CHAPTER 10

Insect Farming Innovations: A Pathway to Self-Reliance in Agrifood Systems in Africa

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Insect farming as an innovative approach to transforming agrifood systems

Insect farming has emerged as a transformative and sustainable approach to addressing the interconnected challenges of food insecurity, environmental degradation, and economic vulnerability in Africa's agrifood systems. By converting organic waste into high-value products (protein-rich feed, frass fertilizers, and bioactive compounds), insect farming offers an efficient circular economy solution that bridges nutrition, livelihoods, and ecological resilience (Lalander et al. 2025; Mei et al. 2024; Barragán-Fonseca et al. 2022; Xia et al. 2021; Van Huis 2020; Barragán-Fonseca et al. 2017; Van Huis and Oonincx 2017; Yi et al. 2014). Almost all of an insect's body is edible, a trait that maximizes nutrient output while minimizing waste. This trait distinguishes insect farming from conventional livestock systems and underscores its potential to combat malnutrition and improve food security (Aidoo et al. 2023; Melgar-Lalanne et al. 2019; Payne et al. 2015; Van Huis et al. 2013). Insects are a rich source of high-value products such as oil, chitin, and antimicrobial peptides, such as α-helical, cysteine-rich, proline-rich, and glycine-rich peptides with emerging uses in the pharmaceutical and agricultural sectors as well as in aquaculture (Mei et al. 2024; Xia et al. 2021; Sahoo et al 2021; Yi et al. 2014).

The environmental footprint of insect farming is lower than that of traditional livestock systems, as it requires less land, water, and feed while generating fewer greenhouse gas (GHG) emissions (Dobermann et al. 2017; Van Huis et al. 2013). Moreover, insect farming can reduce zoonotic risks associated with wild harvesting and ensure a more stable and controlled supply of protein (Beesigamukama et al. 2023; Dobermann et al. 2017; Van Huis et al. 2013). Compared to conventional livestock, insects yield more nutrients per unit of land, water, and feed (Dobermann et al. 2017). The low market entry barriers to insect farming make it especially suitable for youth and women, contributing to inclusive pathways toward green employment and entrepreneurship (Beesigamukama et al. 2023; Meerts et al. 2023; Abro et al. 2022; Verner et al. 2021; Abro et al. 2020).

Given its multifaceted benefits, the insect farming industry is gaining global traction, with increasing investment and policy attention from national governments and international organizations, including the Food and Agriculture Organization of the United Nations (FAO) and the World Bank (Tanga and Kababu 2023; Verner et al. 2021; Van Huis et al. 2013). Institutions such as the International Centre of Insect Physiology and Ecology (*icipe*) are leading in the development of innovative insect farming models, incorporating circular economy principles to support safe, controlled, and climate-resilient production systems (Leppla and De Clercq 2019; Van Huis et al. 2013; Newton et al. 2005; Sheppard et al. 2002; Ramos-Elorduy 1997).

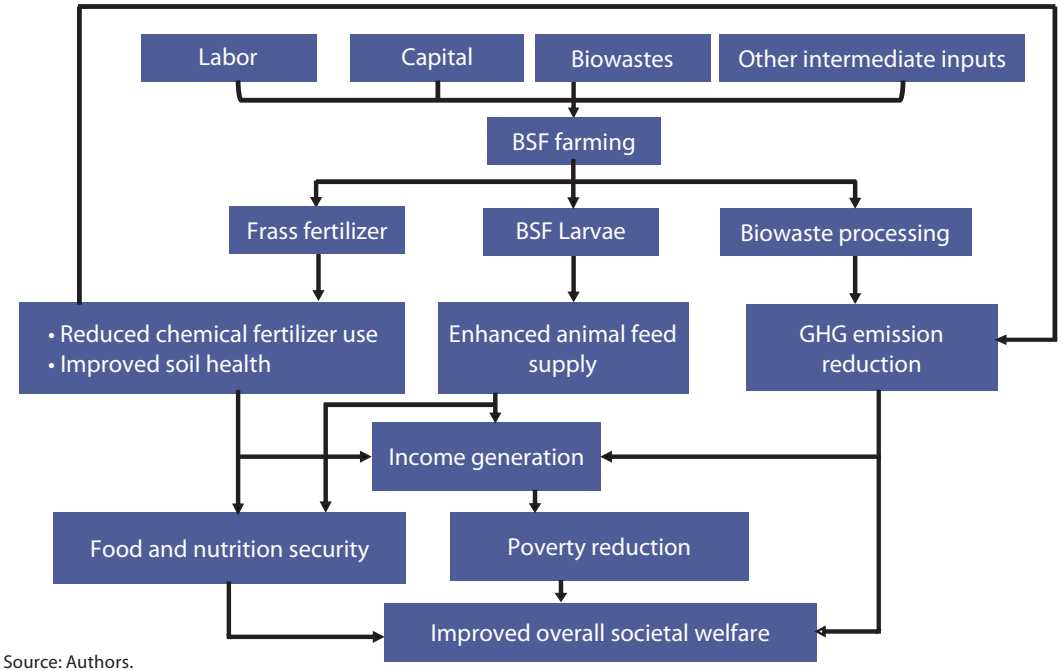
This chapter examines insect farming as a frontier innovation that can accelerate Africa's journey toward self-reliant, inclusive, and climate-resilient agrifood systems. Drawing on evidence from Africa and beyond, it demonstrates how insect farming contributes to food and feed security, welfare, soil health, climate change mitigation, and employment.

We organize the rest of this chapter as follows. In the second section, we demonstrate the impact of insect farming in Africa by examining the contribution of Black Soldier Fly (BSF) farming to economic growth, job creation, poverty reduction, and climate mitigation. We focus on BSF farming because it is the most widely promoted insect species with established large-scale production systems across many countries on the continent (Caparros Megido et al. 2024; Tanga and Kababu 2023; Tanga et al. 2021). BSF farming also has more reliable data on key parameters to support our analysis. In the third section, we analyze the market potential for insect farming products. In the fourth section, we discuss emerging innovations in the insect farming industry that African policymakers and entrepreneurs can leverage to strengthen the sector. In the fifth and sixth sections, we examine the enabling factors and barriers to scaling insect farming in Africa, respectively. In the seventh and eighth sections, we outline supply-side and demand-side policy options for African policymakers. Finally, in the ninth section, we provide concluding remarks.

Benefits of BSF farming in Africa: A conceptual framework

This section presents a conceptual framework that illustrates the socio-economic and environmental pathways through which BSF farming can contribute to resilient and inclusive agrifood systems in Africa. BSF larvae production has emerged as a leading insect-based innovation due to its high bioconversion efficiency, ability to process diverse organic waste streams, rapid growth cycle, and rich nutrient content, making it well-suited for the

FIGURE 10.1—CONCEPTUAL FRAMEWORK



Source: Authors.

production of animal feeds and organic fertilizers (CCAC 2025). BSF farming is booming across many countries on the continent, compared to other commercially viable insects such as crickets and mealworms (Caparros Megido et al. 2024; Tanga and Kababu 2023). Although the literature on the valuation of BSF farming in Africa is still emerging, existing studies suggest that it has great potential to contribute to several Sustainable Development Goals (SDGs), including poverty alleviation, climate action, and zero hunger (Abro et al. 2020; Abro et al. 2022; Verner et al. 2021).

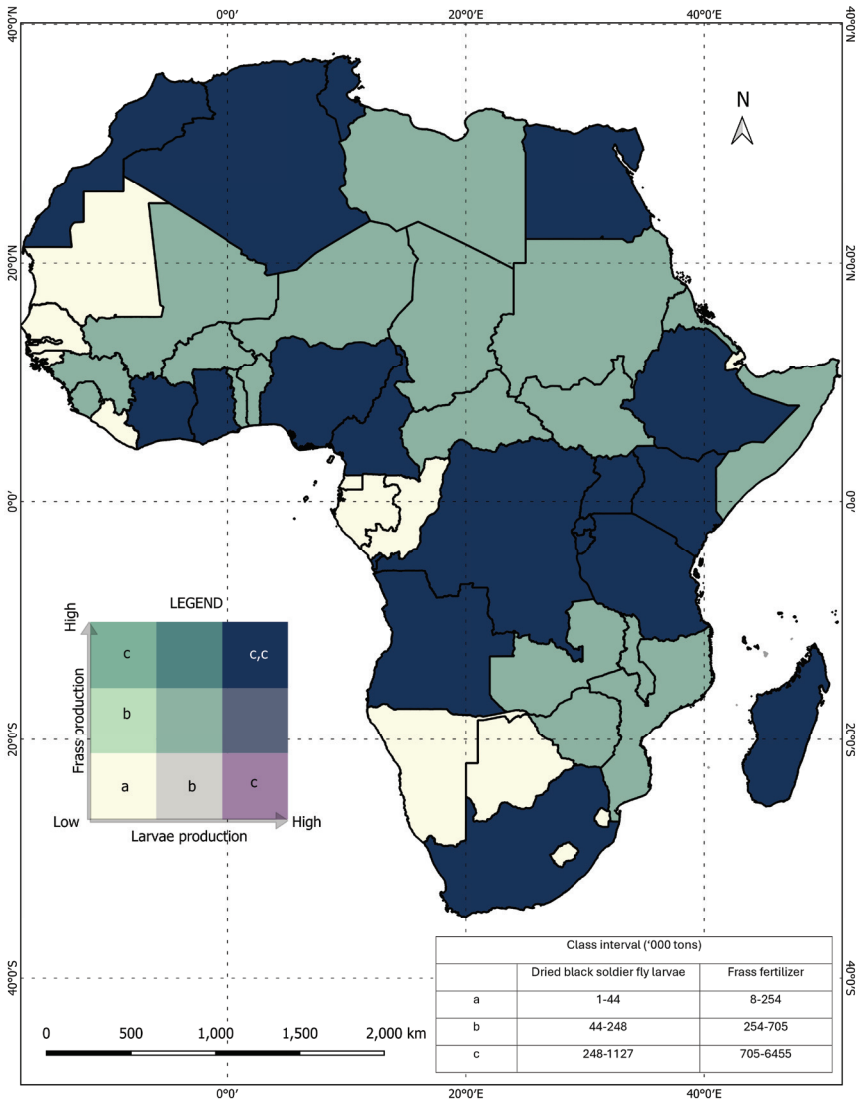
Our conceptual model is structured around four interconnected benefits of BSF farming within the agrifood system (Figure 10.1). First, BSF farming transforms organic waste into two key outputs: protein-rich larvae for animal feed and frass fertilizer for soil enrichment. This conversion promotes productivity gains and enhances resource use efficiency. Second, various environmental benefits emerge with the diversion of biowaste from unmanaged decomposition and from reduced dependence on chemical fertilizers, which in turn reduce GHG emissions. With proper certification, these emission reductions can be monetized in voluntary carbon markets, providing additional income for BSF entrepreneurs. Third, the economic and social benefits are evident: BSF farming creates employment, generates income for workers, delivers returns for entrepreneurs, and fosters the development of small and medium enterprises, thereby contributing to poverty alleviation and inclusive economic growth. Finally, in terms of food and nutritional security, BSF larvae serve as an affordable, high-protein feed source for poultry, fish, and pigs, supporting productivity in livestock and aquaculture. Further, frass fertilizer enhances soil health, improving crop yields and strengthening household food security.

Protein and frass fertilizer production in Africa using BSF farming

Africa generates an estimated 98.50 million tons of biowaste annually (World Bank 2025). This vast and underutilized resource presents a transformative opportunity. With the appropriate processing infrastructure, BSF farming can upcycle this biowaste into high-value insect protein and organic frass fertilizer. To estimate the potential yield of insect protein and frass fertilizer, we conducted a comprehensive literature review on BSF conversion efficiency across different biowaste substrates. Our review of studies indicates that processing 1 ton of biowaste with BSF larvae yields an average of 82 kg of dried larvae, with outputs ranging from 22 to 385 kg (Banks et al. 2014; Newton et al. 2005). Additionally, the process generates approximately 472 kg of frass fertilizer per ton of biowaste, with reported values ranging from 27 to 878 kg depending on substrate type and rearing conditions (Beesigamukama et al. 2022; Groeneveld et al. 2021).

Full utilization of the existing biodegradable waste for BSF farming in Africa can produce 8.08 million tons of dried BSF larvae per annum, equivalent to 76 percent of the 10.64 million tons of the soybeans used annually on the continent (FAO 2025). Figure 10.2 depicts production potential across different African countries. Additionally, the continent can generate 46.29 million tons of

FIGURE 10.2—POTENTIAL CONTRIBUTION OF BSF FARMING TO PROTEIN AND FRASS FERTILIZER PRODUCTION IN AFRICA



Class interval ('000 tons)		
	Dried black soldier fly larvae	Frass fertilizer
a	1-44	8-254
b	44-248	254-705
c	248-1127	705-6455

Source: Authors.

Note: (Disclaimer: The boundaries, names, and designations used on this map are derived from publicly available shapefiles and do not imply official endorsement or acceptance by the authors or their affiliated institutions.)

frass fertilizer annually. This is equivalent to 1.34 million tons of nitrogen, 0.74 million tons of phosphorus, and 1.1 million tons of potassium. Based on current nutrient usage levels, frass fertilizer could supply about 33 percent of nitrogen, 45 percent of phosphorus, and 121 percent of potassium used in African agriculture (FAO 2025).

Potential economywide effects of BSF farming in Africa

As illustrated in the conceptual framework, the BSF farming value chain encompasses multiple sectors, creating both direct and indirect economic links with significant economywide benefits. Quantifying such effects, however, is a complex undertaking due to the multiple pathways through which BSF farming interacts with agriculture, waste management, and feed industries.

To address this issue, we estimated the economywide impacts of BSF farming for nine African countries – Cameroon, Egypt, Ethiopia, Ghana, Kenya, Rwanda, Tanzania, Uganda, and Zambia – using the International Food Policy Research Institute's (IFPRI) recursive dynamic computable general equilibrium (CGE) model. We chose these study countries mainly because of data availability and organizational priorities in research and development activities.

While the CGE model is presented in Diao and Thurlow (2012), our main contribution to the CGE model and its underlying Social Accounting Matrix (SAM) database is the integration of BSF farming as a distinct economic activity, achieved by leveraging existing input-output data from insect farms in Africa. To track welfare impacts, the CGE model captured consumption expenditure for representative households in the SAM. This enabled us to estimate the number of people in each study country who are living above their respective national poverty lines. We extended the CGE model by designing a separate environmental impact module to account for the impacts of BSF farming on GHG emissions. The environmental impact module tracks GHG emission levels if biowaste is landfilled and/or left in dumpsites, as commonly practiced, and if the biowaste is treated with BSF farming. It also captures reductions in GHG emissions from using BSF larvae and frass fertilizer in agricultural production.

Once we established a business-as-usual scenario in the absence of BSF farming, we designed two policy scenarios to estimate the economywide benefits over a 10-year planning horizon (2024-2033) if the study countries developed the capacity to exploit 25 percent and 50 percent of their biowaste

using BSF. After simulating the three scenarios, we obtained the net gains from BSF farming by subtracting the estimated values of the 25 percent and 50 percent policy scenarios from those of the business-as-usual scenario. The estimated values constitute potential contributions to economic growth, job creation, poverty reduction, and GHG emissions from BSF farming.

While GDP and poverty reduction estimates are directly obtained from the CGE model, the job creation potential warrants further discussion. Using the labor-valued contribution of BSF farming from the CGE model, we conducted a back-of-the-envelope calculation to translate the value added into estimates of job creation. We divided the total labor value added contribution of BSF farming by the product of per capita agricultural value added and the share of the wage bill relative to total value added. We factored in the wage bill because workers do not receive compensation equivalent to the full value they add, a phenomenon that is well documented in the literature (Maarek and Orgiazzi 2020).

We present the results for the 25 percent scenarios in Table 1 below. We expressed all these parameters in 2023 purchasing power parity (PPP) US$ per ton of biowaste processed. Converting the parameters to tons of biowaste processed allowed us to extrapolate these benefits to the continental level based on the available biowaste in Africa. For the sake of brevity, we did not report the results of the 50 percent scenario. However, compared with the 25 percent scenario, GDP gains nearly doubled, while labor demand declined slightly, likely due to economies of scale as the amount of processed biowaste increased twofold. The number of people lifted above the poverty line also rose modestly. Despite these quantitative differences, both scenarios convey the same key message. Scaling BSF farming has substantial potential to drive sustainable economic growth while generating inclusive development benefits through job creation and poverty reduction in the study countries.

Extrapolation to the rest of the continent

We recognize that the nine countries differ considerably in terms of economic size, demographic structure, and waste generation capacity, which poses a challenge for extrapolation. Simply averaging the parameters would bias the results toward large economies such as Egypt and Ethiopia, potentially overestimating continent-wide benefits. Instead, we developed a similarity-based mapping approach to align the nine countries with the rest of the continent. We constructed a similarity index using Euclidean distance across four normalized indicators: GDP, total population, urbanization rate, and annual organic waste generation. Before computing the distances, we normalized each variable using z-scores to ensure comparability and prevent larger-magnitude variables, such as GDP and population, from dominating the results. This step ensured that economic, social, and environmental indicators contributed equally to the similarity measure, as recommended in distance-based analysis (Korir and Visi 2024; Wang et al. 2022). We successfully matched the nine countries with the rest of the countries based on the similarity index.

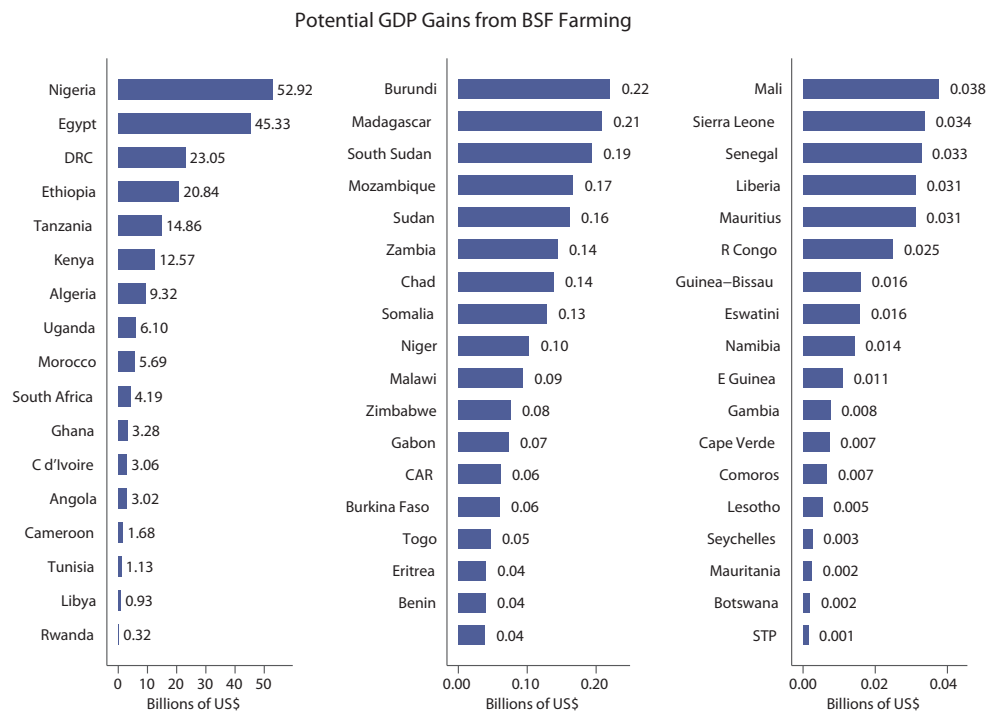
For the sensitivity analysis, we performed extrapolations using both the average and median values instead of the similarity index. The results show that using the average values of the nine countries tends to overestimate the outcomes as expected. In contrast, using the median values produces lower estimates, perhaps underrepresenting countries with higher potential. Therefore, to obtain more balanced and representative results that reflect structural and contextual similarities across African economies, we present in the following subsection the extrapolation findings based on the similarity index approach.

TABLE 10.1—PARAMETERS ESTIMATED FROM THE CGE MODEL UNDER THE 25% SCENARIO

Parameters per ton of biowaste processed				
Countries	**GDP gain (2023 PPP US$)**	**Job creation (number of people)**	**Poverty reduction (number of people)**	**GHG emissions reduction (Tons of C02e)**
Kenya	3,940	0.25	0.22	0.80
Egypt	3,855	0.30	0.06	0.81
Ethiopia	3,641	0.09	0.87	0.85
Tanzania	3,222	0.14	0.86	0.86
Ghana	1,385	0.06	0.08	0.57
Uganda	1,162	0.21	0.17	0.79
Cameroon	615	0.21	0.04	0.69
Rwanda	145	0.20	0.03	0.70
Zambia	111	0.06	0.11	1.00

Source: Authors.

FIGURE 10.3—POTENTIAL CONTRIBUTIONS OF BSF FARMING TO ECONOMIC GROWTH IN AFRICA



Source: Authors.

Contribution of BSF farming to economic growth

We measure economic growth by the net gains in GDP resulting from BSF farming. Figure 10.3 presents the potential GDP gains from BSF farming for each African country, obtained from our continent-level extrapolation based on the CGE model results from the nine countries. Scaling up BSF farming to fully utilize all available biowaste in Africa has the potential to generate $211 billion annually, equivalent to about 2.21 percent of the continent's GDP. Across countries, the estimated potential contributions of BSF farming range from the low end of 0.004 percent of Botswana's total GDP to the high end of 14 percent of the Democratic Republic of Congo's GDP. These economic growth potential benefits are substantial and could translate into significant distributional impacts, particularly in job creation and poverty reduction, which we discuss in the following subsection.

Welfare effects of BSF farming

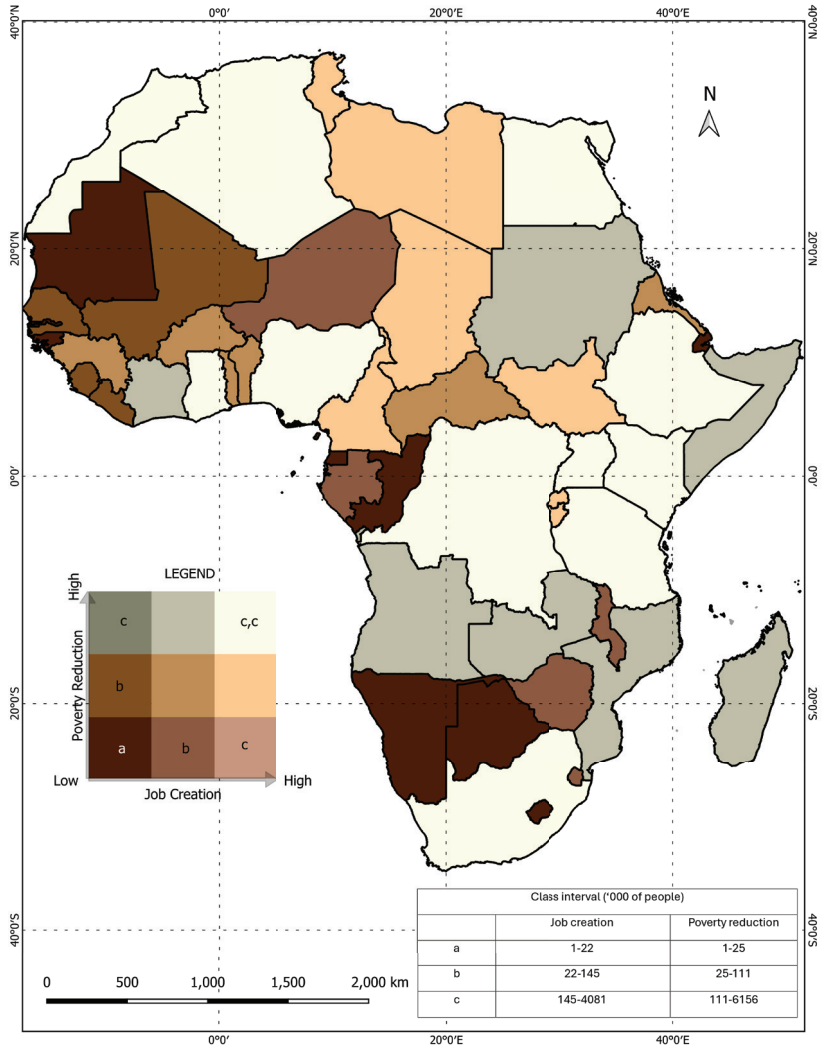
Figure 10.4 presents the potential contribution of BSF farming to job creation and poverty reduction in Africa. According to the latest FAO (2025) data, the number of unemployed people in Africa is about 36 million. Assuming 100 percent utilization of the biowaste, frictionless market entry, and building on the nine countries' CGE model estimates, our extrapolation suggests that BSF farming has the potential to create approximately 17 million full-time equivalent jobs annually, representing 46 percent of the current official unemployment figure (FAO 2025). The employment potential, however, varies widely across countries, ranging from about 812 jobs in São Tomé and Príncipe to 4.1 million jobs in Nigeria.

In terms of poverty reduction, our continent-level extrapolation indicates that BSF farming has the potential to lift approximately 22 million people above the national poverty lines in the respective study countries. Around 464 million people currently live below the poverty line in Africa (World Bank 2024). Our poverty reduction estimates, therefore represent a potential reduction of 5 percent. While this reduction is not sufficient to address poverty at scale, it is still a meaningful contribution that could complement other poverty alleviation strategies. Moreover, because BSF farming creates jobs along diverse segments of the value chain, including waste management and agriculture, it has high potential to benefit low-skilled workers, women, and youth, making it an inclusive pathway for poverty reduction and sustainable economic growth.

Effects of BSF farming on greenhouse gas (GHG) emission reductions

If we fully exploit existing biowaste using BSF, our extrapolation based on the CGE model for the nine countries predicts an annual reduction of GHG emissions by 76.6 million CO_2 equivalent tons (Figure 10.5). This estimated value is about 0.64 percent of Africa's total agricultural GHG emissions, which are 11.97 billion tons of CO_2e annually (FAO 2025). The economic value of GHG reductions from the nascent BSF value chain could reach $486 million, based on Forest Trends' Ecosystem Marketplace price data of $6.34 per ton of CO_2e and assuming the continent has the capacity to participate in the voluntary

FIGURE 10.4—POTENTIAL EMPLOYMENT AND POVERTY EFFECTS OF INSECT FARMING



Source: Authors.

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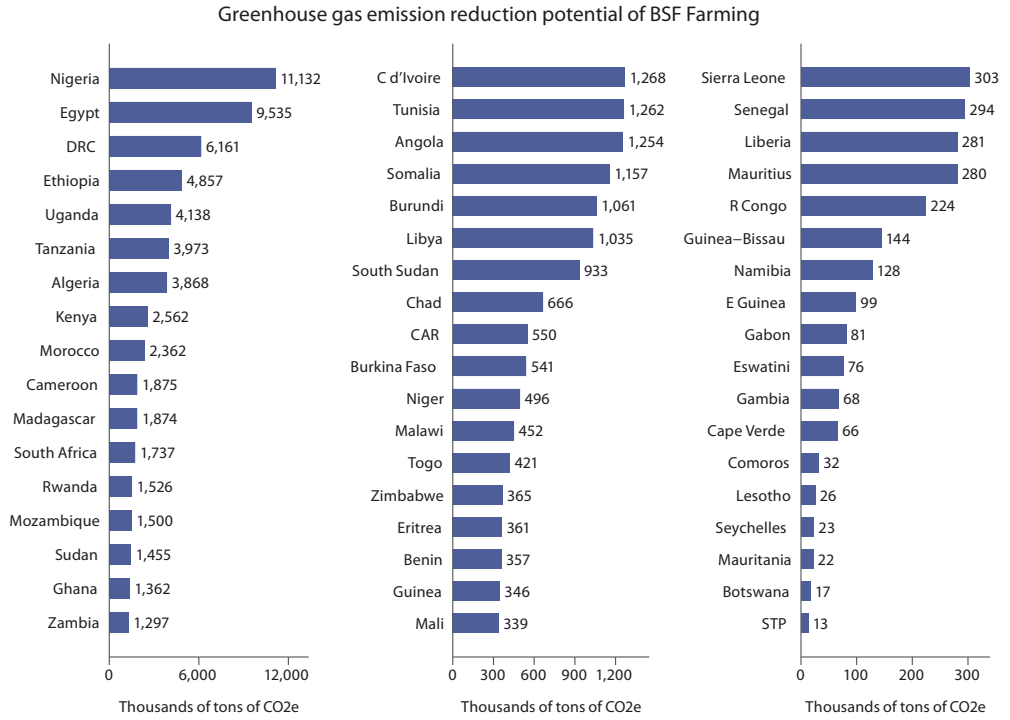
FIGURE 10.5—CONTRIBUTION OF BSF FARMING TO THE REDUCTION OF GREENHOUSE GAS EMISSIONS IN AFRICA



Source: Authors.

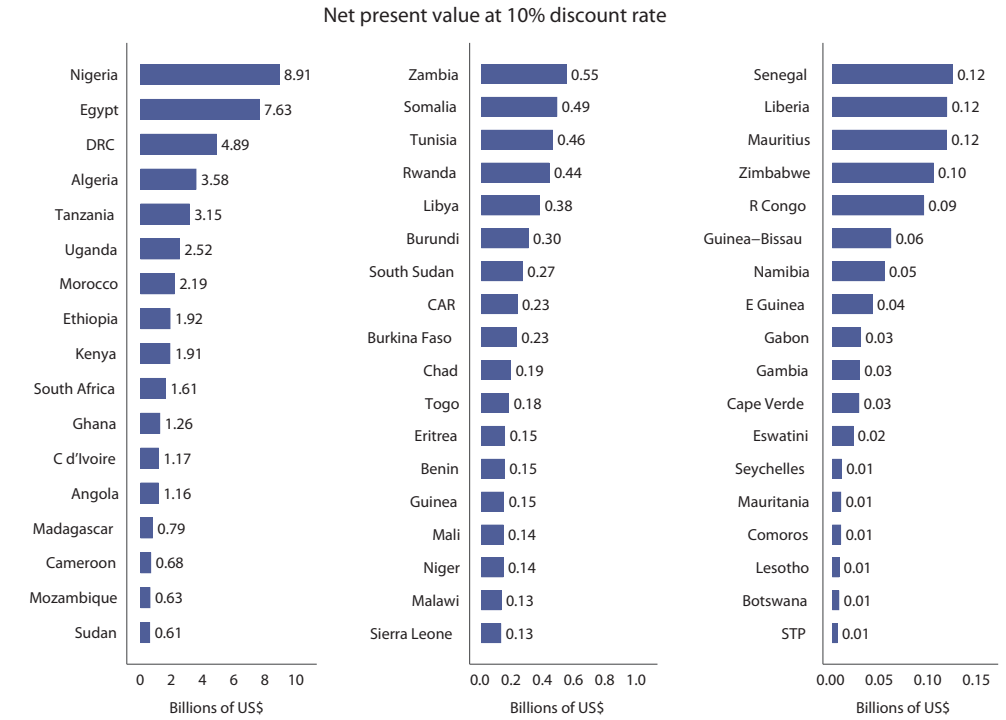
carbon credit market (FTEM 2025). The valuation of emission reductions can vary significantly due to volatility in carbon prices, which differ across marketplaces, transaction volumes, and sellers' negotiating power. Carbon prices currently range from about \$0.10 to \$170 per ton of CO_2e (FTEM 2025). Although participation in voluntary carbon credit markets can provide substantial benefits, the certification process is both time-consuming and costly. Some estimates indicate that the certification process can take approximately 2.5 years, and expenses reach up to \$135,000 (CCAC 2025). Nevertheless, once certification is successfully completed, it can be a good source of income for entrepreneurs. While all countries can benefit, those with higher volumes of biowaste have the potential to earn more income from potential participation in the carbon credit market (Figure 10.5).

Public and animal health effects of BSF farming

In addition to the quantified benefits discussed above, BSF farming can provide important public and animal health benefits, which can be assessed qualitatively. Studies show that BSF-based feeds enhance gut health, boost immunity, and reduce disease incidence in poultry, fish, and pigs compared to conventional feeds (soybean and fish meals) (Rossi et al. 2025; Khan et al. 2024; Malematja et al. 2023). Additionally, BSF oils contain bioactive compounds such as antimicrobial peptides like α-helical, cysteine-rich, proline-rich, and glycine-rich peptides, which support disease resistance and enhance overall animal performance (Pascon et al. 2025; Zhou et al. 2024; Tanga and Ekesi 2024; Yi et al. 2014). However, there are risks if the larvae are reared on contaminated substrates or in unsanitary conditions, which may introduce microbial or chemical hazards into the food chain (Meyer et al. 2021; van der Fels-Klerx et al. 2018; EFSA Scientific Committee 2015). To safeguard both human and animal health, strong regulatory frameworks, food safety standards, and education on hygienic production practices are essential (Jones et al. 2024; FAO 2021; Lalander et al. 2019; Van Huis et al. 2013). The use of BSF frass as a natural fertilizer reduces dependence on chemical fertilizers associated with waterborne health risks and environmental degradation (Beesigamukama et al. 2022; Lopes et al. 2022). Moreover, by re

Source: Authors.

FIGURE 10.6—POTENTIAL SOCIAL RETURNS GIVEN MODELED INTERVENTION COSTS OF BSF FARMING IN AFRICA



Source: Authors.

cycling organic waste, BSF farming improves sanitation and reduces the spread of disease vectors such as flies and rodents, which thrive in unmanaged waste environments (Barragán-Fonseca et al. 2022; FAO 2021; Van Huis et al. 2013).

Can the potential societal returns from BSF farming justify public sector support?

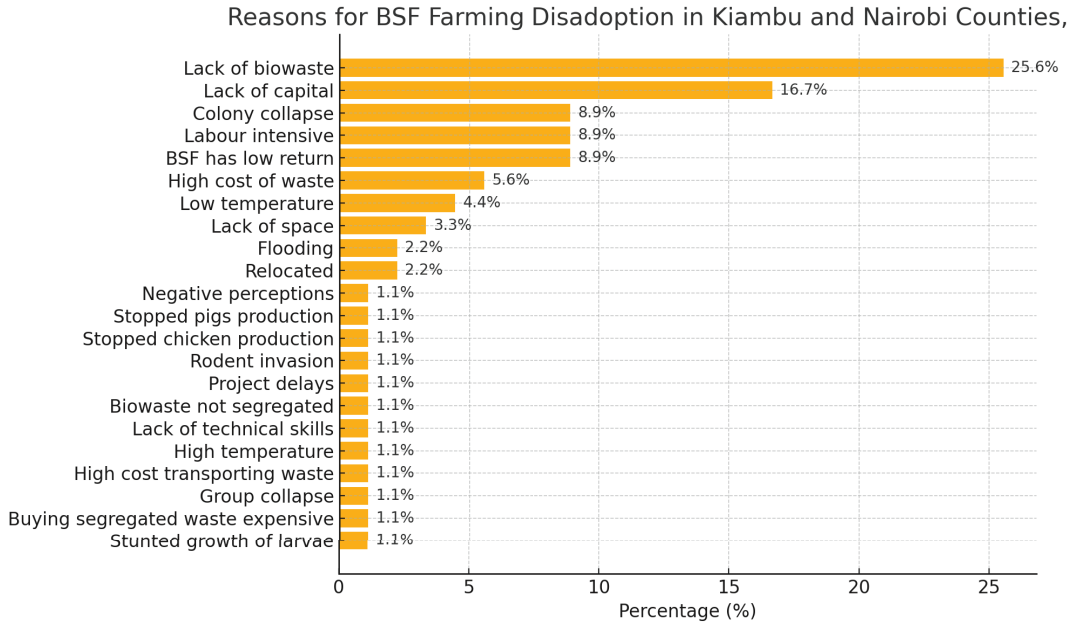
To understand the potential social returns given the modeled expected intervention costs of BSF farming, we calculated net present values at a 10 percent discount rate. We used GDP as the main social benefit indicator because it reflects the broader economic impacts of BSF farming at country level. Although GDP does not capture how benefits are distributed across different groups, it provides policymakers with a clear understanding of the overall contribution of BSF farming to economic performance. The intervention cost data per ton of biowaste processed through BSF farming are derived from the CGE models of the nine countries. Our results show consistently positive net present values across the continent, indicating that BSF farming could potentially have higher social returns than the business-as-usual scenario, given the modeled intervention costs (Figure 10.6). Nonetheless, conducting profitability studies remains essential for making a strong microeconomic business case, as they provide

concrete evidence of the financial viability of BSF farming at the enterprise level.

Adoption challenges of BSF farming

Although data on profitability remains limited, more than 2,300 insect farms in Africa have demonstrated the sustainability of their operations (Tanga and Kababu 2023). Approximately 2 percent of these enterprises are large-scale companies with fully automated industrial-scale facilities that supply substantial volumes of products to national and international markets (Tanga and Kababu 2023). Large-scale insect farms require significant investments in technology and infrastructure to operate facilities that produce insect larvae meal, oils, protein powders, and frass fertilizers. Medium-scale enterprises also have dedicated facilities with controlled production environments (e.g., temperature and humidity), incorporating mechanized harvesting and processing equipment. For example, medium-scale BSF farmers in Uganda use a modified greenhouse system constructed from local materials (Abro et al. 2022).

FIGURE 10.7—KEY CONSTRAINTS TO SMALL-SCALE BSF FARMING



Source: Authors.

The majority of existing insect farms operate at a small-scale level. They often pursue insect farming as a side business alongside other livestock farming enterprises such as poultry, fish, and pig rearing (Tanga et al. 2021). These farmers use locally made materials to establish their facilities. A recent case study in the Kenyan counties of Kiambu and Nairobi shows that out of 750 potential small-scale insect entrepreneurs trained by *icipe* for one week, only 100 are currently profitably farming BSF, while 575 never started operations, and 75 started and then stopped BSF farming.

As Figure 10.7 shows, the main reasons for dropping BSF farming were the lack of adequate biowaste (reported by 25.6 percent of farmers), followed by insufficient capital (16.7 percent) and labor-intensive management (8.9 percent). Several farmers cited technical challenges, including colony collapse (8.9 percent), larval stunting (1.1 percent), and limited technical skills (1.1 percent), which were exacerbated by the lack of follow-up support after training. Environmental constraints, such as low temperatures in highland areas (4.4 percent) and flooding (2.2 percent), reduced the odds of colony survival. Economic barriers included high waste collection and transportation costs (5.6 percent and 1.1 percent, respectively), as well as low perceived returns (8.9 percent). Social and institutional factors, including farmers' group collapses (1.1 percent), negative community perceptions (1.1 percent), and relocation (2.2 percent), further hindered continuity. Additionally, farmers who initially used BSF for on-farm livestock feed stopped after reducing or ending their pig and poultry production. These findings underscore the importance of reliable biowaste supply chains, accessible infrastructure, technical extension support, and community education to sustain BSF farming.

Insect farming market potential

The global market for insect-based products is rapidly expanding (Abro et al. 2025; Montanari et al. 2021). On average, forecasts suggest the edible insect market will expand from $1.84 billion in 2025 to $5.34 billion by 2030, implying an average Compound Annual Growth Rate (CAGR) of 22.25 percent (Table 2). However, there is considerable variation around these estimates: 2025 values range from a low of $0.69 billion to a high of $4.01 billion, while 2030 forecasts range from $0.89 billion to $11.05 billion, with reported CAGRs varying between 5.3 percent and 50.2 percent. These disparities could be due to methodological differences – such as regional focus, product scope (e.g., the inclusion of feed versus human food), and assumptions about policy support – underscoring the sector's volatility as it transitions from a niche to a mainstream market. Even at the lower end, a CAGR above 5 percent signals robust growth, while upper-bound projections of almost 50 percent imply a transformative market under aggressive adoption scenarios.

TABLE 10.2—GLOBAL EDIBLE INSECTS MARKET SIZE AND PROJECTIONS (2025-2030)

	Market size (Billions of US$)		
Market companies	**2025**	**2030**	**CAGR (%)**
Meticulous Research	2.39	8.42	28.60
Precedence Research	1.77	4.41	20.00
Markets and Markets	1.90	8.02	33.40
Grand View Research	1.69	5.17	25.10
Global Market Insights	2.07	3.22	9.20
FactMR	0.69	0.89	5.30
Imarc group	1.39	3.30	18.82
Future Market Insights	0.83	1.85	17.20
Business Research Company	3.10	9.50	25.10
Meta Tech Insights	0.76	2.48	26.70
Intellectual Market Insights	1.45	11.05	50.20
Research and Markets	4.01	5.73	7.40
Average	1.84	5.34	22.25

Source: Authors.

Note: Authors' compilation based on reports prepared by the market companies. Data was accessed from each company's website on May 7, 2025.

While these projections provide a snapshot of potential growth, they come with caveats. First, many reports prioritize Europe and North America due to data availability, largely excluding Africa, Latin America, and Southeast Asia, where insect consumption is common but informal economies dominate, and data is sparse. The values presented in Table 2 represent broad global estimates and are subject to considerable uncertainty, particularly because region-specific projections – such as those for Africa – are still unavailable. Second, variability in product definitions skews results. Some analyses focus narrowly on whole insects or protein powder, while omitting emerging segments like frass fertilizer, which is increasingly central to the economic viability of insect farming. Finally, given these gaps and the rapidly evolving product landscape, the estimates should be treated as directional rather than definitive. Further empirical research — especially field surveys and longitudinal data collection — is needed to refine projections and inform investment decisions.

Innovations within the insect farming industry

In the previous section, we proposed insect farming as an innovation with potential socioeconomic and environmental benefits, supported by empirical estimates derived from modeling results. As insect farming gains traction, new production methods and practices continue to emerge worldwide, potentially transforming the sector. This section aims to highlight these emerging innovations in Africa and beyond, providing insights that may interest policymakers, insect entrepreneurs, and other industry stakeholders. Such information can support informed adoption, facilitate technology transfers, and inspire locally adapted innovations.

Automation and smart production systems

Innovations are transforming insect farming from a raw biomass production industry to a value-added sector, overcoming scalability challenges and redefining its role in the global food and feed system. The first set of innovations is automation. Major insect-producing companies, such as Flybox and Entocycle in the UK and Soldier Fly Technologies in the USA, employ automated feeding systems, robotic harvesters, and AI-driven climate-control systems to optimize

insect production. While automation is a typical characteristic of insect farms in high-income countries, farms in Africa and Asia have also begun adopting such technologies (Ibitoye et al. 2025; Cortes Ortiz et al. 2016). Some insect companies, such as Flybox and Manna Insect, have already ventured into African markets.

Precision insect farming

Precision insect farming leverages data analytics and machine learning to refine production processes. Companies like Entocycle (UK) use machine learning algorithms to predict larval growth patterns and optimize feed conversion ratios in BSF farming. Similarly, Beta Hatch (USA) uses Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) gene-editing tools to enhance desirable traits in mealworms, such as faster maturation or higher protein content. Invertapro (Canada), on the other hand, pioneers selective breeding programs for crickets to improve disease resistance and yield. These precision approaches not only boost productivity, but also align insect biology with industrial scalability.

Modular and vertical farming systems

Modular and vertical farming systems are overcoming spatial limitations, particularly in urban settings (CCAC 2025). For example, Manna Insect (UK/East Africa) and Flying SpArk (Israel/Denmark) use stackable climate-controlled units that enable them to achieve high yields with limited space and a low environmental footprint. Sanergy (Kenya) integrates BSF modules into sanitation infrastructure to manage human waste through recycling using BSF larvae. The company has installed Urine-Diverting Dry Toilets to safely collect human waste in accordance with World Health Organization (WHO) protocols. It also employs youths in local communities to maintain the toilets and collect and transport waste to BSF recycling facilities. These modular systems integrate insect farming technologies into sanitation programs in resource-constrained settings.

Innovations in harvesting and processing

Innovations in harvesting and processing address bottlenecks in post-production efficiency. Traditional methods of manually separating larvae from substrate are being replaced by mechanized solutions. Hexafly (Ireland) has developed a vacuum system that helps to efficiently separate BSF larvae from the frass, ensuring that both components are clean and ready for further processing. This method is designed to handle large volumes, making the process more efficient and scalable. Innovafeed (France) has developed a scalable centrifugal separation technology for extracting oil from insect larvae. The process involves mechanically pressing the larvae and separating the oil from the solid part using centrifugation. Insect frass fertilizer is refined into a premium input with startups like Hexafly pairing frass with biochar to create "carbon-negative" fertilizers. Additionally, microbial inoculation techniques are being developed to enrich frass with beneficial bacteria for frass-based biostimulants for crop production (Caron-Garant et al. 2023). Insect companies are also developing environmentally friendly and innovative methods, such as enzymatic hydrolysis and microbial demineralization, to produce high-value chitin for various industrial applications (Hahn et al. 2020; Bastiaens et al. 2019).

Product safety, quality, and preservation

Overcoming consumer skepticism regarding the safety and quality of insect-based products is a key focus of the insect farming industry. Insect companies such as Aspire Food Group (USA/Ghana), Jimini (France), and Insectipro (Kenya) have extended the shelf life, improved safety, and preserved the nutritional quality of their products through innovative drying and preservation techniques. Modified atmosphere packaging, which extends the shelf life of perishable food products by altering the composition of the atmosphere inside the packaging, is being deployed to extend freshness and prevent oxidation (Ojha et al. 2021). These innovations have enabled insect companies to market and sell insect powder and whole insects globally, over an extended period.

Open-source and collaborative innovation models

Open-source and collaborative innovation models are promoting inclusivity in insect farming. Organizations such as the International Platform of Insects for Food and Feed (IPIFF), the North American Coalition for Insect Agriculture (NACIA), the Asian Food and Feed Insect Association (AFFIA), the Insect Protein Association of Australia (IPAA), the Academic Society of Insects as Food and Feed (ASIFF), and the African Association of Insect Scientists (AAIS) play a central role in facilitating knowledge-sharing and dissemination of best practices. These regional bodies are involved in policy advocacy, attracting private sector investments, and bridging the gaps among research institutions, donors,

investors, insect entrepreneurs, and governments. Universities and research institutions contribute by publishing open-access studies on affordable insect-rearing methods. These collaborative efforts reduce the risk of patent monopolies and enable small-scale producers to access advanced technologies without incurring high costs. Digital innovations are further enhancing cross-sectoral and institutional collaboration. Online platforms such as Insect Farm Hub, GreenSpoon, and Insect Hub are instrumental in supporting the wider adoption and commercialization of insect-based products.

Overall, innovations within the insect farming sector are progressing rapidly, though the level of technological readiness differs across regions. In Asia and Europe, automation and precision farming systems are approaching maturity, while in Africa, modular and vertical insect farming systems are beginning to expand. Most large-scale insect companies globally have already adopted advanced drying and preservation techniques that improve efficiency, product quality, and shelf life. Digital marketing and e-commerce platforms are also transforming the industry in Asia, Europe, and North America, enabling farmers to reach wider markets and strengthen consumer trust. However, such digital innovations remain limited in Africa, where adoption is often constrained by infrastructure gaps.

Enabling factors for scaling insect farming

Policies and standards

A confluence of enabling factors supports the scaling up of insect farming as a sustainable solution for food and feed systems. Favorable policies and production standards are foundational to this growth. Regulatory frameworks, such as the European Union's (EU) Novel Food Regulation (2018) and recent approvals of insect-based ingredients in aquaculture and pet food, have reduced barriers to market entry. Interest groups for edible insect farming in Africa, Asia, Australia, Canada, Latin America, and the United States are collaborating with relevant government agencies to ensure the seamless implementation of future edible insect regulations (Barragán-Fonseca 2024; Larouche et al. 2023; Nolet and Lever 2023). South-South and North-South cooperation has been central in shaping the emerging regulatory and production standards for insect farming in Africa. South-South collaborations, such as those led by *icipe* and regional farmer networks, foster knowledge exchange and context-specific innovations within African countries. Meanwhile, North-South partnerships – like those involving European, Australian, and South Korean institutions – bring technical expertise, funding, and policy support. These collaborations are instrumental to the development of harmonized regulations and safety standards in Africa and beyond.

In Africa, countries like Ethiopia, Kenya, Rwanda, Tanzania, and Uganda have established standards for the production and processing of edible insects (Tanga and Kababu 2023). The African Organization for Standardization (ARSO) has developed harmonized standards for insect farming across the continent to ensure safety, quality, and sustainability. These standards include guidelines for production, processing, and regulatory frameworks to facilitate intra-African and international trade (ARSO 2025). ARSO has formal relationships with regional economic communities, including the East African Community (EAC), the Economic Community of West African States (ECOWAS), and the Southern African Development Community (SADC). While ARSO provides a continental policy and regulatory framework, these regional bodies can contribute to implementation in their respective areas of jurisdiction, making their collaboration essential for building a unified African system on insect policies and standardization. These regional bodies should collaborate on knowledge sharing and the promotion of insect-based policies and standards. Supported by vibrant institutional actors, these policies and standards not only ensure safety and quality but also incentivize private sector investments, fostering trust among producers and consumers alike.

Entrepreneurship and investment

Central to the sector's momentum is the presence of vibrant entrepreneurs who blend innovation with pragmatism. Startups are transforming insect farming from a niche practice to an industrial-scale production (IPIFF 2025). Small-scale insect producers are also at the forefront of this transformation. For instance, small-scale insect producers in Kenya, Thailand, and Uganda are adopting cricket, mealworm, and BSF farming as low-input, high-return enterprises, often supported by cooperatives that aggregate produce for regional markets (FFP 2025; Sungu et al. 2023; MuKamau et al. 2021; Hanboonsong et al. 2013). In East Africa alone, more than 2,300 insect-producing farmers exist (Tanga and Kababu 2023). The quest for sustainable sources of food, feed, and employment, as well as the pursuit of climate change mitigation options, combined with

strong support from donor investments, particularly in low- and middle-income countries, has accelerated the expansion of insect farming. Donor-supported development initiatives pair financial support with technical assistance, bridging critical infrastructure and knowledge gaps and enabling resource-constrained countries to participate in the global insect value chain (Tanga and Kababu 2023; Tanga et al. 2021).

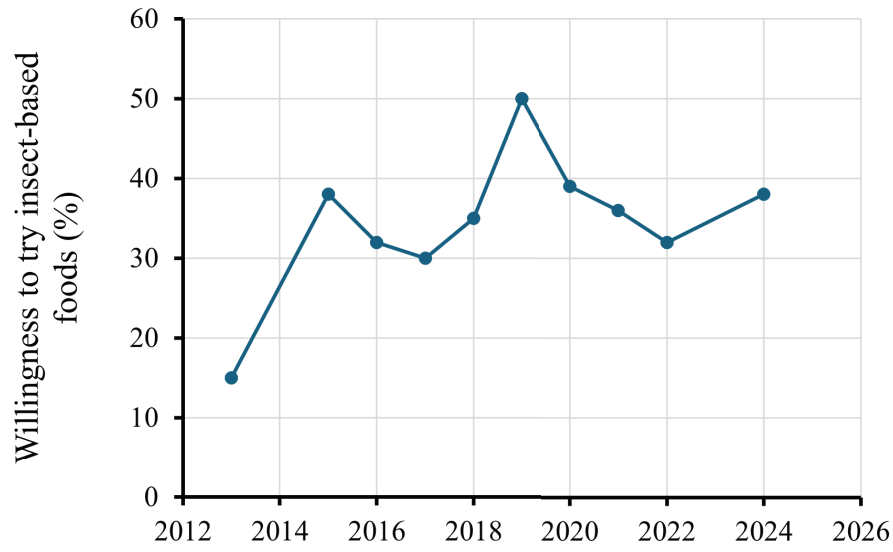
Shifting societal perceptions and culinary innovations

A slow but steady shift in societal perceptions about the use of insects for food and feed is reshaping consumer and industry attitudes. The use of insects in food and feed is already culturally acceptable in many communities across Africa, Asia, and Latin America (Abro et al. 2025; Omuse et al. 2024; Mulungu et al. 2023; Hurd et al. 2019). This acceptance is slowly growing in Western markets as well, albeit at a low base (Figure 10.8). Parallel to this shift in perceptions is the emergence of new culinary trends that are integrating insects into mainstream cuisine. Chefs and food innovators are pioneering creative applications of insect-based cuisine. High-profile culinary events, such as the "Insects to Feed the World 2024" conference in Singapore, showcased insect-based dishes, normalizing their inclusion in everyday diets (IFW 2024). Additionally, the rise of "future foods" startups emphasizes premium, chef-curated products that appeal to adventurous and eco-conscious consumers (Hwang et al. 2023).

Functional foods and nutritional innovations

Accompanying these culinary advancements is the emergence of innovative, functional food products that position insects as ingredients with important health benefits. Companies are formulating insect-derived proteins, oils, chitin, and chitosan into products targeting specific consumer needs, such as protein bars for athletes, iron-fortified snacks for pregnant women, insect-enriched complementary foods for children, and pet foods (Adegboye 2022; Valdés et al. 2022; Placentino et al. 2021). For example, insect companies market cricket-based protein bars or crunch snacks as a sustainable energy source, while others produce insect-based ingredients for gluten-free baking (Chapul Farm 2025; Insectipro 2025). These innovations align with broader trends in personalized nutrition and functional foods, expanding the sector's appeal beyond sustainability.

FIGURE 10.8—WILLINGNESS TO TRY INSECT-BASED FOOD IN WESTERN COUNTRIES



Source: Authors' presentation based on publicly available data from Abro et al. (2025).

Barriers to scaling insect farming

Consumer acceptance and societal perceptions

Despite the existence of enabling environments as discussed in Section 10.5, the expansion of insect farming as a sustainable food, feed, and organic fertilizer solution faces several interlinked barriers, the majority of which are rooted in societal perceptions, structural challenges, and access to finance and markets. A key obstacle is limited awareness and poor consumer preferences, particularly for insect-based human food (Abro et al. 2025). Although marketing campaigns and celebrity endorsements (e.g., athletes promoting cricket protein bars) are helping to shift preferences, mainstream acceptance of insect-based foods remains elusive, especially among older populations. Psychological barriers, such as neophobia and disgust, pose significant challenges to consumer acceptability, particularly in countries and regions where entomophagy is culturally unfamiliar (Abro et al. 2025).

High costs and economies of scale

The higher prices of insect-based products are another major barrier due to the nascent production systems and limited production volumes (Kamau et al. 2021; Niyonsaba et al. 2021; Han et al. 2017). Compared to conventional protein sources, insect-based feeds and foods remain expensive (CCAC 2025; Biteau et al. 2024; Larouche et al. 2023; Meerts et al. 2023). For instance, BSF-based feeds remain expensive, costing nearly $2,500 per ton in Africa, whereas soybean and fishmeal sell for about $500 and $1,700 per ton, respectively (CCAC 2025). Moreover, dried and roasted crickets cost 4,900 Kenya Shillings (KES) per kg, while dried larvae cost KES 2,450 per kg in Kenya. This is in comparison to beef, which sells for under KES 1,200 per kg (GreenSpoon 2025). Limited economies of scale, labor-intensive practices, and energy-intensive drying processes further inflate costs (Kolobe et al. 2023). While automation could reduce these expenses, entrepreneurs face a dilemma because they cannot scale without sufficient investment, while investors hesitate to finance expansion without demonstrated scalability.

Inconsistent inputs and resource constraints

Another significant constraint is the inconsistent availability of quality inputs, particularly waste for feeding insects. For instance, BSF larvae require consistent access to sorted, nutrient-rich organic waste to achieve optimal growth and nutrient profiles. In low- and middle-income countries, however, inefficient waste collection and segregation hinder the reliable supply of such waste (Kaza et al. 2018). Additionally, the lack of standardized insect breeding stock results in variable performance and can undermine commercial production (Caparros Megido et al. 2024; Hansen et al. 2024). Insufficient capital further hampers insect farming expansion (Nyangau et al. 2024). Although the sector attracted approximately $2 billion in investment between 2014 and 2021, recent years have seen a slowdown (Shah 2024).

Patents and technological dependency

Patenting of key insect production and processing innovations may widen inequalities (Hamm et al. 2020; Kim et al. 2019; Schiemer et al. 2018; Müller et al. 2016). Proprietary innovations – such as automated rearing systems, genetic selection algorithms, or optimized feed recipes – are largely controlled by firms in Europe and North America. These patents may restrict access for small-scale insect producers in low- and middle-income countries who often lack the capital required for licensing. Ultimately, this may result in technological dependencies that limit local innovations and could further exclude small-scale entrepreneurs from the expanding insect value chain (Fechner and Shapanka 2018; Schiemer et al. 2018; Müller et al. 2016).

Policy options for scaling insect farming

Supply-side policy options

Scaling insect farming requires targeted policy interventions to address critical supply-side challenges. First, policymakers must prioritize research and development (R&D) on substrate innovation to ensure the feed safety and nutritional quality of insect-based products. These efforts should focus on using low-cost, non-competing biowaste streams, rather than conventional feeds that have other important uses (Biteau et al. 2024). Optimizing biowaste-based feeds would enhance resource efficiency and align insect farming with circular economy principles. Making optimized feed formulations publicly available can also help small-scale insect farmers, particularly those with limited or no access to proprietary products.

In addition to more focused efforts targeting substrate optimization R&D, governments should invest in waste management infrastructure to secure consistent supplies of sorted biowaste for insect production. In low- and middle-income countries, improving waste collection, sorting, and pre-treatment systems is essential for many insect-based enterprises such as BSF farming, which relies on organic waste for its feedstock. Concurrently, policies should also address ancillary costs, such as land acquisition and capital equipment, which hinder farm establishment. Strategic incentives, such as targeted subsidies, could help offset initial costs, given the environmental benefits of insect farming (e.g., waste valorization, emission reductions). For instance, Yang-Jie and colleagues (2023) demonstrated that a $32/ton subsidy for biowaste treatment in China improved farm viability. However, to avoid fiscal strain, subsidies should be time-bound and paired with non-monetary incentives, such as allocating land for insect farming facilities or offering tax exemptions for green technologies.

To further reduce financial barriers, governments should facilitate access to green financing for insect enterprises. The East African Grain Council and *icipe* are collaborating with financial institutions to create financial products for insect farmers. Some insect farming enterprises get direct funding from donors, but most face financial difficulties. Linking farms to climate funds, low-interest loans, or blended finance mechanisms would enable investments in automation, energy-efficient equipment, and certification processes. Such financial support is especially critical for small-scale production.

Equally vital is addressing the skills gap among potential insect entrepreneurs. Policymakers should integrate technical training that covers rearing techniques, biowaste management, and business planning into vocational education systems. Curricula could be embedded within existing programs in waste management, the circular economy, or material sciences to leverage institutional expertise. Practical, short-term courses would equip entrepreneurs with competencies to scale operations profitably while minimizing production failures. Besides addressing skill gaps, integrating insect farming into existing agricultural extension and advisory services will help accelerate the transfer of knowledge and innovations from research centers to the edible insect industry. Further, the agricultural extension system and advisory services can help identify and remediate insect farming challenges such as poor yields caused by nutritional imbalances, temperature stress, or microbial infections.

The creation of knowledge-sharing platforms can enhance feedback and the co-creation of solutions for emerging challenges along the edible insect farming value chain. Strengthening industry associations is another policy priority. In regions like Africa south of the Sahara and the Pacific, where formal networks are still in their early stages, fostering organizations similar to NACIA and IPIFF would help enhance collaboration. These associations could coordinate shared infrastructure (e.g., drying facilities, aggregation centers), advocate for regulations, and standardize product quality and safety protocols. Collective action would expand production volumes and mitigate risks for individual producers.

Finally, diversifying insect species under cultivation is essential to mitigate risks from disease outbreaks or market shocks. The current reliance on a handful of species, such as black soldier flies, mealworms, and crickets, leaves the industry vulnerable to systemic disruptions, including disease outbreaks. Increased R&D funding for the domestication of alternative species and productive strains within the same species would enhance resilience and expand product applications (Abro et al. 2025; Omuse et al. 2024; Kolobe et al. 2023).

Demand-side policy options

Demand-side policies would have to address consumer acceptance, accessibility, and affordability for scaling insect farming. Ensuring safety and nutritional quality is critical to overcoming consumer skepticism (Lalander et al. 2025; Hamam et al. 2024). Regulatory frameworks should mandate rigorous quality assessments and the certification of insect-based products to verify their safety and nutrient profiles (Siddiqui et al. 2023; Niassy et al. 2018). Such quality control measures should also be supported by scientific evidence. Transparent labeling and third-party verification can build trust and enhance acceptability, particularly in countries where insect consumption is not practiced.

Once safety is assured, targeted marketing and behavioral nudges can reduce cultural barriers and increase awareness. For instance, introducing insect-based foods through low-commitment trials – such as supermarket sampling – and emphasizing health benefits (e.g., high protein or iron content) can appeal to environmentally conscious individuals and younger people. Normalizing consumption by integrating insects into familiar dishes (e.g., cricket flour in bakery products) rather than framing them as exotic novelties has also proven to be an effective strategy (Tan and House 2018). Companies like Protix (Netherlands) and Insectipro (Kenya) have successfully leveraged attractive packaging to draw environmentally conscious and younger people. Rebranding products with neutral or appealing descriptors (e.g., "crispy snacks" instead of "fried insects") further enhances acceptability. Crucially, taste is often a decisive factor for consumer acceptance of insect-based products (Wendin and Nyberg 2021; Mishyna et al. 2020; Ghosh et al. 2018). Successful market entry for insect-based foods hinges on delivering flavorful, familiar sensory experiences from the outset, leveraging processing and formulation strategies to mask unfamiliar textures or aromas. For entrepreneurs and food innovators, prioritizing taste optimization through careful recipe design, flavor pairing, and cooking methods, is essential to turn eco-friendly ingredients into mainstream food choices.

In countries or regions where insect consumption is already an existing norm, strategic product placement and default positioning can enhance

visibility and trial rates. Studies in consumer behavior suggest that positioning insect-based products in the mainstream protein sections of supermarkets – rather than niche aisles – signals their equivalence to conventional proteins (Phonthanukitithaworn et al. 2023; Vandenbroele et al. 2020; Goldstein et al. 2008). To complement this, social norm nudges, such as signs that highlight popular adoption (e.g., "most shoppers choose insect-based products"), or comparisons to familiar choices (e.g., "as normal as chicken"), can leverage conformity to effect perception shifts (Castro-Santa et al. 2023; McGrath 2023). Emphasizing cultural heritage, for instance, by framing insects as traditional or authentic foods, can also increase pride and willingness to consume, particularly among urban youth (Hurd et al. 2019). Linking insect farming to community resilience, as seen in various East African initiatives promoting BSF farming for youth enterprises, reinforces the role of insect-based products in local identity and food security (Tanga et al. 2021). Further, promoting insect-based products requires targeted consumer education to overcome cultural biases and increase acceptance (Rumpold and Van Huis 2021). Educational interventions that emphasize environmental benefits (e.g., lower carbon footprints) and nutritional value (e.g., high protein content) can reshape perceptions and foster long-term acceptability (Chow et al. 2021; Nonaka and Yanagihara 2020).

Functional food product development can also offer a pathway to mainstream adoption by aligning insect-based products with health trends. Incorporating insect-derived ingredients with clear labelling into scientifically validated formats – such as protein bars, fortified snacks, or supplements – emphasizes their functional benefits (e.g., immune support) rather than their origin (Temple 2022; Acosta-Estrada et al. 2021). This approach can mitigate cultural resistance by integrating insects into existing markets for functional foods, where consumers prioritize health outcomes over novelty.

Lastly, price parity and availability must be prioritized. Despite growing interest, insect-based products remain expensive due to fragmented supply chains and small-scale production (Escalante-Aburto et al. 2022). Policies should incentivize economies of scale through subsidies and incentives for bulk production. Simultaneously, improving distribution networks through partnerships with retailers or e-commerce platforms can enhance accessibility. Addressing these challenges is critical to transforming insect-based foods from niche offerings to affordable, everyday staples.

Conclusion

Insect farming holds tremendous promise as a sustainable and inclusive pathway for transforming agrifood systems and building self-reliance in Africa. It offers a rare convergence of solutions: waste valorization; production of low-carbon protein and organic fertilizers; restoration of soil health; creation of green jobs; and the empowerment of youth and women. Evidence from Africa and elsewhere shows that insect farming can deliver measurable impacts in agricultural productivity, food and nutrition security, poverty reduction, and environmental sustainability.

However, realizing this potential requires addressing both structural and perceptual barriers. Supply-side investments must prioritize context-specific, efficient waste management at source; substrate optimization; infrastructure development; semi-automation; capacity building; and marketing strategies, which include functional feed and food design. Strengthening data systems, applying economywide modeling to assess impacts, and fostering innovations in digital monitoring and production optimization are also critical measures to implement. Additionally, insect farming innovations should be mainstreamed into agricultural extension systems and vocational training programs. On the demand side, policies and strategies should focus on safety regulations, market incentives, inclusive product development, enhanced awareness among consumers and producers, behavioral nudges, and affordability. A robust enabling environment that supports innovation, financing, knowledge sharing, and regional standardization is also essential.

To ensure equitable and scalable adoption, insect farming must be formally integrated into national and global livestock and agrifood policies. Strengthening data systems to enable evidence-based policymaking and fostering public-private research collaborations will lay the groundwork for inclusive transformation. With the appropriate mix of policy formulation and stakeholder engagement, insect farming can shift from a niche innovation to a mainstream solution, driving efforts toward sustainability, economic independence, food sovereignty, and environmental stewardship across the continent.

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