Opportunities for organic agriculture in Uganda

Commissioned by the Agricultural Counsellor of the Dutch Ministry of Agriculture, Nature and Food Quality, based in Kampala, Uganda

Esther Ronner, Laurie van Reemst, Mark van der Poel

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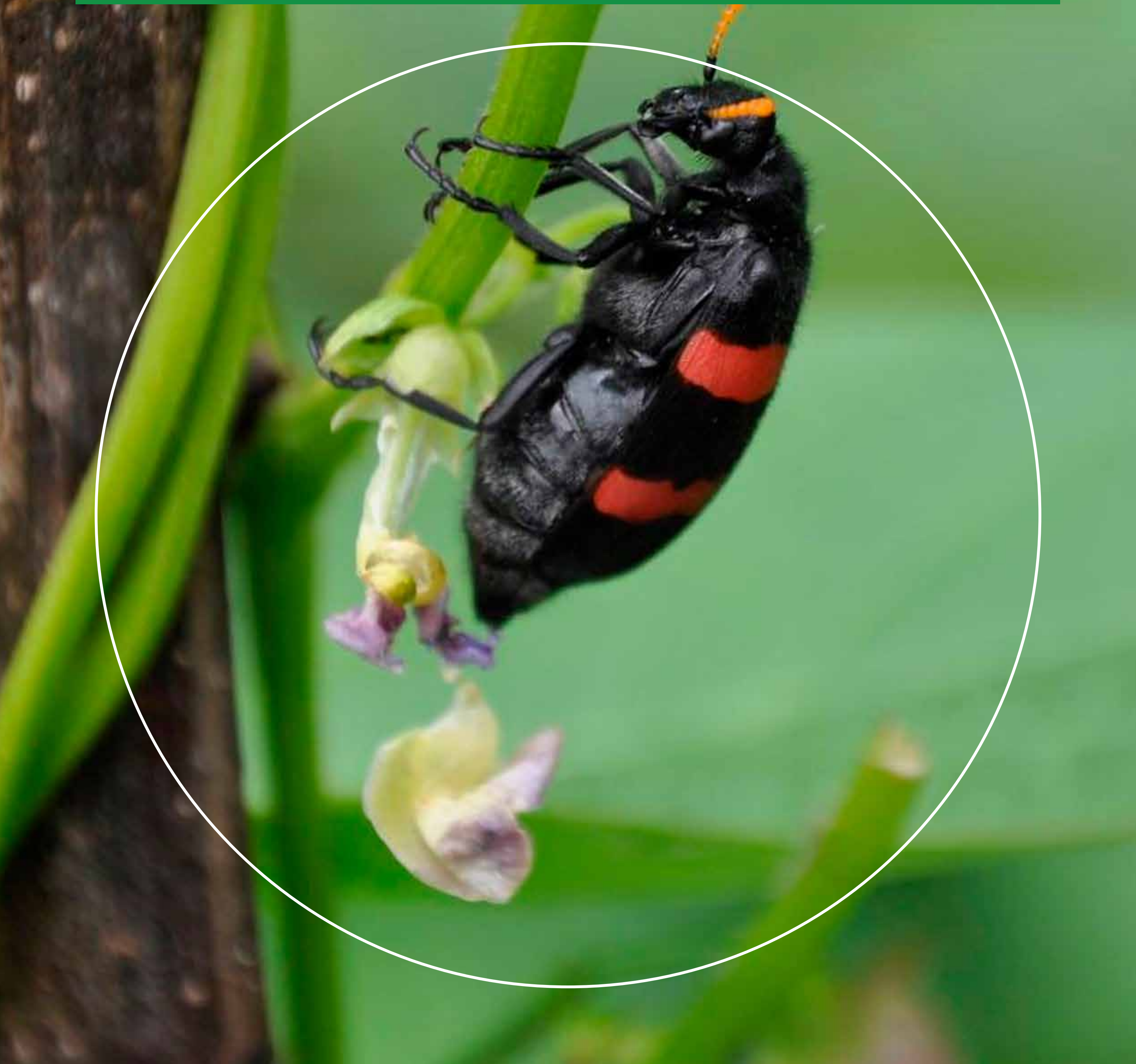

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Reviewed by:
Dr. Carlos Brazao Vieira Alho, Researcher Sustainable Land Use (Wageningen Environmental Research)

Approved for publication:
Karin Andeweg, Team Leader Water & Food
(Wageningen Environmental Research)

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In dit rapport onderzoeken we mogelijkheden voor de ondersteuning van de biologische landbouwsector in Oeganda, door middel van literatuuronderzoek en interviews. We documenteren bestaande initiatieven in de biologische landbouw in Oeganda, van de productie van biopesticiden en biologische meststoffen tot overkoepelende organisaties en platforms, en we geven inzicht in mogelijke aanvullende praktijken voor verder onderzoek en verspreiding. Het rapport geeft een overzicht van de belangrijkste uitdagingen en kansen, en biedt aanbevelingen zoals verbeterde kennisvoorziening voor boeren, identificatie van business cases, verbeterde regelgeving en kwaliteitscontrole, systematische studies naar de effectiviteit en (economische) haalbaarheid van biologische landbouwpraktijken, en meer consumentenbewustzijn om de vraag naar veilig geproduceerd voedsel te stimuleren.

In this report we explore opportunities to support the organic agriculture sector in Uganda, gathered from literature review and interviews. We document existing initiatives in organic agriculture in Uganda, from the production of biopesticides and biofertilisers to umbrella organisations and platforms, and provide insights into potential avenues for further research and dissemination. The report synthesises main challenges and opportunities, and offers recommendations including enhanced knowledge provision for farmers, identification of business cases for organic agriculture, enhanced regulation and quality control, systematic studies documenting effectiveness and (economic) feasibility of organic agriculture practices, and increased consumer awareness to drive the demand for safely produced food.

Keywords: organic agriculture, Uganda, sustainability, organic fertiliser, biological pest control

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Wageningen Environmental Research (WENR) values the quality of our end products greatly. A review of the reports on scientific quality by a reviewer is a standard part of our quality policy.

Approved reviewer who stated the appraisal,

position: Researcher Sustainable Land Use (Wageningen Environmental Research)

name: Carlos Brazao Vieira Alho

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Approved team leader responsible for the contents,

name: Karin Andeweg

date: 19-12-2023

Executive summary

In September 2020, Uganda launched a national organic agriculture policy aimed at guiding investments in the sector. The Ministry of Agriculture, Animal Industries and Fisheries (MAAIF) took up the challenge to meet national self-sufficiency while keeping the agricultural system largely organic. In this context, we conducted a scoping study to explore the opportunities to support principles, practices and products related to organic agriculture in Uganda, taking into account the potential for different types of farmers and production systems. Specifically, the objectives of this study were to: 1) identify currently existing initiatives around organic agriculture in Uganda; 2) identify challenges and opportunities to further develop the organic agriculture sector in Uganda; and 3) develop recommendations to support the organic agriculture sector in Uganda. We used a combination of literature review and interviews with stakeholders in the organic agriculture sector. The study focused largely on the Ugandan national market and the potential demand for organic products, and less on the potential for Uganda as an exporter of organic (niche) products.

We first explore the principles of organic agriculture after the definition by the International Federation of Organic Agriculture Movements (IFOAM), which emphasises its holistic approach to sustaining soil, ecosystems, and human health. IFOAM considers four principles: health, ecology, fairness, and care, which outline a comprehensive system beyond mere chemical avoidance. While IFOAM aims for global harmonization, the organisation also stresses flexibility for regional adaptations and the aim of expanding organic practices, not just certification. Shifting to the Ugandan context, the historical development of organic agriculture in Uganda shows a predominant focus on export of certified organic products. While input use in Uganda is generally still low, recent market liberalisation combined with poor regulation enforcement, information provision and quality control have resulted in widespread promotion and availability of (cheap) agro-chemicals. This opened up opportunities for farmers to use these products, but also came with increased risks for improper use, unprotected spraying, and the use of poor-quality or counterfeit products.

The report highlights the importance of context-specific measures, considering the varied needs and circumstances of different farmer sub-groups. In Uganda, the horticultural sector stands out with a relatively high input use, with resulting concerns about injudicious pesticide use, potential health risks, and the need for improved monitoring and information dissemination. Based on the documentation of existing initiatives in organic agriculture in Uganda, from producers of biopesticides and biofertilisers to umbrella organisations and platforms (Chapter 3), and potential organic agriculture practices that may be of interest for further research or dissemination (Chapter 4), we identified challenges and opportunities for organic agriculture in Uganda.

Key **challenges** include:
- Pest and disease management: holistic, organic systems approaches to pest and disease management show a delay in effectiveness, yet, farmers demand urgent solutions. Besides, biological pest control strategies are more knowledge intensive compared to chemical pest control which makes uptake of these strategies limited to large-scale, commercial farmers with good access to agricultural extension.
- Biofertiliser production: there is a general lack of unused organic material for biofertiliser production in Uganda. Existing waste streams are often already allocated or of poor quality. Transportation of voluminous organic fertilisers also poses logistical challenges, requiring proximity between waste sources and production and usage locations. Smallholders in Uganda generally face nutrient and organic matter scarcity in their soils, making it challenging to substantially improve soil fertility without external inputs.
- Documentation, regulation, and standardization: despite having an organic policy, Uganda lacks a legal framework, impeding the allocation of government funds for policy implementation. Moreover, knowledge on organic agriculture exists but lacks proper documentation, regulation, and standardisation, impacting scalability. Inconsistent quantity and quality of sourcing materials for biofertilisers and biopesticides also hinders consistency and scalability.
- Demand for organic produce: changing mindsets about the potential benefits of organic practices is a significant challenge among both farmers and consumers. Currently, inadequate packaging, branding, and

information on packages of organic products hinders the commercialisation of organic products. Distinguishing organic products from conventional ones is difficult, posing challenges in marketing, pricing, and promotion. Expectations about the potential for growth of the organic sector in Uganda are modest, and the demand for organic produce likely remains a niche for the time being.
- Demand for organic inputs: a viable business case is essential for the adoption of biological pest control. Farmers need an assured output market of a certain value to invest in such products. The purchasing power of smaller farmers is too low, making the demand for commercial biological pest control products among this group unlikely in the shorter term. Also, there is a trade-off between potential cost savings through a reduction in preventive spraying of chemicals and increased labour requirement for scouting and managing pests.

Opportunities for organic agriculture include:
- Increasing consumer focus on safe food: Uganda witnesses a growing concern for food safety among consumers and policymakers. Producers have potential opportunities to stand out by marketing their crops as sustainably and organically produced, meeting the budding demand for safe food from hotels, restaurants, and supermarkets.
- Consumer perceptions and market opportunities: a recent study highlights consumer concerns about food safety, with a willingness to pay a premium for safe food. Producers can tap into this market by ensuring traceability and substantiating claims of safety.
- Enhancing organic product quality and marketing: enhancing the quality and consistency of organic inputs and products contributes to credibility and trust in the market. Improved documentation, standardization, packaging, and value chain connections can contribute to better marketability.
- Finding local niches: biofertiliser or biopesticide production offer opportunities to expand organic practices at the local level. Incentives to reduce mineral fertiliser use in sectors like horticulture, tea and coffee provide openings for increased adoption of organic inputs.

The **recommendations** that we derive to support different actors in the organic agriculture sector are:
- General: (certified) organic production may not be feasible for most Ugandan farmers for the time being. Considerable steps towards sustainability are already to be made by emphasising general good agronomic practices including Integrated Soil Fertility and Integrated Pest Management.
- Farmers: empower farmers with knowledge on organic practices, promoting informed decision-making. Utilise platforms like farmer exchange programs and exhibitions for experience sharing. Focus on crops with high returns first, conduct awareness campaigns on the negative effects pesticide, and train farmers on judicious fertiliser use. Connect farmers to international organizations for guidance on organic farming practices.
- Input Suppliers: explain business cases for organic inputs, emphasising cost reduction through reduced spraying. Improve packaging and branding of organic products, and document input composition for better information. Find scalable models to extend the reach of organic inputs to smaller farmers.
- Government: implement the existing organic policies and create a legal framework for organic farming. Enhance regulation, standardization, and quality control of organic inputs, establishing a quality control system. Regulate pesticide use, engage with agro-dealers for proper control, and streamline registration processes for biopesticides.
- Research: conduct systematic research on the effectiveness of ingredients of (home-made) pesticides. Tailor solutions to specific crops and regions. Stimulate research on increasing shelf life without chemical pesticides. Prioritize social and economic research to understand local preferences and feasibility. Identify natural predators for viable crops and develop strategies for their introduction on farms.
- Consumers: increase consumer awareness about pesticide risks and promote the demand for safely produced food. Connect consumer groups with a demand for safe food to suppliers of organically produced food.

1 Introduction

1.1 Why organic

In September 2020, a national organic agriculture policy was launched that aims to guide and support investments in the organic agriculture sector. In this policy, the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF) took up the challenge to meet national self-sufficiency while keeping the agricultural system largely organic. Uganda has a comparative advantage for organic production in Africa, amongst others due to its history of limited use of inputs in agriculture (Bendjebbar and Fouilleux, 2022). Two of the targets mentioned in the policy are therefore 1) the increase in the contribution of the Organic Agriculture sub sector to the GDP to reach over 50% of the Agricultural GDP and 2) Increase the productivity of Organic Agriculture by more than 50%, in the period of 2020-2025. These ambitions fit also in Uganda's Vision 2040, in which agriculture is going to be one of the key sectors that has to propel Uganda to a middle income country.

The organic agriculture movement in the Global North largely stems from the desire to move away from an overuse of fertiliser, nutrient losses to the environment, extensive spraying of chemicals causing increased resistance in insect populations and resulting in adverse health and environmental effects (European Union, 2020). However, the situation among smallholder farmers in Africa, and particularly in Uganda, is quite different. For instance, the majority of Ugandan smallholder farmers use almost no mineral fertiliser on their farm, with an (the average use is around 2kg/ha, one of the lowest in the world, Amann et al., 2021). Due to a lack of capital, there is a general low use of external inputs in Uganda (Amann et al., 2021; Falconnier et al., 2023), resulting in soil fertility depletion. These soil-related farming practices have continued for decades, and start to become a noose for the farmers and their environment, since most farmers produce less and less from the same field, continue depleting their soils and, in combination with the increasing population pressure, resort to deforestation in search for additional land to sustain their living (Mugizi and Matsumoto, 2021).

At the same time, farmers have to deal with an intensifying pressure of crop pests and diseases. Between 84-100% of the Ugandan smallholder farmers indicates to use pesticides, of which the largest part (80%) comes from the informal market (Andersson and Isgren, 2021). Many farmers started using these pesticides relatively recently and apply them to crops as preventive measures. On top of this, pesticides seem to be used on cash crops and food crops alike. Therefore, the current use of pesticides may lead to numerous health and environmental risks, showing an urgent need to develop and promote alternative pest control strategies that rely less heavily on synthetic pesticides (Andersson and Isgren, 2021).

This calls for a transition to farming systems that are more sustainable, not only for the farmers (in the short and the long-run), but also for the environment. However, this transition and the extent by which organic farming practices play an important role, may differ for different sub-groups of farmers:

1. Low input farmers who use little external inputs may benefit from the introduction of organic practices and products to increase their production (e.g. remote rural areas with limited access to markets, etc.);
2. Moderate input farmers who use limited chemical inputs (fertiliser + herbicides/pesticides) may benefit from advice on Integrated Pest Management (IPM) and Integrated Soil Fertility Management (ISFM) to reduce the use of chemicals and move towards more sustainable alternatives;
3. High input farmers, who overuse chemicals (mainly synthetic pesticides), and who will benefit from alternative pest management and/or better tailored fertiliser and pesticide advice;
4. Export oriented farmers, who aim to export their produce and who are bound by (EU) regulations on the use of pesticides and who are potentially interested in (organic) certification.

Hence, when exploring the potential for organic agriculture practices, it is important to consider the relevant context to find the most appropriate measures.

1.2 Study aim and methods

In this study, we aimed to explore the opportunities to support principles, practices and products related to organic agriculture in Uganda taking into account different types of farmers and production systems. Specifically, our objectives were to: 1) identify currently existing initiatives around organic agriculture in Uganda; 2) identify challenges and opportunities to further develop the organic agriculture sector in Uganda; and 3) develop recommendations to support the organic agriculture sector in Uganda. The study focused largely on the Ugandan national market and the potential demand for organic products, and less on the potential for Uganda as an exporter of organic (niche) products.

We used a combination of literature review and interviews with stakeholders in the organic agriculture sector. Literature on input use in Ugandan agriculture was searched using the query: "*input* OR *pesticide* OR *insecticide* OR *herbicide* OR *fertilizer* OR *fertiliser* AND *Uganda*". Through snowballing, additional relevant literature was included. Targeted information was also sought on potentially interesting organic inputs, products or strategies for further exploration for their potential use in Uganda. A total of 15 interviews were held with different organisations, supplemented with information from the internet.

The report starts with an overview of a general definition, principles and standards of organic agriculture (Section 2.1), which are then translated into their relevance and implications for the Ugandan context (Section 2.2). Next, it gives an overview of the current use of inputs in Uganda, with a focus on the sectors for which organic agriculture and/or a shift to organic practices is most warranted (Section 2.3). After that, we present an overview of currently existing initiatives around organic agriculture in different sectors, including the production of organic inputs such as biopesticides and biofertiliser (Chapter 3), followed by some potential avenues for further exploration (Chapter 4). The report ends with a synthesis of the main challenges and opportunities (Chapter 5), and recommendations (Chapter 6) to further support the organic agriculture sector in Uganda.

2 Background

2.1 Organic agriculture: what are we talking about?

The International Federation of Organic Agriculture Movements (IFOAM - Organics International) defines organic agriculture as:

> *"a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects."*

IFOAM is a membership-based organisation, with members from over 100 countries. Their work aims to contribute to an increased uptake of organic agriculture - certified or non-certified, and of organic principles and methods. The organisation has defined four principles of organic agriculture:
- The principle of health - Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.
- The principle of ecology - Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
- The principle of fairness - Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
- The principle of care - Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

These principles show that organic agriculture is more than the avoidance of chemical inputs, it is a whole system approach based upon a set of processes resulting in a sustainable ecosystem, safe food, good nutrition, animal welfare and social justice. The Rodale Institute further emphasizes the need for the integration, interaction and combination of strategies:

> *"In organic production, overall system health is emphasized, and the interaction of management practices is the primary concern. Organic producers implement a wide range of strategies to develop and maintain biological diversity and replenish soil fertility."*

IFOAM has developed an internationally applicable organic standard that, together with the IFOAM Accreditation Requirements, which are used for organic certification. The standard is set up according to a general principle, followed by recommendations, requirements and potential (regional) exceptions. See for example under crop production:

4 . CROP PRODUCTION

4.1 Choice of Crops and Varieties and propagation of planting materials

General Principle

Species and varieties cultivated in organic agriculture systems are selected for adaptability to the local soil and climatic conditions and tolerance to pests and diseases. All seeds and plant material are organic.

Recommendation:

Operators should give preference to organically bred varieties (varieties from organic breeding programs, see 4.7) when available.

Requirements:

4.1.1 Operators shall use organically produced seed and planting material whenever available in appropriate varieties and quality. When organic seed and planting materials are not available in sufficient quantity or quality for the required variety or equivalent varieties, in-conversion materials may be used. When none of these are available, conventional materials may be used provided that they have not been treated with post-harvest pesticides not otherwise permitted by this standard.

Regional or other exception

Where post-harvest chemical treatment is prescribed by law for phytosanitary purposes, treated seed and plant material may be used.

While the IFOAM standard aims to harmonize organic standards worldwide, it allows for regional exceptions or adaptations based on a clear justification and for a limited period of time only (aiming to adhere to the international standard over time). Moreover, whereas the certification requirements for a certain product or market may be strict, the principles and recommendations as described in this standard leave room for interpretation and adaptation to local conditions.

IFOAM explicitly aims to expand organic practices, not necessarily certified organic agriculture. In that sense, the standard could serve as a general guideline for producers in Uganda who aim to take steps towards organic production, also when certification is not their final goal.

A summary of some other relevant principles and requirements from this standard, potentially applicable to the Ugandan context, are:

- **Diversity in crop production**: Crop rotations for annual crops shall be established to manage pressure from pests, weeds and diseases and to maintain soil fertility, unless the operator ensures diversity in plant production by other means. Crop rotations shall be diverse and include soil-improving plants such as green manure, legumes or deep rooting plants.
- **Soil fertility and fertilization**: The fertility program should be based on material of microbial, plant or animal origin, such as green manure, compost or mulch, obtained through the following sources in this order of priority: a.) organically produced on the farm; b.) of organic quality, obtained from the surrounding farms or natural environment; c.) other inputs – specified in an annex of the standard, which include mineral fertilisers as part of a program addressing long-term fertility needs together with other techniques such as organic matter additions, green manures, crop rotations and nitrogen fixation by plants; in the form in which they are naturally composed and extracted (e.g. rock phosphate, muriate of potash, calcium); and excluding synthetic fertiliser, including urea.
- **Pest and disease management** requirements are:
  - The organic production system shall include biological, cultural and mechanical mechanisms to manage pests, weeds and diseases. These include: a.) choice of appropriate species and varieties; b.) appropriate rotation programs, intercropping and companion planting; c.) mechanical cultivation; d.) protection of natural enemies of pests through provision of favorable habitat, such as hedges, nesting sites and ecological buffer zones that maintain the original vegetation to house pest predators; e.) natural enemies including release of predators and parasites; f.) mulching and mowing; g.) grazing by animals; h.) mechanical controls such as traps, barriers, light and sound. i.) on-farm preparations from local plants, animals and micro-organisms.
  - When the measures above are not sufficient, pest, disease and weed management substances permitted as specified in an annex may be used.
  - Substances that do not appear in the annex are prohibited for use in organic production.
  - Exceptions may be granted to protected cropping structures in instances of severe disease or pest infestation that cannot be otherwise remedied.

Bottomline of these principles and recommendations is that the priority should be on an integrated set of biological processes and strategies, but that in case there are no viable alternatives, certain mineral fertilisers or pesticides may be used, but in a restricted form. Some general criteria that IFOAM suggests to judge the use of substances in organic production and processing (with more specific criteria for fertilization, plant protection, weed control, and processing):

I. use of the substance is consistent with the principles and objectives of organic agriculture.
II. the substance is necessary/essential for its intended use.
III. approved alternatives are not available in sufficient quantity and/or quality.
IV. manufacture, use and disposal of the substance does not result in, or contribute to harmful effects on the environment.
V. The substance has the lowest negative impact on human or animal health or the environment when compared to alternative substances.
VI. * the consumer is not deceived concerning the nature and quality of the substance.
VII. * consideration is given to social and economic impacts of sourcing and manufacturing the substance.

*commonly and primarily used in the private sector for evaluating substances.

Over time, farmers could integrate more and more organic practices, moving towards organic agriculture. IFOAM expresses the aim to do this in a non-reversable manner, hence switching back and forth between organic and conventional is to be avoided.

2.2 Organic agriculture in the Ugandan context

Certified organic agriculture reached sub-Saharan Africa in the 1980s, with increasing demand for tropical products from consumers in the Global North (Bendjebbar and Fouilleux, 2022). In the 1990s a number of organic agriculture initiatives from European donors started, for instance in coffee, cocoa and cotton, and followed by tropical fruits and vanilla. Together, these initiatives resulted in the formation of the National Organic Agricultural Movement of Uganda (NOGAMU) in 2001, an umbrella organisation supporting organic producers. Currently, Uganda is one of the leading African countries producing and exporting organic products. Uganda had 210,353 certified organic producers in 2019, which is the second largest number in the world and the largest in Africa (Willer et al., 2021). However, these certified farmers only produce 5% of the global organic market, which means there is potential to expand this market share. The area under organic production has been increasing over the past 10 years, but remains small, with only 1.8% of the total agricultural land in Uganda (GIZ, 2021).

The agricultural sector in Uganda has had a focus on cash crops for export since colonial times. In the 1970s, under Idi Amin’s regime, the agricultural sector collapsed, with failing extension services and a ban on the import of chemical products (Bendjebbar and Fouilleux, 2022). Hence, chemicals could not be used. A few religious NGOs focusing on food security promoted locally available techniques and organic farming practices, which were logically the easiest (only) option available to farmers. In the 1980’s, when Yoweri Museveni came to power, the Ugandan economy opened up, and foreign investors were encouraged to invest in export value chains. NGOs were also allowed in, to help rebuild the economy. The ‘free of chemicals’ agricultural context provided a fertile ground for organic agriculture initiatives, and allowed an easy transition into certified organic agricultural products (Bendjebbar and Fouilleux, 2022). Up to date, the organic agriculture sector in Uganda remains largely focused on certified organic production for export.

Since the 2000’s, agricultural policies in Uganda started focusing on the promotion of commercial agriculture. However, government investments in the agricultural sector remain low and public extension services are virtually absent. Rapid market liberalization combined with poor regulation enforcement and information provision and quality control have resulted in widespread promotion and availability of (cheap) agro-chemicals (Andersson and Isgren, 2021). While this opened up opportunities for farmers to use these products, it also came with increased risks for improper use, unprotected spraying, and the use of poor-quality or counterfeit products.

Slowly, through a growing awareness among the upper/middle class in Kampala, the national demand for safe and healthy food is growing, and a few supermarkets and restaurants have started offering organic products (GIZ, 2021). The question is to what extent this demand will spread to other parts of the country, at what speed, and under which conditions. For instance, to what extent will consumers be willing to pay a premium price for organic products that will enable producers to shift to organic production? These factors will partly determine the success of organic agriculture initiatives focused on the national market. On the other hand, the increasing availability of biofertilisers and biopesticides may enable producers to increase the supply of organic produce.

2.3 Current use of inputs among smallholder farmers in Uganda

2.3.1 General use of inputs

A nationally representative survey (LSMS 2019-2020) across the four regions in Uganda indicates a generally low use of external inputs among smallholder farmers in Uganda (Table 1). Mineral fertilisers and pesticides were generally used by less than 5% of farmers, with the exception of Central Uganda. The use of organic fertiliser was only slightly higher, emphasizing the general tendency of an underuse of fertilisers with soil fertility depletion as a result.

Table 1 *Use of inputs (% of farmers) in rural and urban regions of Uganda in 2019-2020*

	Mineral fertiliser	Organic fertiliser	Pesticides
Central rural	5	11	14
Central urban	7	20	14
Eastern rural	4	5	7
Eastern urban	4	5	3
Northern rural	1	0	5
Northern urban	0	0	4
Western rural	1	4	3
Western urban	1	2	4

Source: LSMS data 2019-2020

The farmers who used organic inputs mostly obtained these products from their own livestock (79%) and from crop residues (20%). The limited number of farmers who bought organic inputs, obtained these products from private traders or fellow farmers. The use of inputs was concentrated in a limited number of crops. Fruits and vegetables represented the crops where mineral fertiliser and pesticides were mostly used. Mineral fertilisers were also used in coffee, maize, rice, tea, Irish potato, banana, beans, groundnut and cassava. Pesticides were additionally used in cotton, soybean and sweet potato. Farmers indicated that the use of pesticides included insecticides (55%), growth regulators and harvest aids (30%) and miticides/fungicides (both ~3%). Organic fertiliser was largely used in banana, and also in coffee, maize, beans, cassava and sweet potato.

Other studies on a smaller, more detailed scale, show a mixed picture:

- On Mount Elgon in 2014/2015, less than 10% of farmers used mineral fertiliser in beans, and 20-25% used organic fertiliser (Ronner et al., 2018).
- In banana-based systems close to Mbarara and Fort Portal (2018), 55% and 12% of farmers indicated to use organic fertiliser in banana, respectively. Mineral fertiliser was hardly used, only on tomato, onion and watermelon. Pesticide use was also limited, but in 80% of cases, farmers who used mineral fertiliser also used pesticides (Tober, 2019).
- In Irish potato cultivation in the southwest of Uganda, 55% of farmers used mineral fertiliser, 41% organic fertiliser, 72% fungicides and 73% pesticides (Priegnitz et al., 2019).
- A study in four districts across Uganda (Freeman and Qin, 2020) found that herbicides and pesticides were used by 60% and fertilisers by 35% of their respondents. Input use was most significantly limited by cost,

which includes actual cost of these products, as well as cost to access the products (i.e., travel expenses, time needed to travel, etc.).

- A study among farmers growing a combination of cassava, millet, maize and banana in Tororo district found that 84% of respondents used chemical pesticides (Andersson and Isgren, 2021).
- A study in 12 districts in Central and Eastern Uganda on the control of fall armyworm in maize indicated that 90% of respondents faced problems with fall armyworm, and from these respondents 84% indicated to spray chemical pesticides (Nyangau et al., 2022). Less than 1% used biopesticides, plant-based pesticides or hand-picking of the worms. Similar figures were found for the control of maize stem borers in the same study. The study also indicated a low awareness of biopesticides: only 20% of respondents had ever heard of them.

Overall, these different numbers show that the use of inputs varies depending on the crop, region and aims of the study. This corroborates the notion that an understanding of the cropping/ farming system at hand is needed to find the most appropriate entry points for a more sustainable farming system. In some cases this may be a reduction of chemical inputs, in other cases it may mean better information provisioning, improving access to certain crop-specific inputs, etc.

2.3.2 Input use in the Ugandan horticultural sector

The horticultural sector is among the sectors in which the use of inputs is higher than average. For instance, Ddamulira et al., (2021) found that 90.9% of tomato farmers in eight districts across Uganda used fertilisers (including organic fertilisers), and 95.7% of farmers used chemical pesticides and fungicides to manage tomato pests and diseases. Most farmers perceived the use of chemicals as the most effective method to control pests. Majority of farmers sprayed weekly (62.1%) and biweekly (3%), respectively, while 20.7% and 3% of farmers sprayed two and three times a week. Spraying three times per week is beyond what is recommended, an indication that chemicals are either wasted or not effective on the target pests and diseases. None of the farmers mentioned that the mixtures or dilutions they use were following the recommendations by the manufacturer, which means that injudicious use of pesticides is common. Such pesticide use is not only potentially harmful to people and the environment, but also an important part of production costs.

In Uganda, the use of pesticides is increasing with an increasing consumption of fruits and vegetables (Ssemugabo et al., 2022). A number of studies focuses on pesticide residues found on fruits and vegetables produced by Ugandan farmers. For instance, Ngabirano and Birungi (2022) conducted a study on pesticide residues on vegetables produced in Kabale district, Uganda. They found that from sprayed vegetables (cabbage, cauliflower, tomato and beetroot) sampled from markets, 86% contained detectable pesticide residues, of which 8% had residues that exceeded Maximum Residue Limits (MRLs). Ssemugabo et al., (2022) sampled 160 fruits and vegetables from farms, markets, street vendors, restaurants and homes in Kampala Metropolitan Area and found that fonofos, fenitrothion and fenhexamid concentrations were above the EU MRLs in all tested fruits/vegetables (watermelon, passion fruit, tomato, cabbage and eggplant). Furthermore, 18 pesticides exceeded health benchmarks and potentially pose chronic health risks to consumers, especially to children. Such studies indicate that better information on the use of pesticides among producers, as well as improved monitoring and surveillance on markets in Uganda would help to protect consumers from potential health risks.

3 Existing organisations focusing on organic agriculture practices in Uganda

In this section, we describe a number of existing organisations in Uganda that are related to organic agriculture practices. We first focus on organisations that work on alternatives for chemical pest and disease control, or on the production of organic fertilisers. Next, we describe the organisations that have a more overarching role in the organic agricultural sector, for instance as a platform, or in supporting specific aspects of the organic agriculture sector.

3.1 Organisations working on (biological) alternatives for pest and disease management

3.1.1 Milkweed

Milkweed offers services and programs that combine IPM principles and practices to design programs biased towards providing biological controls. Individual needs and situations differ from farm to farm but the programs are based on the following six major components:

1. Pest identification
2. Monitoring and assessing pest numbers and damage
3. Guidelines for when management action is needed
4. Preventing pest problems
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

Through promoting IPM, Milkweed is committed to help farmers to produce products which contribute positively to the health and wellbeing of society.

Next to this they also produce several ‘biologicals’, which are naturally occurring microorganisms, plant extracts, beneficial insects or other organic matter, all sourced from Uganda. The products they produce are fungi, bacteria or mites that are ‘natural enemies’ for common pests and diseases.

Figure 1 *In search of potential ‘natural enemies’ for diseases*

One advantage of the products that Milkweed makes is the shelve life of about one year, in contrast to when people make biological crop protection products themselves, which often have a shelve life of around 12 weeks.

At the same time, Milkweed faces challenges with making official products for export, as this is very expensive. Authorities will add taxes, and your products need to be certified which is adding on to the costs. Milkweed argues for a unified approach in quality control and coordination of various bio-initiatives, to tackle additional challenges such as the imperative to stand against the chemical lobby, the complexities of certification processes and the need to prevent chemical spraying on neighboring farms.

3.1.2 Koppert

Koppert aims to contribute to sustainable solutions for horticulture and agriculture by providing alternatives to chemical pesticides. The company has its origins in the Netherlands, but also supplies products to horticultural farmers in East Africa. Koppert started in Kenya 15 years and later opened the Koppert Uganda subsidiary in 2020. Koppert has been active in promoting biological crop protection solutions in Uganda for the last 8 years. The company ships its products from the Netherlands production facilities to Uganda by air. While Koppert directly services the large scale flower farms and flower propagators in Uganda, the company has also partnered with a local distributor - Holland Greentech Uganda – to serve smaller farmers. Holland Greentech serves as an umbrella organisation for the supply of horticultural solutions of Dutch origin products that Koppert offers, include natural enemies for in greenhouses, biopesticides (which are also available in small packets for one knapsack, targeting smaller farmers), and insect traps.

While Kopperts' products are generally about 15-20% more expensive or have at least a comparable price to conventional crop protection products, the idea is that farmers can reduce on the use of other chemicals. This should give farmers an attractive return on investment; an important evaluation criteria for Koppert in the development of new products. For instance, Koppert offers a tomato-package which contains three to four products for pest control, to be applied over the season. The use of this package reduces the use of chemicals by 50-60%. While the combination of products that Koppert offers works, farmers may still require additional chemicals – being fully organic is not the strategy for Koppert. For instance, farmers could spray chemicals early in the season, and then follow up with biological products so that at harvest there are no residues left on the crop.

Most products/ strategies are extensively tested in partnership with the Ministry of Agriculture of Uganda (MAAIF), together with farmers, before they enter the Ugandan market. Further, Koppert has a lot of experience from the Kenyan market where the company has been active for longer. Lessons learned in Kenya are also applied to Uganda. For instance, the use of small packs to serve smaller farmers. For Uganda, the company picks the products and strategies that are most easy to apply or replicate at scale.

Koppert's philosophy and strategy imply that their products need personal support: biological products need more help than conventional products. It is also for this reason that Koppert cooperates with Holland Greentech. Holland Greentech employs agronomists, who are in direct contact with farmers. Koppert also supports Holland Greentech to access smaller farmers, and gives extension officers from Holland Greentech trainings in the use of their products. While currently only 5-10% of Koppert's products goes to smaller farmers, the connection to smaller farmers started only three years ago. In the coming three to four years the company will place more emphasis here, as they consider the segment not exhausted yet.

3.1.3 Holland Greentech Uganda

Holland Greentech started in Rwanda in 2015 and Uganda in 2016 and was founded by VDS ACAMPO in the Netherlands. Holland Greentech does not endorse organic farming; instead, they predominantly promote seeds with a pesticide coating. However, they actively engage in integrated pest management (IPM) and biological pest control. This involves a preventive approach to controlling pests and diseases using methods like sticky traps, pheromones, mycorrhiza, and biofungicides. When necessary, they incorporate synthetic pesticides. In executing IPM, they extensively collaborate with Koppert's registered products in Uganda. For fertilization, they initially use manure, followed by inorganic NPK fertilisers. Their future plans include a shift towards more organic practices, incorporating organic fertilisers and seeds.

The cost of implementing IPM techniques, such as placing sticky traps on one acre, was 50,000 Ugandan shillings in 2022. This investment aids in identifying field insects, enabling farmers to make informed decisions and reduce costs with the help of identification cards. Applying mycorrhiza to one acre also costed 50,000 Ugandan shillings in 2022. Currently, there is a prevalent practice of indiscriminate spraying, emphasizing the need for a mindset change. Transitioning from conventional spraying methods, like using mancozeb, to full IPM typically takes a year for Holland Greentech. After this period, the company can scale down its guidance.

While organic farming has a long way to go in Uganda, the push towards healthy and sustainable agriculture is recognised as essential. The private sector's involvement is crucial, but there remains a significant gap. Consumer perspectives indicate a lack of value attached to organic produce. Although the private sector can contribute to biopesticides, reliance on other countries for these products persists. Milkweed Ltd, an emerging example (see 3.1.1), primarily focuses on virus and bacteria control, with a specific emphasis on horticulture.

3.1.4 Real IPM Uganda

Real IPM Uganda was set up in 2016 as a company to enable farmers and growers access a range of biopesticides and biological control agents. The products are manufactured by Real IPM Kenya. Comparable to Koppert, Real IPM aims to supply preventive biopesticides that reduce reliance on chemical pesticides, minimise the development of resistance in key insect pests and protect biodiversity. The company provides consultancy services about their products to the international horticultural fresh produce industry, as well as plantation crops such as coffee, sisal, cashew, macadamia, pineapple and others. The company works with both large and smaller growers.

3.2 Organisations working on biofertilisers

3.2.1 Safisana

Safisana is a waste-to-energy company, with their headquarters based in the Netherlands, that produces biogas and organic fertilizer out of organic waste streams. In Safisana's model, faecal sludge from (public) toilets in urban areas, and organic waste from food markets, abattoirs and local food processing industries serve as input (feedstock) for Safisana's recycling plants. Through a natural process of anaerobic digestion, the organic waste and faecal sludge is transformed into biogas. This renewable energy is subsequently sold to biogas off-takers (to replace fossil fuels) or used to produce electricity that is sold to the national electricity companies. The residue from the digester (called digestate) is further processed into an organic fertiliser or soil amendment. Proof of this concept are their two current recycling plants in Accra and Kumasi, Ghana.

Some of the organic waste streams are un-used and available for free (this waste generally goes to landfills, when companies want to avoid contamination) or the waste can even be delivered on-site (such as sub-standard/ spoiled human food), as is done in Accra where Safisana has a service agreement with the FDA (Ghana Food and Drugs Authority). However, much of these organic waste streams are already committed in some part of the food supply chain. Some are mixed with other foods for human consumption, others serve as livestock feed.

While biogas is the main product, organic fertiliser is a valued output from the treatment process as well. The digestate (slurry that comes out of the digester after 30-40 days of digesting) is separated in a solid and liquid part. The solid part forms the basis for the organic fertiliser (compost) and requires co-composting with other waste streams such as market waste and a substance for aeration (such as cocoa husks or coconut shells) to speed up the process. Co-composting implies the sourcing of waste from different locations, which has (logistical) cost implications. The focus of this organic fertiliser is on soil improvement (organic matter) more than on (direct) plant nutrients.

The promising part of Safisana's model are the large volumes: tens of tons of compost would be produced per day. For Uganda, a pre-feasibility market study was completed in 2022 for setting up a recycling plant in Kampala, next to the existing wastewater treatment plant of Uganda's National Water and Sewerage Corporation. As part of this assessment, the company conducted a sourcing study of potential waste streams in Kampala that can be used in the digestion or co-composting process. Examples of such waste streams are organic waste from food markets, waste from food and beverage companies, waste that is no longer deemed safe for human consumption and needs to be destructed, waste from the fish industry, slaughterhouses, flower farms (e.g. Wagagai, Royal van Zanten), avocado processing factories (Avolio), chicken farms and milk and bread factories.
In 2024 a broader feasibility study will be done (by a third party) on behalf of NWSC and the Dutch Government (Invest International and the Netherlands Embassy in Uganda) on the decentralisation of faecal sludge treatment in Kampala and the possibilities for valorisation of this waste.

3.2.2 Proteen

Proteen feeds urban organic waste to Black Soldier Fly (BSF) larvae. BSF larvae are efficient in converting organic matter into protein. After a short rearing period these larvae can be harvested, dried and processed into high-quality protein feed for livestock production. The composted material that they leave behind as excreta (called frass) can be used as biofertiliser.

Proteen's aim is to use underutilized waste streams for composting with BSF. Currently, Proteen uses waste from urban markets in Kampala to breed BSF baby larvae. These baby larvae are largely sold to outgrowers in peri-urban areas around Kampala, who subsequently use the mature larvae as chicken, pig or fish feed. In addition, the company pilots the composting of wet coffee pulp, an underutilized waste stream at coffee washing stations, after which the BSF frass is returned to coffee farmers. Initial trials show promising results of the frass on coffee yields.

The BSF larvae require a specific diet for optimal growth. Proteen experiments with different types of waste and its composition. For instance, waste from flower companies and lakeweeds were turned into biochar, to make the frass drier and therefore easier to separate from larvae at harvest. In addition, the use of biochar helps to store carbon, which can be interesting for companies that aim to offset carbon.

In 2022, volumes of biofertiliser produced (and sold) were still small – 25 tons of substrate per month (at an application rate of 2 t/ha this would be sufficient to supply 150 ha of cropland). The costs of the biofertiliser are lower than mineral fertiliser, and also lower than e.g. the organic fertiliser Fertiplus (imported from the Netherlands, see 3.2.5). Hence, at a localized, relatively small scale, the use of BSF frass could be potentially interesting to complement or partially replace mineral fertiliser.

Figure 2 *Proteen's biofertiliser, and crates with black soldier fly larvae in the background*

3.2.3 Biota-nutri

Biota Nutri produces clear, liquid fertilisers which are plant based. The fertiliser is organically certified in the Netherlands. In Uganda, Biota Nutri tried to develop something similar, but in granular instead of liquid form. This resulted in two plant based organic granular NPK fertilisers, that have been developed in and for the Ugandan market. In the development phase they aimed to develop a product with a nutrient content as high as possible, which is difficult because of its plant-based nature. In general, potassium is more easily extractable from plant materials than nitrogen and especially phosphorus. Biota Nutri also struggles to find a continuous stream of plant residues as basis from which to develop their product, as many waste streams have other purposes already.

3.2.4 Other organic fertiliser input dealers

Fertiplus is and organic fertiliser, developed in the Netherlands by Royal Brinkman and available on the Ugandan market. Several different waste streams are used (~22), which are tested frequently, to produce highly standardized quality products for the organic market. Producing something similar in the Ugandan context takes time and dedication and good laboratories to be able to constantly test the residual streams used to produce such a product. Furthermore, the sources of residual stream need to be organic as well, posing another problem.

Biobloom is a company selling organic inputs: organic fertiliser, biopesticides, native microbes and dry compost manure.

VermiPro is a company developing organic and bio inputs that address key production challenges ranging from soil health, fertility, plant growth, yield, disease, and pest management.

3.3 Umbrella organisations, platforms and other organisations

3.3.1 Participatory Ecological Land Use Management Uganda (PELUM)

PELUM, a regional network of 250 civil society organisations across 12 countries, focuses on improving small-scale farmers' livelihoods through ecological land use management. PELUM Uganda, active since 1995, shares skills, undertakes research, and advocates for policies supporting farmers.

A main challenge that the organisation notes in the uptake and commercialisation of organic inputs is the lack of standardisation. Organic practices often lack standardised inputs, including biopesticides, biochar or vermicomposting, which hinders consistency and reproducibility. Other challenges include the lack of hard evidence for the effect of such products on disease control, the possibility for validation of concoctions, a lack of application guidelines, and safety concerns for products like vermi-tea, which raises questions about the effect of such practices on soil fertility and pest management. Moreover, the lack of consistency makes it difficult to attract research funding compared with other, more standardised agricultural practices.

PELUM therefore emphasises the need for experiential learning and social trust in spreading organic practices. In that regard, PELUM hosts the Knowledge Hub East Africa in Uganda (see below), which is meant for training and to facilitate a ripple effect.

3.3.2 Knowledge Hub East Africa (KHEA)

Knowledge Hub East Africa (KHEA) is part of the knowledge centres for Organic Agriculture in Africa (KCOA), a partnership that aims to scale up adoption of organic and agroecological farming practices through a network of five knowledge hubs in Africa. The aim of the hub is to improve access to knowledge on organic agriculture and agroecology, to strengthen the technical and professional capacity of multipliers, and to foster networking and strengthening relationships in the sector.

The existing knowledge on organic practices lacks documentation and regulation, benchmarks and standardisation. Yet, while these practices may not be highly commercialised, they do exist within organisations and farmer groups, with known suppliers producing organic inputs like manure and pesticides.

KHEA signals a main challenge in the need for a mindset change about the contributions that organic practices may have to livelihoods. Although those directly involved understand, extending this awareness to consumers is challenging. Marketing, pricing, and promotion of organic produce remains problematic, with little differentiation perceived between organic and conventional products. Value chain actors need to emphasise these differences and demonstrate the unique qualities of organic goods.

The lack of documentation and standardisation also poses challenges to scaling up practices from household to commercial levels. However, KHEA does see the market potential for organic produce, both local and international, as a significant opportunity. The middle class in Uganda recognises the added value of organic products. Packaging is a key issue, as well as the consistency of the quality and performance. Despite the challenges, KHEA sees organic farming as economically viable.

3.3.3 YALTA initiative

The YALTA initiative focuses on supporting youth in agriculture, aiming to bridge the gap in farming, which has predominantly been left to women and older individuals. The initiative promotes agroecology and seeks to engage youth in agriculture with a business-oriented mindset, emphasising principles, practices, and market access. The focus lies on business that earn an income.

Despite exposure and the emergence of several agroecological entrepreneurs among the youth, these entrepreneurs face challenges, notably in pest and disease management. In pest and disease control, swift solutions are crucial, as even minor crop issues impact marketability. Patience is often lacking, which makes people resort towards conventional solutions. The need for fast-acting pest and disease management is evident, while it often requires time to increase the population of natural enemies.

An example of an alternative explored for fungal diseases in tomato includes sodium bicarbonate hybrid. Although not extensively documented, this research indicated some reduction in fungal disease impact compared to conventional methods. However, the commercial viability of such alternatives remains challenging.

Additionally, there are increasing concerns about organic fertiliser’s value chains. For instance, with respect to the feed that is consumed by cows producing manure; which may well have been exposed to conventional pesticides. Also, the process of using animal waste in agriculture prompts questions about pathogen elimination and overall safety assurance.

3.3.4 Horticulture Market Acceleration Project (HortiMAP)

HortiMAP is a four-year (2021-2024) horticulture project funded by the Dutch Government through the Embassy of the Kingdom of Netherlands in Kampala. The project is implemented by TechnoServe, in partnership with PUM and Wageningen University & Research (WUR). HortiMAP aims to ensure the sustainable local supply of fruits & vegetables, job creation along the horticultural value chain and a competitive performance of Uganda's fruits and vegetables in regional and distant export markets. The project focuses on capacity building of SMEs and local supply chains, and entrepreneurship plus agronomy trainings to farmers and retailers.

On the production-side of the project, there is a focus on good agronomic practices in horticulture, access to organic and non-organic inputs, and specific support to selected organic input suppliers (of bio-pesticides and organic fertiliser). On the market-side of the project, the focus includes safe and healthy food for local markets, and quality control on inputs: to what extent are they safe to use for producers and consumers.

Specifically, the project works on access to seed varieties with a tolerance to pests and diseases, to reduce the need for chemicals. Also, the project focuses on enhanced knowledge and awareness about the safe handling of chemicals, and on the use of organic inputs and a shift towards IPM. HortiMAP has identified tomato and cabbage as vegetables with pressing challenges of heavy use of chemicals and resulting concerns for consumption as both vegetables are often consumed raw. The project will explore ways to produce these vegetables in a safer way. Additionally, the project cooperates with input companies like Xclusive Biological Company (XBC), Dutch Seed Center, VermiPro and Real IPM for seed and organic products for onions, cabbage and tomatoes, among other crops. HortiMAP only works with (organic) products that are certified by MAAIF, and that have gone through their validation process. HortiMAP also works with demo plots that double as test sites to verify the effectiveness of different products. The combination of demonstration plots, awareness creation and a training on the use of organic products should ensure upscaling of the use of organic inputs.

3.3.5 House of seeds

House of seeds LTD is a professional seed company which started in Uganda in 2010 and is currently distributing seeds from the Dutch breeding company Enza Zaden and trading several Dutch vegetable brands like ProSeed and Monarch seeds. House of seeds has shifted part of their product portfolio to the distribution of organic products, and is currently engaged in the second season of biological vegetable growing demo plots in the Eastern part of Uganda with these products (under the HortiMAP project). This involves a special selection of highly pest resistant and tolerant vegetable varieties in combination with the use of biological pest control and the use of organic fertilizers.

A challenge is that the Ugandan law does not allow any untreated vegetables seeds (i.e. seeds without a pesticide coating) into the country. This law makes it impossible for seed importers to import organic, untreated seeds. Due to the current availability of high quality seeds this demanded treatment is no longer needed. However, a lack of awareness on why and when this procedure should be applicable or not, prohibits current changes in the law.

Since the COVID-19 pandemic, there has been a 22% increase in the demand for organic produce in Europe. However, Ugandan farmers have not embraced this opportunity, largely because traders pose obstacles. So far, the business mindset in Kenya appears more favorable towards organic production for instance. To address issues with traders, the traders need to be involved in a shift towards organic production. This could be done by engaging traders in creating access to quality seeds that still meet their preferences in terms of taste, color, and size of the produce. The focus should be on providing a comprehensive package including quality vegetable seeds, (bio)fertiliser recipes and/or crop-specific fertiliser recommendations, and biological pest control tailored to different pests and diseases.

The export of Ugandan agricultural products faces challenges of interceptions, more than other African countries, whereby export produce destined to the EU market exceeded thresholds values of pesticide residues. While produce of a scattered origin is difficult to trace, the transition to a nucleus farm with out-growers proves more manageable, allowing better control of spraying activities. Moreover, this also reduces the challenge of neighbors spraying chemicals, which residues end up on organically-destined produce. Therefore, the use of biological pest control for vegetable exports should be more promoted. The Dutch flower cutting industry in Uganda is the best example that this is do-able in Uganda.

On the producers' side, organic fertilisers are adopted more easily then biological crop protection (biologicals), because of the importance of visual proof that a pesticide works (which takes at least 3-5 days), and the challenge of short expiry dates for biological pest control products: since biologicals are hard to get for small holder growers, ideally you shelve certain pesticides for later use, but the expiration date of the biologicals is often much shorter, adding to the problem. The movement towards biologicals and organic fertilisers is challenged by the dominance of the chemical lobby, issues of shelf-life, and the need for proper training and support for those producing their own biologicals.

3.3.6 CABI

The Center for Agriculture and Bioscience International (CABI) is an international, intergovernmental not-for-profit organisation that aims to improves people's lives by providing information and applying scientific expertise to solve problems in agriculture and the environment.

Amongst others, the organisation focuses on reducing crop losses through better pest and disease management. CABI puts emphasis on lower-risk solutions and the promotion of biological control. The use of chemical pesticides has an instant effect, while biopesticides take sometimes too long to demonstrate results, showing a gradual reduction in pest presence after several days. That's why CABI first promotes lower-risk solutions like biological control, through the release of natural enemies of invasive species like the Asian fruit fly and papaya mealybug.

Biopesticides aim to infect insects with pathogens, but their registration is challenging due to regulatory requirements favouring conventional methods. CABI therefore also works on the registration of bio-products, and East-African regulations on such registrations. CABI has a network of Plant Doctors (governmental Extension Agents), which contribute to Integrated Pest Management (IPM) by diagnosing pests and diseases. Plant Doctors use tablets for data collection, enabling quick response to outbreaks and modification in advice. Hazardous pesticides, classified as Class 1 and Class 2a, are outlined and strongly discouraged from use. Plant Doctors educate farmers on proper pesticide use. Challenges around hazardous pesticides include illegal entry of products and misuse across different crops.

The Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) regulates agro-input dealers, and efforts are made to engage them in understanding the risks associated with various products. Trained farmers and agro-input dealers play a crucial role in disseminating information. Prevention through traps is considered, but the choice between prevention and control/treatment is debated.

CABI conducted citizen science projects in Ghana and Kenya, evaluating homemade biopesticides' efficacy, including substances like wood ash and chili products. The standardization of these homemade solutions is explored, to get a standard.

3.3.7 FAO

The Food and Agriculture Organisation (FAO) of the United Nations is an agency leading international efforts to defeat hunger and increase nutrition and food security. In Uganda the FAO advocates for Integrated Pest Management (IPM) through incorporating it into production practices, hence they talk about Integrated Pest and Production Management (IPPM). Agronomic practices play a crucial role in safeguarding plants from pests. The emphasis is on using less hazardous pesticides and creating opportunities for nature's own pest control mechanisms, such as natural enemies. Best practices are promoted among farmers, considering their ability to analyse situations across seasons and address issues early.

FAO's focus is on providing information about IPPM to vulnerable farmers, instead of commercial farmers. The goal is to equip farmers with knowledge, so that they can make informed decisions. For this they establish farmer field schools, typically consisting of 30 participants, to learn about different commodities. Facilitators analyse what is available and appropriate for the farmers, adapting knowledge from various sources, including institutes, to the local context.

While FAO primarily targets vulnerable farmers, it recognises challenges in promoting organic practices, driven by poor land holdings and soil fertility depletion. With a growing population, there are concerns about the sustainability of current agricultural practices. Organic farming, despite its potential benefits, may face limitations in addressing the needs of smallholder farmers due to issues related to quality, quantity, and the diversity of products.

Transformation is deemed necessary, with a call for government support to shift from subsistence to commercialised farming. FAO's global policy aligns with these goals, implemented within the national context, addressing limitations and promoting sustainable agricultural practices.

3.3.8 Rikolto

Rikolto is an international NGO, with a primary focus on horticulture and a food systems approach. Food safety is a main concern for the organisation, aligning with a broader vision of providing good food for cities. Research predicts a significant urban migration by 2050, particularly among women and youth. Cities serve as hubs for innovation and food piloting, making them crucial for adopting new practices.

Rikolto has experimented with short food chains (mainly for horticultural crops), collaborating with Kampala Capital City Authority (KCCA), and with implementing agricultural technologies like vertical gardening at household level. They see that the emphasis on food safety is driven by urban dwellers' interest in multiple income sources, like producing horticultural crops in their small gardens. When neighbours come to buy peoples' products, producers really try to improve their food safety, because they don't want to see their neighbours to become sick.

Furthermore, public markets are dominated by horticultural products, and Rikolto recognizes the role of vendors in promoting safe produce. The organisation partners with Holland Greentech to enhance market stalls and address postharvest handling challenges. Collaborations with MAAIF and farmer groups aim to encourage people to grow their own food and promote regenerative agriculture to reduce reliance on pesticides, and people produce safer food if they produce for themselves.

Related to food safety, Rikolto also raises concerns about the long-term impact of pesticides on human health, exploring factors triggering the increase in cancer cases in Uganda. Overall, the organisation emphasizes the importance of addressing the health implications of pesticide use.

Finally, in terms of inputs, there is a disconnect between input dealers selling products in towns and their actual use in villages. Rikolto therefore introduces a village agent retail model to bridge this gap, combining purchases to make inputs more accessible to farmers. The organisation recognizes the market potential for organic fertilisers and pesticides but emphasizes the need for effective communication between selling agents and farmers.

4 Other organic practices with potential for further exploration

In this section, we describe a number of organic agriculture practices in more detail, that were mentioned in conversations with stakeholders; or that are not yet widely used in Uganda but are worth further exploration for potential future research or dissemination.

4.1 Biological pest control

4.1.1 Natural enemies and insect predators

Natural enemies and insect predators are increasingly being employed as pest-control strategies in organic agriculture. While the diversity of existing predator-prey interactions makes this a complex field, crops generally have a particular set of insect pests that are of major (economic) importance. For instance, cowpea has >100 pest species in Africa, but only four pests are of major economic concern for Uganda (Adipala et al., 2000). Understanding of pest-predator interactions in Uganda has recently seen advancement in potato (Okonya, 2013), wheat (Macharia, 2016), cotton (Howe et al., 2015), tomato (Chepchirchir et al., 2021), and maize-soybean (Ojuu, 2021), but this understanding remains incomplete and far from being widespread (Okonya and Kroschel, 2016). Farmers are generally unaware of beneficial pest-predator interactions: only 5% of potato farmers in six districts across Uganda indicated to be knowledgeable of pest-predator interactions, while the majority of farmers used synthetic pesticides (Okonya and Kroschel, 2016).

Natural enemies thrive in an environment conducive for their population, which means that non-crop habitats that support these species are needed to maintain healthy populations of natural enemies (Ojuu, 2021). For instance, fall armyworm (FAW) incidence in maize-soybean cropping systems of Eastern Uganda was found to be significantly higher in fields further away from wetland habitats which inhibit wasps as natural predator for fall armyworm (Ojuu, 2021). Diminishing natural areas therefore also means a decline in beneficial habitats (forests, woodlands, wetlands) for natural enemies (Pomeroy, 2017).

4.1.2 Home-made concoctions

Natural bio-control and home-made concoctions are used by many farmers that cannot afford or access synthetic agrochemical pesticides. Home-made pesticides are generally based on extractions from indigenous pesticidal plants and other ingredients. Some well-known examples of biopesticide elements include the use of leaf extracts from Tephrosia vogelii (Moshi and Matoju, 2017); cultivating the endemic insect baculovirus; the use of neem oil extract from *Aza.dirachta indica*; seed powder extract from *Jatropha curcas*; *Bacillus thuringiensis* (Bt) as toxic bacterium to insect larvae when ingested; and the fungus *Trichoderma* (Ayilara et al., 2023). These natural products are either used in an isolated form or mixed with other naturally occurring elements. Ingredients used for concoctions vary widely but are known to include animal manure or urine, water, chili pepper, garlic, tobacco, ash, mint, basil, lavender, cottonseed, marigold, rosemary, salt, vinegar, dish soap and others depending on availability (Islam and Morshed, 2013; Mfarrej and Rara, 2019). Such concoctions are often home-made and therefore remain under the radar of scrutinous academic research.

Figure 3 *Example of home-made bio-pesticide in the making in Bududa district*

Traditional pest control using natural elements is widespread in Uganda. For instance, around the lake Victoria basin in Uganda, 100% of 117 respondents used botanical products for traditional pest management (Mugisha-Kamatenesi et al., 2008). A lack of studies on indigenous knowledge of natural organic pesticides limits further understanding of the effectiveness of the different ingredients.

4.1.3 Pyrethrum

Pyrethrum is a fast-acting, powerful insecticide derived from the flowers of pyrethrum daisy, *Tanacetum cinerariifolium.* Owing to its broad-spectrum efficacy and low environmental and mammalian toxicity, pyrethrum has been widely used in agricultural, veterinary, and indoor pest-control products (Macover, 1995). Pyrethrum is more widely used in neighbouring Rwanda, with Rwanda being the second largest producers of pyrethrum and has approximately 15% of the global market share (National Agricultural Export Development Board Rwanda, 2019).

4.1.4 Integrated Pest Management

Integrated Pest Management (IPM) is focused on a stepwise combination of approaches rather than a single pest control method. Four steps inform different pest control decisions (EPA, 2023):

1. Action is only taken when pest populations exceed a certain threshold. This threshold is linked to a level at which pests will become an economic threat.
2. Pesticides are only used when needed (for example, when a threshold is exceeded); not all insects need control.
3. Prevention of pests through crop rotation, use of pest-resistant varieties and using pest-free planting material
4. Once a threshold is exceeded, proper control methods for a specific pest are evaluated. Pest-specific mechanical (traps, weeding) and chemical (pheromones, targeted products) products are preferred over general ones. Broad spraying of non-specific pesticides is a last resort.

IPM is especially promising in systems where current use of chemicals is high (such as tea, tobacco, cotton or horticulture) (Orr, 2003). In such systems, farmers could save costs by reducing the use of chemicals. However, farmers often prefer chemical control over additional labour, which IPM requires. Also, IPM is relatively complex and a concept like the ‘threshold when economic loss occurs’ as a criterion to spray is complicated to judge (Orr, 2003). As indicated earlier, more complicated approaches to pest control require continued support from extension officers.

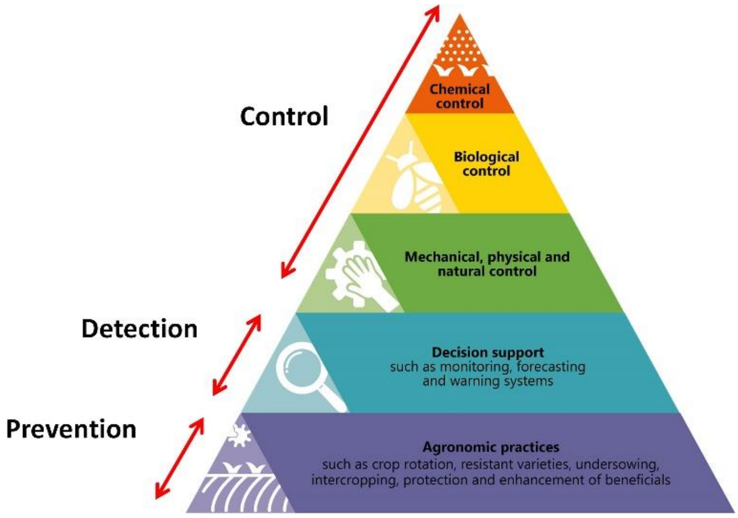

Figure 4 *Steps in integrated pest management. Source: (Collier, 2023)*

4.2 Biofertilisers

4.2.1 Biochar

Biochar production via pyrolysis (i.e., conversion of biomass at high temperature and low oxygen concentration) and its application has been advocated over the past decade as a strategy to improve soil quality (Schmidt et al., 2021), as well as for soil carbon sequestration (Liu et al., 2016). In several meta-analyses on the application of biochar as soil amendment, compelling evidence is found for its beneficial effect on soil water retention, microbial action and plant nutrient supply (Schmidt et al., 2021). Although also applied in isolation, a combination with compost (Zahra et al., 2021) or with other chemical or organic fertilisers (Wang et al., 2019; Bai et al., 2022) is more effective.

In 2014, Uganda Radio Network already reported novel research on biochar conducted at Ikulwe Agriculture Research Station in Mayuge district. There, agricultural residues like coffee husks and maize cobs were used as feedstock for biochar production with positive results shown in terms of soil fertility, agricultural productivity and protection against some plant feeding and soil-borne diseases (URN, 2014). Following this, two studies were done to analyse the effects of corncob biochar (Apori et al., 2021) and coffee husks biochar (Kiggundu, 2019). The first study concluded that biochar co-applied with compost and NPK fertilisers resulted in significant improvements on plant growth and some soil chemical properties (e.g., soil pH, available phosphorous and potassium, and soil organic carbon), more so than when solely applying NPK or compost. The latter study on coffee husks found that biochar-amended soils had a higher water holding capacity and increased availability of soil nutrients for crop growth compared to biochar-free soils. Long-term trials (10 years) also showed a lasting effect from a single dose of biochar on crop yields (Sundberg et al., 2020).

Competing uses for biomass is often mentioned as a restraining factor for biochar production in sub-Saharan Africa. For instance, rural Ugandan households frequently depend on woody materials for fuel, which could be potentially used as feedstock for biochar production. Using unused residues of cereals and legume crops such as maize, sorghum, millet and groundnut as feedstock for biochar production may present a viable outcome (Roobroeck et al., 2019).

4.2.2 Lakeweeds

Lakeweeds and reed are potential sources of organic matter and crop nutrients in agriculture. These plants grow on nutrients that they take up from the water, and catch nutritious silt in between their roots. Harvesting these plants for application in agricultural fields can make a contribution to recycling of nutrients in agriculture.

The excessive proliferation of water hyacinth (Eichhornia crassipes) in Lake Victoria, for instance, makes this a weed that could be extracted for use in agriculture. Water hyacinth is mostly seen as a burden, posing ecological threats to lake biodiversity and economic threats to local fishing communities (Begum Rasmiya et al., 2022). Its fast-growing properties and high moisture content (~95%), make this floating, invasive aquatic plant difficult to eradicate (Liao et al., 2023). Instead of eradication, it has therefore been proposed to shift the approach to its sustainable exploitation (Güereña et al., 2015), and efforts are ongoing to identify this potential (Musinguzi et al., 2022), including for agricultural use.

One suggestion is for water hyacinth to be used as organic mulch (Woomer et al., 2000; Begum Rasmiya et al., 2022). Trials in India and China have shown that mulching with water hyacinth significantly increased soil carbon, plant available nutrients (NPK) (Balasubramanian et al., 2013) and improved soil moisture content in the top 0-90cm soil column (Xu et al., 2017). Focussing on Uganda, a case study on the southern shore of Lake Kyoga investigated the effects of using lakeweed as mulch and found a reduction in soil temperatures (up to 15%) and evaporation (up to 100%), an increase in soil water retention (up to 150%) and biological activity, as well as a suppression in weed growth (up to five times lower) (Dekkers, 2019).

Water hyacinth could also be composted. A case study in Sri Lanka reveals that several soil chemical, biological and physical factors improve by using water hyacinth as compost (Begum Rasmiya et al., 2022). This study even suggests that water hyacinth compost is 'far better than animal manures' in terms of improving soil properties. Crop production improvements are reported in experiments with water hyacinth for okra, potato, tomato (Sannigrahi et al., 2002) and maize (Xu et al., 2017). Such improvements can be attributed to various plant agronomic growth parameters such as germination percentages, leaf mass, leaf area index, plant height, length of shoot and root, biomass content and others (Begum Rasmiya et al., 2022).

However, challenges to lakeweed exploitation exist as well. Mechanized removal of lakeweed from lakes and rivers is expensive and energy and labour intensive (Malik, 2007). Furthermore, the use of these lakeweeds is likely restricted to areas close to the lake, as transport costs of such bulky materials often poses the main bottleneck for adoption (depending on the price that a buyer is willing to pay for the use of this material). The usefulness of different types of materials is another consideration: water hyacinth contains only 2-3% dry matter, whereas reeds contain about 18% dry matter. This makes the extraction and use of reeds more efficient than the use of water hyacinth (H. van den Broek, personal communication). Furthermore, there exists a chance of heavy metal accumulation along with a low level of awareness on its composting practice (Begum Rasmiya et al., 2022).

4.2.3 Vermicompost and vermi-tea

Vermicompost and vermi-tea have become established soil amendments in organic agriculture. Vermicompost is the product of composting organic materials with the intentional help of earthworms and bacterial communities. Vermi-'tea' can be considered as the liquid content of this compost, which shows similar application effects as its compost variant (Vuković et al., 2021). Using vermicompost has been found to enhance soil physical, chemical and biological properties, which in turn improves plant growth and plant yield (Lim et al., 2015; Yatoo et al., 2021). This enhanced yield is attributable to the improved nutrient richness but also to other processes at play including improvements in structure, aeration, water retention, porosity, microbial action and others. Despite the benefits of using vermicompost as organic soil amendment being well understood, questions remain around the best composition of microbial communities, the selection of organic waste as parent compost material, and its effects on heavy metals in the soil, amongst others.

In Uganda, several vermicomposting trials have been established over the past decade, most notably by Makerere University Agricultural Research Institute Kabanyolo (Komakech et al., 2015; Jjagwe et al., 2019). Both studies address the issue of urban environmental pollution due to poor disposal of cattle manure in Kampala, and both found positive results when using vermicomposting as a strategy to repurpose discarded manure. For instance, Komakech et al., (2015) evaluated the effects of different organic fertilisers on maize yield. The study found no significant differences when using either stored cattle manure, vermicompost, or digestate (the resulting effluent from biogas production) as organic fertiliser. However, interviews conducted with farmer groups demonstrate that farmers generally preferred using vermicompost and stored manure over a digestate. Farmers appreciated vermicompost because of its high nutrient content, lack of odour, and being low in volume compared to alternatives. However, they noted availability and costs to be their main concern. Komakech et al., (2015) also assessed effects of storage and found a significant drop in nitrogen content of vermicompost when storing for a longer time due to volatilization, leaching and/or aerobic degradation. This implies that vermicompost should be harvested and applied to the field on a regular basis. To address the availability and cost, sensitization about the practice could be a first step in building experience with vermicompost. Initial costs for construction of the required area and purchase of earthworms could present a financial hurdle, though the return on investment looks promising. For instance, a study in Kampala with a vermicompost reactor demonstrates that this system is technically and economically viable for improved urban manure management (80% cattle manure and 20% food waste) (Lalander et al., 2015). The study found a return on investment after 5 years of about 200%.

In areas where there is little to no functioning of organic waste management, vermicomposting could offer a viable solution. Though, if farmers already apply their available manure as a crop fertilization strategy, it remains contested what added value vermicompost has to offer, since Komakech et al., (2015) found no significant differences in crop yields when comparing stored manure with vermicompost. Jjagwe et al., (2019), however, also analysed the physio-chemical properties of the vermicompost over the duration of one year. They found significant increases in N, P and K content amongst other factors, while a decrease was found for soil carbon and pH values. They conclude that vermicomposting offers a greater potential for retaining nutrients of cattle manure than other methods such as stockpiling, composting and anaerobic digestion. The authors also found lower emissions associated with vermicomposting compared to the aforementioned alternatives.

4.2.4 Rabbit urine

Rabbit urine is a waste product of rabbit keeping that can easily be turned into a useful by-product when collected from above-ground rabbit pens (Said, 2018). The beneficial properties of rabbit urine include its nutrient content as well as its physical form. Concerning the first, the nutrient (N, P, K) content of rabbit urine is found to be higher than that of livestock and poultry (Sunadra et al., 2020). When applied in field tests, researchers found direct benefits of rabbit urine application to plant growth and crop yields for e.g. tomatoes, melons and cereals (Indabo and Abubakar, 2020; Mutai, 2020; Sunadra et al., 2020). Moreover, rabbit urine has an alkaline nature (pH=8.5) due to high calcium levels (Mutai, 2020). Concerning the physical form, rabbit urine is more easily collected than that of livestock or ruminants (when the rabbits are kept in pens), and it can be transported and stored efficiently without requiring large facilities. Rabbit urine should be diluted with water and/or used in combination with other fertilisers since it can scald leaves when directly applied as a foliar fertiliser (Mutai, 2020).

Despite rabbit urine mostly being used by farmers as biofertiliser, the urine has also been found to act as biopesticide (Lekamoi, 2022). Rabbit urine contains ammonia, a highly volatile compound, which is easily converted to ammonium – commonly used in pest control. On field experiments in Tanzania, the authors assessed the effects of *Tephrosia vogelii* combined with rabbit urine on insect pests and pollinators of sesame. They found a smaller number of insect pests compared to the control, same as synthetic pesticide, when spraying with the biopesticide. Moreover, a larger number of pollinators and natural enemies were found on rabbit urine-treated plants compared to those sprayed with synthetic pesticides (Lekamoi, 2022).

In Uganda, the use of rabbit urine as fertiliser and pest-repellent is known for numerous crops (Lekamoi, 2022; Sumani, 2022). Yet, researchers relate that rabbit urine application remains limited due to low levels of rabbit rearing at household level (Bwengye, 2023). The potential of rabbit urine is expressed in a study on cattle manure utilisation in central Uganda. Where farmers mentioned an increased yield as being the main reason for using cattle manure, bulkiness, weight and high transportation costs were among the downsides listed by farmers (Muhereza, 2014). The researchers found a relatively low nutrient content (0.42-0.56% total N) in cattle manure which they attributed to poor collection, handling and storage. Highlighting the promising traits of rabbit manure, it could pose a viable addition or even alternative to the use of cattle manure. At the same time, because of the volatility of urine, especially in a tropical climate with high temperatures, proper attention for storage and application of urine remains as important as for cattle manure.

5 Synthesis of challenges and opportunities in the organic agriculture sector in Uganda

5.1 Challenges for organic agriculture

5.1.1 Pest and disease management

- One of the main challenges in organic agriculture is pest and disease management. While a holistic, balanced system approach is necessary, impatience often drives reliance on quick conventional solutions. The urgency for rapid pest and disease management solutions is compounded by the absence of natural enemies, whose population growth requires time and patience. The direct effectiveness of chemicals, combined with risk aversion, a lack of knowledge and no time for 'trial-and-error', hinders the adoption of organic approaches that are slower in the decrease of pest and disease incidents. Organic farming starts with prevention of infestations, through e.g. sticky traps, to be able to identify early on which pests are present in the field.
- The use of biological pest control strategies is more knowledge-intensive and requires more support from agricultural extension officers than chemical pest control. This complicates the sale of these products through regular agro-dealers, and to any farmer. Therefore, biological products are mainly sold to large-scale, commercial farmers who are well-connected to extension agents.
- Biological pest and disease management works best if all farmers in an area apply the same measures. However, individual decision making prevails at the moment, and the engagement and experiences with people promoting inorganic or organic methods may influence individuals differently.
- Commercial farms in greenhouse horticulture are among the players who currently use biological pest control products. Challenges with these products in greenhouses include that this pest control is partly done by the use of predatory insects. To sustain a population of these beneficial insects, the insects require enough food, including the unwanted insects. Feeding the beneficial insects therefore also re-introduces the unwanted insects, which obviously poses a risk to the producer.

5.1.2 Biofertiliser production

- There is a general lack of unused organic material (crop residues, manure, food waste and waste from processing) in Uganda, which poses a challenge to the large-scale application of organic material for biofertiliser production. Most waste streams have a destination already, and when they are not used, this is for a good reason (e.g. their degradability is low, they are difficult to obtain, lack nutritional content, etc.). Hence, users of potentially interesting waste streams either compete for same source and there is no net win, or what is there is of poor quality or available in small, localised volumes only. For example, a large, unused potential waste stream is the organic waste (from households, from urban markets) dumped at landfills. However, this waste is mixed with all kinds of other materials (plastics, tins, etc.), hence the resulting compost is unusable.
- Transport of organic material poses logistical challenges too: organic fertiliser (manure, compost) is generally voluminous (because of its high water content). Hence, both the transport of the waste to a processing facility and the transport of the resulting biofertiliser need to be done in a location close to the source of the waste and the use of the fertiliser.
- The use of organic products like compost may impose the risk that there is still the presence of certain fungi or bacteria if the compost pile does not reach the required temperature to kill pathogens, with potential damage to crops. For commercial companies, introduction of such pathogens may result in great losses, which they cannot risk. The risk associated with the use of organic inputs may therefore be larger than for conventional products.
- There is a general lack of nutrients and organic matter in the soils of smallholder farmers in Uganda, and this is hard to increase substantially without the use of inputs from outside of the farm. In addition, practices like green manure or cover crops to increase nitrogen and soil organic carbon require farmers to

set aside part of their land to grow these crops, which is considered difficult for the majority of smallholders given current land scarcity and population growth.

Figure 5 *Wet coffee pulp from coffee washing stations as one of the few underutilised organic waste streams. Photo credit: Maartje de Jong.*

5.1.3 Documentation, regulation and standardisation

- Knowledge on organic agriculture exists but it is not well documented, regulated or standardised. At the moment, farmers mainly rely on observations and experiences, and lack more guided references, for instance with respect to pest control decisions in organic agriculture.
- Pest and soil fertility challenges vary by crop and region, requiring tailored solutions. Hence, even when information is available, facilitators must adapt this knowledge (often from various sources) to the local context, which enhances complexity and is time consuming.
- There is often an inconsistent quantity and quality of sourcing materials for biological fertilisers and pesticides, posing challenges in ensuring consistent quantity, composition and safety. Moreover, there is a lack of research on the active ingredients of mainly biopesticides, leading to home-made concoctions, made by trial-and-error approaches. Because of this high variability and the lack of standardisation of inputs, there is limited documentation available on the efficacy and composition of organic fertilisers and pest control methods, which hampers their adoption.
- The lack of standardisation and documentation also translates into registration challenges. For instance, biopesticides are difficult to register as regulatory bodies often favour conventional pesticides. With this, supplying organic inputs for large acreages becomes challenging, affecting the scalability of organic farming.
- Despite having an organic policy, the absence of a legal framework in Uganda impedes the allocation of government funds for policy implementation.

5.1.4 Demand for organic produce

- Changing mindsets on the potential contributions of organic practices is a significant challenge, both among farmers and consumers. Farmer attitudes, scepticism about scalability, and quick-wins mentality pose challenges to the uptake of organic practices. From the consumer side, minor crop issues lead to unsalability, because consumers want spotless products.
- The marketing, quality and quantity of organic produce is lacking at the moment. Furthermore, distinguishing organic products from conventional ones is difficult, posing further challenges in marketing, pricing, and promotion of organic produce.
- Inadequate packaging, branding, and information on packages hinders the commercialisation of organic products. This holds for marketing to both local and international markets, in which case you need quality consistency and performance of the produce.

- Expectations about the potential for growth of the organic sector in Uganda are modest. In comparison: in the European Union (EU) the average area under organic production is about 10%, and growing at a rate of about 6% per year. Moreover, organic food contributes only 10% to the total food sales in top-countries Denmark and Austria, while in the majority of countries this is less than 2% (EC, 2023). The premium price that consumers pay for organic products makes organic farming attractive for European farmers. The question is to what extent Ugandan consumers will truly be willing to pay such a premium. The demand for organic produce is therefore likely to remain a niche for the time being.

5.1.5 Demand for organic inputs

- A viable business case is needed for biological pest control. This means that farmers who currently use biological products are farmers who have an assured output market of a certain value. If not, it becomes too risky for farmers to invest in these types of products. In addition to that, the purchasing power of smaller farmers is too low, which makes the demand for commercial biological pest control products among this group unlikely in the shorter term.
- There is a trade-off between potential costs savings through a reduction in preventive spraying of chemicals on the one hand, and an increased labour requirement for scouting of pests and their management on the other hand.
- Farmers currently lack skills in the identification of pest and diseases, which is needed for a more targeted application of pest and disease control measures. Availability of reliable guidance and extension support is limited.
- There is limited scaling/commercialisation of biological inputs (biopesticides and biofertilisers).
- For agro-input companies, bottlenecks to reach smaller farmers mostly relate to manpower: more staff is needed because these farmers are more widespread.

5.2 Opportunities for organic agriculture in Uganda

5.2.1 Increasing consumer attention for safe food

- While Uganda’s organic agriculture sector is largely export-driven, with coffee and cocoa taking up the largest share, there is a growing attention for food safety among consumers and policy makers. Newspaper articles on chemical residues found on fruit and vegetables contribute to this awareness, as well as a more general attention for a ‘healthy lifestyle’, which often includes the consumption of ‘natural’ products. The growing awareness offers potential to producers. For instance, certain hotels, restaurants or supermarkets want to stand out with organic and safe food. Producers could offer their crops as being sustainably or organically produced and ‘safe’.
- A recent study on consumer perceptions of food safety indicated that two thirds of consumers from selected markets in rural and urban areas across Uganda was slightly to highly worried about food safety (Ten Hove et al., 2023). Among those respondents, 50% was worried about chemical residues, and 70% were willing to pay a premium price for safe food (20% were willing to pay double the current market price, the rest a lower premium). This indicates an expanding scope for producers to market their produce as ‘safe’ food, provided that the source of such food and its production methods can be traced, to ensure that this is actually the case.

5.2.2 Enhance quality, consistency and performance of organic products

- Opportunities exist to enhance the quality and consistence of organic inputs and products, to establish credibility and trust in the market. Also, improved documentation and standardisation could create a more organized and scalable organic sector. The sector could also grow by bridging the gap between household-level development of organic inputs and commercialising viable inputs.
- Improving packaging methods for organic products could enhance marketability and attractiveness of organic products. Also, connecting value chain actors to highlight the differences between organic and conventional farming and resulting products could contribute to better marketing and promotion.

5.2.3 Finding local niches

- Risk strongly limits farmers' willingness to reduce the use of chemical pesticides, regardless of the consequences on average profit (Chèze et al., 2020). Testing products on a small scale and fine-tuning them to find the right balance between costs savings, a better environmental outlook and assured effectiveness of the product could contribute to an increased demand for organic inputs.
- Given the complexities and risks associated with biological pest control/integrated pest management, the incentives to reduce on chemical pesticides are mostly found on farms with a current high use of chemicals (e.g. horticulture, tea, coffee, cotton).
- Leveraging local initiatives, such as for the production of biofertilizer or biopesticides, presents an opportunity to expand the reach and impact of organic practices at local level.
- In locations where organic waste is available, and potential users are located relatively close to the source of that waste, biofertilisers pose an interesting alternative to additional mineral fertilisers. In some cases, for instance, empty trucks that go to farmers to source produce can deliver fertilisers to these farmers and return with the harvested product.
- With increasing demand for organically certified coffee and pressure by both consumers and legislation to reduce the greenhouse gas emissions, coffee companies increasingly search for ways to reduce on their use of mineral fertiliser. This provides incentives to the sector (and other sectors like cocoa) to explore the increased use of organic inputs.

6 Recommendations

1. General: finding the right context

- While there are very good (business) cases for organic agriculture, a completely (certified) organic production system may not be the most feasible for the majority of farmers in Uganda. Therefore, a focus on judicious use of inputs in the context of Integrated Soil Fertility Management and Integrated Pest Management could already constitute a major shift towards more sustainable farming systems, and may have more likelihood for broad-scale implementation.
- The use of fertiliser, organic or mineral, is generally low in Ugandan farming systems, which may limit overall biomass production. Combined with competing uses for biomass (e.g. animal feed or energy source) this may hamper the availability of biomass for the production of organic fertilisers and nutrient recycling. Messages to reduce mineral fertiliser in general may therefore work counterproductive (Falconnier et al., 2023). Instead, a focus on judicious use of mineral fertilisers combined with the use of organic fertiliser may be more sensible.
- Similarly, a reduction of the preventive use of chemical pesticides, especially highly hazardous pesticides, could already greatly reduce environmental and human health risks. Emphasis could be on the use of lower-risk pest control solutions based on the pesticide sensitivity classification system Even producers of biological pest control products (Koppert, Real IPM) generally do not aim for biological solutions alone.
- General good agronomic practices such as crop rotations, diversification, composting of household waste, retention of crop residues in the field, etc. contribute to the wider sustainability and resilience of production systems.

2. Farmers: Knowledge empowerment

- Motivate farmers with better knowledge on organic agriculture practices and systems, enabling them to make informed decisions.
- Train farmers through platforms like farmer exchange programs, farmer field schools, exhibitions, and parades to promote experience sharing and learning.
- Start with the most promising/viable crops: crops that give farmers a high return, such as fruits and vegetables, and crops in which farmers already invest in inputs.
- Conduct awareness campaigns to shift mindsets towards the possible negative effects of pesticides and promote more sustainable approaches. Discuss negative effect of chemical pesticides (food safety, dying bees etc).
- Train farmers on the judicious use of mineral fertilisers, for instance using the 4R approach of applying the Right fertiliser type, at the Right rate, at the Right time and in the Right place. And indicate co-benefits of organic fertilisers such as compost, in terms of soil organic carbon, water holding capacity, soil biodiversity, etc.
- Connect farmers to international organisations such as Access Agriculture, IFOAM, and FiBL for dissemination of and guidance on organic farming practices.

3. Input suppliers: Commercialisation support

- Focus on good business cases for organic inputs and produce. For instance, what makes organic inputs more attractive than conventional products from a farmer's perspective? This could be reduction in costs, or an increase in produce price. But it must have an attractive return on investment as incentive for farmers to shift to organic inputs.
- Improve packaging, branding, and information on organic product packages to facilitate commercialisation.
- Document the composition of biopesticides and other organic inputs to improve information on packing of inputs.
- Support input suppliers to expand their scope to smaller farmers to increase the reach and availability of organic inputs.
- Link companies with a 'problem' of organic waste (e.g. coffee companies, flower farms) to initiatives on biofertilizer.

4. Government: Regulation, registration, standardisation and quality control

- Organic agriculture stakeholders to advocate for the implementation of the existing organic policy and work towards creating a legal framework for organic farming.
- Improve regulation, standardisation and quality control of organic inputs. Set up a quality control system to ensure that producers are truly adhering to guidelines set for safe food, and explore simplified control systems with regular checks that can be implemented relatively easy in the short term.
- Regulate the use of (hazardous) pesticides, and strengthen engagements with agro-dealers to ensure proper regulation and control of agricultural products.
- Work towards easier registration processes for biopesticides and establish guidelines for the East African market (partner with CABI, which is already working on this).

5. Research: Systematic research, tailoring and profitability

- Conduct systematic research on active ingredients of alternative pesticides to enhance knowledge on what works, under which conditions.
- Tailor solutions to specific crops and regions.
- Stimulate research on increasing shelf live without using chemical pesticides and preservatives.
- Conduct social and economic research before experimental research to understand local preferences and economic feasibility.
- Conduct research on natural predators that fight pests and diseases in viable crops, as well as potential strategies to introduce this to farmers and the potential return on investment.
- There is a growing attention for food safety among consumers and policy makers, which can increase the demand for organic produce. At the same time there are also perceptions and fears that may not be substantiated. Research to substantiate claims on food safety concerns can help setting priorities.

6. Consumers: Enhance awareness on food safety

- Enhance knowledge and awareness among consumers about potential risks associated to an overuse of pesticides, to enhance the demand for safely produced food.
- Link consumer groups with a demand for safe food (hotels, restaurants, supermarkets or communities) to suppliers of organically produced food.

References

Adipala, E., Nampala, P., Karungi, J. & Isubikalu, P. (2000). A review on options for management of cowpea pests: Experiences from Uganda. *Integrated Pest Management Reviews,* 5**,** 185-196.

Amann, A., Herrnegger, M., Karungi, J., Komakech, A.J., Mwanake, H., Schneider, L., Schürz, C., Stecher, G., Turinawe, A., Zessner, M. & Lederer, J. (2021). Can local nutrient-circularity and erosion control increase yields of resource-constraint smallholder farmers? A case study in Kenya and Uganda. *Journal of Cleaner Production,* 318**,** 128510.

Andersson, E. & Isgren, E. (2021). Gambling in the garden: Pesticide use and risk exposure in Ugandan smallholder farming. *Journal of Rural Studies,* 82**,** 76-86.

Apori, S.O., Byalebeka, J. & Muli, G.K. (2021). Residual effects of corncob biochar on tropical degraded soil in central Uganda. *Environmental Systems Research,* 10**,** 35.

Ayilara, M.S., Adeleke, B.S., Akinola, S.A., Fayose, C.A., Adeyemi, U.T., Gbadegesin, L.A., Omole, R.K., Johnson, R.M., Uthman, Q.O. & Babalola, O.O. (2023). Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. *Frontiers in Microbiology,* 14.

Bai, S.H., Omidvar, N., Gallart, M., Kämper, W., Tahmasbian, I., Farrar, M.B., Singh, K., Zhou, G., Muqadass, B., Xu, C.-Y., Koech, R., Li, Y., Nguyen, T.T.N. & van Zwieten, L. (2022). Combined effects of biochar and fertilizer applications on yield: A review and meta-analysis. *Science of The Total Environment,* 808**,** 152073.

Balasubramanian, D., Arunachalam, K., Arunachalam, A. & Das, A.K. (2013). Water hyacinth [Eichhornia crassipes (Mart.) Solms.] engineered soil nutrient availability in a low-land rain-fed rice farming system of north-east India. *Ecological Engineering,* 58**,** 3-12.

Begum Rasmiya, S.L., Himaya, S.M.M.S. & Afreen, S.M.M.S. (2022). Potential of water hyacinth (Eichhornia crassipes) as compost and its effect on soil and plant properties: A review. *Agricultural Reviews,* 43**,** 20-28.

Bendjebbar, P. & Fouilleux, E. (2022). Exploring national trajectories of organic agriculture in Africa. Comparing Benin and Uganda. *Journal of Rural Studies,* 89**,** 110-121.

Bwengye, E., Nagawa, G., & Tumwesigye, W. (2023). Diversity of the On-Farm Crop Dry Spell Adaptation Technologies in Isingiro Town Council, Isingiro District, Uganda. *African Journal of Climate Change and Resource Sustainability,* 2**,** 102-116.

Chepchirchir, F., Muriithi, B.W., Langat, J., Mohamed, S.A., Ndlela, S. & Khamis, F.M. (2021). Knowledge, Attitude, and Practices on Tomato Leaf Miner, Tuta absoluta on Tomato and Potential Demand for Integrated Pest Management among Smallholder Farmers in Kenya and Uganda. *Agriculture,* 11**,** 1242.

Chèze, B., David, M. & Martinet, V. (2020). Understanding farmers' reluctance to reduce pesticide use: A choice experiment. *Ecological Economics,* 167**,** 106349.

Collier, R. (2023). Pest insect management in vegetable crops grown outdoors in northern Europe – approaches at the bottom of the IPM pyramid. *Frontiers in Horticulture,* 2.

Ddamulira, G., Isaac, O., Kiryowa, M., Akullo, R., Ajero, M., Logoose, M., Otim, A., Masika, F., Mundingotto, J., Matovu, M. & Ramathan, I. (2021). Practices and constraints of tomato production among smallholder farmers in Uganda. *African Journal of Food, Agriculture, Nutrition and Development,* 21.

Dekkers, M.F. (2019). *The use of water weed Salvinia Molesta as mulch.* MSc thesis, Wageningen University.

EC. (2023). *Organic farming in the EU – A decade of organic growth, January 2023* [Online]. Brussels: European Commission, DG Agriculture and Rural Development. Available: https://agriculture.ec.europa.eu/news/organic-farming-eu-decade-growth-2023-01-18_en.

European Union (2020). Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system. Brussels: European Commission.

Falconnier, G.N., Cardinael, R., Corbeels, M., Baudron, F., Chivenge, P., Couëdel, A., Ripoche, A., Affholder, F., Naudin, K., Benaillon, E., Rusinamhodzi, L., Leroux, L., Vanlauwe, B. & Giller, K.E. (2023). The input reduction principle of agroecology is wrong when it comes to mineral fertilizer use in sub-Saharan Africa. *Outlook on Agriculture,* 52**,** 311-326.

Freeman, K. & Qin, H. (2020). The Role of Information and Interaction Processes in the Adoption of Agriculture Inputs in Uganda. *Agronomy,* 10**,** 202.

GIZ (2021). Sector brief Uganda: Organic Agriculture. Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit.

Güereña, D., Neufeldt, H., Berazneva, J. & Duby, S. (2015). Water hyacinth control in Lake Victoria: Transforming an ecological catastrophe into economic, social, and environmental benefits. *Sustainable Production and Consumption,* 3**,** 59-69.

Howe, A.G., Nachman, G. & Lövei, G.L. (2015). Predation pressure in Ugandan cotton fields measured by a sentinel prey method. *Entomologia Experimentalis et Applicata,* 154**,** 161-170.

Indabo, S.S. & Abubakar, A.A. (2020). Effect of rabbit urine application rate as a bio-fertilizer on agromophorlogical traits of uc82b tomato (lycopersicon esculentum mill) variety in Zaria, Nigeria. *Dutse Journal of Pure and Applied Sciences,* 6**,** 344-352.

Islam, M.S. & Morshed, A. (2013). Study on Homemade Bio-Pesticides and Organic Pest Management in Organic Farming. *The International Journal of Engineering and Science,* 2**,** 18-25.

Jjagwe, J., Komakech, A.J., Karungi, J., Amann, A., Wanyama, J. & Lederer, J. (2019). Assessment of a Cattle Manure Vermicomposting System Using Material Flow Analysis: A Case Study from Uganda. *Sustainability,* 11**,** 5173.

Kiggundu, N.a.S., J. (2019). Pryloysis of Coffee Husks for Biochar Production. *Journal of Environmental Protection,* 10**,** 1553-1564.

Komakech, A., Zurbrügg, C., Semakula, D., Kiggundu, N. & Vinnerås, B. (2015). Evaluation of the Performance of Different Organic Fertilizers on Maize Yield: A Case Study of Kampala, Uganda. *Journal of Agricultural Science,* 7.

Lalander, C.H., Komakech, A.J. & Vinnerås, B. (2015). Vermicomposting as manure management strategy for urban small-holder animal farms – Kampala case study. *Waste Management,* 39**,** 96-103.

Lekamoi, U. (2022). *Effects of Tephrosia vogelii formulation with rabbit urine on insect pests and pollinators of sesame in Singida, Tanzania.* MSc Thesis, Nelson Mandela African Institution of Science and Technology.

Liao, Z., Chen, S., Zhang, L., Li, S., Zhang, Y. & Yang, X. (2023). Microbial assemblages in water hyacinth silages with different initial moistures. *Environmental Research,* 231**,** 116199.

Lim, S.L., Wu, T.Y., Lim, P.N. & Shak, K.P.Y. (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. *Journal of the Science of Food and Agriculture,* 95**,** 1143-1156.

Liu, S., Zhang, Y., Zong, Y., Hu, Z., Wu, S., Zhou, J., Jin, Y. & Zou, J. (2016). Response of soil carbon dioxide fluxes, soil organic carbon and microbial biomass carbon to biochar amendment: a meta-analysis. *GCB Bioenergy,* 8**,** 392-406.

Macharia, M., Tebkew, D., Agum, W., & Njuguna, M. (2016). Incidence and distribution of insect pests in rain-fed wheat in Eastern Africa. *African Crop Science Journal,* 24**,** 149-155.

Macover, D.R. (1995). Constituents of pyrethrum extract. *In:* Casida, J. E. & Quistad, G. B. (eds.) *Pyrethrum Flowers: Production, Chemistry, Toxicology, and Uses.* Oxford, UK: Oxford University Press.

Malik, A. (2007). Environmental challenge vis a vis opportunity: The case of water hyacinth. *Environment International,* 33**,** 122-138.

Mfarrej, M.F.B. & Rara, F.M. (2019). Competitive, Sustainable Natural Pesticides. *Acta Ecologica Sinica,* 39**,** 145-151.

Moshi, A.P. & Matoju, I. (2017). The status of research on and application of biopesticides in Tanzania. Review. *Crop Protection,* 92**,** 16-28.

Mugisha-Kamatenesi, M., Deng, A.L., Ogendo, J.O., Omolo, E.O., Mihale, M.J., Otim, M., Buyungo, J.P. & Bett, P.K. (2008). Indigenous knowledge of field insect pests and their management around Lake Victoria basin in Uganda. *African Journal of Environmental Science and Technology,* 2**,** 342-348.

Mugizi, F.M.P. & Matsumoto, T. (2021). A curse or a blessing? Population pressure and soil quality in Sub-Saharan Africa: Evidence from rural Uganda. *Ecological Economics,* 179**,** 106851.

Muhereza, I., Pritchard, D., Murray-Prior, R. (2014). Utilisation of cattle manure and inorganic fertiliser for food production in central Uganda. *Journal of Agriculture and Environment for International Development,* 108**,** 135-151.

Musinguzi, L., Kamya, A., Nsega, M. & Okello, W. (2022). Common water hyacinth (Pontederia crassipes) invades Lakes Edward, George, and Kazinga Channel: A call for immediate action. *Journal of Great Lakes Research,* 48**,** 1723-1727.

Mutai, P.A. (2020). The potential use of rabbit urine as a bio fertilizer foliar feed in crop production. *Africa Environmental Review Journal,* 4**,** 138-147.

Ngabirano, H. & Birungi, G. (2022). Pesticide residues in vegetables produced in rural south-western Uganda. *Food Chemistry,* 370**,** 130972.

Nyangau, P., Muriithi, B., Diiro, G., Akutse, K.S. & Subramanian, S. (2022). Farmers' knowledge and management practices of cereal, legume and vegetable insect pests, and willingness to pay for biopesticides. *International Journal of Pest Management,* 68**,** 204-216.

Ojuu, D., Kyamanywa, S., & Odong Lapaka, T. (2021). Influence of wetland borders on prevalence of fall armyworm and wasps in maize-soybean cropping system in Eastern Uganda. *International Journal of Pest Management,* 1.

Okonya, J.S. & Kroschel, J. (2016). Farmers' knowledge and perceptions of potato pests and their management in Uganda. *2016,* 117**,** 11.

Okonya, J.S., & Kroschel, J. (2013). Pest status of Acraea acerata Hew. and Cylas spp. in sweetpotato (Ipomoea batatas (L.) Lam.) and incidence of natural enemies in the Lake Albert Crescent agro-ecological zone of Uganda. *International Journal of Insect Science,* 5.

Orr, A. (2003). Integrated Pest Management for Resource-Poor African Farmers: Is the Emperor Naked? *World Development,* 31**,** 831-845.

Pomeroy, D., Tushabe, H., & Loh, J. (2017). The state of Uganda's biodiversity 2017. National Biodiversity Data Bank. Kampala: Makerere University.

Priegnitz, U., Lommen, W.J.M., Onakuse, S. & Struik, P.C. (2019). A Farm Typology for Adoption of Innovations in Potato Production in Southwestern Uganda. *Frontiers in Sustainable Food Systems,* 3.

Ronner, E., Descheemaeker, K., Almekinders, C.J.M., Ebanyat, P. & Giller, K.E. (2018). Farmers' use and adaptation of improved climbing bean production practices in the highlands of Uganda. *Agriculture, Ecosystems & Environment,* 261**,** 186-200.

Roobroeck, D., Hood-Nowotny, R., Nakubulwa, D., Tumuhairwe, J.-B., Mwanjalolo, M.J.G., Ndawula, I. & Vanlauwe, B. (2019). Biophysical potential of crop residues for biochar carbon sequestration, and co-benefits, in Uganda. *Bulletin of the Ecological Society of America,* 100**,** 1-3.

Said, M.I., Asriany, A., Sirajuddin, S. N., Abustam, E., Rasyid, R., & Al-Tawaha, A. R. M. (2018). Evaluation of quality of liquid organic fertilizer from rabbit's urine waste fermented using local microorganisms as decomposers. *The Iraqi Journal of Agricultural Science,* 49**,** 990-1003.

Sannigrahi, A.K., Chakrabortty, S. & Borah, B.C. (2002). Large scale utilization of water hyacinth (eichhornia crassipes) as raw material for Vermi composting and surface mulching in vegetable cultivation. *Ecology Environment and Conservation,* 8**,** 269-271.

Schmidt, H.-P., Kammann, C., Hagemann, N., Leifeld, J., Bucheli, T.D., Sánchez Monedero, M.A. & Cayuela, M.L. (2021). Biochar in agriculture – A systematic review of 26 global meta-analyses. *GCB Bioenergy,* 13**,** 1708-1730.

Ssemugabo, C., Bradman, A., Ssempebwa, J.C., Sillé, F. & Guwatudde, D. (2022). An assessment of health risks posed by consumption of pesticide residues in fruits and vegetables among residents in the Kampala Metropolitan Area in Uganda. *International Journal of Food Contamination,* 9**,** 4.

Sumani, M.D., Kanukisya, B. K., & Mwaikokesya, J. M. (2022). Defying the odds to learn innovative farming in Uganda: experiences of small-scale farmers from Bududa District. *Papers in Education and Development,* 39.

Sunadra, I.K., Wirajaya, A.A.N.M., Mudra, N.L.K.S., Yuliartini, M.S., Kartini, L.P., Udayana, I.G.B. & Mahardika, I.B.K. (Year) Published. Response to Growth and Yield Melon Plant (Cucumis Melo L.) in the Giving of Rabbit Urine and KNO3. 2020.

Sundberg, C., Karltun, E., Gitau, J.K., Kätterer, T., Kimutai, G.M., Mahmoud, Y., Njenga, M., Nyberg, G., Roing de Nowina, K., Roobroeck, D. & Sieber, P. (2020). Biochar from cookstoves reduces greenhouse gas emissions from smallholder farms in Africa. *Mitigation and Adaptation Strategies for Global Change,* 25**,** 953-967.

Ten Hove, H., Yiga, P., Glaser, J. & Kihangire, A. (2023). Fresh fruit and vegetable consumption in Uganda; Barriers, facilitators and current consumption practices. Wageningen: Wageningen Centre for Development Innovation.

Tober, F. (2019). *Unbalanced investments? A characterisation of banana-based farming systems in western Uganda.* MSc thesis, Wageningen University.

URN. (2014). *New Organic Fertilizer Introduced to Farmers. Audio 11 Jul 2014* [Online]. [Accessed 14 July 2023].

Vuković, A., Velki, M., Ečimović, S., Vuković, R., Štolfa Čamagajevac, I. & Lončarić, Z. (2021). Vermicomposting—Facts, Benefits and Knowledge Gaps. *Agronomy,* 11**,** 1952.

Wang, Y., Villamil, M.B., Davidson, P.C. & Akdeniz, N. (2019). A quantitative understanding of the role of co-composted biochar in plant growth using meta-analysis. *Science of The Total Environment,* 685**,** 741-752.

Willer, H., Travnicek, J., Meier, C. & Schlatter, B. (2021). *The world of organic agriculture. Statistics and emerging trends 2021,* Bonn, Germany, Research Institute of Organic Agriculture FiBL, Frick, and IFOAM - Organics International.

Woomer, P.L., Muzira, R., Bwamiki, D., Mutetikka, D., Amoding, A. & Bekunda, M.A. (2000). Biological Management of Water Hyacinth Waste in Uganda. *Biological Agriculture & Horticulture,* 17**,** 181-196.

Xu, D., Qiu, X. & Xu, Z. (2017). Effect of water hyacinth mulch on soil temperature, water content and maize yield (Zea mays L.) in southeast China. *Environmental Engineering & Management Journal,* 16.

Yatoo, A.M., Ali, M.N., Baba, Z.A. & Hassan, B. (2021). Sustainable management of diseases and pests in crops by vermicompost and vermicompost tea. A review. *Agronomy for Sustainable Development,* 41**,** 7.

Zahra, M.B., Fayyaz, B., Aftab, Z.-E.H. & Haider, M.S. (2021). Mitigation of Degraded Soils by Using Biochar and Compost: a Systematic Review. *Journal of Soil Science and Plant Nutrition,* 21**,** 2718-2738.

Wageningen Environmental Research
P.O. Box 47
6700 AA Wageningen
The Netherlands
T 0317 48 07 00
wur.eu/environmental-research

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Wageningen Environmental Research
P.O. Box 47
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 07 00
wur.eu/environmental-research

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