the Affordable Inputs Programme.

Smallholder farmers heavily rely on chemical fertilisers, primarily because of associated subsidies. Consequently, the shortage of chemical fertilisers has led most of Malawi's farmers to seek subsidised mineral fertilisers. Nonetheless, access to mineral fertilisers for smallholder farmers remains severely limited due to high prices, restricted credit availability, inadequate information dissemination, insufficient training, and limited market access. The issues of farmers lacking access to markets, inadequate information, and insufficient training persist.

Moreover, the extensive road network in the country, often in poor condition, and the limited availability of timely deliveries have compounded the challenges faced by farmers. The absence of a local fertiliser manufacturing company in Malawi has led to the government importing chemical fertiliser. Fertiliser imports into the country consistently experience delays, whether sourced from the government or private entities. The open market policy permits fertiliser importation from various sources, introducing concerns about the authenticity and quality of these fertilisers. Instances of bags containing mixtures of fertiliser and sand are not uncommon.

The nation lacks a robust system for verifying the quality of different types of fertilisers. These challenges are expected to persist for at least the next five years, primarily due to logistical complexities in importing and distributing fertilisers. The situation is worsened by long transport distances from neighbouring countries like Tanzania and Mozambique. Moreover, the high cost of road transport is exacerbated by the poor state of the national road network. The successful importation of fertilisers is also contingent on positive diplomatic relations. By the time these fertilisers reach farmers, they often arrive too late for the appropriate crop stage. The exorbitant prices of chemical fertilisers place them out of reach for many farmers, compelling them to rely solely on the government's allocation of 50 kilograms per farmer. Additionally, corruption in the transport system further exacerbates the issue, with instances of adulteration, such as mixing sand with the imported product, not being uncommon.

Government policies are not effectively aligned with disaster risk management strategies. While the government is encouraging farmers to use organic manure and compost, such as Mbeya manure, and promoting the use of fertiliser trees alongside crops, there's also a push to diversify crops beyond maize to include legumes. Interestingly, the "fertiliser crisis" stemming from the Ukraine war has had an unexpected positive impact on the demand for organic fertilisers in Malawi, as individuals explore alternative options.

Farm internal organic fertiliser

Due to the challenges mentioned earlier, many farmers are increasingly turning to on-farm organic fertilisers. However, the application rate of these fertilisers is often insufficient, primarily due to the severely degraded and eroded state of the soils. The continuous loss of topsoil and essential nutrients necessitates significant efforts to rejuvenate the soil. Unfortunately, there is a lack of systematic assessment of the application rates for organic fertilisers, as farmers decide based on what is available and affordable to them. Many farmers are unable to afford mineral fertilisers, leading them to seek alternative methods to enhance soil fertility. Currently, even farmers who were initially hesitant to discuss organic fertilisers are actively engaging in conversations about them. Advisory services promote the production of on-farm compost; some farmers sell it, some mix 50 kg with 10 kg Urea or NPK, practices that already have been applied before Covid-19 and the Russian war against Ukrainian.

Off-farm organic and biofertilisers

Production and technology

Off-farm organic fertilisers and biofertilisers play a crucial role in enhancing yields by complementing on-farm produced organic fertilisers, which are often insufficient. Ensuring the availability of off-farm OFBF enables farmers to improve their efficiency, allowing them to focus more on crop production rather than allocating labour to on-farm fertiliser production. It's essential to build soil health, as the current available farm internal organic matter isn't adequate. One of the barriers to organic fertiliser production is the lack of raw materials. The potential sources of organic matter for the production of OFBF include waste from the organic agriculture value chain and green waste. However, a significant challenge is the scarcity of raw materials, which are needed in substantial quantities. Many organic fertiliser producers are currently operating at limited capacities, preventing them from making a national impact.

There are donor-funded initiatives linked to specific programmes, and sustainability becomes challenging once the programme concludes. The current production of off-farm organic fertiliser is insufficient to have a measurable impact on national-level production. There are no subsidies for organic fertilisers, but farmers benefit from projects. There is no comprehensive overview available about the various initiatives producing off-farm organic fertilisers.

Currently, only a small fraction of the 58 000-member strong Malawi Organic Growers Association (MOGA) utilises off-farm organic fertilisers and biofertilisers. The main reason for this limited adoption is concerns about poor quality, which could potentially compromise the organic status of their produce, particularly for certified farmers. The use of organic liquid fertilisers among organic farmers is minimal due to concerns about poor quality resulting from inadequate national quality control measures, leading to rejections of these fertilisers. MOGA, being a farmer association for organic producers, has not assessed the impacts of mixing chemical fertilisers with off-farm organic fertilisers. However, there are positive observations suggesting that off-farm organic fertilisers and biofertilisers, when used in conjunction with on-farm soil amendments, can regenerate soils, reduce erosion, and increase organic matter levels. Additionally, it's important to note that OFBF can only complement mineral fertilisers, as combinations of the two are not accepted in organic farming.

There are diverse initiatives with different products, production capacities underway:

- Progressive farming practices, involve on-farm or nearby compost production using diverse organic materials. Certain forward-thinking farmers even vend these blends to peers (termed as Mbea fertiliser). Subsequently, these blends are combined with inorganic counterparts like NPK or urea, such as 10 kg of urea or NPK per 50 kg bag. Practitioners of this method generally achieve higher yields. This trend predates the era of Covid-19 and the Ukrainian conflict, but has now notably intensified, driven by the quest for viable alternatives.
- A company is producing Bionitrate fertiliser based on urine, with a total production capacity of 1.2 million litres per year, priced at USD 1 per litre, and a recommended application rate of 250 litres per hectare. Prices have increased by 20%, while mineral fertilisers have seen a 50% price hike. Currently, the factory facilities' capacity cannot meet the rising demand, which has reached 50 million litres per year. The production process involves proper urine harvesting, installation of treatment tanks, development of technology for urine pH measurement during production, understanding the relationship between soil pH and nutrient uptake levels for different crops, and packaging development. The product lifespan of Bionitrate fertiliser is one year, after which it deteriorates. However, it can still be used, albeit with adjusted application rates, and it can also be repurposed to improve compost quality. Unfortunately, there is no documentation available regarding the product development process. The company received minor funding and received support and demonstration plots from the University of Lilongwe. Challenges faced include the lack of subsidies, the stigma associated with using urine as fertiliser, and limited production resources. The procurement of raw materials and the required technologies are locally available and straightforward, with a repayment period of 10 years. In some cases, the raw material is also directly resold. Demand outstrips supply, and production costs remain low, encompassing labour, maintenance of harvesting and processing facilities, packaging, as well as storage and transport of raw materials and the final product. These costs are potential risk factors. The net return on investment is 40%, and the company maintains records of costs and sales.
- Various small-scale initiatives are emerging, including a developing company named Almena. An individual with a plot of land is using locally available resources such as maize husks, ashes, chicken manure, and human urine collected from the neighbourhood to produce 20 bags, each weighing 50 kilograms during the first season. The application of these organic materials has demonstrated a positive impact on crop growth. To scale up the business and produce 200 bags, the individual anticipates rising prices for the raw materials. Other producers are already selling 50kg bags for prices ranging between USD 2 and 3.
- Another approach involves utilising kitchen waste, garden greens, greens harvested from the surrounding forest, and residues from mushroom production to create liquid organic fertiliser through a 14-day fermentation process. This organic fertiliser is then packaged in bottles for sale. The liquid waste from this process is also used for producing compost. The success of demonstration plots has motivated approximately 500 neighbouring farmers to purchase the product, leading to increasing demand. Currently, the production capacity stands at 1 000 litres every three months, with a cost of USD 1.70 per litre, covering one hectare of land. A challenge faced is securing capital for purchasing materials, especially when demand is high. The workforce

consists of two employees for production and three marketers who work on commission (earning USD 20 per month per person). The next steps include certification, collaboration with researchers, and advertising through radio, which is a cost-effective means of promotion.

- Several rhizobia products are available in the market, originating from countries like India, Brazil, and some European nations. Assessing their quality can be challenging. Advisory services collaborate with the International Institute of Tropical Agriculture (IITA) to promote Rhizobia usage. The recommended application rate is approximately 300 grams per hectare, costing around EUR 3 (equivalent to an application rate of 50 grams per 10 kilograms of seed). This has shown positive effects on soils and legume yields, obviating the need for mineral fertilisers for legumes. The private sector is scaling up production with standardised products. For example, Agri Input Supply produces between 300 000 to 500 000 50-gram bags of inoculants annually, with a capacity for up to 1 million 50-gram bags per year. Three other young companies are also contributing to meet the rising demand. This demand has been steadily growing since the inception of a pioneer company in 2014. The technology for these products was initially sourced from international research institutes like IITA, with collaboration from the Department of Agricultural Research in Malawi. Peat serves as the carrier material, with technology contributions from India, Asia, and Europe. The cost is relatively high due to brokerage fees. There is also internal quality control in place. Liquid formulations have a shelf life of 1 to 2 years, while solid formulations last 6 to 12 months. Extending shelf life through a cooling chain is possible but not economically viable, which limits access for people.
- Additionally, new products are entering the market, including seaweed blends enriched with trace elements like iron, designed for foliar feeding of crops. These products serve as growth inducers, enhancing nutrient absorption from the soil. This is a departure from traditional inoculants, which primarily focus on nitrogen fixation and conversion from the air, resulting in residual nitrogen in the soil. In contrast, these boosters work to solubilise nutrients like phosphorus and potassium, making them readily available for crop uptake. The synergy comes from using a combination of both approaches. Employing such a combination yields superior results as one product releases nutrients while the other supports their uptake.

Research

The Department of Agricultural Research Services and the Department of Land Resources Conservation are organising trials to test organic fertilisers, such as Mbeya fertilisers, which are blends of organic materials. Interestingly, the renowned Lilongwe University does not offer a subject focused on the off-farm production of organic fertilisers and biofertilisers, despite covering topics related to on-farm production and soil fertility management in its curriculum.

Regarding Rhizobia, Japanese researchers from the University of Kyoto have played a pivotal role in ensuring product quality through their support. Additionally, Malawi's Agriculture Research and Extension Trust has made substantial contributions to this effort. The valuable insights obtained from their research findings are integrated into product labels to provide essential information to users. Collaborative efforts with IITA have been concentrated on promoting the use of Rhizobia as legume inoculants. The difference in crop production between fields treated with inoculants and those without is quite striking, underscoring the significant untapped potential in this area.

In a different context, many off-farm organic fertiliser initiatives have encountered challenges during national quality testing, particularly regarding nutrient levels, resulting in product rejections. In response, several companies are now blending their organic products with chemical fertilisers to enhance the likelihood of passing nutrient tests. However, prioritising the safety of its members, the Malawi Organic Growers Association (MOGA) conducts chemical residue testing on samples of organic fertilisers and biofertilisers. Regrettably, a significant portion of these products has been found unsuitable for use as organic fertilisers or biofertilisers. As a farmer association primarily serving organic producers, MOGA has not yet assessed the implications of combining chemical fertilisers with off-farm organic fertilisers.

Despite these challenges, a few farmers have taken matters into their own hands, purchasing biofertilisers from the market or importing them from countries like Zimbabwe and South Africa. These products are used to supplement on-farm produced organic fertilisers or for further processing.

At present, there is a noticeable gap in documented literature regarding the current status of off-farm produced organic fertilisers and biofertilisers in Malawi. However, their adoption could significantly enhance crop yields, particularly in light of the significant shortage resulting from the limited supply of chemical fertilisers. Moreover, there is a lack of dedicated research on the production of organic fertilisers and biofertilisers in the region. A comprehensive assessment of the utilisation of off-farm organic fertilisers and biofertilisers is yet to be conducted, and it may present challenges due to their complementary nature with on-farm organic fertilisers. Nonetheless, some observations have yielded promising results. When applied alongside on-farm soil amendments, the combination of off-farm organic fertilisers and biofertilisers has demonstrated positive impacts, including soil regeneration, reduced erosion, alterations in soil properties, and increased levels of microorganisms.

Economy and market

The production of organic fertilisers and biofertilisers is economically viable because the raw materials are readily available locally. However, in some cases, these resources (especially mineral deposits) are highly regulated or protected. The few companies engaged in production offer their products at prices significantly lower than mineral fertilisers. Nevertheless, they face the challenge of limited production capacity to meet the growing demand. At present, there are no subsidies in place for off-farm OFBF, with farmers primarily benefiting from project-based initiatives.

In case of Rhizobia, market directly to farmers for first-hand information and feedback, but also engage with retailers to expand the customer base, even though this may lead to some loss of information tracking. Collaboration with research institutions is essential. However, maintaining the quality of Rhizobia until it reaches communities and farmers can be a concern if supply chain management, including proper cooling, is not effectively ensured.

Successful Rhizobia application typically results in a reduced need for other fertilisers, with nitrogen top dressing being the primary addition. The yield increase attributed to Rhizobia is estimated to be around 40%, but this outcome is closely tied to the implementation of good agricultural practices. Economically, the viability of Rhizobia inoculants remains strong when considering their cost and the per-hectare requirement. To cover one hectare, approximately 5 to 6 packs of 50 grams are needed, with each pack priced at around 2.500 Malawi Kwacha (equivalent to about EUR 2.30 as of March 2023).

The introduction of using human urine as fertiliser for edible crops faced significant challenges due to prevailing social values and taboos, leading to stigma and resistance to adoption. Unlike subsidised chemical fertilisers, this product did not benefit from subsidies, making its market entry more difficult. The initial capital acquisition was also a challenge, as the founder relied on personal resources, resulting in gradual growth for the initiative. Currently, the company relies exclusively on direct sales and lacks alternative distribution channels, although plans for the future are in place. While initial marketing faced resistance, engagement with farmer organisations played a crucial role in increasing adoption among their members. The demand for the product has grown, but the existing facilities are insufficient to meet this demand. Additionally, 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. The initiative has received valuable support across various domains. Production costs consistently remain lower than sales, typically resulting in a 40% return on investment for the business. These cost centres include labour expenses, maintenance of harvesting and processing facilities, packaging, storage, and transport of both raw materials and the final product. Notably, transport costs for both inputs and finished goods are pivotal in ensuring profitability. The company diligently maintains comprehensive records of both costs and sales.

Knowledge, education and training

The government is actively promoting the use of organic manure and compost, such as Mbeya manure, and encouraging the planting of fertiliser trees alongside crops. Additionally, farmers are being urged to diversify their crop production beyond maize and explore other options like legumes. Field demonstrations, radio advertisements, and flyers have proven to be the most effective means of promoting these initiatives. Training of agro-dealers is crucial, given the frequent turnover in personnel. Community-based demonstration trials have shown significant adoption rates, such as with Rhizobia among farmers. The University of Lilongwe has been instrumental by providing demonstration plots to showcase these technologies, particularly for Bionitrate, during annual open day events.

Policy, regulations and certification

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. The policy strongly recommends the utilisation of organic agricultural value chain wastes and green waste as primary sources of organic fertilisers. The government's guidance is to use organic fertilisers without mixing them with mineral fertilisers. Currently, while the government discusses organic agriculture, there seems to be some lack of clarity regarding its purity, as they simultaneously mention the use of chemical fertilisers alongside Mbeya organic fertilisers.

There are existing general regulations for mineral resources exploitation in the country which are not exclusive to mineral fertilisers production. Regulatory frameworks on mineral fertilisers do exist with the National Fertiliser Policy and Act overarching. Generally, there is no clear linked disaster risk management and policies but in response to Covid-19 extra fertiliser donation was received by the government toward smallholder farmers and in response to the Russia-Ukraine war fertiliser crises, the government did put in place Agriculture Emergency Food Production Project, having realised that the crises have a negative impact on food security. There is no clear strategy to deal with fertiliser shortages beyond subsidies.

In 2023, the government of Malawi introduced an organic fertiliser policy, accompanied by the establishment of a regulatory framework for standardising production. This milestone is indeed a commendable accomplishment. There are no direct regulations on OFBF importation although it is envisaged that the fertiliser bill that is soon to be enacted would be of help to the situation. There are no OFBF subsidies to either producers or farmers.

The support for the industrial production of OFBF lacks clarity, even though the National Fertiliser Policy of 2021 encourages the expansion of production, marketing, and use of both high-quality inorganic and organic fertilisers.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology

Currently, the discussion does not necessarily revolve around replacing mineral fertilisers with organic and farm-based fertilisers. Instead, the focus is on complementing the two approaches. This means working towards reducing the reliance on inorganic fertilisers. In soils with good nutrient levels, there's more potential to reduce the use of inorganic fertilisers compared to poorly managed soils. Ideally, both methods should work together. However, in situations where challenges like accessibility or costs arise with inorganic fertilisers, farmers should still be able to achieve production using organic fertilisers alone.

While the use of OFBF is expected to increase, it's not anticipated to completely replace mineral fertilisers but rather to supplement them. The lack of raw materials poses a significant barrier to the production and use of off-farm produced organic fertilisers and biofertilisers, as these materials are needed in large quantities. To scale up production and meet the growing demand, resources and raw materials must be secured. The primary challenge in the production and use of organic fertiliser and biofertiliser is the limited capacity to rapidly meet national demand, primarily due to the absence of mechanisation.

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. The increase in livestock numbers will result in the increased production of dry faecal matter, which contributes to organic waste. Additionally, crop production has been steadily increasing each year, leading to more crop residues, which will also contribute to organic waste. Therefore, there is an urgent need for farmers to transition towards using on-farm organic fertilisers.

Organic fertiliser companies should develop crop-specific products that cater to the individual nutrient requirements of different crops. Instead of offering a one-size-fits-all product, they should focus on tailoring their offerings to meet the specific needs of each crop.

Taking Bionitrate as an example, applying the liquid Bionitrate organic fertiliser has proven challenging for farmers, as some have resorted to using cups for application. Farmers are more accustomed to using granulated products. In response, the Environmental Industries Company is currently in the process of planning an investment in a granulating machine. This machine will be used to convert Bionitrate organic fertiliser into a granulated form, which can then be blended with other organic raw materials to create a granulated product. This product will be made available alongside the liquid Bionitrate organic fertiliser for sale to farmers.

Research

The positive impact of organic fertilisers is clearly visible, but for a comprehensive understanding of its effects, an extended observation period is recommended. It's crucial to assess the cumulative impact of long-term application on microorganisms and pH levels. Therefore, it's advisable to establish an annual OFBF impact assessment programme. Assisting producers in documenting product contents and displaying them on labels is essential. To ensure quality, research stations should be engaged to conduct random sample testing.

The long-term environmental and ecosystem effects of organic fertilisers and biofertilisers are not fully understood and require assessment. To achieve this, there's a need for standardisation and the development of an assessment framework. Universities and researchers are well-suited for this important task.

Enhancing collaboration between researchers and OFBF companies is essential for collectively addressing challenges and allowing researchers to propose methods for quality improvement. Unfortunately, there is currently a lack of dedicated funding for research in the field of OFBF.

Economy and market

The private sector should take proactive initiatives in producing off-farm organic fertilisers and biofertilisers while ensuring sustainable financing. Currently, some initiatives rely on donor funding and are tied to specific programmes, which can lead to challenges in sustainability once the programme concludes. Future of OFBF is stabilising the domestic market and based on that exporting toward Zambia, Mozambique, and Tanzania. The market holds great potential for these products, provided that they maintain high standards of quality.

Using Bionitrate as an example, a substantial allocation of resources is essential to further elevate awareness levels. Collaborative efforts with government extension services are also crucial to imparting knowledge to farmers about the proper application of Bionitrate organic fertiliser. The impact of expansion and growth necessitates significant capital investment, which would notably mitigate production and distribution expenses. However, the company currently lacks the necessary capital and collateral for borrowing. As a solution, the company has placed a strong emphasis on engaging potential investors to facilitate this crucial endeavour.

Knowledge, education and training

Companies producing OFBF should deepen their collaboration with farmer organisations like MOGA so that, together, they can involve farmers in farmer participatory research to attain the desired product quality. By working together, they can involve farmers in farmer participatory research, leading to the achievement of desired product quality. Crop-specific organic fertilisers, as well as rhizobia, are necessary.

To increase the adoption of OFBF, more education, awareness-raising, demonstrations across the country, product promotions (e.g., via radio), and research are required. Greater education is necessary to enhance the adoption of off-farm OFBF. A country strategy for organic fertiliser and biofertiliser production, along with educational efforts, is essential to ensure that all stakeholders have a shared understanding and approach in this domain.

Multistakeholder engagement and synergies are essential, particularly when it comes to sourcing inputs (such as organic waste) and managing the resulting waste. The critical question lies in how we substantiate the effectiveness of technologies like inoculants for crop production. This is the juncture where the need for promotion becomes paramount. One viable avenue is conducting community-level demonstrations, enabling all farmers to witness the tangible outcomes of the given technology.

Promoting awareness of certified OFBF would greatly benefit those interested in transitioning to organic practices, without jeopardising farmers' organic product certification.

Policy, regulations and certification

In Malawi, the Affordable Input programme currently includes inorganic fertilisers through a subsidy initiative. Expanding this programme to encompass items such as inoculants could result in a comprehensive package that includes seeds, inoculants and other essential fertilisers. Government departments are distributed throughout the country, providing the infrastructure for promotional activities. However, the challenge lies in procuring the necessary materials that would facilitate these organised promotions. Ensuring the availability of these materials is pivotal to encourage widespread adoption among farmers.

Malawi has significant untapped potential for the adoption and utilisation of bio and organic fertilisers. To harness this potential, the government should focus on developing robust policies and a regulatory framework to ensure quality control and proper application rates. Overall, there is a need for policies that are more closely aligned with disaster risk management strategies and the country's overarching policies.

Achieving the goal of replacing mineral fertilisers with organic fertilisers or biofertilisers in Malawi relies on a proactive approach, increased production by companies, and heightened awareness efforts. Through these measures, the substitution of chemical fertilisers becomes feasible. Political commitment plays a pivotal role in making this transition possible. The fertiliser policy must acknowledge organic fertiliser companies, ensuring their registration and taxation while providing incentives for duty-free equipment imports. Legislation should be established to evaluate OFBF companies, accompanied by accessible quality analysis data. The Malawi Bureau of Standards should formulate a supportive standard for quality assessment purposes. The regulatory framework should encompass measures to enhance accessibility to organic fertilisers, including establishing companies across various regions with allocated funds to support research in organic fertiliser and biofertiliser domains.

It is anticipated that there will be more investment in industrial fertiliser production than in on-farm internal activities, even though it's important to strengthen on-farm organic manure production.

Current production and uptake would be enhanced if investors come on board and invitation of investors is on the cards now in an endeavour to expand production and marketing of, e.g., Bionitrate organic fertiliser. Government support with subsidies would go a long way in improving marketing. With government support it is envisaged that mineral fertiliser will be outcompeted by Bionitrate organic fertiliser. The expansion of the project might be hindered by government policies that are not supportive, for instance the subsidies that only support chemical inputs. However, it is hoped that the legislative framework put for standardisation will go a long way to help in upscaling production and marketing. On another note, quality of the product may be weakened by collection and processing in unhygienic conditions, and this boils down to the need to erect proper technology.

There is a pressing need for a comprehensive policy and regulatory framework to control quality, including hygienic measures, and establish application rates. The Malawi Bureau of Standards plans to address this in 2023. This framework should cover both organic and inorganic farming. Additionally, the registration of organic fertiliser producers, the development of a country strategy for organic fertiliser and biofertiliser production, and educational initiatives are essential.

Private sector financing, including affordable capital, and equal subsidies compared to mineral fertilisers should be considered for sustainable growth. An efficient fertiliser application strategy should be based on an overall approach to increase soil fertility, which can be monitored through soil testing.

Solutions are required for transport, including temperature control for rhizobia, extending shelf life, and ensuring quality control. Distribution systems, both to local shops and fields with precise application technology, should be developed. Government departments across the country can play a crucial role in this process.

Incorporating an evaluation of the effects of OFBF on soils within the legislative framework is vital for the organic sector's growth. Harmonising and standardising organic fertiliser production will boost end-user confidence. Furthermore, the certification of organic fertilisers and biofertilisers would enhance the professionalism of the industry.

To summarise, the pivotal catalysts for augmenting the production and utilisation of OFBF in Malawi include: strong government commitment; comprehensive awareness campaigns; government backing for organic fertiliser and biofertiliser producers; standardisation of both organic fertilisers and biofertilisers.

8.2.9 Rwanda

I Status quo

Mineral fertilisers

Currently, a significant portion of mineral fertilisers is sourced from Russia. However, the ongoing war situation has disrupted the availability of fertilisers, resulting in escalated prices. In response to this, the Rwandese Government has stepped in by providing subsidies for mineral fertilisers.

Since 2007, there has been a consistent upward trajectory in the importation of mineral fertilisers in Rwanda. The Rwanda Bureau of Standards plays a pivotal role in determining which fertilisers are allowed into the country and which are prohibited. In Rwanda, fertiliser standards from the FDA, the Rwanda Bureau of Standards, the Food and Drug Agency of Rwanda, and guidelines from the Rwanda Agriculture and Animal Resource Development Board all apply.

The consequences of the conflict have negatively impacted accessibility, subsequently affecting production. As a result, crucial crops such as potatoes, maize, beans, soya beans, and bananas have been provided with free fertilisers. Despite the ongoing crisis casting a shadow over overall food production, the government has implemented measures to safeguard the cultivation of strategic crops. Government-led initiatives continue to provide support to farmers, and donor-backed programmes contribute to the availability of mineral fertilisers. These government initiatives and projects consistently assist farmers, occasionally supplying them with free fertilisers for vital crops. During crises, donors have stepped in to provide the government with free fertilisers to aid farmers.

The Nkunganire system is a digitised management approach for Rwanda's agricultural input subsidy programme, jointly administered by the Rwanda Agriculture Board (RAB) in collaboration with BK TecHouse. Subsidies for fertilisers vary depending on the type of crop, with government contributions ranging from 30% to 75%. Higher subsidies are directed towards strategic crops. The government plays a significant role in enhancing the accessibility and availability of mineral fertilisers. Considerable investments have been made in training farmers and providing support for the efficient use of fertilisers across various crops, thereby promoting commercial crop growth. This proactive approach has led to an increased demand for fertilisers among farmers.

The market for mineral fertilisers is notably accessible, with products even available in local villages. Additionally, certain government schemes directly supply farmers. Initially, the affordability of fertilisers was maintained through government subsidies. However, due to rising costs, these subsidies have been reduced, impacting both fertiliser demand and application. These combined factors have had a negative impact on food production. Currently, in Rwanda, chemical fertiliser market prices stand at EUR 70 per 100 kg for NPK. Additional fertilisers are available, including DAP (diammonium phosphate) priced at EUR 65 and Urea ranging from EUR 31 to 47 per 100 kg. However, farmers participating in the Nkunganire system benefit from contract farming. Under this system, they gain access to these chemical fertilisers through loans or at significantly reduced rates, with deferred payment until after the harvest.

In response to the crisis, Rwanda has partnered with Morocco to establish its own phosphate fertiliser manufacturing plant. Additionally, the government has made strategic investments in harnessing methane for Urea production. There has been a substantial commitment to farmer training as well. Typically, mineral fertiliser application adheres to recommended rates based on specific crop needs, although the mechanisation of application is not widespread. Additionally, the government has constructed a sizable warehouse in Dar es Salaam, designed for dual fertiliser imports, allowing storage for up to two seasons in advance. This strategic move helps mitigate potential disruptions in the importation process, ensuring sustained availability within the country. Furthermore, it serves as a means to reduce the likelihood of price increases.

However, there is also critical discourse surrounding traditional chemical fertilisers. It's worth noting that these fertilisers often contain elevated levels of cadmium and environmentally degrading phosphorus. Critics argue that mineral fertilisers are not ecologically sustainable because they provide limited support for soil self-regeneration and may potentially harm microorganisms. Furthermore, it's worth noting that agricultural extension personnel often lack sufficient training, and farmers across different agro-ecological zones, each with varying rainfall patterns and soil types, tend to receive standardised recommendations for fertiliser use.

Farm internal organic fertilisers

Farmers are accustomed to using compost derived from household waste and often combine it with mineral fertilisers. Given the high cation exchange capacity of many soils, adding organic matter is considered essential. In some cases, smallholder farmers have limited access to organic fertilisers, which they mix with mineral fertilisers. Farmers possess a good understanding of organic fertilisers, their application, and their importance, despite these fertilisers being primarily homemade or traditional composts. Locally, they refer to them as "imborera" or "ibishingwe," with the latter term denoting household waste. During conversations with farmers, they frequently emphasise that they would never consider planting crops without applying organic fertilisers (imborera). In their view, a harvest cannot be expected without using imborera in addition to NPK or DAP (chemical fertilisers). Their typical approach involves applying compost first and then NPK later.

The Russia-Ukraine war has prompted farmers to think more creatively and has increased the demand for OFBF. Training programmes on the production and utilisation of organic fertilisers, particularly compost, have led to an upsurge in demand for organic fertilisers and biofertilisers over the past two years. Interestingly, due to a government training initiative focused on compost production, smallholder farmers are now producing substantial volumes of compost. However, instead of using the compost on their fields, many prefer to sell it to companies and larger farms to generate income. They then rely on government-subsidised mineral fertilisers for their own agricultural needs.

Off-farm organic fertilisers and biofertilisers

Production and technology

In Rwanda, approximately 80% of the population relies on biomass. There are very few established organic fertiliser companies. Those organic fertilisers on the market undergo rigorous testing, including pilot tests, before being released. The quality is high and has a positive impact on both soil fertility and yields, sometimes even surpassing the results achieved with mineral fertilisers. Over the last two years, there has been a noticeable increase in small enterprises producing organic fertilisers. As a result, farmers now have access to well-packaged organic fertilisers and biofertilisers in the market.

Rwanda has 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. Notably, 70% of this waste is organic in nature. Waste collection services are awarded through tenders by either the City of Kigali or district authorities, depending on the location. Private waste collectors typically either use the collected waste to produce OFBF themselves or deposit the waste at designated dumpsites where producers can purchase the materials for organic fertiliser production.

The Rwandan government has made substantial investments in waste management, continually striving to minimise waste and develop a robust circular economy. Waste collectors are selected through tenders, and while the practice of waste separation at the source is gradually gaining ground, it is not yet universally adopted. Efforts are underway to encourage and build capacity for waste separation over time. Waste collection is carried out on a weekly basis.

The available organic fertilisers and biofertilisers fall short of meeting market demands. Private organic producers, especially those catering to export markets, often procure waste materials from waste management companies. The primary challenge is the quality of household waste, which is typically not separated at the source, necessitating manual sorting and increasing the workload. Another significant obstacle is the lack of appropriate technological equipment for waste sorting, storage, and delivery, particularly specialised equipment required for organic fertiliser production, often necessitating imports. Competition for raw materials is another challenge, as livestock and other users also vie for organic matter. Production of organic fertiliser necessitates specialised equipment that must be imported. Additionally, there has been an enduring debate regarding the use of faecal matter as a raw material for organic fertiliser. While technically feasible, cultural and social norms have hindered the utilisation of this type of raw material. Collaborative discussions and strategies are needed to address competition for suitable raw materials for organic fertiliser production. Efficient waste separation remains a formidable challenge, resulting in lower-quality organic raw materials. For instance, out of 20 tons of household waste collected, only 2 tons may be suitable for compost production.

While the number of established organic fertiliser companies is limited, their products undergo rigorous testing before entering the market. The quality is generally considered good, with these fertilisers consistently enhancing soil fertility and crop yields. In some cases, yields have even surpassed those achieved with mineral fertilisers. Many farmers express a special interest in establishing their own organic factories. Some cooperatives that use organic fertilisers have achieved notable success in coffee and tea production. Most farmers who purchase off-farm produced organic fertilisers and biofertilisers are engaged in certified organic production for export. These cooperatives have observed increased productivity.

The primary goal of applying organic fertilisers on farms is to improve crop quality rather than quantity. This approach is favoured despite the drawbacks associated with chemical fertiliser applications, such as soil degradation, acidification, and nutrient depletion. There is a widespread understanding of the relevance of organic fertilisers for soil health and sustainable yields. However, there is also the opinion that relying solely on organic farming systems with the application of organic or even biofertilisers would not meet the food production needs of the population.

Many farmers still practice conventional farming and use mineral fertilisers, although a few organisations are now promoting organic agriculture. Organic agriculture is a relatively new concept, as historically, farmers would refer to mineral fertilisers when discussing fertilisers. Farmers are accepting off-farm produced organic fertilisers and biofertilisers, especially those engaged in certified organic production. Availability remains a challenge, particularly for those participating in strict organic markets.

Organic production currently encompasses certified organic products for export markets, including coffee, tea, essential oils from various herbs, pineapples, and pyrethrum (used in organic pesticides). For the local market, organic products include beans, bananas, Irish potatoes, vegetables, cassava, some fruits, and limited maize, which is government-supported. Farmers and farmer groups have reported improved yields when using biofertilisers and organic fertilisers. Switching from home-made composts to off-farm produced OFBF has resulted in significant crop yield increases, along with better crop health when transitioning from mineral fertilisers to organic fertilisers and biofertilisers.

The success factors of off-farm produced organic fertilisers and biofertilisers include ease of application, environmental safety (non-harmful to people, animals, and microorganisms), and the capacity to increase yields, sometimes surpassing mineral fertilisers. The combination of organic and mineral fertilisers can be used during a transition period, but it is not recommended when a farmer is growing for the organic market. The recommendation is to use organic and mineral fertilisers separately because mineral fertilisers do not support the life of microorganisms, whereas organic fertilisers and biofertilisers do. However, off-farm produced organic fertilisers and biofertilisers can be combined.

Research

The government has initiated support for OFBF research. Researchers have conducted tests on products and run trials, but a systematic research programme is lacking. The high cost of soil and product analysis presents a barrier to developing an appropriate fertiliser strategy. Producers are connected with researchers to ensure compliance with all specified standards, and these researchers conduct tests on the product and carry out trials.

In Rwanda, the Rwanda Agriculture Board (RAB) and the Institute of Agriculture, Animal Husbandry, and Environment Management (ISAE) are the main research institutions with expertise in soil and fertiliser analyses. However, their services can be expensive.

Economy and market

Currently, the government does not provide subsidies for organic fertilisers. It is argued that organic fertilisers are ultimately more expensive than mineral fertilisers , making them affordable for only certain farmers, particularly those engaged in export crops. This poses a challenge for subsistence farmers, who predominantly rely on on-farm organic fertilisers. Off-farm produced organic fertilisers and biofertilisers are becoming more expensive than mineral fertilisers, primarily because the latter are subsidised.

Key barriers to the widespread adoption of off-farm produced 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 lead by ETH Zurich in cooperation with CGIAR in Rwanda). In contrast to mineral fertilisers, the production of organic fertiliser and biofertiliser is often more expensive. Moreover, organic products themselves tend to have higher price tags (when certified). The primary cost and investment factors associated with the production of organic fertilisers and biofertilisers are related to labour, including waste sorting, production, and delivery, all of which significantly contribute to the overall product cost.

The financial instruments that already exist target bigger projects and are very competitive. Despite financial limitations, efforts are ongoing to develop new solutions. For example, REMA and FONERWA collaborate on seed capital provisions to support specific initiatives. The main costs and investments revolve around labour, production, and delivery.

Knowledge, education and training

Farmers, in general, have an awareness of organic fertilisers, and many presently employ them in conjunction with mineral fertilisers. Nevertheless, some farmers also market their organic fertilisers to larger companies. The government has launched an awareness campaign to educate smallholder farmers about the significance of utilising their composts instead of selling them. This campaign also promotes the establishment of compost-making cooperatives at the village level, with a specific emphasis on assisting rural youths in entering the OFBF production sector through grants. The Rwanda Agriculture Board (RAB) 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. To date, approximately 14 villages have received training, with three to five certified compost producers in each village. However, the primary barrier to wider adoption is that smallholder farmers often prefer to sell their compost for immediate income, rather than using it for farming. Lack of knowledge remains a significant challenge, which is why the government is prioritising capacity-building programmes.

Organic fertilisers are also part of the curriculum at the University, where students are taught about their benefits. Given the weathered and nutrient-depleted nature of tropical soils, organic matter is crucial for improving soil retention capacity. International organisations like the FAO recommend the use of products with high organic matter content for farmers in tropical regions, like Rwanda.

Radio Huguka, covering 60% of Rwanda, plays a crucial role in disseminating extension messages to farmers and facilitating feedback from producers. Based in the Southern Province of Rwanda, Radio Huguka is a community radio station primarily dedicated to agricultural extension and rural development. It specialises in providing extension services through community radio, actively promoting organic fertilisers and biofertilisers as part of the broader initiative to advance Ecological Organic Agriculture. Although Radio Huguka does not offer direct training, it collaborates closely with organic and biofertiliser producers and farmers, using its broadcasts to share valuable information about these agricultural practices within the context of the Ecological Organic Agriculture initiative.

In the past five years, there has been a growing interest in organic agriculture, leading to various organisations, including the Ministry of Agriculture and Mineral Resources, initiating training programmes for farmers in the production and application of on-farm compost. The government has also implemented capacity-building programmes to educate farmers about the advantages of producing and using organic manure. Nevertheless, there remains a significant knowledge gap regarding organic production within the public domain, and agricultural education does not adequately address this issue. This gap presents challenges in providing effective support to farmers in the realm of organic agriculture.

Literature on organic agriculture is available through the Rwanda Organic Agriculture Movement (ROAM), serving as the primary source of this information. Interested parties can access this literature through ROAM. ROAM's approach does not endorse the use of mineral fertilisers by farmers. Instead, they provide training to their members, encouraging them to explore alternative solutions and embrace sustainable agricultural practices such as crop rotation, intercropping and agroforestry. Their training programmes also emphasise teaching members how to produce organic fertilisers, like compost, using indigenous plants readily available on their farms or in nearby areas. Furthermore, data collection was conducted last year to assess how farmers have adopted ecological organic practices, as part of the Ecological Organic Agriculture (EOA) project. The EOA initiative aligns with the African Union's 2012 Decision on Organic Farming (Doc. EX.CL/631 (XVIII)).

Rwanda BioSolution, another NGO, collaborates with smallholder farmers and cooperatives, currently serving six cooperatives and around 100 farmers. Most smallholder farmers primarily engage in subsistence, non-commercial agriculture. However, the cooperatives they partner with operate commercial farms.

Policy, regulations and certification

The Ministry of Agriculture in Rwanda has established a national agriculture policy, which includes provisions for both organic and mineral fertilisers. Additionally, there is a strategic plan for agricultural transformation, phase four, which encompasses organic fertilisers and mineral fertilisers. However, specific regulations for mineral fertiliser production are not yet in place, especially considering that mineral fertiliser manufacturing has not commenced within Rwanda. Nevertheless, there are existing regulations for mineral exploitation in the country.

It's crucial to emphasise that Rwanda presently lacks an organic agriculture policy, resulting in a disparity in the level of support and attention that organic fertilisers and biofertilisers receive from policy makers when compared to mineral fertilisers. This absence of a supportive policy framework presents significant challenges for the production and marketing of OFBF. The existing national policies for fertilisers remain somewhat limited in scope. For instance, the national fertilisers policy clearly promotes the use of both inorganic and organic fertilisers. It provides clear guidelines and practical recommendations for inorganic fertilisers, including subsidies. However, when it comes to organic fertilisers, there is a lack of detailed clarifications. Furthermore, regulations are not yet in place, especially considering that mineral fertiliser manufacturing has not yet commenced in Rwanda. Nevertheless, regulations for mineral exploitation in general do exist.

In the realm of organic fertilisers, the government's strategy primarily centres on enhancing quality through research aimed at identifying potential raw materials and strengthening farmers' capacity in both production and application. Ongoing discussions revolve around budget allocation to incorporate organic fertilisers and biofertilisers into the existing fertiliser subsidies, which, at present, exclusively cover mineral fertilisers.

To aid OFBF producers, the Government of Rwanda offers tax exemptions on equipment and packaging materials, which facilitates their startup. However, it's crucial to note that Rwanda currently lacks an established waste sorting regulation or system. Consequently, organic fertiliser producers have yet to receive government support for their commercial production endeavours.

The importation of OFBF is not as extensive as that of mineral fertilisers, but there are companies importing OFBF alongside mineral fertilisers. Import licenses are mandatory for these imports. Similar to mineral fertilisers, there are regulations governing imports, requiring testing before entry into the country and conducting trials before distribution is permitted. The regulations include criteria for importers, and importers are typically selected through a public tender process. Generally, there are up to six companies eligible for fertiliser importation in Rwanda. Importation of OFBF, while not as prevalent as mineral fertilisers, is undertaken by some companies alongside mineral fertilisers. Import licenses are necessary for this purpose as well. Like mineral fertilisers, there are regulations governing these imports, including safety testing before entry into the country. Additionally, pilot runs are conducted for new fertilisers to assess their performance before they are supplied to retailers and farmers.

There are research inquiries regarding the potential production of organic fertilisers from human waste (see Ecosan) in Rwanda. However, it is likely that the local government has prohibited the use of these fertiliser sources. While some local farmers may occasionally utilise them, there is minimal to no existing research on off-farm fertiliser production from these sources, and there is no definitive answer regarding government approval.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology: -

Research

There is a need for increased investment in research and development for organic fertilisers and biofertilisers. Much of the current research information has been generated long ago and often outside of Africa. More knowledge regarding efficient production technology that is both easy to implement and enhances production while reducing the cost of OFBF is essential. Through further research, it may be possible to combine all types of fertilisers (organic, mineral, and farm internal organic fertiliser) for optimal results.

Economy and market

The development of the circular economy strategy, which aims to minimise Rwanda's carbon emissions by 2050, is expected to have a significant positive impact on OFBF production. The Rwanda Green Growth and Climate Change Strategy is another influential factor that will drive the growth of organic fertilisers and biofertilisers. There is substantial potential for increased adoption of organic fertilisers and biofertilisers if production scales up and prices become more affordable. Implementing supportive policies for the production of high-quality OFBF, along with subsidies for these products, is imperative.

To further the development of organic farming, it is essential to support Participatory Guarantee Systems (PGS). Supporting local organic guarantee schemes will also bolster the utilisation of OFBF, even in the local market, as consumers show a strong desire for locally-produced organic products. The government's recognition of organic fertilisers and biofertilisers as viable alternatives, particularly in the context of rising mineral fertiliser prices due to the Russia/Ukraine conflict, adds further weight to their importance.

Knowledge, education and training

To empower farmers in making informed decisions regarding their fertiliser choices, there is a need to invest in training and enhance knowledge about efficient production techniques. Simplifying production methods can increase output and reduce the cost of OFBF. The government should also continue its efforts to train farmers in household-level compost production. Raising awareness about the benefits of OFBF and providing guidance on their proper use is essential, and utilising social media and radio can be valuable components of the marketing strategy.

The government's encouragement of agriculture extension workers to train farmers in compost production and its support for farmers in addressing acidic soils with lime are commendable initiatives. Rwanda's government is committed to ongoing training for farmers in household compost production. In the short term, the government aims to build the capacity of farmers and various user groups.

Policy, regulations and certification

The government acknowledges OFBF as a viable alternative, particularly in light of rising mineral fertiliser prices due to the Russia/Ukraine war. Consequently, the government is encouraging agricultural extension workers to educate farmers on compost production and is also assisting farmers with lime to rectify acidic soils. Anticipated is the continued growth in demand for compost and organic fertilisers. Developing supportive policies is essential since mineral fertilisers are more potent and intricate than organic fertilisers. ROAM is advocating for the government to include organic inputs in subsidies to make them more affordable for farmers. There is considerable potential for off-farm produced OFBF if production capacity increases (with more producers) and prices become more farmer-friendly.

In the medium term, the government is committing to waste management initiatives. Providing grants to support organic fertiliser companies will boost production, and the availability of organic waste should increase with the refinement of the circular economy strategy. An increase in the volume of waste materials is foreseen. The only challenge lies in securing sufficient capital to establish compost-making businesses. Local organic fertiliser production is bridging the gap created by the shortage of mineral fertilisers, and the demand for compost and organic fertilisers continues to rise.

8.2.10 Senegal

I Status quo

Mineral fertiliser

In Senegal, the fertiliser situation presents several notable trends and challenges that have significant implications for farmers. One of the central issues is a shortage of fertilisers, a problem exacerbated by high and increasingly unaffordable prices of mineral fertilisers. Farmers have responded to this scarcity in three primary ways: some have shifted towards crops that require fewer fertilisers, others have resorted to localised production of fertilisers for personal use and sale, and policy makers have made public declarations about addressing the fertiliser scarcity, though practical actions sometimes fall short.

The root of the problem lies in the exorbitant prices of mineral fertilisers, which are driven up by the dominance of a few private entities in the fertiliser market. These high prices pose substantial challenges, particularly for small-scale farmers who struggle to afford them. For example, the cost of a 50 kg bag of NPK fertiliser has more than doubled, ranging from CFA 24 000 to 30 000 depending on the type. While a 50 kg bag of common NPK 15:15:15 fertiliser can cost around EUR 40, organic fertilisers cost around EUR 213/ton with NPK 1:1:1 and EUR 305/ton with NPK 4:3:3 (composted with chicken manure and fortified with phosphate). Liquid organic fertilisers are also available at a lower cost, making them an attractive option for farmers.

Moreover, the geographical concentration of fertilisers in the capital city, Dakar, further hinders accessibility for farmers in remote regions. This concentration leads to supply chain inefficiencies, making it difficult for those outside Dakar to secure an adequate supply.

Another concern is the inconsistent and haphazard application of fertilisers by farmers. Many rely on rough estimates and available resources rather than precise measurements, leading to potential overuse of fertilisers and environmental concerns. Interestingly, environmental priorities related to mineral fertiliser use are generally low among Senegalese farmers, with only around 5% expressing interest in such matters.

While the government offers partial subsidies for fertilisers, the availability of these subsidies varies seasonally and does not cover the full needs of farmers. Consequently, fertiliser sales have decreased, and some farmers tend to apply excessive amounts, surpassing their crops' actual requirements.

The environmental impact of suboptimal fertiliser use is a growing concern. Fertilisers are often spread without proper incorporation into the soil, leading to emissions into the atmosphere and potential contamination of the water table. To address these issues, there is a need for a multifaceted approach, including stricter regulation, improved oversight, and analysis of fertilisers to ensure they adhere to specified quantities and guidelines.

In response to the challenges posed by the scarcity and cost of chemical fertilisers, the Senegalese government has initiated subsidies for specific crops and, more recently, for organic fertilisers. However, it's still too early to determine the full impact of these subsidies, as they've only been in place for a short period and coincided with the onset of the Covid-19 pandemic and the fertiliser market crisis.

Geo-political events, such as the war in Ukraine, have further disrupted fertiliser imports, impacting local production. This has led to significant price increases, affecting farmers' purchasing power and overall production costs. While the government provides subsidies to certain groups and associations, such as winegrowing structures, these subsidies may not fully offset their costs. Non-subsidised urea, for instance, is even more expensive.

In light of these challenges, farmers are increasingly turning to organic fertilisers. Subsidies covering approximately 80% of the cost make organic fertilisers an attractive option (subsidies for organic fertilisers limited to a total of 10 000 t in 2022). However, there is still an inadequate supply to meet the growing demand, especially from organic farmers producing for export (mainly in the North of Senegal).

The transition from chemical to organic fertilisers is ongoing, but the challenge lies in striking a balance between immediate productivity needs and long-term environmental sustainability. While awareness of environmental concerns is growing among farmers, short-term productivity goals often take precedence.

It is important to recognise that the issue of fertiliser scarcity is complex, with varying perspectives and challenges faced by different types of farmers. However, there is a collective effort to promote sustainable agriculture practices and reduce dependency on chemical fertilisers. Ultimately, the goal is to empower farmers as entrepreneurs and promote self-sufficiency in agriculture, moving away from a model that relies heavily on chemical fertilisers and multinational corporations. This approach aligns with broader sustainability goals and addresses the challenges posed by fertiliser scarcity in Senegal.

Farm internal organic fertiliser

In Senegal, it is a common practice for farmers, who are often also livestock breeders, to utilise internal organic fertilisers. They raise animals like sheep and cows, and the waste generated by these animals is collected and returned to the fields. However, there is a prevalent issue where the waste is applied directly to crops without undergoing the composting phase, which could eliminate weed seeds and certain plant diseases. This composting phase is often overlooked, but organic manure is still used to improve soil quality. In some cases, farmers even purchase organic manure because the quantity generated by their animals is insufficient. The use of organic fertilisers is widespread among Senegalese farmers. The types of organic fertilisers vary, including those derived from animal waste, industrial production, and farmer self-production. Approximately 50% of Senegalese farmers employ organic fertilisers as a common practice.

Crop residues are partially used to feed animals, while the remainder is left in the field as organic fertiliser, although not to its full potential.

Many small-scale farmers in Senegal use a combination of organic and mineral fertilisers to manage their land. The availability of organic fertilisers on farms can be limited, as not all farmers have sufficient animals to produce enough manure. This shortage often leads them to resort to mineral fertilisers. While some farmers produce their compost, this can be resource-intensive and challenging.

In regions known for winter crops such as cereals and groundnuts, a unique and effective practice has emerged. During this season, farmers adopt a method where they permit animals to graze in their fields, a practice notably prevalent in the Kamba region. In this area, collaborations are established with seasonal herders from the north. These herders enter into agreements with farmers, allowing their animals to graze in the fields after the harvest, thereby contributing to soil fertilisation. As the rainy season approaches, the herders return to the north, leaving behind enriched fields.

These practices contribute significantly to farmers' stability. In the Niayes region, all gardeners and vegetable growers recognise the importance of soil fertilisation. They utilise resources like poultry waste, readily available due to numerous chicken houses, and fish waste, particularly from sardines. An innovative approach involves incinerating sardines and using the resulting waste as fertiliser for fields.

Off-farm produced organic and biofertilisers

Production and technology

Farmers in Senegal are increasingly recognising the limitations of relying solely on inorganic fertilisers, understanding that this approach can deplete the soil and lead to reduced yields, particularly in comparison to European counterparts. The ongoing financial crisis has heightened interest in organic fertilisers among farmers, driven by constraints in accessing chemical fertilisers. In the past, when chemical fertilisers were affordable, there was little enthusiasm for producing organic alternatives. However, as challenges in obtaining chemical fertilisers persist, more farmers are turning to manure from their animals as a valuable resource, with an estimated 5 to 10% currently adopting these organic fertilisers.

The crisis in mineral fertilisers, has also prompted conventional farmers to explore organic options due to limited choices. Notably, there are companies addressing this situation (e.g., Elephant Vert, Cepad service, Biotech service, MNA, and Biotope). OFBF product examples:

- One company specialises in sanitation; they collect wastewater, treat it, and store it in tanks, which are then sold to farmers. Additionally, the Bomas company, Senegal's national sanitation office, treats and sells sewage sludge to farmers at an affordable price.
- In Senegal, biofertilisers are considered less important than organic fertilisers. However, a mixed organic and biofertiliser known as Bokashi is gaining recognition among producers. Bokashi is a quick compost enriched with bacteria that significantly enhances soil fertility. This fertiliser is widely used in organic farming, especially in the southern part of Senegal. Within farming associations, some proactive farmers have taken the initiative to produce their Bokashi fertiliser and transferred successfully into a business. Despite the positive impact of these organic fertilisers, formal assessments regarding their effectiveness are still pending.
- Producers of biodigesters typically collect approximately 30% of the organic fertiliser generated by farmers over a certain period as a form of payment for the biodigester service. The remaining portion remains in the hands of the farmers, giving them the option to sell it back to the biodigester producer at a mutually agreed-upon price. This arrangement not only allows farmers to generate income but also grants them the flexibility to use a portion of the organic fertiliser for their personal needs. Consequently, some farmers, especially women, have initiated home gardening projects, utilising the compost produced with the biodigester.
- The public wastewater treatment company, ONAS, produces compost as a by-product of its wastewater treatment process. Since the onset of the pandemic and the war in Ukraine, there has been a surge in demand for compost. Some players took advantage of low prices, purchasing the entire stock. ONAS, being a public entity, was not primarily focused on profiting from compost, creating an opportunity for others to exploit the market need.

- Household waste management poses numerous challenges, particularly regarding recycling. The arduous task of distinguishing and separating green/organic waste from the rest of the waste stream is a time-consuming process, even in Europe where recycling practices are well-established. The ultimate fate of this waste often remains uncertain. Nonetheless, Senegal has embarked on a significant initiative focused on household waste management. This programme receives co-financing from major donors such as the World Bank, European Investment Bank, and African Development Bank. While the primary focus of the programme may not be on organic waste, discussions have transpired regarding the potential for converting it into organic fertilisers or other useful products. A national public company named SONAGED is tasked with managing waste in the country, further highlighting efforts in this crucial area.
- In the northern region, the largest banana producer in Senegal is contemplating the establishment of four banana plantation sites with plans to produce their compost. This initiative aims to create an ecosystem of food processors, both large and small, operating in close proximity. If successful, this could become a significant source and market for organic fertilisers and other waste value streams.
- Decentralised sewage wastewater management is a crucial consideration in areas lacking a centralised system. Some regions employ trucks for periodic waste removal. Certain companies advocate using this waste for treated irrigation water and organic fertiliser production, indicating potential for further development.
- Innovative solutions are also emerging, such as utilising Black soldier flies for animal feed and producing rich compost from their larvae. While only two small players currently explore this approach in Senegal, substantial expansion potential exists.
- ELEPHANT VERTE, a significant producer operating in multiple countries with headquarters in Morocco, is active in Senegal, Mali, and Côte d'Ivoire, with Swiss origins. While ELEPHANT VERTE previously partnered with the largest sugarcane producer in northern Senegal to locally produce compost from sugarcane waste and local materials, this arrangement has remained inactive for the past three years. Currently, ELEPHANT VERTE operates another production site in a different agricultural region of Senegal, with potential plans for additional sites, contingent on funding. ELEPHANT VERTE offers three different biofertilisers (biostimulants) in Senegal comprising two products aimed for the rhizosphere and one for foliar application. For all products data sheets and product compositions are available.
- In the Niayes region, coastal farmers consistently incorporate their organic manure—whether animal waste, fish remnants, or cow dung—to create compost.
- Negotiations are ongoing between crop and livestock farmers in certain areas, resulting in coordinated post-harvest animal grazing, e.g., rice cultivators procure manure from sheepfolds to enrich their rice fields.
- There are also individuals who purchase compost from various sources, blend it with different substances, and market it as organic fertiliser.

Interestingly, the majority of companies in this sector have foreign origins, although a few local entities exist. Notably, there's a presence of imported liquid organic fertilisers in Senegal.

While this shift towards organic fertilisers gains traction, there remains a significant need for extensive awareness campaigns, effective marketing strategies, and rigorous testing to demonstrate the benefits of combining OFBF with inorganic chemicals, or transitioning to entirely organic methods on a larger scale.

Despite the potential benefits of OFBF, their availability in Senegal remains a challenge, with quantities from external sources often insufficient. The government reserves subsidies for organic fertilisers, but these are limited, and many producers are unfamiliar with these products. Farmer organisations engaged in agroecology and organic farming are more acquainted with these alternatives, highlighting the need for widespread promotion and awareness campaigns.

Observing ongoing developments, such as increased organic matter production and the revival of practices like crop rotation, fallowing, and pasturing animals, suggests a future with reduced reliance on chemical fertilisers is achievable. Given the unpredictability of rainfall due to climate change, individuals relying on organic matter have a better chance of successful harvests. However, challenges persist, particularly concerning input availability and limited plant material for organic fertiliser production in Senegal's arid environment.

As a result, combining organic and inorganic fertilisers is a prevalent practice among farmers, with the choice dependent on their preferences and farming practices. Buyers not affiliated with organic fertiliser companies have acted as intermediaries, recognising the market demand for fertilisers during the scarcity of chemical alternatives. This situation underscores the need to establish standards for organic fertilisers, raise awareness, conduct comprehensive testing, and ensure quality.

Furthermore, embracing practices like pasturing animals, implementing fallow periods, introducing nitrogen-contributing trees, and optimising the entire value chain empower rural communities, particularly women and youth. These practices help revitalise rural areas and encourage people to remain in the countryside rather than migrating to overcrowded cities.

Research

At the Farmer Organisation level, there has not been an official assessment of the effectiveness of organic fertilisers. However, research initiatives led by universities have undertaken such assessments. Notably, these researchers often have a strong inclination toward mineral fertilisers, leading them to scrutinise the mineral content of organic fertilisers like Bokashi. Their assessment parameters have sometimes indicated that organic fertilisers may not encompass all essential nutrients.

There is some research on the different types of fertilisers, however very limited. Comparative tests with chemical fertilisers on one plot, organic fertilisers on another, control plots without any fertilisation, and a fourth treatment employing traditional farming practices revealed distinct differences. Plants receiving organic fertilisers displayed enhanced resistance, longevity, production, and quality. They also exhibited increased resilience to insect pests and diseases. For those who are already familiar with these fertilisers, there is little doubt about their effectiveness, although wider adoption remains a challenge due to limited awareness. There has not been an official assessment comparing the effectiveness of locally produced organic fertilisers and off-farm produced OFBF.

Larger agricultural companies have conducted rigorous tests on their organic fertiliser products. A notable example lies with an association of horticultural farmers near Dakar. Their extensive testing yielded excellent results, surpassing those obtained with inorganic fertilisers. Interestingly, three different organic fertiliser producers with similar formulas were tested. However, one producer stood out by incorporating additional components, such as microorganisms, leading to superior results despite offering a comparable price to others.

Quantifying the potential of organic waste remains a complex task, and specific figures have proven elusive. Currently, there is a dearth of available data in this regard. To estimate the waste generated for the ten largest crops, a more comprehensive analysis would be necessary, but such figures are not readily accessible at present.

There are extensive surveys of Senegal's vegetation across various regions to identify plants with inherent fertility-enhancing attributes. Some of these plants exhibit natural insecticidal properties, a realm where scientific guidance is indispensable. Much like the realm of medicinal plants, numerous varieties hold substantial potential and are subject to ongoing scientific advancements.

Economy and market

The organic fertiliser sector in Senegal is experiencing a surge in the establishment of numerous companies, highlighting its potential as a promising market. While cost considerations still play a significant role, many enterprises are setting up operations in this sector.

Currently, the organic fertiliser market in Senegal is primarily comprised of small and medium-sized enterprises (SMEs), with no dominant major player. The main companies are estimated to be between 10 and 12. The two largest producers in Senegal each yield approximately 15 000 tons of organic fertiliser annually, contributing to a total production volume of around 30 000 tons with various formulations each year. When including other smaller organic fertiliser producers, the total yearly production volume amounts to an estimated 70 000 tons. This burgeoning industry is assuming a crucial role in meeting farmers' needs and addressing the pressing land degradation challenges confronting the nation.

Senegal's organic fertiliser market presents a dual opportunity, catering to both larger agro-industrial players and smallholder farmers. This diverse landscape encompasses various crops like sweet corn, green beans, and mangoes, all of which benefit from the use of organic fertilisers. The market potential for organic fertilisers in Senegal is substantial, with increasing interest from both smallholder farmers and larger agro-industrial players.

Efforts are underway to cater to a broader consumer base and reach small farmers through a network of approved distributors. However, to harness the full potential of organic fertilisers, smallholder farmers require substantial support, ideally from donors like the EU, to raise awareness regarding the crucial role of soil nourishment.

The organic fertiliser market in Senegal is becoming increasingly competitive, driving innovation and motivating companies to continually enhance their offerings. A notable characteristic of organic fertiliser production is its relatively short setup time, typically around two weeks. This sets it apart from other agricultural practices due to its lower capital intensity and higher labour intensity, making it an economically favourable choice for both producers and consumers.

In recent years, there has been a significant change in the allocation of state subsidies for fertilisers in Senegal. The state has increased subsidies for organic fertilisers, reflecting their recognition of the benefits. Currently, 10% of the total fertiliser subsidies in Senegal are directed towards organic fertilisers, with the potential for this percentage to increase further in the future (currently intended for the next season are 20%). Between 80 to 90% of the full price for organic fertilisers is subsidised However, the challenge for the producer or organic fertiliser dealer is that the state pays the subsidies 12 to 24 month later. Therefore, the producers need to be able to have sufficient cash as waste raw material and waste transport etc. must be paid.

Sales representatives engage proactively with farmers, conducting product demonstrations and highlighting the numerous advantages of organic fertilisers. However, it is important to acknowledge that organic fertilisers can still be relatively expensive. For instance, a 50 kg bag of off-farm produced organic fertiliser costs approximately CFA 9 000 (with a range of CFA 7 000 to 10 000 = EUR 10 to 15). Moreover, in comparison to inorganic fertilisers, organic fertilisers have a lower coverage area per bag, requiring a larger quantity for one hectare. This can lead to increased expenses if a farmer heavily relies on off-farm produced organic fertilisers.

Nevertheless, there are more cost-effective options available. Directly purchasing manure from sources like ruminants is relatively inexpensive, priced at around CFA 800 (EUR 1.20) per 50 kg bag, while poultry droppings are available at CFA 2 000 to 2 500 (EUR 3.00 to 3.80). It's worth noting that off-farm produced organic fertilisers, which are priced at approximately CFA 9 000 (EUR 13.70) per 50 kg bag, can be costly and offer limited diversity in terms of their composition. However, some organic fertilisers are fortified and cost around EUR 213/ton with NPK 1:1:1 and EUR 305/ton with NPK 4:3:3 (composted with chicken manure and fortified with phosphate).

In addition to smallholder farmers, larger agro-industrial players in Senegal are displaying a growing interest in organic fertiliser. Many of these sizable farmers focus on export-oriented agriculture, particularly in the northern regions of the country, which witness a high demand for organic products in Europe due to their premium value and adherence to stringent standards. Consequently, the demand for organic fertiliser among these larger farmers is steadily increasing. While some of these larger-scale farmers have resorted to importing granulated organic fertiliser from abroad, this solution is not sustainable due to the associated high costs. Consequently, more private sector entities have entered Senegal's organic fertiliser market in recent years, recognising both the escalating demand and the severity of land degradation issues plaguing the country.

One significant aspect of the organic fertiliser landscape in Senegal is the biodigester programme, primarily centred around households. Private sector players in the biodigester industry have recognised that producing organic fertiliser through household biodigesters can be more financially rewarding than focusing solely on biofuel/biogas production. The national programme, supported by the state and other donors, has identified and certified six biodigester private sector players operating at household levels across the country. These companies provide households with biodigesters, and households do not need to pay upfront, as the upfront costs are often too high for the households to bear. The households pay by providing the produced organic fertiliser (digestate) from the biodigester. However, households keep a share of the organic fertiliser produced, mainly derived from cow dung and vegetable waste. Remarkably, the income generated from organic fertiliser compared to selling biodigesters is substantial, with a ratio of 1 to 10. This indicates that these producers earn ten times more revenue from selling organic fertiliser than from installing biodigesters. While biodigesters and biogas production remain part of the equation, many producers are increasingly drawn to larger-scale ventures, such as collaborations with slaughterhouses. However, the primary focus for these entrepreneurs is establishing their own organic fertiliser production units, given the promising profitability and growing demand for organic fertilisers in Senegal.

Farmers in Senegal are showing a genuine interest in producing their own organic fertilisers using locally available waste materials. While this practice holds economic promise, it requires structured support to reach its full potential. The acceptance of organic fertilisers among farmers is crucial, as they can command higher prices for their produce, thanks to the extended shelf life associated with organic fertilisers. One producer reported that his onions have a shelf life of 6 months vs. 2 to 3 months with inorganic fertilisers.

Efforts are currently underway to comprehensively organise fertility systems in different ecological zones across the country. For instance, in regions like the Senegal River valley, initiatives are being implemented to transition from costly diesel-powered pumps to more sustainable solar-powered pumps for irrigation. Moreover, village-based organic matter, sourced from sheepfolds, is being actively used in conjunction with off-farm produced organic fertilisers as part of broader sustainability efforts.

Knowledge, education and training

Organic matter remains relatively unknown in Senegal's agriculture, demanding substantial efforts to educate and train farmers about its benefits. Nevertheless, once farmers experience the positive outcomes, they become advocates of organic products. A significant hurdle lies in the ingrained mindset and training of agronomists, which heavily leans towards conventional agriculture and chemical fertilisers. The current agricultural education predominantly emphasises chemical fertilisers, obstructing the transition to organic alternatives. One of the primary challenges revolve around the risks associated with improper usage or substandard quality of organic fertilisers, potentially discouraging communities. This quality control issue remains the foremost obstacle.

Moreover, the effective utilisation of organic fertilisers demands a higher level of technical knowledge compared to chemical counterparts. In some instances, farmers, especially in sub-Saharan Africa like Senegal, mistakenly believe that increasing the application of inorganic fertilisers will double their yields. Influence from well-funded inorganic fertiliser companies has perpetuated this mindset, promoting the misconception that excessive use of inorganic fertilisers leads to significantly higher yields. Consequently, there's an urgent need for extensive knowledge dissemination and practical testing among smallholder farmers to catalyse the adoption of organic fertilisers in Senegal.

While training farmers and imparting knowledge is essential, the actual implementation can be challenging. To facilitate a successful shift towards organic fertilisers, comprehensive efforts in education and awareness must permeate every level of the agricultural sector. Challenges related to knowledge and accessibility to these products persist. NGOs offer support by procuring in bulk and reselling to farmers, but it remains a complex endeavour.

Education and capacity building are undeniably pivotal, not only for farmers but also for extension services within the agriculture ministry. The sector suffers from a significant knowledge and know-how deficit, necessitating the promotion of good agricultural practices. Currently, there is a dearth of specific literature regarding the impact of organic fertilisers, regardless of their source. Despite some efforts in this direction, they remain insufficient.

In certain regions, environmental education courses are being introduced in schools across various ecological zones. This practical education equips young individuals with valuable skills and seamlessly integrates them into local agricultural systems.

Considering a territorial approach to agroecology, the focus narrows down to specific communes. Here, a comprehensive agricultural system encompassing production, fertilisation, training, processing, marketing, and local consumption can be piloted. Collaborative efforts with local authorities and communities play a pivotal role in advocating for and implementing this approach on a larger scale.

Policy, regulations and certification

Since 2021, the Senegalese government has been gradually increasing its support for organic fertilisers, marking a significant shift in agricultural policy. By 2022-2023, it is expected that the government will have subsidised a total of about 11 000 tons of organic fertilisers, underscoring their recognition of the pivotal role these products play in agriculture.

While the strides toward supporting organic fertilisers are encouraging, Senegal's agricultural landscape faces numerous challenges. One pressing issue is the absence of standardised regulations for organic fertilisers, leading to the emergence of numerous companies lacking necessary expertise and experience. This regulatory gap poses a potential threat to the credibility and progress of the organic fertiliser industry in Senegal.

In the current landscape, Senegal lacks established standards for the application and use of organic fertilisers. This lack of standardisation has led to uncertainty regarding required application rates, ranging from 3 to 5 or even 6 tons per hectare. The result is a competitive but potentially confusing market.

Despite government subsidies, several obstacles continue to impede the widespread adoption of organic fertilisers. Additionally, specific attention must be paid to regions, women, and young individuals actively seeking opportunities in rural areas. Sustainable financing mechanisms should be established, moving away from last-minute fund allocation during campaigns and instead aligning policies with sustainable principles.

Engaging international partners becomes crucial in disseminating the experimental vision being cultivated. Their support can serve as a catalyst for meaningful change and upliftment within local communities. Financial partners, investing substantial sums, should adopt a participatory and inclusive approach within communities before disbursing funds, ensuring the transformative impact aligns with the objectives of NGOs, governmental technical experts, local authorities, women, and young individuals.

II Future perspectives and recommendations

Farm internal organic fertiliser: -

Off-farm produced organic and biofertilisers

Production and technology

Senegal holds substantial potential for organic fertilisers. A pragmatic approach may involve combining organic and inorganic fertilisers based on regional and crop-specific requirements. Yet, maximising the benefits of organic fertilisers hinges on comprehensive awareness-raising campaigns and education initiatives aimed at smallholder farmers. The demand for organic fertilisers in Senegal is expected to surge, paralleled by increased production. Companies proactively preparing for this expansion by building up its inventory.

While achieving a 100% substitution of mineral fertiliser with off-farm produced organic fertilisers may not occur instantly, the trend of farmers transitioning to organic practices is unmistakably rising. To facilitate this shift effectively, organic fertiliser providers should furnish farmers with precise application rates for diverse crops and guidance on optimal timing. Such support is vital for farmers to harness organic fertilisers to their full potential.

While SMEs are active players in the organic fertiliser sector, there is a noticeable absence of quality assurance measures and regulatory oversight. Implementing rigorous quality checks and certification systems can bolster the credibility of organic fertiliser producers and guarantee product compliance with essential standards.

To cater to a broad spectrum of agricultural needs, organic fertiliser producers are exploring granulated solutions enriched with microorganisms and biostimulants. This innovation can elevate the efficacy and convenience of organic fertilisers, rendering them more appealing to farmers. Focusing on refining the packaging and accessibility of organic fertilisers on a smaller scale is imperative. The development of granulated formulations simplifies farmers' ability to regulate application rates. Additionally, diversifying fertiliser acquisition methods can enhance their widespread utilisation.

Organic farming emerges as a viable alternative to chemical fertilisers, particularly when combined with complementary practices like fallowing, crop rotation, intercropping, and mixed farming. Indigenous knowledge becomes pivotal in this context, emphasising the significance of reviving historically prevalent crop associations. This practice involves pairing nitrogen-producing crops like cowpeas with maize or other companion crops, enriching both agricultural practices and local consumption traditions.

A comprehensive perspective on land use is indispensable. Strategically designating specific areas for fallow periods while concentrating production efforts elsewhere holds relevance for agriculture, livestock husbandry, and fishing. In the fishing sector, the depletion of fish populations in oceans has triggered conflicts among small-scale fishermen. Creating sanctuaries for fish in biological resting zones has become a point of contention.

A thoughtful approach is imperative, involving close collaboration with local communities to devise sustainable solutions for rural development. There is need to move away from impractical practices like transporting organic materials over long distances and instead focus on establishing decentralised systems that work with local producers. The goal should be to create farming practices that complement each other, reducing overreliance on chemical fertilisers. In this context, biostimulated organic amendments hold promise for the future.

Research

Rather than relying solely on chemical or organic fertilisers, a comprehensive and multidisciplinary approach to fertilisation is essential. Solutions may come from various sources, and their potential should be rigorously explored through scientific research. Researchers should invest more in developing knowledge products to educate farmers on the use and impact of off-farm produced organic fertilisers and biofertilisers. Packaging of these fertilisers, particularly those from local entrepreneurs, should be improved to make them attractive, traceable, and include application rates and measurement units. Research on biofertilisers should be strongly encouraged and adequately resourced, as they have the potential to significantly boost agriculture. Diversification of biofertilisers is crucial, as there is currently limited variety in the market. In addition, exploring the potential of natural resources like the *Acacia albida* tree in fertilisation should be supported by scientific research. This includes investigating its role in continuous soil fertilisation and reducing the need for chemical fertilisers.

Scientific research should focus on validating the impact of these fertilisers on crop behaviour, yield, and production quality across various crops. Additionally, there should be research on their environmental impacts, both positive and negative, to ensure sustainable practices. Establishing monitoring systems to assess the efficacy and quality of these fertilisers is vital. Community capacity should be built to evaluate fertiliser quality comprehensively, beyond simple nutrient content assessments. Ensuring the credibility of biofertilisers is crucial for their widespread adoption.

Economy and market

The organic fertiliser market in Senegal has experienced significant growth recently, attracting numerous companies to enter this sector. Market assessments indicate a demand for approximately 400 000 tons of inorganic fertilisers and 300 000 tons of organic fertilisers. To promote organic alternatives effectively, collaboration with organic fertiliser producers is essential to develop sound market strategies. This could involve offering competitively priced products, which would enhance affordability for farmers, resulting in increased sales and industry expansion. The awareness of the adverse impacts of chemical fertilisers is driving this transition, and there's potential for further growth. However, organic fertiliser producers face competition from large chemical fertiliser companies, which might attempt to hinder their production. Additionally, Senegal's unique Sahelian environment poses challenges due to limited availability of raw materials, especially plant residues.

Senegal's domestic market for organic farming is steadily growing due to a preference for locally produced goods. This trend is advantageous for the organic fertiliser sector. Furthermore, there is untapped potential in agro-wastes, not only for fertiliser production but also for other eco-friendly applications such as animal feed and biofuels. However, valid quantifications of available organic wastes is lacking.

In the organic fertiliser industry, the private sector plays a pivotal role, often partnering with NGOs. However, marketing efforts are sometimes neglected, and investments in this aspect are limited. The prevailing approach involves direct sales to agro-industrialists or through a distributor network. Challenges arise from delayed state payments for subsidies, impacting cash flow and timely bank payments. There is a need for additional measures to optimise this situation. Increasing the quantities of state-subsidised organic fertilisers is recommended, recognising that while subsidies may not be a long-term solution, they provide vital support to farmers. To align with the Senegalese state's agroecological approach, it is suggested to subsidise at least 50% of both organic and mineral fertilisers. Another option for farmers interested in organic fertilisers is to purchase manure and compost it themselves in their fields, potentially resulting in lower costs compared to chemical fertilisers. The goal is to secure substantial subsidies for organic fertilisers, though current circumstances fall short of expectations. For instance, Mali subsidises 100 kt/year, while Senegal, despite its potential due to poor soil conditions, targets 50 000 t. Practical strategies should account for transport costs and demand variations in different regions.

Establishing a business around off-farm produced organic fertilisers requires meticulous cash flow management, given the 4-5-month production and marketing cycle. The current market price for a 1-1-1 fertiliser stands at CFA 140 000/t (approximately EUR 213/t). Doubling the margin and production cost is critical for establishing a sustainable business model. However, the organic fertiliser industry remains cash-intensive, with payment delays and cash flow challenges. Adequate funds are essential for compensating waste producers and ensuring smooth operations. Trustworthy individuals are pivotal for business growth and to prevent financial mismanagement. While many small companies produce 30-50 tons annually, some, like the mentioned company aiming for 10 000 tons in 2022, aspire for larger production. There is a growing interest from major accounts like CSS and Indian farms with substantial potato cultivation. New major accounts continue to join the market.

Addressing challenges related to sourcing and production volume in the organic fertiliser industry in Senegal can be significantly improved by establishing multiple production sites strategically located across the country. This strategic move would reduce transport costs, enhancing the affordability of organic fertilisers for both smallholder farmers and agro-industrial companies. Proximity to waste sources is crucial for efficient and cost-effective organic fertiliser operations.

Senegal currently has an ample supply of raw materials for organic fertilisers, although opinions on this matter vary. Nonetheless, 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. Procuring raw materials and maintaining daily cash availability pose significant challenges in this industry, emphasising the importance of consistent waste collection, requiring substantial investments in equipment and modernisation. Ensuring a stable supply of waste materials and cultivating loyalty among suppliers are ongoing efforts demanding attention.

Efforts are underway to optimise household waste for organic fertiliser production, focusing on cleaner and better-sorted green/organic waste. The potential establishment of composting units in select cities, with hopes of securing donor funding, is being considered. Initial targets include major markets, hotels, and gastronomy establishments for efficient waste sorting. Alternative sourcing options like wastewater treatment are being explored in parts of Dakar and other cities with centralised systems. All these activities should be further developed.

The ongoing crisis and farmers' challenges in affording chemical fertilisers could expedite the transition towards organic agriculture. If chemical fertiliser producers do not respond adequately, farmers may increasingly consider organic alternatives, favouring organic agriculture over conventional methods, especially if sustainability gains precedence over profits.

Knowledge, education and training

In navigating the path towards sustainable agriculture and widespread organic fertiliser and biofertiliser adoption requires a multifaceted approach that encompasses education, economic empowerment, effective communication, and policy support at various levels.

To ensure the continued adoption of OFBF, especially in a scenario where subsidies may decrease, digital campaigns on social networks and mobile platforms can play a vital role. These campaigns should effectively inform farmers about the benefits and options of choosing organic fertilisers. Equally important is providing proper training to farmers to understand dosage, fertiliser types, and supply management effectively. Raising awareness among farmers is pivotal to this process.

Recognising that rural communities aspire to more than just sustenance is essential. People desire a certain level of comfort, including access to electricity, radios, and comfortable living conditions. This shift towards improved living standards is often inspired by observations of urban lifestyles. Therefore, the transition to ecological agriculture should aim to economically enrich these communities. Encouraging entrepreneurship within agriculture becomes crucial, envisioning agriculture as a family enterprise where each member contributes according to their skills and training. Restricting agriculture to subsistence levels risks driving younger generations away from rural life, leading to demographic imbalances. Robust agricultural development is necessary to prevent this trend and avoid the dominance of multinational corporations with industrialised farming practices. In this context, communities must present their localised political vision, driven by their unique interests and mechanisms for change.

Enhancing training, information dissemination, and scientific support is imperative. This can be achieved by harnessing farmers' wisdom and expertise collaboratively. Such efforts could lead to the development of a highly efficient agricultural landscape.

A key success factor lies in popularising OFBF. Bridging the gap between research and extension is crucial to ensure that valuable research results reach farmers effectively. Involving extension services, NGOs, and technology dissemination experts in agriculture extension, training, and awareness-raising is essential to demonstrate to stakeholders that organic fertilisers can effectively replace or reduce chemical ones.

Emphasising the involvement of young people and women is vital, considering the potential of the agricultural sector to create numerous jobs and address income scarcity issues in Senegal.

Training technicians, agronomists, and farmers is crucial to promote organic agriculture and agroecological practices for sustainable production. Special attention should be given to proper dosage of organic fertilisers to avoid over-application, particularly when using solid or liquid fertilisers, which can lead to wastage and inefficiency. Transitioning to a granulated format for organic fertilisers can be more beneficial, enabling easier and more accurate application, thereby optimising the limited supply available to farmers. At the state level, establishing a dedicated unit focused on training and pedagogy can significantly contribute to knowledge dissemination. Simplified materials, including drawings and community radio broadcasts, can be highly effective in communicating agricultural knowledge. Leveraging social networks, given farmers' frequent use of mobile phones and decreasing TV viewership, can also enhance awareness and education.

Success in promoting organic fertilisers requires effective selling skills, good communication, and a deep understanding of the agricultural field. Learning from past mistakes and continuously improving strategies are vital for progress and growth in this sector.

Farmers accustomed to using chemical fertilisers need guidance to understand the benefits of organic fertilisers and their proper application. Given the poor soil quality in terms of organic matter, substantial amounts of organic matter sources such as cow dung are needed to improve organic matter levels compared to organic fertilisers. Key success factors include active outreach through community radio, local language advertising, and television to raise awareness about organic fertilisers. Continuous communication with farmers is essential to prevent them from reverting to chemical fertilisers due to unavailability. However, funding for awareness campaigns remains a challenge, emphasising the necessity of state support for extension services.

Policy, regulations and certification

The challenges and opportunities surrounding organic fertiliser production and utilisation present a multifaceted landscape that requires careful consideration, strategic planning, and collaboration among stakeholders at various levels.

Current regulations lack specificity when it comes to OFBF. To address this, it is recommended that the State takes a more serious approach to OFBF. This shift could result in improved conditions for producing organic fertilisers, ensuring higher quality. Neglecting to do so may lead to issues, as numerous companies are venturing into organic fertiliser production without ensuring quality.

While the State has ambitious ideas in this realm, effective implementation faces significant challenges. Addressing these challenges requires greater efforts at the State level. National governments, as demonstrated during the recent Agroecology Days, play a crucial role in promoting sustainable agriculture. For instance, the Minister of Agriculture highlighted the need to move towards self-sufficiency in organic fertilisation and acknowledged that perpetual fertiliser subsidies are unsustainable. This recognition underscores the necessity for innovative approaches.

The National Biogas Programme is taking steps towards promoting organic fertilisers by providing an 80% subsidy, albeit with relatively small quantities. It's noteworthy that the majority of fertiliser subsidies are currently directed towards chemical fertilisers (80%), with only a 20% allocation for organic fertilisers in the upcoming campaign (2023/2024). This discrepancy highlights the need for further promotion of organic alternatives.

Empowering communities to generate organic matter at a reduced cost is essential. Concerns arise when considering the possibility of state subsidies discontinuing, leaving communities uncertain about their sustainability practices. Thus, there's a need to empower regions and localities within their resource constraints. Establishing functional systems for local organic matter production is critical as a safeguard against future challenges.

Efforts should be made to integrate organic fertilisers into existing policies that regulate chemical fertilisers and pesticides. Decentralising organic fertiliser production and distribution, ideally on a regional basis, can reduce transport and logistics challenges. Standardising organic fertiliser production and embracing technological advancements is also crucial, considering the labour-intensive nature of transport and application.

A dedicated policy framework is essential to support companies and farmers choosing OFBF. The inadequacy of current agricultural policies concerning OFBF must be addressed. Regulatory improvements and state arbitration can be beneficial for both industry professionals and farmers. Innovative approaches, such as post-harvest payments, can enhance relationships within the sector.

Transparency and accuracy are key factors in enhancing the regulatory framework. The involvement of a new Director of Agriculture is seen as a positive step, emphasising a commitment to improved practices and zero tolerance for malfeasance. The Horticulture Directorate plays a pivotal role in subsistence agriculture, warranting additional focus.

Quality control is paramount. Standardisation ensures consistent composition and analysis results, providing reliability to users. It's important to note that while the gross margin stands at 45%, the final margin is lower (15-17%). This final margin depends on timely payments, emphasising the need for financial predictability.

Despite the challenges, there is genuine optimism for substantial changes and positive developments in the sector. These changes can also be catalysts for job creation, supporting the establishment of facilities for natural compost production and green manure systems. This approach fosters autonomy while leveraging research to modernise agroecology and create comprehensive chains. Moreover, there's potential for the production of fertilisers and protective products to create a continuum of action research. Establishing production units that generate employment opportunities aligns with this vision. Collaboration among stakeholders is crucial to achieving the envisioned transformation in agricultural practices in Senegal.

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. This approach contributes to sustainability by maximising resource utilisation.

8.2.11 South Africa

I Status quo

Mineral fertilisers

South Africa enjoys self-reliance in fertiliser production, satisfying its entire demand and even exporting to neighbouring regions through multiple companies. However, while farmers have convenient access to fertilisers, affordability remains a considerable obstacle. The Fertiliser Association of South Africa plays a pivotal role in overseeing fertiliser production, distribution, and trade across all regions. In response to this challenge, the government extends fertiliser assistance to smallholder farmers through the Comprehensive Agriculture Support Programme (CASP).

The cost of mineral fertilisers in South Africa has steadily risen, influenced by factors like the Ukrainian conflict and exchange rate fluctuations, further impacting food prices. However, it's unclear if this has affected the organic fertiliser market, which does not directly compete with mineral fertilisers in the country. Unlike regions like Asia or Europe with higher mineral fertiliser usage, South Africa's usage remains low at under 20 kg per year/ha. While the fertiliser market has grown, high costs have prompted farmers to explore alternatives and seek scientific guidance for optimal mineral fertiliser use.

Farmers in South Africa must comply with CASP regulations to access subsidies. Although the country does not import fertilisers, the Ukraine-Russia conflict indirectly impacted it through rising fossil fuel prices, increasing production and logistical costs. This led to higher fertiliser prices but also presented opportunities as other countries, previously importing from Russia, turned to South Africa. Despite price fluctuations, subsidy levels have not changed, reducing coverage for farmers due to increased costs. While mineral fertilisers are accessible, their high prices make them unaffordable for many, spurring interest in organic and bio fertilisers as alternatives.

The current fertiliser market, which has been in existence for many years, has experienced a gradual increase in participation over time. This market predominantly serves commercial farmers, driven by the high prices of mineral fertilisers. It effectively provides all the necessary resources and there haven't been reported issues regarding the quality or nutrient content of mineral fertilisers. Specific minerals required for fertilisers are readily available.

However, affordability remains a significant challenge for smallholder farmers, who often rely on government subsidies. When subsidies are in place, the government plays a crucial role in ensuring that fertilisers are accessible and available through extension support services.

The availability of information on mineral fertiliser quality and application practices varies depending on the farmer's scale of operation. Fully commercialised farmers receive ample support from fertiliser companies, including extension services. In contrast, small-scale farmers often lack access to usable information and face knowledge gaps. Government extension support is limited and is mostly sponsored by input suppliers, focusing on promoting specific products rather than addressing farmers' actual needs.

Criticisms directed at mineral fertilisers primarily revolve around their perceived negative environmental consequences, such as improper application practices leading to water pollution. Additionally, there's concern about farmers applying mineral fertilisers indiscriminately without properly assessing soil conditions or considering potential consequences. This knowledge gap regarding soil and crop requirements is further exacerbated by the transfer of knowledge, which often disproportionately benefits commercial farms sponsored by input suppliers. Smallholder farmers struggle to afford these practices, and government advisory services are often limited.

Despite historical dependence on mineral fertilisers, there is a growing interest among farmers to transition to alternative fertilisers, including OFBF. Nevertheless, many farmers lack the knowledge and solutions required for a successful transition.

Farm internal organic fertilisers

The Farmer Association encourages nurturing and enriching the soil to reduce reliance on external inputs. However, during the transition to organic farming, support with off-farm produced inputs becomes essential. Organic guarantee assessments cover soil and on-farm production of soil amendments like teas, with compost making playing a significant role in enhancing soil health and sustainability.

The ideal approach would be for each farm to produce its own fertiliser through composting. Biodynamic farmers exemplify this principle, utilising self-produced compost in smaller but high-quality quantities, which is commendable. Advantages of producing your own compost include better control over the product, but this process requires ingredients, manpower, and skills. However, some organic farmers appear to be merely fulfilling the requirements for organic certification while purchasing compost from external sources. Such practices should not be permitted in organic systems.

In organic farming, grazing is essential as cows are ruminants and should primarily feed on grass. Feeding them in feedlots leads to manure production without adequate consideration for animal welfare and the environment. In such cases, a substantial amount of nitrogen ends up in the subsoil, raising concerns about the farming system that produced the manure.

Off-farm produced organic and biofertilisers

Production and technology

Several initiatives in South Africa are focused on producing organic fertilisers. Organic fertilisers offer significant benefits for maintaining long-term soil health and have ample potential in the South African context. While they improve yields, combining them with biofertilisers (biostimulants) can lead to even higher yields. Biofertilisers release nutrients slowly, making them less readily available to plants. However, they play a crucial role in correcting any environmental disruptions and contribute positively to the overall ecosystem. Unlike mineral fertilisers, biofertilisers do not cause pollution as they do not wash into water bodies. Farmers have more knowledge about chemical fertilisers compared to OFBF due to the availability of support from extension services. Replacing mineral fertilisers with OFBF is not a prevalent topic, as the number of organic farmers is relatively small compared to the total farming population. OFBF product examples:

- Importing EM from Japan as an agent for the registered mother tincture of EM stock, offering various products made from locally available ingredients, including Multi EM, Fermented Plant Extract, Fermented Fish, Bokashi, and Fermented Chicken Manure. Additionally, EM5 insect repellent and EM 3 in 1 insecticide are available, both affordable with a pH range of 3.1-3.3. Production includes about 2 500 litres of probiotics for human consumption and approximately 1 200 litres per year for crop production. Just one litre (priced at 150 rands) can cover up to 1 000 hectares of farmland.
- Compost production totals 5 000 tons across various products, with new items undergoing trial testing. The primary focus is on NPK quality standards, allowing a maximum allowable variation of 10%, tested by third-party laboratories. Solid fertilisers have available local technology, but producing liquid fertilisers requires stainless steel equipment, potentially limiting accessibility in all parts of SSA. Depreciation typically spans five to ten years. Long-term farmers express satisfaction with the products, particularly regarding soil health and crop quality. Maize farmers are not our primary customers.
- A public-private partnership with Duzi Turf, Umgeni Water, and Msunduzi Municipality facilitates co-compost production at a municipal scale (established within the RUNRES research collaboration). The public utility provides dewatered sewage sludge, while the municipality supplies garden/green waste. Co-compost supports turf grass production and enhances soil fertility management and yields for farmer-cooperatives in the Sobantu community.
- The installation of an Integrated Decentralised Wastewater Treatment System (DEWATS) and pour flush urine diversion at Sikhululiwe School, led by Umgeni Water, addresses sanitation challenges at the school and improves livelihoods in the Vulindlela community. The pilot-scale innovation aims to influence regulations and policies regarding human waste and water/wastewater treatment sludge reuse.

- RUSUS, a farmer cooperative, plans to produce faecal sludge-derived biochar with support from Partners in Development (PID) and the local municipality of Mzunduzi. This innovative approach addresses pit latrine challenges, generates employment, and enhances farming productivity. Enhanced biochar will be sold to the local community and nearby urban centres, contributing to economic growth and sustainability.
- The implementation of an Agroecology Living Lab expands composting initiatives to a network of church-affiliated farmers' cooperatives, extending the impact within the agricultural community. The Agroecology Living Lab addresses issues identified during the initial evaluation phase, ensuring that compost effectively reaches local producers rather than benefiting only large commercial farmers. Partnering with a national church network established a location-based living lab for training and promoting agroecological principles among farmers, enhancing sustainability and resilience in their practices. Simultaneously, co-composting activities continue at the Agroecology Living Lab, exploring the integration of faecal sludge management to address on-site sanitation challenges associated with ventilated improved pit latrines.
- This project specifically examines the feasibility of using digestate as an organic fertiliser. Biodigesters are fed with various raw materials depending on the local availability, such as feedlot waste, vegetable scraps, or sewage. In the case of sewage, it undergoes treatment to remove heavy metals and other undesirable substances before being used as a fertiliser.

OFBF's impact on soil is primarily assessed visually, considering factors such as biomass, colour, and visible life in the soil. Supplying nitrogen in organic farming is challenging, requiring slow-release forms to prevent crop deficiencies. The aim should be optimal yields, not maximum, to avoid disease risks. Effective Microorganisms (EM) benefit soil health and are cost-effective. There is a database of approved products, including OFBF and organic pesticides, for farmers' reference. Biofertilisers enhance the soil microbiome, although yield disparities with mineral fertilisers exist. Promoting biofertilisers could overcome this issue. Off-farm sources help with compost supply, but transparency and labelling of commercial products remain concerns for farmers.

The adoption of off-farm organic fertilisers is rising, positively impacting crop yields. Many farmers now use them in commercial organic farming, contributing to their overall uptake in agriculture. Off-farm organic fertiliser production has also increased significantly, especially in large animal operations, producing over 100 tons of compost monthly. They offer advantages like affordability and accessibility. The demand for these fertilisers is likely to persist, particularly for farmers without access to animal manure. Many South African farmers own extensive land and focus on commercial production, making organic fertiliser availability a challenge. While full transition to biofertilisers might not be universal, some farmers are gradually reducing mineral fertiliser use and integrating organic and biofertilisers to some extent. There's potential for combining mineral fertilisers, OFBF, and on-farm organic fertilisers.

OFBF play a crucial role in South Africa's organic farming, facilitating multi-cropping systems. Limited water availability often hampers on-farm compost production, leading farmers to complement their on-farm compost with off-farm unpacked OFBF.

Many of the organic farmers do not own cattle, so they purchase all their fertilisers off-farm. Some acquire reasonably organic or unpolluted manure from nearby farms, while others buy organic fertilisers from commercial sources like rainbow chickens. However, these sources may not align with organic standards due to concerns like hormone use.

In East and Southern Africa, soil acidity is a common concern, with a need to determine its specific type, whether it's caused by aluminium toxicity or can be gradually neutralised through compost.

Primary concerns with off-farm produced OFBF include the source of the product, specifically, whether the manure used for composting originates from factory farming or animals in feedlots, and whether hormones are used.

It is important to note that a significant portion of certified organic fertilisers in South Africa is derived from chicken manure-based products. However, these products are losing their organic certification due to a shift in chicken farms towards battery systems, which are not permitted under organic certification guidelines.

Some farmers tend to overuse manure, particularly dairy farmers, pig farmers, and chicken farmers, who treat manure as a waste product and apply excessive quantities (20, 30, 50 tons) to a few fields year after year. This practice leads to the accumulation of toxic levels of nitrogen and phosphate in these fields, posing a hazard as these nutrients can be washed into nearby streams and groundwater. To address this issue, Telborne Organics offers organically acceptable fertiliser that contains phosphate, addressing the deficiency commonly found in most composts that are low in phosphate and nitrogen. Telborne Organics' products are of high quality and cater to a growing market. In contrast, other off-farm produced organic fertilisers might lack certification and exhibit lower quality.

Research

Significant research efforts are currently underway to explore the potential of OFBF in regenerating degraded land and restoring productivity. These initiatives include collaborative projects with partners in Sweden, spanning five years, aimed at developing biostimulants/biofertilisers. In addition to studying plant growth and soil health, this research delves into the molecular and biochemical pathways of plants. Scientists are investigating how genes are activated or suppressed following the application of these biofertilisers/biostimulants. Multiple researchers across South Africa are actively engaged in such projects, often in partnership with universities, with a specific focus on biofertilisers. Other research collaborations explore the use of human and household and green waste for co-composting and biochar production from human waste (e.g., RUNRES project).

In developing regions, a notable number of master's studies and a few PhDs are centred around composting and assessing the impacts of organic practices. However, advancing organic research further requires increased financial support to conduct high-quality studies led by individuals well-versed in organic agriculture principles. Such funding is critical for expanding our understanding of organic farming methods and their potential benefits for sustainable agricultural development. Taking EM (Effective Microorganisms) as an example, science holds significant potential in this field, although it remains subject to biases.

Various trials are ongoing, including those involving compost like Talborne compost. It's noteworthy that no environmental impact assessments have been conducted for OFBF at the farmer level. Additionally, research is exploring the feasibility of using digestate as an organic fertiliser. Biodigesters are fed with diverse raw materials based on local availability, including feedlot waste, vegetable scraps, or sewage. In cases involving sewage, it undergoes treatment to eliminate heavy metals and other undesirable substances before being used as a fertiliser.

Economy and market

Extensive research is being conducted to evaluate the economic feasibility of using digestate as a fertiliser. The relative cost of organic fertilisers, in contrast to mineral fertilisers, presents an interesting dynamic. Mineral fertilisers offer easy accessibility, while organic fertilisers' procurement involves physical collection from production sites. Over time, mineral fertiliser prices have significantly increased, whereas compost remains more cost-effective. Cost-benefit and techno-economic analyses are critical areas of research.

Farmers see benefits in OFBF for soil and crops but weigh them against costs. OFBF boost soil fertility, but their financial viability varies among farmers. Affordability and accessibility drive adoption, emphasising the need for sales support and awareness campaigns. Collaboration between commercial farmers and organic fertiliser companies is growing, with some larger scale operations producing up to 100 tons per month. Transparency regarding nutrient sources remains a challenge.

The organic fertiliser market is expanding, particularly for certified organic crops, and there is a substantial demand for high-quality compost. While organic fertilisers used to be priced higher than inorganic ones, they are now competitively priced. Increased mineral fertiliser costs have enhanced the competitiveness of organic fertilisers. While organic fertilisers have witnessed growth, government subsidies do not extend to them. The distribution of OFBF is uneven, with certain regions lacking access, and pricing sometimes exceeding that of mineral fertilisers. Commercially regionally produced organic fertilisers enjoy low transport costs and variable transparency regarding their content.

Market channels include direct customer sales, retail spaces for agriculture and horticulture, distributors providing financing to farmers, and field agents representing certain products. Exporting to several countries is part of some producers' operations, although nutrient-rich products are priced higher than manure and compost-based alternatives. False marketing remains a concern that necessitates attention within the industry.

The popularity of organic farming is growing in South Africa, creating a niche market for organic products. Interestingly, the increased usage of mineral fertilisers is partially attributed to geopolitical factors, creating a competitive advantage for OFBF. South Africa's rising demand for organic produce is tempered by counterfeit products entering the market, driven by the allure of premium prices.

Knowledge, education and training

Agriculture faces several challenges, including a lack of support and knowledge. Farmers often struggle due to the limited capacity of advisory services to interpret soil analysis. However, the Agricultural Research Council (ARC) is actively addressing these issues by conducting participatory research and trials with smallholder farmers. Moreover, there are training opportunities for students who visit organic fertiliser producers. These producers employ different composting methods, with some following a static approach and others adopting a dynamic approach that involves weekly compost turning. Obstacles to organic fertiliser usage, stemming from knowledge gaps among agriculture extension agents and deficiencies in education curriculums, are being addressed. Even though there is not an official OFBF strategy document, the association emphasises soil fertility management, whether through off-farm or on-farm practices.

While the combination of organic and mineral fertilisers can be beneficial, it requires specific skills, knowledge, close observation of soil development, and a clear understanding of the economic aspects. It's crucial to note that all types of fertilisers can potentially contribute to soil salinisation. Additionally, the impact of biomass on soil structure often goes unnoticed, highlighting the need for further investigation.

Measurement tools for OFBF are still lacking, particularly concerning the assessment of microbial life forms and their influence on crop growth. The role of biomass in soil structure is another aspect that deserves more attention.

In the realm of organic farming, some educational challenges persist. Conventional farmers might struggle to grasp concepts like Effective Microorganisms (EM) as they tend to prioritise crop management over soil health. Raising awareness and providing outreach efforts are vital to promote these practices effectively.

Resistance to change is also encountered, mainly because agricultural industries may have vested interests in their own products. This resistance is further compounded by the fact that advisory services are often trained by these industries, discouraging the promotion of alternative methods like EM. Farmers, in general, have limited knowledge about biofertilisers. However, there's a ray of hope as younger farmers with internet access tend to be more open to new ideas and practices.

Plans to expand exports across Africa are challenged by the fact that soil biology is often neglected in soil science education. Additionally, there are concerns about misinformation in the agricultural sector. Some critics question the use of organic fertilisers, while certain companies engage in "greenwashing" by making sustainability claims without sufficient evidence, which can create confusion among farmers. There are efforts to bridge these knowledge gaps include incorporating soil assessments in organic guarantee evaluations, encompassing on-farm production of soil amendments like compost and compost teas.

Surprisingly, research findings indicate disparities in environmental consciousness. Educated individuals in the global north tend to be more environmentally aware, but this trend reverses in the south, particularly among those involved in agriculture and soil management. The age factor is also significant. Older individuals appear less open to adopting new practices, while younger generations show greater receptiveness to novel ideas and techniques. Moreover, religious beliefs can influence environmental attitudes, necessitating careful consideration when disseminating information to diverse audiences.

Policy, regulation and certification

Efforts at the Agriculture Research Council have been geared towards advocating for farmers' access to organic inputs. This campaign yielded success when the government took the historic step of providing financial support for the purchase of organic fertilisers, particularly Talborne Organics. This marked a significant milestone, that the government financially supported organic fertiliser application.

Advocacy in this realm is of paramount importance because policy makers often struggle to fully grasp the realities on the ground concerning OFBF. However, there is a positive shift in government recognition of the importance of OFBF, even though there is still a lack of a clear strategy to promote OFBF to the same level as mineral fertilisers. While there is a government strategy for the use of mineral fertilisers, the emphasis on soil health is relatively limited.

The uptake of organic inputs in South Africa faces hurdles related to the registration of fertilisers. Both off-farm OFBF must undergo the same cumbersome screening process as mineral fertilisers, making their adoption less attractive to farmers. On the regulatory front, South Africa has been focusing on simplifying the registration process for bio remedies, aiming to align with CODEX Alimentarius and list environmentally friendly pesticides. This opens the possibility of incorporating OFBF into this regulatory framework.

As of now, South Africa lacks a specific regulatory framework for the production and use of OFBF. Regulatory bodies struggle to keep pace with advancements in the industry, which often favours established players in the mineral fertiliser sector. Corruption and inefficiencies further hinder progress, with the registration of new fertilisers, including organic ones, taking up to three years.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology

OFBF hold immense potential as a sustainable alternative to mineral fertilisers, especially when integrated with efficient waste management practices. In the region, there are valuable, yet untapped, resources like by-products from the timber industry that could be harnessed effectively. To fully capitalise on the benefits of OFBF, it is crucial to develop a waste management strategy that combines the utilisation of organic materials such as wood chips and cow manure, which are currently underutilised.

Both chemical and organic fertiliser applications require careful analysis, as do biological soil indicators. Monitoring soil structure over time in relation to inputs and outputs is essential to detect potential issues like salt accumulation.

One pressing issue is the prevalence of poor and degraded soils, which reduce the effectiveness of fertilisers and, consequently, decrease farmers' demand for them. Introducing compost in these areas can lead to noticeable yield improvements even with current fertiliser usage, potentially spurring greater demand for compost. This approach holds particular significance for enhancing food security in the sub-Saharan African region, where ensuring an adequate food supply takes precedence over adopting cleaner production systems. The goal should be to increase fertiliser utilisation to meet growing food demands, positioning compost as a complementary solution rather than a substitute.

Research

Expanding the research framework is imperative, particularly in the realm of soil quality. Universities should incorporate OFBF into their curricula, emphasising the need for advocacy as policy makers often struggle to connect with on-ground realities. Fortunately, there's growing governmental recognition and support for biofertiliser use.

In Africa, much of the research is funded by global northern entities, aligning with their frameworks and interests. However, there's a local need for increased research funding to support this vital work. Capacity can be a challenge, as some institutions lack the necessary resources for comprehensive research.

Economic viability is of paramount importance. Demonstrating the economic feasibility of biofertilisers is essential to attract investments from companies without requiring additional support. Proving its feasibility will be pivotal in garnering investor interest.

The environmental perspective, especially emissions, is another critical aspect. While recycling is often associated with sustainability, not all recycling projects are environmentally sustainable. To ensure sustainability, we must assess performance indicators, conduct emissions tests, and perform lifecycle assessments. Lifecycle analysis is an emerging discipline, especially in the global north, where skilled professionals are scarce. It traditionally falls under economics but is expanding, particularly within environmental engineering, due to concerns about climate change. Quantifying project's environmental performance active in this area is crucial for claiming e.g., carbon credits. However, a significant challenge lies in the shortage of trained personnel to perform these calculations.

Research tailored to consumers' and farmers' needs should lead to precise recommendations on application rates. Furthermore, further research into organic farming practices is crucial for sustainable agricultural development.

Research on OFBF is increasingly driven by practical needs, with collaboration among researchers being a top priority. The interest in reducing mineral-based inputs is catalysing OFBF production. As the emphasis on organic soil and soil health preservation grows, long-term adoption of OFBF is anticipated. To effectively utilise off-farm organic fertilisers, it's essential to thoroughly analyse organic materials for each purchased unit, considering that batch quality can vary. Proper batching of each compost made and sold is crucial, even if it incurs higher costs for both parties involved.

In the short to medium term, effective technology transfer to farmers will be vital for OFBF adoption. Farmer participatory trials will play a pivotal role in showcasing the benefits, including increased yields, residual effects, and soil health improvements. A holistic approach is recommended, as biofertilisers enhance plant growth through their impact on plant biology, while organic fertilisers provide essential minerals for both plant growth and soil health.

Research funding for biofertilisers and organic fertilisers is available but limited. Instead, investing in research focused on developing biofertilisers using locally available resources is advisable.

South Africa possesses a wealth of untapped indigenous agricultural knowledge dating back to its early history. Exploring and learning from these traditional practices is essential when investigating organic fertilisers. Research efforts should concentrate on understanding and integrating indigenous knowledge systems to complement the historical use of mineral fertilisers.

Economy and market

The registration of organic inputs is a crucial step in the selling process. However, there have been unsustainable price increases in some of the raw materials. Prices are not decreasing due to increased production, as inflationary pressures continue to drive them up. While economies of scale may reduce our product costs by around 10%, achieving significant reductions beyond that seems unlikely.

There are intentions to expand export activities across Africa. However, exporting organic products across borders requires compliance with phytosanitary requirements. Upscaling might be easier to achieve, and more sales will be conducted through agents. However, it's essential to ensure that these partners are reliable and well-trained in organic products and principles.

There's potential for OFBF to gradually replace more and more mineral fertilisers, but the transition process faces obstacles due to limited and intermittent funding. The financial support available is not on a large scale, and we need to demonstrate the proof of concept before attracting more substantial financial backing.

On the other hand, the escalating prices of organic fertilisers may exert pressure that leads to increased financial support for bolstering agricultural production and reducing input costs. As the need to support agriculture becomes more apparent, there's hope for additional funding to facilitate the adoption of OFBF as a viable alternative.

Organic agriculture holds significant potential, especially for high-value products in greenhouse conditions. Opportunities exist for seedling production, including indigenous tree seedlings, flowers, and medicinal crops.

The absence of visible organic products in shops indicates a demand, particularly among wealthier consumers who value the importance of consuming nutritious and high-quality food. Currently, many retailers in Africa lack organic sections in their stores, but there is a growing interest in exploring this concept. Engaging with supermarket managers and franchises presents a chance to test the viability of introducing organic sections and determine if there is a potential price premium.

The awareness and demand for organic products in Africa mirror those in Europe, making it a timely opportunity to explore and develop a thriving organic market in the region. While starting from scratch, the potential for success is significant, given the increasing global consciousness about healthier and sustainable food choices.

Knowledge, education and training

Integrating the organic sector into colleges of agriculture is essential to facilitate training for extension officers. Prioritising consumer education is also crucial. Education for farmers and advisers plays a pivotal role, and universities must enhance their contributions to agricultural education. Success stories shared through word-of-mouth can inspire neighbouring farmers to adopt organic practices.

Transdisciplinary innovation platform approaches such as those of the RUNRES project should be established country wide. This approach encourages active participation and contributions from all stakeholders in addressing sustainability challenges. Collaborative efforts and mutual understanding among different entities are vital in tackling the sustainability challenges in agriculture.

Regarding human excreta-based fertilisers, although there may be genuine health concerns, addressing perceived risks through education and awareness is crucial for their successful adoption in agriculture. Providing farmers with essential information and boosting their confidence in using these fertilisers can lead to greater acceptance and utilisation.

Policy, regulation and certification

The policy landscape is gradually embracing a circular economy approach, generating interest in the recovery of organic fertilisers. To enhance composting and recycling practices, involving the Department of Agriculture as a potential off-taker for compost is essential. While composting is a well-established technology, its integration into human excreta waste streams remains uncommon. Previous composting innovations faced marketing challenges due to their bulky nature. Government engagement in compost marketing through subsidies or direct purchases for farmers could boost adoption by creating a critical mass and fostering understanding of the benefits of compost. Policy makers must prioritise research to drive meaningful development.

Exploring cross-sectoral synergies is another avenue to mitigate risks associated with these new investments in the financial sector. By bringing together stakeholders from waste management, water and sanitation, and agriculture, can pave the way for more sustainable and efficient solutions. These sectors, although diverse in their operations, hold significant potential for complementing and supporting each other in advancing organic fertilisers.

Guidelines for both organic fertilisers and chemical fertilisers are currently the same, imposing stringent conditions on organic fertilisers. To address this, there is a need to establish a clear differentiation between the two.

As advice to farmers, it is crucial that OFBF have proper certification. If not, they must be registered through ACT36 of the Department of Agriculture, which requires repealing and helps ensure traceability. In South Africa, it is mandatory to register any agriculture product before selling it.

The Department of Environment should conduct environmental impact assessments to evaluate the benefits to the country. It can be observed on maps that as more farmers adopt organic agriculture, waterways are protected from chemical pollutants.

The composting industry faces challenges, and many composters are being pushed out of the market. Many times, benefits like job creation and environmental advantages cannot be fully realised by the individuals investing in greener systems. This is where the government plays a crucial role in supporting these initiatives through tax incentives, regulatory support, or by becoming a market for the products, thus reducing the burden on the entrepreneurs.

The government can help de-risk investments in these industries by providing financial support, which is common in European Commission projects, where economically beneficial projects are funded even if they are not financially feasible. However, in many African countries, such support is not prevalent, leading to potentially valuable technologies with positive environmental and food security benefits being left unfunded due to the lack of incentives for entrepreneurs to pursue them. Synergies can be achieved when these entities come together and collaborate, leveraging their strengths. Additionally, these entities could also provide the necessary investment through blended financing, which would help de-risk the investments. Moreover, their involvement would act as a launch pad, generating interest from other companies as they recognise the sensible investment opportunities.

Another advantage of cross-sectoral synergies is policy harmonisation. Currently, different departments, such as the Department of Water and Sanitation and the Department of Forestry & Fisheries, have their own circular economy encouraging policies. However, they are not fully aligned and harmonised. By fostering cross-sectoral engagements, to address these disparities and facilitate discussions to harmonise policies, making it more encouraging for investment.

From the farmer's perspective, substantial government support is still required to ensure that they can internalise the changes, especially considering the shift in perceptions about fertilisers and the potential returns. The government should guide the farmers initially and provide a sustainable exit plan to allow them to continue independently.

8.2.12 Uganda

I Status quo

Mineral fertiliser

Uganda is grappling with low mineral fertiliser application due to escalating prices and limited access, especially in remote regions. The country's fertiliser usage per hectare is notably below recommended levels, with around 95% of farmers avoiding mineral fertilisers due to availability constraints and high prices. An NGO assessment highlighted fertiliser packaging issues, while counterfeit products continue to plague the market, posing quality and reliability challenges.

Traditional farming predominates in Uganda, with 90% of farmers relying on ancestral knowledge for natural and organic production methods. Consequently, Uganda has the lowest synthetic fertiliser application rate in the Sub-Saharan region, averaging two kilogram per hectare. However, this knowledge about mineral fertiliser usage is mostly confined to research centres, where comprehensive assessments are conducted. About 68% of smallholder farmers favour organic alternatives, although a few large-scale farmers still opt for mineral fertilisers.

Due to the ongoing fertiliser crisis, fertiliser prices in Uganda have more than doubled since early 2022, raising concerns about crop production and potential food shortages. Agriculture is pivotal to Uganda's economy, employing 72% of the population and significantly contributing to GDP and national income.

DAP (Di-Ammonium Phosphate) is the most common fertiliser in Uganda, but its price has nearly doubled since pre-pandemic times. Commercial farmers predominantly use inorganic fertilisers, whereas smallholders rely on organic sources for soil fertility management. Uganda's fertiliser input projection indicates growth, driven mainly by commercial farmers.

Application practices are basic, and few farmers adopt advanced techniques, resulting in potential losses. Uganda is facing a crisis as production costs surge, affecting businesses heavily reliant on synthetic fertilisers and pesticides. Disruptions caused by the Russian-Ukraine war further exacerbate the situation. Moreover, logistical challenges and fuel prices contribute to the overall cost increase, affecting not only small players but also large multinational companies in crops like coffee and beans. Domestic manufacturing of inputs is urgently needed. However, the high costs of fertilisers and inputs render them unaffordable for many farmers, necessitating subsidies from national companies, donor agencies, or the government, although such support might be unsustainable.

There is an increasing awareness of challenges tied to imported mineral fertilisers, prompting a willingness to explore alternatives. This is an opportune moment to mobilise stakeholders around these initiatives, similar to the successful dialogue on organic fertilisers. A growing trend involves combining synthetic and organic inputs, particularly in areas previously reliant on synthetic fertilisers. Cheaper alternatives are becoming appealing to farming businesses.

Despite Uganda's favourable soils and rainfall, declining soil fertility drives a growing need for fertilisers. While mineral resources like rock phosphate exist, there is no specific policy for their use in fertiliser production.

Uganda has a national fertiliser policy in place, yet concerns persist about its effectiveness and enforcement, with banned products entering the market. Safety issues, proper application methods, and protective gear usage remain areas of concern, necessitating accessible extension services.

Farm internal organic fertiliser

Uganda faces the necessity of internal organic fertiliser adoption due to diminishing soil organic matter content. 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.

In the realm of banana cultivation, a key staple in Uganda, large-scale farmers also employ cow manure. However, a challenge arises as most of this manure is retained for personal use, leaving no surplus for other farms.

Farmers' application of cow manure diverges from conventional composting methods; they create manure piles, leaving them to rest. After a duration, they collect the matured manure for application. The timing of manure application aligns with Uganda's two distinct growing seasons—a three-month rainy season followed by an equivalent dry spell, then repeating with a second rainy stretch and another three-month drought. In accordance with this pattern, farmers accumulate manure heaps during the dry season, away from planting periods. When rains commence, and planting time arrives, they deploy the stored manure onto their gardens.

Off-farm produced organic and biofertilisers

Production and technology

The fertiliser crisis presents a significant opportunity to scale up the production of organic inputs. This surge in interest has led to inquiries and efforts to improve manufacturing in the organic sector. Even major organisations like USAID, previously disinterested in organic farming, are now supporting domestic input manufacturing.

Uganda's agricultural transformation is being driven by the forefront role of OFBFaligning with sustainable practices championed by the Participatory Ecological Land Use Management (PELUM) Association. This movement, spearheaded by PELUM's extensive network of over 300 organisations, is propelling the adoption of ecologically sound farming techniques. A distinct focus within this movement is on nurturing the cultivation of OFBF. PELUM's member organisations are establishing biofertiliser units to educate farmers about crafting their own organic inputs.

The primary consumers of organic fertilisers in Uganda are predominantly commercial farmers, particularly those engaged in coffee, banana, and tea cultivation. Although some smallholder farmers express interest, the challenge lies in cultivating awareness regarding the quality of organic fertilisers. However, these farmers do acknowledge the deterioration of soil fertility in Uganda and actively seek remedies to address this issue. Despite the pressing demand for alternative fertilisers, the apprehension among farmers to rely on untested existing products poses a challenge. Blending mineral and organic fertilisers through a balanced strategy for soil fertility management might emerge as a more sustainable and promising long-term resolution.

The discernible positive impact of OFBF is particularly conspicuous in regions with a robust culture of certified organic farming. This is in stark contrast to areas heavily reliant on mineral fertilisers or devoid of inputs altogether. Furthermore, the mainly large-scale farmers, often export oriented are purchasing commercial OFBF products.

While the potential for off-farm produced OFBF is evident, they do come with inherent limitations. The financial burden of consistent replenishment is notable. In contrast, on-farm produced OFBF are proving cost-effective over time. Therefore, a preference leans toward on-farm crafted alternatives over off-farm choices.

Opting for a combination of organic and mineral fertilisers can be favourable. However, the reliability on off-farm inputs, be they organic or inorganic, can be marred by issues like deceptive labelling or incorrect composition.

While not all off-farm inputs are inherently problematic, the prevalence of counterfeit products underscores the necessity of certifying the origin of external inputs. This holds true for both off-farm and farmer-sourced inputs, safeguarding against potential risks and inefficiencies stemming from farming practices. Other challenges arise; for instance, the use of mixed coffee husk waste led to the spread of coffee wilt disease across Uganda, significantly impacting coffee quality. Such incidences highlight the need for proper knowledge, technology, and management of composting processes.

Sludge from wastewater plants in Kampala is often insufficiently treated for hygiene as the demand is very high. Studies have highlighted the hazards linked to using this sludge as fertiliser due to its questionable safety. Nevertheless, farmers are willing to take the risk, driven by demand that overshadows safety concerns.

Further challenges are logistics to collect organic waste. Both in urban and rural settings, waste segregation is not a prevalent practice, contributing to the complexity and costs. Processing technology applied is often of low quality. Currently, there are no specific tools in place to assess the availability of organic waste in Uganda. The government, particularly the Ministry of Agriculture, does not have a direct involvement in this aspect.

There are diverse activities on producing organic fertilisers, including residues from markets, industrial waste, fruit waste, coffee and banana residues, hotels and residues from farms. Products are compost, bioslurry, some microorganism-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. Diverse companies are active to offer commercial products. The product quality differs as no continuous monitoring of products exists. However, when a company intends to sell a product as “fertiliser”, it needs to be tested on nutrient contents and to be registered.

A Danish company has introduced an innovative technology for producing composts using market waste (and potentially other wastes such as faecal sludge for co-composting). Discussions are underway to connect them with more farmers (see Annex: Business case 2 – Biofertiliser Africa Ltd.). Investment costs are about EUR 1 million per 10 container units producing 7 000 t/year of organic fertiliser.

A recent president’s directive mandates waste recycling in urban areas in Uganda. Recyclable materials, including plastics, are to be collected, sold, or handed over to recyclers for proper recycling.

The Clean Development Mechanism project, backed by the World Bank, aimed to establish about 12 compost plants with 70-ton daily capacity. Presently, none of these, including the Mbale plant, are operational. Quality tests conducted in 2019 were affirmative, but their status deteriorated in the last 1-2 years. Corruption, particularly supervisors redirecting funds meant for private operators, led to the downfall of these plants in some cases. No source separation of waste hindered the process. Insufficient equipment for waste turning and lack of fuel funding exacerbated the issue. As a result, these treatment plants became dumping sites, attributed to management failures rather than market demand.

In the 1990s and early 2000s, there was a significant push in Uganda to promote ecological sanitation toilets based on the urine diversion model, known as urine diversion toilets. These toilets produced two fractions: faecal material and urine. However, due to the lack of services for emptying and managing these toilets or urine containers in urban areas, they eventually failed. As a result, many of these toilets were converted into other types of sanitation systems.

Research

Concerted efforts are underway to compile literature and comprehensively document the knowledge pertaining to organic farming practices. While traditional practices have yielded a repository of knowledge, the absence of thorough documentation, particularly in a scientific framework, remains conspicuous. Researchers are addressing this gap, striving to synthesise scientific evidence with farmers’ practices. It is worth noting that there is limited public funding available for research in the field of organic fertilisers and biofertilisers. Many universities and researchers are open to collaborating in research and product testing, but they usually provide platforms for research without financial support. This can sometimes be challenging due to high expectations and limited funding. PELUM is working to forge connections between farmers and diverse research institutions, aiming to unravel the active chemical constituents, their optimal levels, potential toxicity, and the ideal fermentation durations for top-tier quality OFBF.

In terms of research activities, there are some to mention. In close collaboration with the academic community, particularly Uganda Martyrs University, PELUM is venturing into a realm of possibilities within two prominent value chains: tomatoes and pineapples. Moreover, a comparative study has showcased the transformative potential of organic fertilisers. Bananas nurtured with these organic inputs have demonstrated vigorous growth and robust health. Presently, PELUM is immersed in a comprehensive comparative study spanning diverse value chains, including maize, experiences with various biochar and Bokashi treatments. A report is expected by May-June 2023. Currently, research efforts are also being made to concentrate urine into a solid fertiliser, making it less voluminous and more manageable for transport and use. Finally, there are also ongoing research endeavours exploring sustainable landfill practices, involving the extraction of resources from landfills for utilisation. However, the success of such initiatives heavily relies on the implementation of waste separation.

A crucial facet of research aims to underscore the efficacy of all farm inputs, including organic fertilisers, highlighting their potential for delivering results at a reduced cost. While off-farm produced organic fertilisers and biofertilisers might harbour uncertainties regarding quality and potential negative impacts on ecosystem services due to limited research, on-farm organic fertilisers buttressed by scientifically supported practices emerge as the preferred choice, owing to their foreseeable benefits.

Economy and market

Several start-up companies have ventured into the organic fertiliser space, capitalising on the growing demand for organic inputs (e.g., Imagine Her, which is an organisation supporting Start-ups by youth in Uganda). Numerous trainers are now educating farmers and students on how to produce organic fertilisers. As organic inputs gain popularity, organic fertilisers have become the latest trend in the agricultural sector.

PELUM, an association with a regional network of over 250 civil society organisations in 12 countries, extend to the private sector as well, reflecting resolute commitment to bolstering the prominence of trading in organic fertilisers. Rather than merely endorsing mineral fertilisers, the objective is to galvanise the private sector to embrace OFBF. PELUM endeavours pivot on rendering these organic alternatives not just competitive but compelling in terms of packaging and branding. PELUM encourages its members to participate in trade fairs, where they can showcase their products and establish connections with potential consumers. PELUM creates a marketing platform for its members and other NGOs such as ESAF help to link to more customers. Advisory services have no role played as yet but the in-house advisory services have been very instrumental in pushing the OFBF products.

90% of manufacturers in this sub-sector of OFBF are either seeking organic certification or financial support to develop and scale up their technologies, indicating that the companies are still in their infancy and not fully commercialised. They are actively looking to build networks and distribution channels.

The production of organic fertiliser on a grand scale presents challenges due to its time-consuming and labour-intensive nature. In contrast, inorganic fertilisers are easily accessible in stores, offering a more convenient choice for numerous farmers. While expanding the scope of organic fertiliser production for commercial use could potentially boost its appeal, the current reality is marked by confined small-scale production. There are some profits being realised by some companies. However, there is often no clear calculation of incomes and expenditures.

The escalating production of OFBF underscores its lucrative prospects as a viable business venture also for farmers. Consequently, there is demand for guidance on the intricacies of upscaling production, ensuring a consistent supply, and keeping pace with the burgeoning demand. But a discernible method for quality assessment of the product appears to be lacking. Moreover, farmers have developed skills in producing OFBF for sale, expanding beyond their own consumption. The demand for these products is increasing, with some farmers even scaling up production and trading among their peers. Success factors for organic fertilisers and biofertilisers include their affordability compared to mineral fertilisers, their positive impact on human health and the environment, and their proven effectiveness. When these inputs are locally manufactured, they can replace expensive imports, as inputs should ideally not be costly, being intermediate products.

Besides compost production there are also other products at the market. Biochar is economically more feasible for energy production. Commercial production of biochar and pellets for use as energy or materials has been successful, making it a popular option. Biochar offers long-term soil improvement rather than immediate crop benefits. This might pose challenges in marketing it as a soil amendment since farmers often seek immediate gains from soil treatments. However, biochar has found a strong market as an energy source, particularly in the form of pellets. Some farmers use biochar briquettes for heating chicken breeding houses due to their ability to retain fire for extended periods. The production of briquettes is mainly from faecal sludge, though small-scale initiatives use organic waste like banana peelings for cooking. In case of larger-scale biogas technologies, there are challenges in packaging, transporting, and selling the produced biogas. Biogas technology is not yet widely spread in developing countries like Uganda, making on-site usage more common for now. More information and advancements in biogas technology would be beneficial for broader adoption.

Numerous barriers persist in the widespread adoption of organic fertilisers and biofertilisers. Awareness among farmers regarding the availability of these products remains low, exacerbated by underdeveloped distribution channels. Within the spectrum of challenges, certain actors in the conventional sector, driven by self-interest, endeavour to undermine organic alternatives, safeguarding their stake in the sale of mineral fertilisers. The trust farmers place in the quality of compost products available in the market is notably constrained.

From an economic standpoint, leveraging inputs cultivated on the farm proves economically advantageous. Obtaining fertilisers from external sources introduces additional costs and, more crucially, an element of unpredictability concerning quantity, composition, and content. Conversely, producing on-farm manure yields savings, albeit with attendant labour expenses and occasional reliance on outsourcing. Nonetheless, the balance often tips in favour of on-farm production, chiefly due to cost-effectiveness. The yield and calibre of on-farm produced fertilisers are intricately tied to the availability of raw materials on the farm itself. This self-sufficient approach enables efficient utilisation of available resources, constituting a pillar of sustainable farming practices.

The profitability of employing organic compost resonates palpably through increased crop yields and the provisioning of indispensable nutrients that extend beyond the realms of N, P, and K, encompassing secondary macronutrients and micronutrients. An expedient combination of accessible feedstock and streamlined processing culminates in lower production costs.

However, the domain of waste management grapples with complexities in Uganda. The private sector's focal point frequently gravitates toward waste collection, motivated by the financial reward inherent in this endeavour. Many wastes transport entities function as formidable enterprises, collecting and subsequently disposing of waste without delving into further processing. The establishment of a compost facility through private funding is encumbered by significant hurdles. High land costs in Kampala, coupled with a dearth of incentives, potentially repel private enterprises from waste management ventures.

Economic priorities within waste management can be significantly swayed by fiscal dynamics. A pertinent example emerges within the realm of faecal sludge management, where septic tank emptying services encompass a dumping fee within the charged amount. Conversely, solid waste disposal lacks a corresponding dumping fee. This peculiarity implies that recycling and compost production ventures receive no compensation from waste generators. Considering the comprehensive expenses associated with producing a ton of compost, incorporating collection and transport, devising a selling price that sufficiently encompasses these costs proves challenging. Striking an optimal equilibrium between production expenses and selling price emerges as a pivotal determinant of the viability of composting initiatives, safeguarding their competitiveness in the market.

A Dutch company engaged in Black Soldier Fly (BSF) production operates in facilities owned by the Kampala Capital City Authority, avoiding the need for purchasing and constructing buildings. This approach may provide a more viable solution. Writing proposals and seeking support from organisations like the Dutch company, which prioritises environmental preservation and climate change perspectives, has proven beneficial. Some funders focus on the socioeconomic empowerment of farmers, while others, like the World Bank, emphasise reducing greenhouse gas emissions and promoting local compost usage among smallholder farmers.

In Uganda, there is still a group of input traders who import organic fertilisers and pesticides from various countries like India, Netherlands, and Portugal. Around a decade ago, all external organic inputs were imported and considerably expensive, even more so than synthetic alternatives. However, now there is a growing awareness among farmers about cheaper organic alternatives. Despite this, some individuals still hold onto the misconception that effective organic inputs are pricier than synthetics.

One of the interviewees argued: “We observe that certain high-value crops like coffee, vanilla, pineapple, and avocado are imported from regions close to the equator. Multinational companies dominate the production and distribution of these crops. To make a meaningful impact on small-scale farmers and African soil, we need to find a way to finance the use of our organic fertiliser until the increased yield becomes apparent. Developing a financing model for the initial six to eight months of fertiliser use could make a significant difference.”

Knowledge, education and training

The Ugandan government does not directly offer education and training in OFBF. Instead, training opportunities are provided by the private sector, primarily NGOs. Several obstacles hinder the widespread adoption of organic fertilisers. These include farmers’ limited awareness of their benefits, insufficient training in proper application techniques, a lack of established and reliable products, inadequate funding for organic farming initiatives, and the ongoing development of organic fertiliser standards that are still evolving. Challenges also involve bridging the knowledge gap for product development and appropriate technology.

One significant challenge with organic fertilisers is the lack of understanding and correct application among users. Many farmers are unfamiliar with the proper methods for utilising these inputs, resulting in misuse and potential harm to the environment. Consequently, farmers may not achieve desired outcomes, leading to their reluctance to use off-farm organic fertilisers in the future. Another concern is the limited knowledge and expertise of agriculture extension services regarding OFBF. Without proper support and guidance from these advisory bodies, the adoption of organic fertilisers becomes even more challenging for farmers. Furthermore, the absence of modern technology integration in farming, particularly Information and Communication Technology (ICT), obstructs the ability to detect misuse and counterfeit products.

Numerous positive developments are underway. PELUM Uganda is actively involved in multiple projects aimed at promoting the production, management, application, and consistent supply of organic fertilisers. One noteworthy initiative is the Organic Knowledge Hub for Eastern Africa, operating within the broader Knowledge Centre for Organic Agriculture. This programme primarily seeks to enhance the capabilities of farmers and facilitators who can disseminate technologies for creating biofertilisers from locally accessible materials on their own farms.

One of the most remarkable aspects of Uganda’s shift towards OFBF usage is the active involvement of its farmers. Through peer learning, knowledge exchange, and hands-on experimentation, farmers are discovering innovative approaches to producing potent organic inputs using locally available resources. This grassroots approach not only empowers farmers by giving them more control over their farming methods but also reinforces community resilience and self-reliance. Among organic farmers, there is not a single standardised measure in use. Instead, they rely on diverse traditional knowledge that varies from one family to another and from region to region. Concrete guidelines or recommendations for producing and applying OFBF are not found in books or official sources. While traditional fertiliser inputs are widely understood, some individuals are familiar with composting and even practice it on a small scale for nearby gardens. Nevertheless, employing compost for large farms remains a challenge due to concerns about its quality, particularly when it comes to compost produced municipal solid waste. Consequently, compost piles accumulate at production facilities, and there is a dearth of proper education or training in this domain.

Indigenous knowledge, learning from parental practices, online research, and consulting with established organic fertiliser producers are pivotal resources for establishing OFBF production. Products are often refined through experimentation, trial and error, and by incorporating feedback from farmers who have used them. Presentations have been delivered to researchers at the National Agriculture Research Organisation (NARO), raising awareness about the products and other advisory services. The African Women Leaders in Agroecology (AWOLA) mentorship programme and another supportive organisation, Imagine Her, are actively involved in assisting small OFBF production initiatives. PELUM Uganda has provided significant support and has also contributed to skills development through the AWOLA Mentorship programme. PELUM utilises social media platforms like WhatsApp, Facebook, Twitter, and LinkedIn for promotion and communication. The acceptance of OFBF among farmers is constantly increasing. Previously basic practices are now being adopted on a commercial scale with notable success. Manufacturers have played a role by bringing in product experience and expertise. The professional production of these inputs has rendered them more effective, with optimal concentrations of beneficial microorganisms capable of revitalising soil biology, combatting harmful microorganisms, and even addressing fungal diseases.

Tooro Kingdom, a traditional cultural institution, partners with organic farmers, affectionately terming them “organic ambassadors.” They impart training to farmers in creating their own inputs, practicing composting, and adopting organic farming techniques. This approach draws from traditional wisdom, learning from accomplished farmers, and replicating their methods. NOGAMU, in collaboration with institutions like Uganda Matters University, contributes to OFBF development by offering expertise, training, and trials. Their considerable impact on the agricultural sector has garnered appreciation from diverse stakeholders between 2017 and 2020. Advisory services are experiencing a resurgence, with significant demand and funding partners expressing keen interest in bolstering these offerings.

Uganda Martyrs University offers a range of programmes that centre on organic fertiliser production and sustainable agricultural practices, encompassing:

- Bachelor of Science in Agriculture: This programme lays a robust groundwork in the scientific principles imperative for successful agricultural endeavours.
- Bachelor of Science in Organic Agriculture: This specialised programme delves deeply into the principles and methods of organic agriculture.
- Master of Science in Ecology: This advanced programme elevates the comprehension of organic agriculture, emphasising ecological principles.
- PhD in Ecology and Food Systems: This doctoral programme immerses students in research and expertise pertaining to ecological farming and food systems.

All these programmes underscore the significance of on-farm inputs, production techniques, and sustainable marketing strategies. Furthermore, the university offers a programme designed to bridge the gap between theoretical knowledge and practical skills. This initiative educates students to become self-reliant farmers, arming them with the essential skills and principles of organic and ecological production. The university takes pride in effectively instilling these principles, ensuring that students can confidently apply their knowledge on their own farms and in real-world agricultural scenarios.

Taking Vermipro as an example, a producer of OFBF, they express dissatisfaction with the level of support received from farmer assistance organisations, highlighting that these organisations predominantly focus on training farmers to produce on-farm organic and biofertilisers. Vermipro has invested substantial resources in generating awareness about their products. They have conducted extensive training sessions for farmers nationwide, offering comprehensive explanations of the solutions provided by their products. However, setting up demonstration plots to showcase positive outcomes has proven to be financially demanding. Despite the expenses, results from farmer demonstrations have been overwhelmingly positive, leading to repeat sales from contented customers. Development agencies are advocating for regenerative agriculture, yet their approach does not align entirely with Vermipro's goals, as they encourage farmers to manufacture their own organic fertilisers. The company faces challenges as they undertake awareness-raising endeavours independently, lacking government extension support. Farmer organisations have a limited role in aiding the company's efforts, serving as contact points and providing opportunities to raise awareness during meetings. However, these farmer organisations do not have direct influence over farmers' decisions.

Policy, regulations and certification

Efforts are underway to empower farmers in participating actively in policy discussions, ensuring their ideas are integrated into various processes. This is particularly evident during the development of the National Biotechnology Strategy, where the issue of access, affordability, and management of OFBF is emerging as a viable and sustainable alternative to harmful chemicals. While previous attempts by the government to create organic inputs faced setbacks, these efforts are now being reinvigorated.

Uganda has a comprehensive national organic agriculture policy, yet it requires legislative backing through a bill and subsequent regulations for effective implementation. To bolster the organic sector, it is imperative to consider supporting the certification of OFBF, potentially through subsidies. The organic policy has already proven its worth in Uganda by bolstering the organic sector, leading to widespread recognition and increased adoption of organic fertilisers. Although existing policies emphasise the principles and practices of on-farm and locally sourced materials in organic production, the challenge lies in bridging the gap between policy content and practical execution.

Policies serve as guiding principles rather than mandatory directives, with the true obligation residing in adherence to the laws established by the parliament. For instance, the effectiveness of a well-designed policy on solid waste management hinges on its support from a dedicated law. In Kampala, the solid waste management ordinance stands as a legal framework for residents, while the broader national perspective is addressed by the Public Health Act, covering sanitation requirements but not exclusively focusing on solid waste management or recycling. In contrast, India has implemented legislation that incentivises compost sales, providing sellers a competitive edge over commercial fertiliser vendors.

II Future perspectives and recommendations

Mineral fertiliser: -

Farm internal organic fertiliser: -

Production and technology

As the organic adoption culture matures, a corresponding increase in production and productivity is anticipated. The ideal landscape envisions well-equipped farmers crafting their organic inputs, while those with limited resources can balance on-farm production with off-farm OFBF procurement to manage costs strategically. A discernible surge in demand for alternative fertilisers, especially in the context of Kampala city region, is foreseeable. To fully tap into the potential of off-farm produced organic fertilisers from organic wastes, fostering waste separation awareness is crucial. High-quality fertiliser hinges on thoughtful consideration of soil quality, as feedstock quality is intrinsically linked to it. Enriching the feedstock before marketing it as a fertiliser is an imperative step.

With more than 70% of Uganda's waste being organic in nature, a vast potential for resource recovery exists. Unravelling the factors that underpin successful outcomes is paramount, and dedicated research in this sphere is indispensable to instigate positive transformations and nurture waste separation practices in local communities. As the production and accessibility of OFBF expand, the prospect of gradually supplanting mineral fertilisers becomes feasible. This transformation is foreseeable in the long run, particularly since merely 5% of farmers currently resort to mineral fertilisers, and their application rate remains markedly low.

Economy and market

The organic sector in Uganda is undergoing rapid expansion, poised to drive higher production, demand, and marketing of OFBF. Two key objectives are at the forefront: firstly, lowering production costs; secondly, boosting the use of authentic inputs to amplify production growth and overall productivity. This shift is particularly significant for traditional farmers who have long relied solely on planting, weeding, and continuous soil extraction without employing inputs. The introduction of a more affordable alternative to mineral fertilisers would be welcomed. An essential consideration here is that compost production carries elements that serve a communal benefit by cleansing the environment, and the associated costs should be borne by the public sector.

In order to draw heightened attention from substantial investors, the legislation should encompass these dimensions comprehensively. While local investors presently play a pivotal role, framing compost production in a way that highlights its importance will attract more substantial investments from diverse quarters. Investors ought to subsidise prices, rendering the fertilisers accessible; they should also fortify the products to effectively compete with chemical fertilisers.

Research

For OFBF products, rigorous testing encompassing both laboratory assessments and certification is imperative. Equally crucial is the execution of field tests, perhaps through demonstration plots, enabling farmers to witness the impact on crops firsthand. In the imminent future, the imposition of standardised testing and regulations upon all organic fertilisers is a plausible trajectory. Presently, the primary voids pertain to the awareness surrounding and effective marketing of compost or fertilisers, complete with substantiated and verified outcomes. Further research stands as a necessity to elevate the quality of organic fertilisers, a requirement underscored by the analyses of samples revealing subpar quality.

Knowledge, education and training

To optimise the benefits of organic fertilisers for sustainable agriculture, emphasis must be placed on awareness campaigns, research endeavours, and adherence to established standards. This approach unlocks the complete potential of organic fertilisers in bolstering soil health and amplifying crop yields. Collaborative field testing with farmers, along with the provision of organic fertilisers enriched with nutrients like rock phosphate tailored to specific crop needs, holds promise. Batch-level analyses are essential for determining precise inputs, including enhancers, accounting for variations in NPK content within diverse waste fractions.

Development agencies assume a pivotal role by investing in training centres and demo plots showcasing various organic agriculture technologies. This empowers farmers to select solutions aligned with their needs. Additionally, the presence of government agricultural extension services would significantly bolster farmers' demand for bio-based products. It would also create supplementary distribution channels, driving heightened demand in areas with these services.

Policy, regulation and certification

Supportive policies exist in Uganda, but their effective implementation often necessitates complementary regulatory frameworks. Lobbying for the establishment of these frameworks, including research funding at universities, can amplify backing for organic fertilisers and sustainable agricultural practices. Such frameworks also hold the potential to attract funding from partners interested in supporting agricultural research initiatives.

Given that the existing fertiliser policy predominantly favours mineral fertilisers, there's a need to amend it to incorporate OFBF. Alternatively, a dedicated policy exclusively focused on OFBF might be beneficial.

To foster compost production, enabling laws that extend support through incentives or tax breaks should be introduced. This is vital because the benefits of compost production extend beyond individual gain, actively contributing to environmental well-being by curbing greenhouse gas emissions, pollution, and water contamination.

Acquiring certification for OFBF inputs and comprehending the demand for them to align with national needs are critical areas requiring further attention. Equally important is a profound understanding of optimal production and manufacturing techniques, pivotal for the successful integration of sustainable agricultural practices. Leveraging ICT tools can facilitate the identification of improper applications, while also highlighting fraudulent or ineffective organic fertilisers.

In the journey toward gradual transformation, collaborative efforts involving the government, development partners, donors, and private entities hold the potential for OFBF to gradually supplant mineral fertilisers.

To advance waste collection and management, streamlined bureaucracy and political stability are essential prerequisites. Implementing rigorous regulations on chemical inputs could effectively drive the adoption of organic fertilisers and biofertilisers. Encouraging on-farm soil fertility management systems in conjunction with off-farm organic fertilisers and biofertilisers can bridge gaps and accelerate uptake. The central focus remains on ensuring quality and fostering customer trust. Crucially, certified products undergoing rigorous quality testing play a pivotal role here, necessitating policy enforcement of stringent standards. Moreover, policy measures have the potential to facilitate marketing endeavours, expanding the product's market reach. However, there are also voices arguing, instead of crafting new policies, focusing on advocacy and popularisation proves more effective.

Acknowledging waste management as a public service necessitating government support is crucial for businesses addressing this issue. Implementing a regulatory framework that champions organic agriculture, biofertilisers, and organic fertilisers is paramount. This framework can permeate local governments, supported by demonstration plots showcasing various organic products. These plots empower farmers to make informed choices, thereby increasing demand for organic fertilisers and biofertilisers even in remote areas.

A well-structured regulatory framework could incentivise agro-dealers to stock OFBF products in regions with demonstration plots. Strengthening the capacity of government agriculture extensionists enables practical guidance for farmers.

In Uganda, the National Organic Agriculture Policy addresses numerous critical aspects. However, the absence of the National Organic Agriculture Act creates a regulatory gap that needs immediate attention. Therefore, expediting the legislative process is essential to ensure the effective implementation of this policy.

The key to Uganda's organic sector growth lies in aligning a supportive regulatory framework with the national organic policy. Furthermore, guaranteeing the availability of high-quality, affordable organic inputs is of paramount importance. Collaborative efforts among research institutions, governmental bodies, and private enterprises can promote standardised production processes that maintain the integrity of organic fertilisers while optimising cost-effectiveness.

Additionally, obtaining organic certification for OFBF, particularly with regional market ambitions, is a crucial step. Implementing legislation that mandates the exclusive use of organic fertilisers would strengthen this endeavour. Moreover, introducing policies that limit the importation of organic fertilisers can stimulate the growth of local organic fertiliser businesses. In light of the sustainability of donor support, backing domestic fertiliser manufacturing aligns well with future prospects. The intensified discussions involving the government and private stakeholders indicate a growing momentum towards domestic input production.

8.2.13 Zimbabwe

I Status quo

Mineral fertiliser

Fertiliser use in Zimbabwe, as well as in Southern Africa as a whole, remains quite low due to factors such as high prices. Delays in fertiliser deliveries caused by floods and cyclones, particularly in areas close to the border, are common. These delays can significantly impact crop yields. Mineral fertilisers are readily accessible in urban areas but may pose accessibility challenges in remote regions with poorly maintained and inaccessible roads. Furthermore, there are instances when fertilisers from the presidential input scheme are delivered late in the season. The market for fertilisers exists, but it comes with its own set of problems and challenges. Fertilisers are available in shops, but there has been a significant increase in their prices. This price hike has made it difficult for most farmers to afford the recommended quantities of fertiliser as advised by agricultural extension services. Many farmers face resource constraints and cannot allocate the USD 45 required for a bag of basal fertiliser, or the USD 60 needed for top dressing. Currently, most farmers rely on the presidential input programme when they receive special programmes, but they often lack access to fertiliser for their additional plots. Accessibility remains a significant issue, as suppliers often fail to deliver to remote areas due to the poor state of the roads. As a result, farmers are compelled to travel to service centres, further increasing the overall cost of obtaining fertilisers. Farmers heavily depend on this presidential free input scheme. However, they frequently deviate from recommended application levels and techniques. Instead, they opt for blanket application based on the fertilisers available to them, without considering the specific requirements of each piece of land. There are various types of fertilisers, each designed for specific crops. Although these fertilisers generally meet the chemical and nutritional needs of crops, they fall short in adequately supporting the biological and physical aspects of soil health essential for optimal crop growth. The education level of farmers is another factor to consider, and the absence of extension education often results in farmers resorting to blanket application because they lack knowledge about proper application rates and techniques. The quality of how chemical fertilisers are applied, both in terms of following recommendations and farmers' operations, is generally poor.

Regulations governing the fertiliser market are overseen by the Ministry of Agriculture, Fisheries, Water, Climate, and Rural Development, as well as the Ministry of Industry and Commerce. There is also a five-year plan aimed at strengthening the local industry, including local fertiliser companies, under the Ministry of Industry and Commerce.

Most areas are expected to be covered by government agricultural extension services (Agritex). However, the execution of these services is often unsatisfactory due to the dissatisfaction of extension staff with their remuneration and low number of staff per farmers. Agritex staff members are generally underpaid, which can lead to underperformance and reduced effectiveness of these services. There are also concerns about the accuracy of the element levels indicated on fertiliser packaging. Independent research has shown that the actual element levels in the fertiliser may not align with what is stated on the packaging. This has led to doubts about the quality of fertilisers available in the market. While many companies are emerging in the industry, there is uncertainty regarding whether proper product analysis is being conducted before these products are released onto the market.

The instances of defective mineral fertiliser products in the market can potentially lead to water pollution, as mineral fertilisers are not applied correctly, left uncovered, and are subsequently washed into water bodies during rainfall events.

Soil sampling processes are limited, and in certain areas, soil testing hasn't been conducted for almost 30 to 35 years. This applies to both soil content and soil acidity levels. Consequently, a significant portion of the fertiliser applied may not be efficiently utilised by crops. Zimbabwe imports nearly 50% of the fertiliser required.

Interestingly, the fertiliser crisis has also created some opportunities. There is the capacity to substitute some of the mineral fertilisers imported from outside with country's own manufacturing processes. However, unlike mineral fertilisers, organic fertilisers are not subsidised.

Farm internal organic fertiliser

There are concerns regarding the quality of organic fertilisers, both in terms of composting process, nutrient content and their long-term effects on the soil. Additionally, doubts exist about the availability of a sufficient quantity of animal manure. However, the motivation to use internally produced organic fertilisers stems from the fact that the resulting produce is more appealing to consumers compared to crops grown with mineral fertilisers.

Off-farm produced organic and biofertilisers

Production and technology

The fertiliser crisis is beginning to present some opportunities. The current waste management practices are not climate-smart; they involve disposing of waste in landfills, which is environmentally unfriendly. Produce grown with organic fertilisers is more appealing to consumers compared to crops cultivated with chemical or mineral fertilisers. A wide range of materials are utilised for compost production, including compost toilets, market and abattoir waste, aquatic weed, pig dung, and various raw materials sourced from the municipality of Harare. Vermicompost, which boasts significant nutrient concentrations and has a positive impact on soil pests, is available. Some private companies conduct quality analysis of these products. However, there are factors and risks that could hinder the expansion of production, such as power shortages, reliance on energy sources like diesel and petrol generators, and increasing transport costs that could raise prices.

Access to raw materials is generally straightforward. For example, the Harare City Council has occasionally delivered raw materials, but this arrangement lacks a secure Memorandum of Understanding. However, there is a more formal agreement in place for sourcing pig dung from farms engaged in pig raising. The Environmental Management Agency initially awarded a tender to remove weeds from Harare's water sources, providing another source of raw materials. The choice of raw materials depends on what is readily available.

The blending techniques and catalysts used, while not disclosed due to company confidentiality, are known for their quality. However, upscaling production has proven challenging because the entire process is manual. Transport also presents challenges, except when the City of Harare directly delivers the materials.

On the other hand, the government's Soil Research Institute in Marondera houses the second-largest Rhizobium plant in Africa, trailing only South Africa. This facility produces various strains of Rhizobium for crops like groundnuts, sugar beans, soya beans, peas, and pasture legumes such as lucerne, lablab, and sun hemp (*Crotalaria juncea*). This is a government initiative and it has been supported by initiatives such as projects like N2Africa, coordinated by Wageningen University & Research, which provided funding for some equipment. However, the technology used is quite old, raising concerns about the quality of the products.

OFBF is primarily used for vegetables rather than maize. There is potential for using human excrement via biogas and slurry, but this might require public demystification. External laboratory analysis has shown several benefits of vermicompost, including improvements in soil and crop yield, prevention of fall armyworm infestations in maize, nematode reduction, prevention of siltation, and the utilisation of human excreta as a resource.

The quality of OFBF can vary depending on the source of materials used, such as sugar cane, banana, or maize waste. While the specific blending process and the quality of the final product are considered proprietary and not disclosed, they are known to adhere to certain standards. For instance, vermicompost typically contains nitrogen (N) content ranging from 3.3 to 5, phosphorus (P) content ranging from 2.5 to 3.5, and potassium (K) content ranging from 1.5 to 3. However, because of the low levels as compared to chemical fertilisers, these values are not typically listed on the packaging for fear of misleading consumers as they are more accustomed to assessing fertiliser quality based on these parameters. Notably, soil organic carbon analysis is currently absent from the quality testing process. The presence of contaminants is expected, but there is a lack of analytical equipment, particularly for chemical and biological analysis.

Organic fertilisers and biofertilisers should not be seen as direct substitutes for mineral fertilisers. Instead, their integration with mineral fertilisers is a more effective approach. This integration offers benefits to farmers by reducing the cost of mineral fertilisers while simultaneously improving soil health. In sandy soils, for example, mineral fertilisers can be ineffective without the incorporation of organic materials, as the minerals are susceptible to leaching.

OFBF plays a significant role in complementing the supply of mineral fertilisers. Zimbabwe possesses ample organic waste resources that can be tapped for production. With the current shortage of mineral fertilisers, there is a growing expectation of increased OFBF production. However, the production of OFBF faces challenges, particularly related to manufacturing costs, which can impact product pricing and make them less affordable for farmers. Moreover, there are distribution challenges in ensuring these fertilisers reach the areas where they are needed most.

Research

Literature on this subject is quite limited. There is a lack of comprehensive information regarding the raw materials used in the production of organic fertilisers and biofertilisers. Research institutes and agricultural colleges play pivotal roles in conducting research trials and establishing demonstration plots. Additionally, companies such as the Tobacco Research Board, also play a role in assessing the impact of various fertilisers, including vermicompost, on crop growth. Moreover, one university has established a specialised research unit dedicated to conducting experiments related to crop cultivation, soil science, and soil fertility. However, there’s a need for better coordination and consolidation of research efforts, as well as reporting and information dissemination. Research has shown positive results when integrating organic fertilisers with mineral fertilisers, but it’s important to recognise that the benefits of organic fertilisers may take time to manifest, often over subsequent seasons. Therefore, a gradual transition from mineral to organic fertilisers is recommended, with integration in the initial seasons.

To advance research in this field, collaboration with experts in agriculture entrepreneurship and economics is essential to conduct socioeconomic assessments of biofertilisers and organic fertiliser production. Universities often work with limited investment support, particularly for student-centred projects. While some institutional-level support is occasionally received from companies seeking research on their products, national-level funding for research on OFBF is still a pending challenge.

Research on vermicompost serves as an illustrative example. The Tobacco Research Board conducted a four-year study on the suitability of vermicompost for tobacco, confirming its successful use in tobacco cultivation. The Marondera Horticulture Research Station has also demonstrated its effectiveness in various horticultural products. Zim Earthworm Farms secured a government tender and conducted experiments involving Water hyacinth and Hydrocleis to feed worms and produce vermicompost. Additionally, research on vermicompost and earthworm technology has been carried out. Notably, the Agriculture Extension Services, a government department, engaged in seven years of research in collaboration with Zim Earthworm farms.

One of the commercial organic fertilisers has been endorsed by the government for use in the national climate-smart production project. UN agencies operating in Zimbabwe have also highly accepted the product, often recommending it for use in their projects.

Economy and market

The fertiliser crisis has presented an opportunity to enhance the visibility of OFBF. For farmers, these products are not only more cost-effective but also offer additional benefits like improved climate resilience. There is an increasing demand for OFBF, particularly vermicompost. Advertising is conducted through local newspapers, radio, television, and various social media platforms.

However, the business is not highly profitable. Factors affecting profitability include processing and transport costs for raw materials, transport to distribution points, high labour costs due to manual work, and the absence of technology. The market price for organic fertilisers is approximately 50% of the price of mineral fertilisers. Despite these challenges, organic fertiliser prices (such as compost) remain relatively low because raw materials are readily available and stable in price.

Factors like depreciation, cost of raw materials, transport costs, cost of capital expenditure, borrowing costs, and exchange rates all impact profitability. Notably, the rising prices of inorganic fertilisers have increased demand for organic alternatives. Organic fertilisers cost about 50% less than chemical fertilisers and offer the added advantage of introducing beneficial microorganisms and soil carbon to the land. The business may not be highly profitable, but it is sustainable and has experienced increasing demand over the last decade, particularly since the Russia-Ukraine conflict. These products are available in nurseries and numerous retail outlets, but competition with other market players is rising.

Using Rhizobia as an example, during unstable economic periods, the department faces challenges due to pricing issues, especially given the reliance on the US Dollar. Nevertheless, Rhizobia remains a cost-effective alternative to inorganic fertilisers. One notable challenge is the lack of a robust marketing strategy and adequate support resources. Additionally, there are concerns about unscrupulous dealers selling expired or repackaged products. Evaluating the quality of raw material sources in a more comprehensive, circular manner is essential.

Organic fertilisers have gained significant traction in the market, with growing demand attributed to the environmental benefits they provide. The quantity of organic food exports and local consumption is directly linked to the use of OFBF to facilitate production. Demand for these fertilisers has risen notably since the Ukraine-Russia conflict, mainly because consumers are now seeking more affordable options. Multiple marketing channels are utilised, with the most effective approach being proximity to farmers. Nonetheless, there remains a lack of policy-level financial support and insufficient capital for expanding production.

Key stakeholders include farmers, value chain participants (such as chili and tobacco growers), farmer organisations, and the potato association. Market information is crucial because some farmers perceive the product as inferior. To reach customers, merchandisers are stationed in numerous retail outlets that stock the products. There is also a network of agricultural input shops that distribute other agricultural inputs nationwide, making them easily accessible to farmers in different regions.

While formal advertising channels have been explored previously without significant returns, the use of WhatsApp platforms has proven highly effective in raising product awareness. Various WhatsApp groups are leveraged for this purpose.

Knowledge, education and training

The key stakeholders in this context include farmers, companies involved in chili and tobacco production, farmer organisations, and the Potato Association. The Department of Agriculture Extension Services plays a vital role in disseminating information and raising awareness about OFBF. They also support on-ground demonstrations and assist farmers in adopting these fertilisers. Development partners engaged in farming programmes are recommending the use of organic fertilisers and fortified products over chemical fertilisers.

The government has occasionally supported such initiatives through projects, and these programmes have also received assistance from institutions like the Wageningen University & Research through projects like N2Africa, which has benefitted from equipment purchases. Advertising efforts utilise local newspapers, radio, television, but mostly social media platforms.

Demonstration plots at agricultural colleges play a significant role in training prospective agricultural extension workers. These trainees become familiar with the products and can better support and advise farmers. Some NGOs are also actively involved in supporting demonstration plots.

Policy, regulations and certification

Zimbabwe's economy is heavily reliant on agriculture, making fertiliser production a critical sector. Consequently, the government has consistently offered support by implementing various measures such as tax and duty exemptions, recognising the importance of this industry. The Ministry of Agriculture, Fisheries, Water, Climate and Rural Development, collaborates closely with the Ministries of Finance & Economic Development, Industry and Commerce. These ministries are directly associated with aspects like financing, taxation and border control, which are essential for the importation of raw materials. They have implemented supportive policies and established a legal framework that fosters a conducive environment for the production and marketing of fertilisers.

At present, there is no specific policy or regulatory framework dedicated to organic fertilisers in place. Instead, the existing regulations primarily pertain to inorganic fertilisers. Regulatory authorities focus mainly on measuring nutrient levels like nitrogen, phosphorous, and potassium in fertilisers, without considering factors such as biomass, the introduction of microorganisms into the soil, and soil carbon content that are associated with organic fertilisers. The current policy framework strongly supports mineral fertilisers, and this stance is also reflected in the practices of development partners and sales outlets where mineral fertilisers and related inputs are readily available. Shifting these engagements and policies OFBF has the potential to increase their acceptance among farmers.

II Future perspectives and recommendations

Production and technology

Increasing the utilisation of "internal" organic fertilisers sourced locally and integrating them with mineral fertilisers represents an optimal approach. This integration capitalises on their complementary attributes. Organic waste should be refrained from being discarded at dumpsites; instead, implementing source separation of waste would notably enhance the quality of raw materials.

Investment in front loaders and general mechanisation, particularly in the reorganisation of rhizobia technology, is imperative. Moreover, scrutiny of packaging, storage conditions, and the enduring quality of products over time is warranted. To maintain up-to-date fertiliser recommendations and address soil acidity concerns, conducting more comprehensive soil sampling across the entire nation is pivotal. It is anticipated that increased competition may lead to a reduction in the prices of chemical fertilisers before contemplating their replacement.

The persistent issue of power cuts significantly disrupts production schedules, sometimes necessitating night time operations. In this regard, transitioning the production unit to solar power or establishing a subsidiary factory in locations where power cuts are less frequent, is advisable. The expanding adoption of organic farming could drive an increase in demand, potentially prompting an upsurge in production.

Research

Organic materials play a pivotal role in promoting a healthy environment and sustainability, which has significant economic implications. Using fertilisers more efficiently and reducing their overall consumption can greatly enhance productivity. When discussing productivity, it is crucial to consider not only yield but also the chemical, biological, and physical improvements they bring to the soil, especially from a soil scientist's perspective. Organic fertilisers are advantageous for overall soil health. However, it is essential to note that these fertilisers may contain impurities, highlighting the necessity for comprehensive research to ensure the removal of contaminants. Organic fertilisers and biofertilisers have substantial potential, but thorough research is essential to determine how they can best complement mineral fertilisers and optimise their production. These fertilisers contribute significantly to improving soil fertility by enhancing its biophysical components and even its texture. Furthermore, they play a substantial role in strengthening ecosystem services, fortifying the soil's biophysical aspects, and enhancing its biological quality over time.

The use of human excrements via biogas and slurry as a source of raw materials is a viable option, although it might require public education and demystification. It is essential to consider the source of raw materials, including the type, origin, and sustainability of the supply chain. It's akin to mining from a single location and transporting it to the factory for processing and sale. This approach warrants careful consideration, as it may have negative environmental impacts at the source. Therefore, a more circular assessment of raw material sources is needed to ensure sustainability and minimise potential harm to the environment.

Researchers should initiate investigations into the impact of chemical fertilisers on soil fertility. Allocating additional resources for conducting demonstrations is crucial to generate scientific evidence regarding the benefits of OFBF. Disseminating extension messages backed by scientific findings can incentivise their adoption. Farmers are more likely to replace chemical fertilisers with OFBF when they possess a comprehensive understanding of the background and advantages of these alternatives. The rate of replacement hinges on the support provided for OFBF, which includes research initiatives, awareness campaigns, and effective extension messages that directly reach farmers. The establishment of demonstration centres can facilitate this process. Research efforts should prioritise assessing the nutrient content of resources like Russian comfrey, pigweed, and water hyacinth, followed by evaluating the effects of organic fertilisers on specific vegetables. Guiding students in conducting research projects can be a valuable strategy for this purpose. It is pertinent to acknowledge that farmers often utilise organic fertilisers without being aware of the nutritional content of the resources they employ. The integration of mineral fertilisers, externally sourced organic fertilisers, biofertilisers, and internal organic fertilisers is contingent on cost considerations and the adaptation of assessment parameters. Advocacy for the integration of OFBF with mineral fertilisers should be promoted. However, this integration must be underpinned by comprehensive research on organic fertilisers and biofertilisers before implementation. Combining these approaches can optimise their benefits. Further research is necessary to strike the right balance between effectiveness, efficacy, and quality. It is worth considering that organic fertilisers and biofertilisers may contain toxins with potential long-term implications. Research should encompass a broader spectrum of plants since farmers frequently employ various organic resources without a clear understanding of their composition and their soil impact. Encouraging farmer participatory research and providing knowledge on the proper application and utilisation of organic fertilisers and biofertilisers is essential.

The primary concern is whether there is a sufficient supply of organic fertilisers and biofertilisers to meet the needs of farmers. Additionally, there is need to assess the quality of these products, including their toxicity levels and potential adverse effects on humans. Regrettably, the quality of most organic fertilisers and biofertilisers remains untested. It is imperative to establish a classification system for these products and conduct market research. It is worth noting that many years of research and development would be required to reach a stage where mineral fertilisers can be completely replaced by OFBF.

Economy and market

Prices are expected to remain competitive compared to chemical fertilisers, especially if transport costs remain stable. The introduction of more efficient production methods through new plants may also contribute to cost reductions and, subsequently, affect pricing positively.

The constraints for market development of Rhizobia are primarily related to the absence of a well-defined marketing strategy and the lack of adequate support resources. In most retail shops, mineral fertilisers and their related inputs dominate the market, overshadowing organic fertilisers and biofertilisers. Shifting the focus of these market engagements towards organic fertilisers and biofertilisers could significantly enhance their adoption among farmers.

To expand the market for these products, it is essential to secure the necessary capital for procuring raw materials and covering operational expenses. This financial support is crucial for ensuring that the product can gain a foothold both locally and in international markets.

Before considering imports, it is crucial to conduct a thorough evaluation of a country's internal capacity for producing OFBF. It is important to note that importing dried earthworms, as seen in the cases of Zambia and Botswana, is unnecessary.

Knowledge, education and training

It is important to empower farmer organisations by supporting their initiatives, including the procurement and management of demonstration plots for their programmes. Practical agricultural demonstrations, where farmers can witness the impact of organic production compared to inorganic fertilisers at the farm level, are likely to drive change. It is crucial to enhance farmers' market knowledge and educate them about the benefits of OFBF. Several regional and national initiatives are being explored to facilitate farmers' access to organic fertilisers.

Integrating carbon and factors like water permeability into the equation could boost farmers' acceptance of these fertilisers. For instance, in a heavy rainy season like the 2022/23 rainy season, the performance of crops under chemical fertilisers versus organic fertilisers differs due to leaching of the former. National crop assessments should compare the performance of crops under both types of fertilisers to provide a comprehensive evaluation.

Promoting OFBF requires informative advertising through various channels, including television and radio, as well as unbiased support from public extension services. It is essential to ensure that the promotion of these fertilisers remains neutral and that it is not influenced by the chemical industry. An effective entry point could be motivating urban gardeners and agriculturalists, as their adoption could subsequently influence rural farmers.

Policies, regulations and certification

Transitioning to organic waste-based fertilisers and biofertilisers represents a viable way forward, particularly in light of pressing issues like climate change and the expectation of reduced rainfall in the coming decades. Promising production activities are underway, but they require support at various levels. It is essential to ensure free access to waste through collaboration with city councils. Collaborating with the government's Agriculture Department of Research and Specialist Services is essential for ongoing research and product development. Policies should be established to ensure that biodegradable waste is not disposed of in dumpsites but made available to fertiliser manufacturing companies for conversion into organic fertiliser. Institutions generating waste should adopt climate-smart waste management policies and regulatory frameworks. City councils and similar institutions should invest in waste management technology to unlock the potential of organic waste.

While there is an existing supportive policy and legal framework that facilitates a favourable environment for production and marketing, there remains a crucial need for a comprehensive organic fertiliser and biofertiliser policy. A robust policy framework should encompass standardisation for industrial organic fertilisers and biofertilisers, with active participation from the Standards Association of Zimbabwe. To make well-informed policy decisions, the government should conduct independent assessments to determine pricing and evaluate the impact of these fertilisers on soil properties, including structure, water permeability, water retention, and carbon content.

The analysis of organic fertilisers should take a comprehensive approach. Rather than solely focusing on assessing nitrogen, phosphorous, and potassium levels, it is imperative to consider the broader impact on soil health and ecosystem services. Implementing agricultural demonstrations where farmers can witness the tangible benefits of organic farming compared to conventional inorganic fertilisers at the farm level can be a powerful catalyst for change. Additionally, exploring combinations of both fertiliser types – mineral fertilisers and OFBF - should be considered. To revitalise Rhizobia technology, substantial support is required to reconfigure the entire process. This encompasses investments in demonstration plots, research initiatives, advisory services, and the development of a robust marketing strategy and regulatory framework.

Supporting farmer organisations in procuring OFBF and operating demonstration plots for their programmes can significantly promote the adoption of organic manures, effectively increasing the utilisation of OFBF in agriculture. This entails investments in demonstration plots, research initiatives, advisory services, the development of a marketing strategy, and the establishment of a regulatory framework.

There is still significant untapped potential to boost the demand for OFBF. One promising avenue is the integration of these fertilisers into government food security programmes, such as the presidential input programmes. The government is enthusiastic about promoting this integration, provided they can secure the necessary resources and technology.

Establishing an association or umbrella organisation that brings together organic fertiliser and biofertiliser companies would create a platform for collaboration and shared initiatives. Regulators within the fertiliser sector should rigorously approve and certify these products, ensuring their authorisation before they are released to the market. This process guarantees that these products meet the necessary quality and safety standards.

Regulators in the fertiliser sector should follow rigorous processes to approve OFBF products, ensuring their certification and authorisation before release. Exporting OFBF products to countries like Botswana, Zambia, and Malawi is challenging due to compliance with regulations and laws in those countries. The involvement of key ministries, such as the Ministry of Agriculture, fisheries, water, climate and Rural development, Ministry of Finance and economic Development, and Ministry of Industry and Commerce, which oversee taxation and border control, in the importation of raw materials raises questions about the sustainability of this strategy.

Furthermore, at the continental level, the African Union should remain open to innovative ideas originating from Africa regarding the development of OFBF. An association or umbrella organisation should be established to bring together organic fertiliser and biofertiliser companies. This association can develop a policy framework to guide these companies' production and standardisation within the sector. It should also support research and production, which may include subsidies.

In a recent development, a meeting with 11 EU ambassadors resulted in over EUR 207 million allocated to the Zimbabwean Ministry of Agriculture, Fisheries, Water, Climate and Rural Development to support conservation agriculture, and the green agricultural economy. Additionally, a Statutory Instrument (SI) is in progress to bolster organic agriculture, with a special emphasis on fertilisers.

Governments should strongly consider promoting organic farming as a sustainable approach. To facilitate this shift, a supportive policy framework is vital to secure financial backing. The development of agroecology and organic farming policies, currently in progress, should also be accompanied by a supportive regulatory framework. The Ministry of Agriculture, Fisheries, Water, Climate and Rural Development is actively developing an agroecology and organic strategy, recognising the growing significance of the organic niche market. To ensure the success of organic farming, comprehensive policies covering the entire value chain are being crafted. These policies should prioritise research in organic agriculture and recognise the value of research contributions. A Statutory Instrument (SI) is under consideration to bolster organic farming, with a particular focus on fertilisers. However, a deeper understanding of market dynamics is required. Financial support is crucial, especially for organic research and adoption. Initiatives to obtain organic certification have already been initiated and should be pursued further.

8.3 Business cases

8.3.1 Case 1: Regen Organics - Kenya

Source: Interview KEN-4 & TECHNOSERVE (2023)

1. General

Location	▪ Nairobi, Kenya (3 production units)
Name	▪ Regen Organics (part of Sanergy)
Founding date	▪ 2011
Organisation type	▪ Private company
Products	1. Compost (Evergrow) 2. Compost (Evergrow Gold – Organic certified) 3. Black soldier fly (KuzaPro Insect Protein) 4. Briquettes (EverMoto – ecofuels)
Key partners	▪ USAID, Ecocert Group ▪ Cranfield University (field trial research in 2023)

2. Performance indicators

Amount of produce (t/year)	▪ Compost: 3 600 (2022) ▪ Compost: 12 000 (estimated 2023)
Capital investment	▪ >USD 2.5 million
External funding	▪ Various investors (e.g., U.S. International Development Finance Corporation, AngloAmerican)
Organisation and maintenance costs (€/year)	▪ n/a ▪ largest costs are purchasing organic waste and transport, followed by waste sorting
Retail prices per product (€/t)	▪ n/a
Retail prices per bag (€/50 kg)	▪ between 2 000-3 500 Kenyan Shilling (€15 to €25)
Payback period	▪ n/a
Revenue (€/year)	▪ n/a (operations are profitable)
Revenue streams	▪ Sales of compost most important revenue stream
Gross margin (%)	▪ n/a
Number of employees	▪ 200 – 500
Market share	▪ >50% (=market leader)

3. Production

Waste collection	▪ Well-developed waste supply chain, establishment close to waste sources (=<50 km), main success factor ▪ Food processors are the most important source ▪ Circa 60 000 t/year waste collection (2023)

Waste input type(s)	▪ Organic wastes from food processing, outdoor markets, grocery stores, large hotels, abattoirs
Production	▪ Equipment is largely imported ▪ 8 ha production space for Black soldier flies (BSF), wastes which are not suited for BSF are composted
Requirements for future scaling	▪ Possibility to receive sorted waste at a low price/free of charge ▪ Government incentives (e.g., tax reliefs on equipment) ▪ Favourable interest rates for financing

4. Product development

Products	▪ Compost, animal feed insect protein, briquettes ▪ Products in powder form (manual application) ▪ Quality packaging to strengthen quality perception
Product quality	▪ regular laboratory testing of products, field trials for product relevance and efficacy ▪ Evergrow (N=1.5-3%; P=1%; K=1%) ▪ Evergrow Gold (N=1.5-3%; P=1%; K=1%) (certified organic) ▪ Products are certified by the Kenya Bureau of Standards
Research and development	▪ Own research on recipes: 45 different formulations developed according to available wastes ▪ 2023: Development of specific application recommendations with scientific partner Cranfield University ▪ Ongoing development of granular forms to address market needs of larger, mechanised farming operations
Requirements for future scaling	▪ Development of appropriate application recommendations through field testing ▪ Further product development through product composition/formulation

5. Marketing

Customers segments	▪ 6 500 smallholder farmers (goal to add 10 000 more in 2023) ▪ 300 to 500 mid-size-farms (5 – 100 ha) ▪ Evergrow Gold: organic/export-oriented farmers
Market channels	▪ Retailers nationally (>95%) ▪ Direct sales (<5%)
Requirements for future scaling	▪ Key to success is education/awareness building (=increasing demand) ▪ Increase outreach through partnerships

6. Success factors and challenges

Main success factors	Main challenges
▪ Dedicated investors/international donors ▪ Knowledge and know-how (mother company in United States)	▪ Lacking high quality equipment, need for import of equipment (no tax relief)
▪ Education/high quality demo trials and field days	▪ Expenses for demo trials, awareness building

▪ Regular quality control (trust building)	▪ Expenses for collection/sorting of wastes
▪ Professional packaging (trust building)	▪ Lacking government incentives
▪ Operations close to waste streams (no more than 50 km)	▪ Limited scientific evidence on application rates and effectiveness etc.
▪ Cooperation with retailers	▪ Unfavourable interest rates for investments (e.g., for equipment)
▪ Inorganic fertiliser price increases = (locally produced) organic fertilisers more valued	▪ Costs for collection, sorting, equipment import hinder faster scaling
▪ Degraded soils show positive yield impacts, thus increasing awareness and demand	
▪ Mechanisation (e.g., shredding of material = faster composting, better quality)	

8.3.2 Case 2: Biofertiliser Africa Ltd. - Uganda

Source: Interview UG-10

1. **General**

Location	▪ Uganda - Kampala: Office for admin & sales; Iganga: Production site; Kwanda: Research and science, fertiliser development, demo garden
Name	▪ Biofertiliser Africa Ltd.
Founding date	▪ BACESS A/S DK Reg.: DK25808274 (Technology Owner) established year 21.12.2000 ▪ Biofertiliser Africa Ltd. Uganda, 2017 (subsidiary company)
Organisation type	▪ Private company
Products	▪ Organic Fertiliser (N-P-K)
Key partners	▪ Hans R. Neumann Stiftung, NUCAFE, farmer cooperatives, NGOs, municipalities

2. **Performance indicators**

Amount of produce (t/year)	▪ Compost: 6 000 (2024)
Capital investment (€)	▪ Ca. 1 Mio.
External funding	▪ n/a
Organisation and maintenance costs (€/year)	▪ 250 000 ▪ largest costs are operation – purchasing organic waste and transport, followed by waste sorting
Retail prices per product (€/t)	▪ 500
Retail prices per bag (€/50 kg)	▪ UGX 150 000 (ca. €38) (2023)
Payback period	▪ 3 years
Revenue (€/year)	▪ In piloting phase - upscaling
Revenue streams	▪ Sales of organic fertiliser and other organic inputs most important revenue stream
Gross margin (%)	▪ n/a
Number of employees	▪ 10
Market share	▪ Still in pilot phase – upscaling phase

3. **Production**

Waste collection	▪ Waste supply chain in development, collection from markets ▪ Distance of <60 km
Waste input type(s)	▪ Market wastes (more or less sorted) ▪ NPK Boosted with: Soft rock phosphate, ash, *Tithonia diversifolia and animal manure etc.*
Production (technology)	▪ Modular concept of closed container system, 10 container units with machinery for mixing and chopping wastes to 20-40 millimetre ▪ 10 container units = 10 000 t/year waste input approx. = 7 000 t/year output as organic fertiliser ▪ Temp. and oxygen sensors, control of oxygen level = controlled and documented sanitation of biomass, reduction of GHG emissions; exhaust emissions can be filtered with a biofilter. Control of oxygen level to avoid anaerobe processes and therefore no methane and other GHG outlet ▪ Technology process is verified by EU ETV = Environment technology verification ▪ Temperature increases to min 70 degrees within 48 hours and kept for minimum 1 hour according to international standards for safe organic material recycling heat treatment ▪ Dry matter for treatment process between 30-70% ▪ Containers are locally produced; sensors, electronics, steering and control system are made in Denmark (BACESS A/S technology owner). The system can be controlled remotely worldwide via internet connection
Requirements for future scaling	▪ Investors can accelerate and facilitate faster scaling ▪ Further increasing demand – higher demand than capacity ▪ Higher demand than capacity ▪ Incentives for avoided GHG emissions from landfills and from the avoided emissions due to the closed container system would help accelerate production

4. Product development

Products	▪ Currently, three recipes for coffee cultivation; planting: NPK 4.5:7:2; vegetative stage: 7:3:3; Flowering stage: 2.4:3:9
Product quality	▪ Tested in laboratory and demo gardens over the last 3 years ▪ Product registered with MAAIF authorities Uganda
Research and development	▪ Conducted on-farm field trials (anecdotal: 100% in coffee yields) ▪ Participated as experts in standard development with the Uganda National Bureau of Standards (UNBS) for organic fertilisers in the East African region.
Requirements for future scaling	▪ Cooperation with food processing facilities: business model for on-site processing ▪ Development of new recipes for food processing suppliers, to create a sustainable bio-circular closed loop and get carbon and nutrients back to farmland

5. Marketing

Customers segments	▪ Currently for high value crops/cash crops (coffee) as well as food security in developing countries
Market channels	▪ Field demonstrations, word of mouth, cooperation's with NGOs
Requirements for future scaling	▪ Carbon credits may help to support the adoption of organic fertilisers for other non-cash crops as well as World Bank support ▪ Increasing knowledge and awareness among institutions, retailers, policy makers, customers etc.

6. Success factors and challenges

Main success factors	Main challenges
▪ Higher nutrient levels by fortification ▪ Mining license in Uganda (soft rock phosphate)	▪ Access well sorted organic waste, setting up a sorting system – sort at source
▪ Specific nutrient composition of product, currently for coffee, adaptable for other crops	▪ Financing of inputs by smaller farmers (low cash availability between planting to harvest). Appropriate business models needed for farmers (e.g., cooperative model)
▪ Product applicable in organic farming	▪ Bureaucracy, easier domestic organic fertiliser product registration necessary; corruption and low education
▪ Modular system can be adapted site specific, high flexibility in adoption	▪ Lack of awareness/knowledge on organic fertilisers among institution who provides dealership certificate for the product
▪ Less land necessary due to fast composting process	▪ *Tithonia diversifolia* for nitrogen addition needs (wild plant found throughout East Africa) harvesting and collection needs to be organised
▪ Raw material availability: Organic waste is plentiful available	▪ Risky investment environment
▪ Market drivers: High and increasing demand for alternative fertilisers	▪ Small scale farmers cannot afford price on imported chemical fertiliser. The organic fertiliser market increases by 12% per year worldwide
	▪ No reliable and accredited lab analysis available, therefore currently no human waste used as a good source of nutrients

8.3.3 Case 3: Vermipro Ltd. - Uganda

Source: Interview UG-6

1. General

Location	▪ Kigunga Seeta, Uganda
Name	▪ Vermipro Limited
Founding date	▪ 2018
Organisation type	▪ Private

Products	▪ Organic fertiliser ▪ Biofertiliser
Key partners	▪ National Agriculture Research Organisation Uganda

2. Performance indicators

Amount of produce (t/year)	▪ Organic fertiliser: 500 t/year ▪ Biofertiliser: 6 000 m^3/year
Capital investment (€)	▪ €1.1 million
External funding	▪ none
Organisation and maintenance costs (€/year)	▪ n/a
Retail prices	**Organic fertilisers** ▪ Calphos liquid foliar fertiliser: €11.60/litre ▪ Vermicompost: €58/50 kg ▪ Vermichar: €58/50 kg ▪ Germination booster: €8.40/litre **Biofertiliser** ▪ Superagric biofertiliser: €8.40/litre ▪ SG1000: €11.60/litre
Payback period	▪ n/a
Revenue (€/year)	▪ €350 000/year (not yet profitable)
Revenue streams	▪ Organic fertiliser (tipping fees offered, but material is procured from selected sites) ▪ Biofertiliser
Gross margin (%)	▪ n/a
Number of employees	▪ 21
Market share	▪ n/a

3. Production

Waste collection	▪ Farms within 80 km proximity from the production sites
Waste input type(s)	▪ Farmyard manure (cows, goats, poultry) and other green agriculture wastes
Production (technology)	▪ Vermicomposting, industrial microbiology and biochemistry
Requirements for future scaling	▪ Market access support, in-country production systems where concentrates from the central facility if supplied to complete manufacturing for specific markets and technology transfer

4. Product development

Products	**Organic fertiliser** ▪ Calphos foliar fertiliser, Vermicompost, Vermichar, Germination booster **Biofertiliser** ▪ Superagric biofertiliser, SG1000 (AM –Arbuscular Mycorrhiza)
Product quality	▪ Various product certifications: Kilimohai - Regional Organic Standard (East Africa), USDA Organic Standard, EU Organic Standard ▪ For certification lab analysis have been conducted

	▪ Vermicompost: 0.97 N; 0.9 P; 0.85 K
Research and development	▪ Implementation of demonstration plots
Requirements for future scaling	▪ Support in setting up demonstration plots and training centres for raising awareness, e.g., extension services ▪ Financial incentives may support scaling as implementation of demo plots is costly

5. Marketing

Customers segments	▪ Smallholder farmers, organic certified farmers as well as large scale farms
Market channels	▪ Work with and training of farmer groups, cooperatives ▪ Agro-dealers
Requirements for future scaling	▪ More field demonstrations ▪ Increasing awareness among stakeholders ▪ Financial incentives ▪ Increased training of and product uptake by agro-dealers ▪ Capacity building among governmental advisory services ▪ Regulatory framework that supports the national organic policy

6. Success factors and challenges

Main success factors	Main challenges
▪ Field demonstrations for farmers	▪ High costs for installation of demonstration plots
▪ High local availability of raw materials for organic fertiliser production	▪ Product development including registration and certification ▪ High time investment for product registration/lacking systematic procedure for product registration in Uganda
▪ Increasing local demand and in export markets	▪ Promotion of many technologies by government but not for organic inputs
▪ Engagement of a marketing agency	▪ Low levels of awareness for organic inputs among various stakeholders, thus high time and monetary costs for awareness raising
▪ Product affordability	▪ Farmers are trained to use and apply inorganic fertilisers
▪ Product safety on users, environment and food quality	▪ Company internal mistake to start production without investment in market development
▪ Ease of use of the products	▪ Costs for product certifications
	▪ Agro-dealers are not acquainted with organic and biofertilisers

8.3.4 Case 4: RUNRES – Co-composting Innovation project - South Africa

Source: RUNRES project (personal communication: Dr Benjamin Wilde, Dr Simon Gwara)

7. **General**

Location	▪ Msunduzi Municipality, KwaZulu-Natal Province, South Africa
Name	▪ Co-composting Innovation project
Founding date	▪ 2020
Organisation type	▪ Private Public Partnership
Products	▪ Co-compost
Key partners	▪ Duzi Turf, UKZN, uMngeni Water and ETH Zurich

8. **Performance indicators**

Amount of produce (t/year)	▪ **Total: 5 750 t/year** ▪ Product 1: Bulk co-compost = 2 000 ▪ Product 2: Lawn dressing = 500 ▪ Product 3: Garden mix = 1 500 ▪ Product 4: 50-50 mix (mixed with silt) = 750 ▪ Product 5: Mulch = 1 000
Capital investment (€)	▪ **Total: €220 000** ▪ Equipment = €211 000 ▪ Infrastructure = €9 000
External funding	▪ Swiss Agency for Development Cooperation (SDC)
Operation and maintenance costs (€/year)	▪ **Total: €83 200** ▪ Staff costs = 45 500 ▪ Cost of capital (13%) = 28 500 ▪ Electricity expenses = 2 400 ▪ Water expenses (subsidy from uMngeni Water) ▪ Fuel production cost = 6 800
Retail prices per product (€/t)	▪ Product 1: Bulk co-compost = €28/t ▪ Product 2: Lawn dressing = €48/t ▪ Product 3: Garden mix = €45/t ▪ Product 4: 50-50 mix = €51/t ▪ Product 5: Oversize/composted mulch = €48/t
Retail prices per bag (€/45 kg) (1 bag = 60 dm^3 =60 x 0.75 kg)	▪ Product 1: only sold per ton ▪ Product 2: Lawn dressing = €2.20/45 kg bag ▪ Product 3: Garden mix = €2.00/45 kg bag ▪ Product 4: 50-50 mix = €2.30/45 kg bag ▪ Product 5: Oversize/composted mulch = €2.20/45 kg bag
Payback period	▪ 3-5 years
Revenue (€/year)	▪ Total: €183 400 ▪ €181 000 (compost sales) ▪ €2 400 (tipping fees)
Revenue streams	▪ Compost sales and tipping fees
Gross margin (%)	▪ n/a
Number of employees	▪ 11 casuals, 1 production manager
Market share	▪ n/a

9. **Production**

Waste collection	▪ Production site located next to New England Road Landfill Site (NERLS) and Darvil Wastewater Treatment Plant ▪ The biosolids are supplied by uMngeni Water (a waterboard responsible for wastewater treatment at Darvil) to the co-composting facility. ▪ The green waste is provided by homeowners and garden services directly to the co-composting plant who pay a tipping fee per load of green waste instead of disposing at the landfill. ▪ The silt which is used for making 50-50 mix product is sourced on site from heaps of soils dug from the evaporation or polishing lakes for the wastewater treatment.
Waste input type(s)	▪ Total: 10 000 tons ▪ Green waste = 8 000 tons ▪ Dewatered sewage sludge = 1 000 tons ▪ Silt = 1 000 tons (Sewage sludge not calculated as it is used for moisture regulation.)
Production (technology)	▪ Windrow composting system. ▪ The green waste is chipped or ground to smaller chips to increase the surface area for biological degradation using a woodchipper and a grinder. ▪ The chips are mixed in an improvised feed mixer at a ratio of 1-part biosolids to 3 parts green waste and pulled using a tractor to make windrows. ▪ The windrows are then irrigated with sewage sludge from the wastewater treatment plant using pipes to regulate the moisture content required for achieving theomorphic temperatures. ▪ The compost is turned using a tractor driven compost turner. ▪ The process takes approximately four months where temperatures are monitored using temperature buttons or loggers and a prob. ▪ When the compost is mature, it is loaded into a truck and taken to a trommel where it is sieved into different products.
Requirements for future scaling	▪ Business development and market analysis

10. Product development

Products	▪ See above
Product quality	▪ Total N: 1.6 %, P: 0.28 % (m/m), K): 0.44 % (m/m) ▪ pH: 7.9; C:N ratio: 14.0; carbon (calculated): 23.0 % (m/m)
Research and development	▪ Different mixing ratios were tested ▪ Tests for pathogens, heavy metals and nutrients ▪ First field trials conducted (demo plots)
Requirements for future scaling	▪ Further trials on product efficacy

11. Marketing

Customers segments	▪ Large scale commercial farmers ▪ Plant nurseries ▪ Home gardens ▪ Property development
Market channels	▪ Factory gate = 5% ▪ Direct distribution = 95% (e.g., to property development projects, commercial farmers especially macadamia nut farmers, and plant nurseries. An estimated 75% of the annual production is sold in the first year.)
Requirements for future scaling	▪ Demo trials and dissemination plans ▪ Community campaigns

12. Success factors and challenges

Main success factors	Main challenges
▪ Duzi Turf had an existing market for turf grass or lawn making it easier for them to tap into the existing market segment	▪ There are constantly existing risk of community dynamics impeding with the implementation of phase 2 as the project scales out to other city regions
▪ The project managed to attract the attention of a national government department that deals with the sanitation value chain in South Africa which lays a good foundation for scalability of the innovation	▪ The previously disadvantaged entrepreneurs who are youth and women might not have the prerequisite skills to participate as partners in RUNRES which is co-financing thus impeding inclusive participation in the composting value chain
▪ Having a stakeholder with strong business background and understanding of the regulations ensured swift implementation of the innovation despite government red tape	▪ The RUNRES team has devised a strategy to bring more government departments into the project to help de-risk investment through blended financing but there remains a risk if the officials are not committed
▪ Having a multidisciplinary country team allowed for diverse skills that contributed positively to handling challenges that came with implementation of the project	▪ Implementation of phase 2 will involve moving to new city regions and there is a risk of lack of support for the project from local authorities (traditional leadership, mayors, etc.) which will make implementation difficult
▪ Adaptive management was a critical lesson that helped the team readjust to challenges faced during the implementation of the project	
▪ The importance of reporting progress to stakeholders to keep them interested in the project	
▪ The importance of presenting information about the project in government events and conference as tool of attracting interested parties and establishing synergies	
▪ The Department of Water and Sanitation has also established a partnership with	

RUNRES-UKZN to co-develop of the guidelines for financial mechanisms and economic models to facilitate circular economy in the provision of faecal sludge management services	

8.3.5 Case 5: SAFISANA Ltd. - Ghana

Source: Interview UG-6/UG-9, www.safisana.org

13. General

Location	▪ Ashaiman, Greater Accra, Ghana
Name	▪ Safisana Ghana limited
Founding date	▪ 2010-2017 technology pioneering phase ▪ 2017
Organisation type	▪ Private
Products	▪ Biogas, compost, irrigation water
Key partners	▪ Safisana Holding (Mother company in Netherlands) ▪ Agua for All, Waterworx, Ministry of Foreign Affairs of the Netherlands etc.

14. Performance indicators

Amount of produce	▪ Co-compost: 286 t/year ▪ Electricity from biogas: 600 MwH/year ▪ Irrigation water: n/a
Capital investment	▪ n/a
External funding	▪ African Development Bank, Dutch Ministry of Foreign Affairs, private funds
Organisation and maintenance costs	▪ Currently 70% of operational costs are covered
Retail prices	▪ €4.00/30 kg bag
Payback period	▪ Break even expected for end of 2023
Revenue	▪ n/a
Revenue streams	▪ Electricity, compost, irrigation water, disposal fee
Gross margin (%)	▪ n/a
Number of employees	▪ 30
Market share	▪ n/a

15. Production

Waste collection	▪ Market and food processing wastes (e.g., Nestle, FanMilk) ▪ From toilet operators
Waste input type(s)	▪ Organic market waste: 3.600 t/year ▪ Human waste: 9.700 t/year
Production (technology)	▪ The technology installed is low tech, easy to operate and cost-effective to maintain ▪ Biogas digester ▪ Sludge is dehydrated and mixed and co-composted with market/processing wastes for 90 days

	▪ Wastewater is treated in water treatment plant
Requirements for future scaling	▪ Availability of funding

16. Product development

Products	▪ Biogas ▪ Compost
Product quality	▪ Own lab and quality control officer ▪ Products are verified by Plant Protection and Regulatory Services Directorate (PPRSD) of Ministry of Food and Agriculture and Ghana Standard Authority
Research and development	▪ Own greenhouse and agronomist who does field trials and testing, demo trials and farmer support in application ▪ Own research and technology development ▪ Designed a replicable business model (all-in-one solution for wastewater, solid waste and faecal sludge) ▪ Currently exploring new markets, market feasibility studies for Kumasi (Ghana), India, Mali, Uganda
Requirements for future scaling	▪ Availability of funding

17. Marketing

Customers segments	▪ Compost: Mainly commercial farms (vegetables, maize), currently receiving certification from Cocobod to supply cocoa farmers with compost ▪ Electricity: feed into the local grid
Market channels	▪ Direct sales at production site ▪ Farmer associations ▪ Retailers
Requirements for future scaling	▪ Increased awareness among farmers and other stakeholders ▪ Biogas: Selling of compressed gas for cooking as currently limited uptake of electricity into national grid ▪ Participation in government fertiliser subsidy programme would boost scaling

18. Success factors and challenges

Main success factors	Main challenges
▪ Locally managed, remotely supported by team of experts in the Netherlands	▪ Acquires funding
▪ Operational costs are covered by sales of end-products: electricity to the grid, organic fertiliser to local farmers	▪ Limited uptake of electricity by national grid (only 40%), currently 60% of produced energy is wasted
▪ Renovation of public toilets	▪ Seasonal competition for market wastes with livestock farmers
▪ Increased demand for organic fertilisers	▪ Lacking monetary resources of smallholder farmers to buy compost product

▪ Availability of wastes free of charge	▪ Still limited awareness of usefulness of organic fertiliser and application
▪ Social media presence	▪ Transport of raw materials from processing industry
▪ Low competition in the organic fertiliser market	▪ Need to grow production levels to participate in national fertiliser subsidy programme
▪ Sales in bulk to Farmer associations	-
▪ Official purchase agreement with the national electricity company = constant income.	-
▪ Cooperation with Ghanian Ministries attracts more investors	-

8.4 Overview of producers

Table 20. Overview on organic and biofertiliser companies/organisations in 12 African countries

Country	Company / Organisation	Contact	Type of fertiliser (OF/BF)
Cameroon	RADI Organics	https://blog.gfar.net/2016/02/26/yap-proposal-44-bio-fertilisers-bio-pesticides-christa-marie-a-yenah-cameroon/	OF, BF
	Family Green	https://www.family-green.org/provad/	OF
	Nang et compagnie NETCO	https://www.facebook.com/profile.php?id=100061913925214&locale=en_FI	OF
	AGRODYKE	https://sonediscm.com/why-use-agrodyke/	OF
Côte d'Ivoire	Elephant vert Côte d'Ivoire	https://www.elephant-vert.com/en/	OF
	Lonoci	https://www.lonoci.com/Services	OF
	Green Countries	https://www.facebook.com/greencountries.net/	OF
	FIBL pilot project - palm oil milling waste composting	https://www.fibl.org/en/themes/projectdatabase/projectitem/project/2165	OF
Egypt	Beni Suef	https://agrn.com.eg/en/	OF
	Miegos	https://miegos.com/products/	OF, SA (biochar)
	Bio Energy	https://www.bioenergyegy.com/en/Products/Details/3/compost	OF
	Reliance Egypt	http://www.relianceegypt.com/trad.html#tabs-16	OF
	Shira group	http://www.shiragroup.com/compost.html	OF
	Chitosan	https://chitosaneg.com/	BF

	Vermidutch	https://www.facebook.com/startegypt - com/posts/481760019106525/	OF
	Royal Green Biotech	https://royalgreenbiotech.com/en/nova.php	BF
	Baramoda	https://baramoda.org/	OF
	Ecaru	https://ecaru.net/en/Products/1/compost#ChildVerticalTab_11	OF
	Rokovia	https://rokovia.net/projects/	OF (Planning stage)
	Microbial Inoculant Centre	https://web.facebook.com/mic.asu.agr/?_rdc=1&_rdr	BF
	Shoura Chemicals	http://www.shourachemicals.com/en/home	BF
	Organic Biotechnology	https://www.facebook.com/organic.biotechnology/	OF
Ethiopia	EcoGreen	https://ecogreen.et/	OF
	RUNRES project	https://runres.ethz.ch/innovations/ethiopia/	OF
	Urban NAMA Compost project	https://www.undp.org/ethiopia/projects/urban-nama-compost	OF
	Rokovia	https://rokovia.net/projects/	OF
Ghana	Farmers' Hope organic fertiliser	www.farmershopeafrica.com	OF
	HJA Africa Limited	http://hjaafrica.com/?utm_source=worldplaces.me&utm_medium=organic	BF
	Ga Mashie Aerobic Compost	https://jekoraventures.com/contact/	OF
	Accra Compost & Recycling Plant (ACARP)	http://acarpghana.com/	OF
	JVL-YKMA Recycling Plant	https://seed.uno/enterprise-profiles/jvl-ykma-recycling-plant	OF
	Safisana	https://safisana.org/	OF
	New Okaff Industries Ltd	https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ashanti-Agric-Department-New-Okaff-sensitise-farmers-on-organic-fertilisers-1777346	OF
	JVL Fortifier Compost	https://jekoraventures.com/fortifier-compost	OF
	Jaasgrow company limited	https://www.jaasgrow.com/#product	OF
	Zoomlion Ghana Limited (Tamale)	https://zoomlionghana.com/	OF
	Deco Compost Limited	http://www.deco-farming.com/	OF

	Calli (GH) Company Ltd	https://www.upl-ltd.com/gh/products	BF
	Green grogh	https://www.green-grogh.com/	OF
	Mayiya organic Compost	https://www.facebook.com/mayiyainvestments/?locale=ru_RU	OF
Kenya	Rokosan/Rokovia	https://rokovia.net/projects/	OF
	Regen Organics	https://www.regenorganics.co/	OF
	Safi Organics	https://safiorganics.co.ke/	OF
	TakaTaka Solutions	https://takatakasolutions.com/	OF
	Dudutech	https://www.dudutech.com/	BF, SA
	MEA fertilisers	https://mea.co.ke/	OF
	Ecodudu	http://ecodudu.com/product/shamba-mix/	OF
	Insectipro	http://insectipro.com/	OF
	Sistema bio	https://sistema.bio/	(OF) biodigester
	WonderGro	https://www.facebook.com/ultravetis/posts/wondergrow-is-a-natural-plant-growth-bio-stimulant-that-enhances-your-plant-grow/4032585440117890/	BF
	Ecofix	https://www.efk.co.ke/our-products/	OF
	Essentia Kanan	https://essentiakanan.com/	OF, SA
	Agri-Flora Organic	https://www.facebook.com/profile.php?id=100067200805993&locale=hi_IN	OF
	Kenya Biologics	https://www.kenyabiologics.com/	BF
	Griincom	https://griincom.co.ke/product-category/products/	OF
	Mazao	https://www.junglenuts.co.ke/product/mazao-majik-organic-fertiliser/	OF
	Rutuba Organic	https://www.kenyacic.org/2020/08/rutuba-bio-agric-organic-fertilisers-ltd/	OF
	Wanda Organic	https://wandaaggroup.org/#soko	OF
	Real IPM	https://realipm.com/c/biofertilisers/	BF
	Hygrow	https://www.organicfields.co.ke/	OF, BF
	Bharat Bio Ltd.	https://bbeal.com/	OF, BF
Malawi	Environmental industries	https://environmentalindustriesmw.com/	OF
	Almena Organic fertiliser	-	OF
	Mbeya Organic fertiliser	https://www.facebook.com/groups/264162740587428/posts/1312758855727806/ https://thepopmovement.org/event/the-making-of-mbeya-organic-fertiliser-malawi/	OF

	Nkhokwe Fertiliser Co Ltd	https://nkhokwe.org/	OF
	Funani Organic Fertiliser company	https://buymalawi.mw/members/funani-organic-fertiliser-company/	OF
	Green Finger organic fertiliser	-	OF
	Agri Inputs Suppliers Limited (AISL)	https://www.facebook.com/agroinputsupplierslimited/	BF
Rwanda	Rwanda Environment Care	http://www.recrwanda.org/	OF
	RUNRES project	https://runres.ethz.ch/innovations/rwanda/	OF
	Green care Rwanda Ltd.	https://greencarerwandaltd.com/	OF
	Rwanda BioSolution Ltd.	https://www.facebook.com/rwandabiosolution/	OF
Senegal	Biotech	http://www.biotechservices-senegal.com/biofertilisants/	OF, BF
	Elephant vert	https://www.elephant-vert.com/en/	OF, BF
	Sedab SARL/ Biotoss	https://www.sedabsarl.com/nos-produits https://www.facebook.com/Biotoss/	OF
	Neofarm	https://neofarm.sn/	OF
	National Biogas Programme (organic fertiliser)	https://www.iea.org/policies/4966-senegalese-national-biogas-programme-phase-ie	OF
	ONAS (water treatment centres)	https://www.worldbank.org/en/news/feature/2022/03/18/water-challenges-inspire-innovation-and-a-circular-economy-from-senegal-to-india-and-ecuador https://www.suez.com/en/news/press-releases/in-senegal-suez-wins-the-contract-to-design-and-build-an-urban-and-industrial-wastewater-treatment-plant-hann-bay-dakar	OF
South Africa	Duzi Turf, Umgeni Water and Msunduzi Municipality **RUNRES project**	https://runres.ethz.ch/innovations/south-africa/	OF
	RUSUS, Enhanced Biochar **RUNRES project**	https://runres.ethz.ch/innovations/south-africa/	SA/OF (biochar+ faecal sludge)
	Lindros South Africa	https://www.lindros.co.za/	BF

	Bio-Fertilisers-MBFi	Microbial Biological Fertilisers International - MBFi	BF
	Biostimulants-Agrispex	https://agrispex.co.za/category/biostimulants/	BF
	CODA	https://www.radiclegroup.co.za/products/coda	OF, BF
	Talborne Organics	https://talborne.co.za/	OF
	EcoWhizz	https://ecowhizz.co.za/agricultural-plantosverde/	OF
	Soygro pvt ltd	https://www.soygro.co.za/	BF
	Mycoroot (Pty) Ltd	https://www.mycoroot.com/	BF
	Bloem Organic Compost	https://kompos.co.za/product/compost-bags/	OF
	Ywaste	https://www.ywaste.co.za/about/	OF
	Living Earth	https://livingearth.co.za/	OF
	KYNOCH	https://www.kynoch.co.za/products/#Biostimulants	BF
	Reliance	https://www.reliance.co.za/	OF
Uganda	Rootzone Africa Ltd.	https://rootzoneafrica.com/	OF
	Reticia Products Research	https://www.facebook.com/groups/186157158386040/	OF
	Kwagala bio-fertilisers	https://kwagalafarm.org/?post_type=product	OF
	Bio bloom Uganda	https://www.biobloomug.com/	OF
	Luyukandi organic Fertilisers	No website	OF
	Vermi pro	https://www.vermiproug.com/	OF, BF
	Sukulu Organic Plant	https://www.facebook.com/sukulufertiliseruganda/	OF, BF
	ProTeen	https://weareproteen.com/	OF
	Glowish Agro Solutions	https://glowishagrosolutions.com/	OF
Zimbabwe	ZimEarthworm Farms	http://www.zimearthworm.com/	OF
	Flight serve Enterprises limited trading as Orgfert	https://www.orgfert.co.zw/	OF
	Department of Research and Specialist services	Grasslands Research Institutehttp://www.drss.gov.zw/index.php/library/contact-details/grasslands-research-institute	BF

The list makes no claim to completeness

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