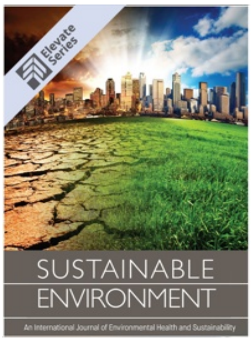

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Sustainable Environment

An international journal of environmental health and sustainability

ISSN: 2765-8511 (Online) Journal homepage: www.tandfonline.com/journals/oaes21

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To cite this article: Junior Senyonga Kasima, Basil Mugonola, Emmanuel Menya, Sulaiman Ndaula & Elly Kurobuza Ndyomugyenyi (2025) Black soldier flies as a latent driver to attaining selected SDGs in a developing country context- the case of Uganda, Sustainable Environment, 11:1, 2478704, DOI: 10.1080/27658511.2025.2478704

To link to this article: https://doi.org/10.1080/27658511.2025.2478704

Published online: 17 Mar 2025.

SUSTAINABLE ENVIRONMENT
2025, VOL. 11, NO. 1, 2478704
https://doi.org/10.1080/27658511.2025.2478704

ENVIRONMENTAL HEALTH, MONITORING AND RESILIENCE | REVIEW ARTICLE
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Black soldier flies as a latent driver to attaining selected SDGs in a developing country context- the case of Uganda

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ABSTRACT

In developing countries, minimal progress has been made towards the attainment of Sustainable Development Goals (SDGs). This is because of low investment in innovations towards this endeavor. In this paper, 143 peer-reviewed journal articles and non-journal sources were reviewed to explore the potential of Black Soldier Fly (BSF) rearing as a cost-effective innovation for achieving SDGs 1, 2, 3, 7, and 13. Uganda was chosen for its median position among developing countries, making its practices adaptable to countries on either side of the scale. BSF can contribute to the attainment of the five SDGs through its products and/or services, including environment-friendly waste management, larvae for animal feeds, frass for organic fertilizer, and chitin for pharmaceutical use. This review discusses the significant potential of integrating BSF into strategies to achieve the selected SDGs in a developing country. However, the limited data on organic waste generation could not permit precise statistical estimates of BSF's potential contribution to each SDG. Future studies, supported by reliable data, should precisely assess the feasibility of BSF rearing as a cost-effective innovation for attaining the SDGs. Future research should also explore the influence of policy and consumer behavior on the adoption and utilization of BSF-based products.

ARTICLE HISTORY
Received 31 December 2024
Accepted 09 March 2025

KEYWORDS
Animal feeds; black soldier fly larvae; biodiesel; climate change

SUSTAINABLE DEVELOPMENT GOALS
Sustainable Development Goals

Introduction

The 17 Sustainable Development Goals (SDGs) were formulated to ensure '*good life*' for mankind, today and tomorrow (Barua, 2020; Houssam et al., 2023; Koch & Krellenberg, 2018; Leal-Filho et al., 2019). Each goal includes sustainability to provide long-lasting solutions to human problems with minimal impact on natural resources (Barua, 2020). The ultimate aim is to achieve an inclusive approach to sustainable development (Mayanja & Nkata, 2019), which leaves no one behind in global development efforts (Annan-Aggrey et al., 2021). To ensure the attainment of this global endeavor, the efforts of individual countries are paramount, and different countries have set localized strategies within their means. Setting country-specific strategies is important, because there are differences in resource endowments across nations. Thus, the priorities set by different nations differ, although the definitive goal is to holistically and sustainably improve the livelihoods of their citizens (Halisçelik & Soytas, 2018).

Unfortunately, a recent assessment showed that the world is still far from achieving the SDGs (United Nations, 2024). In particular, the meagre progress reported was primarily in developed economies, which leaves a gap between these economies and the developing world regarding the attainment of the SDGs (Chaparro-Banegas et al., 2024; Paprotny, 2021). This difference is attributed to the fact that developed countries have allocated more resources to innovations that contribute to the attainment of the SDGs (Chaparro-Banegas et al., 2024; Shulla & Leal-Filho, 2023). However, the poor infrastructural system in different sectors has limited investment in innovations towards achieving SDGs in the developing world (Davies et al., 2019; Hickmann et al., 2023; Hinson et al., 2019).

Notably, it has been quite challenging for the developing countries to utilize their natural resources to achieve the SDGs with minimal impact (Indiana & Pahlevi, 2023), and some of these countries have registered high levels of depletion of their natural resources

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(Barbier & Burgess, 2023). In these countries, there is also remarkable inequality in access to basic resources (Medina-Hernández et al., 2023), whose equal distribution would otherwise create a unified impact in the efforts to achieve the SDGs. Developing countries have to mobilize resources to enable them achieve the SDGs while also ensuring good welfare of their population (Arora & Sarker, 2023). Thus, the developing world must embrace innovations that would help them achieve the SDGs and improve the welfare of their citizens. Achieving these two endeavors would only be possible if developing economies invested in cost-effective innovative approaches. The resources to be mobilized might, therefore, not necessarily be tagged as resources to contribute to attaining the SDGs, but will have to be invested in innovations that may directly or indirectly contribute to the attainment of the respective SDGs.

Among the potential cost-effective innovations is insect farming, which has gained global importance owing to its diverse uses in sustaining human livelihood (Hlongwane et al., 2021; Selaledi et al., 2021). For example, insects are appraised for their potential contribution to improving global food security (Sogari et al., 2019), directly as food and indirectly as ingredients in the food sector. However, in the developing world, where regulations on insect use are limited (Chia et al., 2020), insects remain largely understudied. Black Soldier Flies (BSF) and their larvae (BSFL) have received particular attention from the research community because of their diverse roles and products these insects can provide (Bessa et al., 2020; Popa & Green, 2012; Siddiqui et al., 2022; Wang & Shelomi, 2017). In this regard, the current review seeks to consolidate the diverse body of research on BSF and its potential to contribute to the attainment of the selected SDGs in a developing country context.

The review uses Uganda as a case because it has a favorable environment that supports the growth of insects, including BSF. In addition, Uganda is in the median position of the least developed countries, and most importantly, in Sub-Saharan Africa (SSA) (Guerrero-Ruiz et al., 2021). Most importantly, Uganda's organic waste management system is at stake following the recent '*mysterious fire outbreak*' at Kitezi, one of the biggest waste dump sites in Uganda. Using BSF as an alternative organic waste management strategy could save the potential future tragedy from increased poor organic waste disposal. Since the country holds a median position among the least developed countries in SSA and faces challenges in waste management, development solutions applicable to Uganda could be feasible for other developing countries with similar organic waste management issues. We are convinced that venturing into BSF as a development vehicle could be a sustainable option in Uganda, given the increasing population and the resulting rise in generation of organic wastes, which are substrates for BSF larvae growth (Aryampa et al., 2019). The review first delves into assessing the status of SDGs in the developing world, then narrows its focus to Uganda , highlighting the strategies the Uganda government has put in place to achieve the SDGs, as well as the weaknesses in these strategies. The review then offers insights into how embracing the BSF can contribute to the attainment of some of the selected SDGs. The SDGs discussed are 1,2,3,7 and 13. The first four SDGs (1,2 3 and 7) were recently reported to be critical for Africa (Danladi et al., 2023). However, for Uganda, we also examined the potential contribution of BSF rearing to the attainment of SDG 13, which is particularly important for a green Africa in the future. The potential limitations to using BSF in attaining these SDGs, and policy implications are also discussed. The need for regulation in the use of BSF is also highlighted to ensure that the goal of attaining '*good life*' for all '*today and tomorrow*' is not compromised. This review is an eye opener to developing countries that the '*over-looked*' innovations could actually hasten their efforts towards attaining some of the SDGs by 2030.

It is important to mention that there was an earlier attempt by Raman et al. (2022) to align BSF production with the attainment of several SDGs. However, their focus was on BSF larvae, particularly with regard to animal feed production. Thus, they lightly reported other aspects that BSF could contribute to in sustainable development. Therefore, this review comprehensively explores the potential role of BSF in the attainment of the above-mentioned SDGs. Although a few selected SDGs are discussed here- those to which BSF could directly contribute —it is noteworthy that there is no stand-alone SDG (Wanyana et al., 2024). Thus, BSF could play an indirect role in the achievement of all other SDGs.

Methodology

Although work has been done on the different products and services offered by the BSF, their contribution to the attainment of SDGs is scanty. Thus, we examined studies on the different products and/or services provided by BSF and applied them to the respective SDGs. The BSF products considered in this review were larvae, frass, and chitin. In our search, however, one study by Kaczor et al. (2022) highlighted the extraction of antifungal compounds from the eyes of adult flies. Thus, although limited work has been published on this subject, we have included this article, since it reported on a product that we believe could be explored for future use in the context of the developing world. However, studies on the biology of BSF, such as its life cycle, were excluded.

It was found that the direct contribution of BSF aligns with five SDGs (1,2,3,7 and 13), which formed the basis for our review and search for articles. In our search, we first considered information from the United Nations website on SDGs (https://sdgs.un.org/goals) to ascertain in detail what the five SDGs entail. In addition, we reviewed reports from the SDG secretariate, office of the Prime Minister of Uganda (https://sdgs.opm.go.ug/sdg-secretariat/), to obtain current updates on the five SDGs. From this information, we carefully searched for studies relating to: (1) the current state of SDGs globally and locally, and efforts to ensure the attainment of the same, and (2) services and/or products provided by BSF that could apply to Uganda in its pursuit to attain the five SDGs. These were obtained from Google Scholar and websites of publishing houses, particularly Springer Nature, Springer Link, Elsevier, and Taylor and Francis, among others. To this end, we reviewed 128 peer-reviewed journal articles and 15 publications that were related to the subject but were not journal articles.

Status of SDGs in the developing world

Generally, the progress of developing countries towards achieving the SDGs has been poor, and it is believed that the COVID-19 pandemic worsened the situation (Medina-Hernández et al., 2023). Although no comprehensive report quantifying the effect of the pandemic on the attainment of SDGs exists in the developing world, its effect is undeniable. Gonzalez and Ebbesson (2021), for example, highlighted that global food systems have been distorted by the pandemic, with the developing world being the most affected. Regarding SDG 3, a general report showed that minimal progress has been made in the developing world (Strong et al., 2020). In addition, the pandemic reduced the amount of aid to developing countries, yet an initial look into the possibilities of these countries achieving the SDGs showed the necessity of additional aid to supplement their public finances (Hoy, 2024).

According to the SDG dashboard, Africa regressed in SDG 13 (climate action) and achieved the least progress in SDG 2 (zero hunger), SDG 8 (decent work and economic growth), SDG 10 (reduced inequality), and SDG 12 (responsible consumption and production) (SDG Knowledge Hub, 2022). A report by Leal-Filho et al. (2020) is more benumbing as they postulate that not achieving the SDGs could put the developing world in a more desperate state of aggravated poverty and disease outbreaks. This calls for strategic actions by the developing world towards more feasible alternatives owing to the reduction in foreign aid.

Status of SDGs in Uganda and strategies by the government to attain them

In an effort to achieve sustainable development, Uganda integrated some of the SDGs into its National Development Plans (NDPs). For example, Uganda established agro-industrialization as one of the 18 national programs in NDP III, which encompasses SDGs 1, 2, 8, and 9 (United Nations Department of Economic and Social Affairs, 2020). Similarly, SDGs 12, 13, 14, and 5 are part of the program on climate change and natural resource management. With these and other SDGs included, 95% of NDP III was aligned with SDGs (Office of the Prime Minister [OPM], 2024a).

Furthermore, Uganda sought to operationalize the UN's '*Leave No One Behind (LNOB)*' concept to allow for inclusiveness in obtaining sustainable development (Office of the Prime Minister [OPM], 2024b). Some of the national strategies to operationalize the LNOB strategy include the Parish Development Model (PDM), Youth Livelihood Fund, Women Empowerment Program, and Disability Fund, among others (OPM, 2024a, 2024b). However, even with these inclusive programs, a more recent report on the status of SDGs shows that for the past six years, Uganda has only achieved SDGs 12 and 13 (P. Mugambe & Avogo, 2024).

Weaknesses in Uganda's strategies to achieve the SDGs

In contrast to developed economies, where the attainment of SDGs has been driven by investment in innovations (Chaparro-Banegas et al., 2024), Uganda's strategy in the above initiatives involves giving money to people with no clear roadmap to invest it. Such funds contribute to making people lazy with the idea that '*the government will provide for them*.' Consequently, such efforts have always been labelled according to the government programs, for example '*PDM money*.' On the contrary, encouraging individuals to become involved in cost-effective initiatives and providing funds to boost their already established enterprises could be a more sustainable approach, as it would also stimulate innovation among people.

The position of BSF in Uganda's pursuits of sustainable development

One of the key challenges against Uganda's pursuit of improving the livelihoods of its citizens is poor solid waste management. However, it is unlikely that citizens will invest money obtained from any government program to manage waste. Thus, the government must either directly invest in innovations to manage waste or fund these initiatives, rather than give money to citizens. And, with the increasing waste generation levels, the cost of managing these wastes could as well go beyond the cost of producing them. Castellani et al. (2022) proposed a circular economy to fit Uganda's waste management system. In this regard, we postulate that embracing the use of BSF could be a more viable venture in efforts to '*utilise wastes*' to achieve some of the SDGs discussed here. This could be one strategy to supplement donor funds, as Uganda's economy largely depends on external funding (Mwangu, 2023). Embracing BSF could also promote a more inclusive participatory approach to achieving the SDGs to allow for the involvement of all Ugandans (Ahimbisibwe & Kontinen, 2021).

SDG1- No poverty: Ending poverty in all its forms everywhere

Initiatives set by government of Uganda towards eradicating poverty

Currently, over 40% and 20% of Ugandans live below the international (US. $ 1.90 per day) and national (US. $ 1.77 per day) poverty lines, respectively (OPM, 2024a). The Uganda Poverty Eradication Action Plan (PEAP) clearly spells out in one of its pillars that it aims to '*increase the ability of the poor to raise their incomes*.' This and other poverty eradication initiatives such as *Emyooga, Entandiikwa*, and PDM all spell out on paper the intended efforts to eradicate poverty among the poorest of the poor. Nonetheless, these initiatives have been politicized, which has constrained their ability to achieve the intended goals (Oburu, 2023). Holistic and inclusive social and economic policies, the efficient use of natural resources through innovative approaches, government investment in advancing technological development, and pro-poor leadership that seeks to address the needs of the poor (Ayoo, 2022) could address poverty challenges in developing countries like Uganda. Onen (2023) advised that development initiatives should shift from providing aid to supporting innovations that use local knowledge to contribute to uplifting the livelihoods of Ugandans. This has, however, been lightly adopted in Uganda, yet it would contribute to a reduction in politicizing government programs.

The potential role of BSF in poverty eradication

As a circular economy has been proposed as a sustainable waste management approach that could also improve the livelihoods of Ugandans (Castellani et al., 2022), we are convinced that waste management using BSF is suitable in this pursuit. All stages of the BSF can be used to generate different products. Thus, rearing Black soldier flies yields no waste. For example, in addition to larvae that are feed for animals, use of frass, which is a biofertilizer from BSFL biodegradation, resulted in equal crop performance compared to when synthetic fertilizers were used (Quilliam et al., 2020). Therefore, this initiative could reduce the cost of synthetic fertilizers and their negative effects on the soil. Fortunately, operations leading to these products require low capital and space investment, making the enterprise a viable option for low-income earners in developing countries (Gold et al., 2018; Singh & Kumari, 2019).

Based on studies on larval and frass production from biowaste conversion, the amount of frass and larvae depends on the substrate used (Basri et al., 2022; Quilliam et al., 2020; Salomone et al., 2017). Thus, the choice of substrate will depend on the purpose of the enterprise, whether it is primarily for frass or larvae. Nonetheless, in Uganda, fruit and vegetable wastes are as high as 40% before reaching the final consumer (Food Rights Alliance, 2020). With their high frass (25%) and larvae (12.5%) production capacity (Ahmad et al., 2021), farmers could take on '*dual-purpose BSF enterprises*' owing to the fact that most households practice integrated crop-livestock systems. Because of the diversity in operations that yield waste among households, it is possible that individuals or groups (several even at the village level) could set up BSF-rearing enterprises and sustain them with waste from their households.

Abro et al. (2022) estimated the potential contribution of BSF to poverty eradication and reported both direct and indirect effects (Table 1). The direct contribution of BSF-rearing is the increase in earnings. This could be either through the sale of primary products (larvae and frass) or cuticles of pupae after the emergence of the adults and dead flies for extraction of chitin and subsequently chitosan for use in the food and pharmaceutical industries. Alternatively, farmers raising livestock and crops would use larvae and frass in their respective enterprises to increase productivity and consequential income. The indirect contribution could be through lowering the prices of inputs (larvae and frass), which would reduce production costs and, consequently, reduce the price of the final product. This would ultimately increase consumer savings on products from the BSF-based systems. Another indirect

Table 1. Summarised discussion of the applications of BSF that could contribute to achieving the different SDGs in Uganda

Author (s) and year	SDG	Application	Remarks
Abro et al. (2022)		• BSF rearing could contribute to poverty eradication, directly and indirectly. • The direct contribution could accrue, for example, from the sale of BSF larvae and frass, or the use of these in animal and crop production to increase farm productivity and incomes. • The indirect contribution could be due to reduced costs of inputs (larvae and frass) which lowers production costs and prices of final products. In addition, the authors' calculations realised potential of creating about 500,000 jobs annually in Uganda, if BSFL is used as animal feed	• Since there are other services (environmental) and products from BSF production than animal feeds, we postulate that more jobs could be created if BSF rearing is embraced for the different products and services it offers
Application in crop production Gärttling and Schulz (2022) Klammsteiner et al. (2020) Gebremikael et al. (2022) Urrutia et al. (2023) Kaczor et al. (2022) **Application in Animal production** Biasato et al. (2019) Hong and Kim (2022)		• Frass from BSFL biodegradation has a high nutrient profile suitable for use in crop production. No difference in growth performance was observed when BSFL-frass was compared with NH_4NO_3 for growing rye grass. • In maize only N supplementation was recommended by (Gebremikael et al., 2022) to avoid shortage during the growth period of the plant. • Frass also has pesticidal properties, particularly antifungal properties which were also reported to be present in the BSF eye (Kaczor et al., 2022). • BSFL are a potential cost-effective protein source to replace conventional protein sources (fish and soybean meals).	• This initiative could enhance crop production by enhancing yield, but also offering cost-effective crop production, affordable to smallholder farmers • Similarly, this could counteract the challenge of high feeding costs which has constrained the growth of livestock production in Uganda. Consequently, consumption of animal source foods would be increased.
Geng et al. (2022) Lv et al. (2023); Olza et al. (2023); H. Wang et al. (2020)		• Use of BSFL frass on soils containing heavy metals reduces concentration in the crops. This could reduce cases of heavy metal toxicity since some agricultural soils in Uganda are rich in heavy metals • Chitin from BSF can be used in pharmaceutical industries since it has biomedical properties	• Since biodiesel is a clean energy, using it for cooking could also reduce respiratory cases accruing from use of wood fuel for cooking • Using Chitin in manufacturing pharmaceutical products could be sustainable cost-effective option for Uganda's health sector owing to the recent cuts on aid, for example, from the United States government
Park et al. (2022); Lew et al. (2023a)		• Fuel properties of biodiesel from BSFL raised on food wastes met most of the Korean fuel standards. • BSFL raised on thermally treated sewage sludge at a low temperature yielded biodiesel which met the EN 14,214 and ASTM D6751 standards for biodiesel, except for the flash point.	• Biodiesel is clean energy, and could be affordable in Uganda if produced on large scale. From our estimates (following calculations and assumptions by Koyunoğlu (2024)), Ugandan bus companies could save 0.39 US$ per litre of fuel if they were to embrace the use of biodiesel instead of the traditional diesel.
Ahmad et al. (2023); Pang et al. (2020a); Perednia et al. (2017); Lindberg et al. (2022)		• Using a locally fabricated BSFL bin where households can dump organic wastes could aid in managing organic wastes. Since separation of wastes among Ugandans is partly driven by incentives, we postulate that the sale of larvae and frass from the BSFL bioconversion would stimulate individuals to sort wastes and only include organic wastes in the bins • BSFL bioconversion results in reduce CH_4 and N_2O emissions when BSFL are raised on food wastes. • In comparison with aerobic microbial degradation which emitted 48.6% carbon, emissions during BSFL biodegradation was only 28.5%. Pre-treatment of fruit and vegetable wastes was realised to further reduce CH_4 and N_2O during BSFL biodegradation.	• Uptake of BSFL bins could be high with the possibility that households can harvest larvae and frass for sale, or even for use on their farms. • Embracing organic waste management using BSFL will not only reduce emissions from waste degradation, but also the effects of dependence on wood fuel for cooking

contribution to poverty eradication reported by Abro et al. (2022) was providing employment to different actors along the BSF valve chain. In the authors' calculation, they realized that replacing conventional animal feed with BSF could create over 500,000 jobs annually. Since operations regarding BSF are not limited only to feeds, it is evident that embracing BSF in totality could contribute more jobs than the above estimates.

SDG2- Zero hunger: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

The current status of food security in Uganda

Food insecurity and the consequential frequent hunger cases have remained a challenge in many parts of Uganda. As of January 2023, for example, more than 16 million Ugandans were reported to have insufficient food (Mpuuga, 2023). A third of school-going children go hungry every school day, which affects their health and performance at schools (Taufiq & Ismail, 2020). Among rural Ugandan adults, the effects of food insecurity are far-reaching, even resulting in mental health issues (Perkins et al., 2018). This has a negative effect on food supply since most of the food in Ugandan markets is produced by rural farmers.

Besides the reduced productivity of the soil due to poor management of crop fields (Nabyonga et al., 2022), postharvest losses and food waste also contribute to the high hunger cases in the country (Mpuuga, 2023). For vegetables, for example, about 40% are rejected in the export market because of poor quality, excluding on-farm losses and losses during transportation. The poor management of these wastes also exacerbates production challenges by enhancing climate change processes, which in turn contribute to food insecurity (Taufiq & Ismail, 2020).

Potential role of BSF rearing in attaining zero hunger in Uganda

Black soldier fly larvae frass and its potential of increasing crop production. The advantage of embracing BSF rearing in this multi-faceted challenge is that it grows on waste, producing a biofertilizer (frass), a product of BSFL bioconversion processes (Lopes et al., 2022; Susilo et al., 2024; Visvini et al., 2022). The frass obtained from waste degradation by BSFL has a higher nutrient profile and organic matter content than animal manure and organic fertilizer produced by conventional composting practices (Gärttling & Schulz, 2022). When BSFL frass was compared with NH_4NO_3 in growing ryegrass, which is a perennial plant, no difference in growth was observed, and neither was the soil hygiene compromised (Klammsteiner et al., 2020). Broadly, Lopes et al. (2022) presented the micro- and macronutrient composition of frass from the degradation of different wastes by BSFL. Although the substrate influences the nutrient levels required by plants, a general outlook on the composition shows that the frass is rich in most of the relevant nutrients, and most importantly, the NPK nutrients. However, in maize, Gebremikael et al. (2022) recommended supplementing frass with a readily available N source to avoid shortages during plant growth.

Fortunately, frass from BSFL biodegradation is low in heavy metals, even when the concentration is high in the substrates (Basri et al., 2022). When grown on substrates enriched with mercury, for example, the resulting frass had lower mercury concentrations below the minimum recommendation of 0.7–10 mg Hg/kg by the European Union (Attiogbe et al., 2019). Thus, BSFL biodegradation allows for the incorporation of waste from areas with high heavy metal loads into the food system in the form of frass, with minimal impact of heavy metal leaching into the soils. Such an innovation is especially important in using organic wastes in these areas, as a recent report by Mpewo et al. (2023) highlighted increasing heavy metal loads in some agricultural communities in Uganda.

When brown rice was grown on cadmium-contaminated soils on which frass from BSFL was added as a fertilizer, the frass reduced Cd concentration in the different parts of rice and significantly increased yield (Geng et al., 2022). Exploring this potential in heavy metal-contaminated soils could be a means of reducing the heavy metal burden in Uganda's crop products, which has been reported in different parts of the country (Kasozi et al., 2021; Mongi & Chove, 2020; Tagumira et al., 2022). This could reduce the potential health effects of consuming foods laden with heavy metals. For example, cadmium toxicity has been associated with the development of itai-itai disease (Mitra et al., 2022) and a higher carcinogenic risk (Masereka et al., 2022).

In addition, it has been reported that frass from bioconversion by BSFL have pesticidal properties (Urrutia et al., 2023). The BSFL frass and the eyes of flies have antifungal properties (Kaczor et al., 2022) and the use of the former inhibits the growth of mycelia of a number of plant pathogens (Arabzadeh et al., 2022). Therefore, the use of BSFL frass would reduce crop loss due to pest infestation. However, more research on this effect should be conducted, as differences in the effectiveness of frasses in controlling fungal diseases have been reported (Arabzadeh et al., 2024).

Potential contribution of BSFL to production of animal source foods

There is a relationship between the aptness of consuming animal source foods (ASF) and ownership of livestock in Uganda and other sub-Saharan African countries (Hetherington et al., 2017). This was particularly reported for poultry in Uganda, which is the most common livestock species (Azzarri et al., 2015; Hetherington et al., 2017). The consumption of ASF is increasing because of the increasing number of households keeping livestock, although it is still below the recommended level. However, non-ruminant animal production is primarily constrained by the expensive protein ingredients used in formulating their diets (Nampijja et al., 2023). Conventional protein sources such as soybean and fish meals are coupled as protein sources in human diets, which threatens nutritional security. With increasing global nutrition insecurity concerns, FAO (2022) proclaimed an urgent need to search for alternative protein sources for use in animal diets to reduce competition for fish with humans. The most reliable candidate for this substitution is BSFL, which has proven to be a low-cost alternative protein source in livestock diets (Biasato et al., 2019; Hong & Kim, 2022) (Table 1). BSFL has a high crude protein (CP) content of 40–61% (Addeo et al., 2021; Crosbie et al., 2020; Hong & Kim, 2022) comparable to fish meal with a CP content of 60%. A large body of research exists on the subject of BSFL as an alternative protein source, and we do not intend to go deep into this in this review. However, since these larvae grow solely on organic wastes, sustainable waste generation would sustain the production of BSFL for preparing animal feeds which would reduce the cost burden on feeding livestock and probably contribute to increasing ASF consumption in Uganda and other developing countries.

SDG3- Good health and wellbeing

Despite efforts to ensure the good health of its citizens, nutrition-related diseases have remained persistently high in Uganda (Republic of Uganda, 2024). BSF products primarily present preventive measures, although chitin can also be used in the pharmaceutical industry because of its biomedical properties (Lv et al., 2023; Olza et al., 2023; Wang et al., 2020). First, biodiesel (elaborated under SDG 7) is a clean energy option that can be used to reduce respiratory illness due to the use of wood, for example, as cooking energy (Bede Ojimadu & Orisakwe, 2020; Pallegedara & Kumara, 2022). Embracing the use of biodiesel is a preventive strategy to ensure good health, especially for women who are always involved in cooking. In addition, the use of frass on heavy metal-contaminated agricultural soils, such as those around the steel and iron industries (Mpewo et al., 2023), could reduce heavy metal circulation in the food system (Table 1). This is because the application of BSFL frass to soils with high heavy metal loads results in crops with low heavy metal concentrations (Geng et al., 2022).

In addition, because BSFL bioconversion has minimal negative effects on climate (discussed in detail under SDG 13), we postulate that health-related cases associated with climate change could also be reduced. Recently, Palinkas and Wong (2020) reported that heat stress is one of the direct effects of climate change. In an overview of systematic reviews of the health effects of climate change conducted by Rocque et al. (2021), the authors realized that weather extremes were among the common causes of heat stress. The immediate micro-impact of increasing temperatures in Uganda has been experienced through increased cases of malaria due to warmer nights that favor the activities of mosquitoes (Obubu et al., 2021). With these climate-related health issues, we hypothesize that integrating BSF into Uganda's circular economy policies could contribute to slowing down, or even reversing (in the longer run), climate change processes related to waste management, and consequential health issues.

SDG7- Affordable and clean energy

'......... *The world is not on track to achieve universal access to clean ... energy by 2030'* (IEA, IRENA, UNSD World Bank and WHO, 2024). This is a statement in the recent energy progress report by custodian agencies in ensuring the attainment of SDG 7. The report also shows that less than 10% of Ugandans have access to clean cooking energy, despite being among the countries that have recently received financing for renewable energy. However, sustainable access to clean low-cost energy (both for cooking and other purposes) is important for the different sectors in the country, its economic growth, and that of Africa at large (Fashina et al., 2018).

In Uganda, there is a high dependence on forest resources for fuel, especially cooking energy (Katutsi et al., 2020). Even sawdust-based briquettes which have been embraced by several communities as alternative energy sources, are not environment-friendly because they result from deforestation (Oteu et al., 2024). Earlier research has appraised BSF larvae for biodiesel production (Ishak and Kamari 2019; Ishak et al., 2018; Liewet al., 2023a; 2023b; Mohan et al., 2023; Park et al., 2022; Wong et al., 2019). Some uses of biodiesel include electricity generation, heating, and fuel in diesel engines. Park et al. (2022) assessed the fuel properties of biodiesel from BSFL raised on food waste, and reported that all parameters satisfied the Korean fuel standards, except for oxidation stability (Table 1). However, even for oxidation stability, it necessitated the addition of a meager quantity of *tert-butylhydroquinone* to meet the Korean standards. Similarly, Jung et al. (2022) reported that biodiesel from BSFL produced from food waste and extracted by non-catalytic transesterification met the European Union and Korean standards. In addition, biodiesel from BSFL raised on thermally treated sewage sludge at a low temperature met the EN 14,214 and ASTM D6751 standards for biodiesel, except for the flash point (Liewet al., 2023a). Nonetheless, the flash point was still higher than that of petroleum diesel and was considered safer. Fortunately, biodiesel from BSFL is more environment-friendly than diesel from other sources (Liewet al., 2023b), making it an outstanding clean energy alternative.

Research on the choice of energy sources among rural Ugandan communities has shown that household income is one of the driving factors (Gebru & Elofsson, 2023; Mainimo et al., 2022; Katutsi et al., 2020). We cannot conclude that if biodiesel from BSFL bioconversion is embraced, it will ultimately be of a lower price. However, we postulate that this could contribute to increasing access to clean energy among households and, with favorable policies, might slightly lower the price of fuel. In addition, the multiple benefits of BSF rearing could outsmart the resultant prices of biodiesel. Furthermore, because BSFL biodiesel is safer than the fuel sources used in Uganda and other developing countries, embracing this innovation could reduce expenditure on health cases stemming from the use of other fuel sources. In a study in Sri Lanka, for example, it was found that using firewood for cooking increased the probability of household members suffering from asthma (Pallegedara & Kumara, 2022). A systematic review of research showing the association between wood fuel use and health in SSA (Uganda inclusive) revealed that exposure to smoke from wood fuel is associated with acute respiratory illness and impaired lung function (Bede Ojimadu & Orisakwe, 2020). To reverse this trend, investing in innovative approaches to scale up the use of BSFL-based biodiesel could save the country on these health issues.

Estimate of potential savings in using biodiesel in running diesel engines

With the current Kampala metropolitan population of over 4 million people, daily waste production can go over 3,000 metric tons (MT). This estimate is based on the daily waste generation reported by Ojok et al. (2013), which surpasses the estimates used by Koyunoğlu (2024) to calculate the potential biodiesel yield of a large-scale production plant.

The volume of biodiesel generated from 3,000 MT of organic waste was determined based on the following assumptions (Koyunoğlu, 2024):

- Dry matter 70 wt%
- Moisture content 30 wt%
- Biochemical oxygen demand (BOD) 50000 mg/L
- Biodiesel conversion efficiency 40%
- Biodiesel density 0.88 g/mL

Thus, total dry matter= $\frac{70}{100} \times 3,000 = 2,100\ MT/day$

Biodiesel conversion efficiency (%)= $\frac{Massoutput}{Massinput} \times 100$.

Thus, mass of biodiesel produced $= \frac{40}{100} \times 2100 = 840 MT/day$

Volume of biodiesel produced= $\frac{Mass}{Density}$ *litres*

$$= \frac{840 \times 1000 \times 1000g}{0.88g/mL}$$

= 954,545,454.5 mL

= 954,545.5 L/day

Although minimal information exists on the unit consumption of fuel by the Metu™ buses which are assembled in Uganda, we estimated (basing on our knowledge) that about 16 L could cover a total distance of about 100 km. Thus, the 954,545.5 L produced per day would cover a total distance of 59,659 km which is equivalent to fueling 180 buses moving about 330 km from Kampala (Uganda's capital city) to Gulu, one of the biggest cities in Northern Uganda. Kovbasenko and Simonenko (2023) tested biodiesel on PAZ-32054 buses and found biodiesel consumption to be averagely 14% higher than the traditional diesel. If we are to adopt this level of biodiesel consumption (although it may vary) this lowers to 820,909 L of useable biodiesel which can travel 51,307 km, an equivalent of fuelling 155 buses from Kampala to Gulu.

When using seed oils as the feedstock in biodiesel production, Tibesigwa et al. (2023) estimated the final price of a litre of biodiesel at US $ 1.5. However, we estimate that BSFL biodiesel would cost lower since the oil is a by-product (after defatting the larvae for use in animal feeds). Thus, assuming the cost of a litre of oil to be US $ 1, a bus company would save about US $ 0.39 per litre of diesel using the current price of tradition diesel in Uganda (US $ 1.39). Assuming equal performance (though it might not be the case), it is postulated that using BSFL biodiesel would offer a cost-effective alternative for diesel engine vehicles in the country.

SDG13- Climate action: Take urgent action to combat climate change and its impact

Climate change and adaptation strategies in Uganda

Climate change is a universal current and long-term constraint for achieving sustainable development

(Apollo & Mbah, 2021). The impacts of climate change in Uganda are currently more evident than two decades earlier. Floods, droughts (Twinomuhangi et al., 2021) and unpredictable seasons are among the clearest indicators of climate change in Uganda. This puts Uganda's food security at stake since, even with the adaptation measures, the impacts of climate change will soon circumvent all adaptation strategies. The appraised adaptation strategies suggested by Atube et al. (2021), such as planting drought-tolerant varieties do not reduce the contribution of agriculture to climate change processes. Indirectly, opening up new land for agriculture interferes with the natural ecosystem, thereby affecting natural regenerative processes (Jakovac et al., 2021). Agriculture is one of the primary contributors to greenhouse gas (GHG) emissions in the atmosphere (Gołasa et al., 2021), thereby enhancing climate change processes (Ortiz et al., 2021).

Agriculture's contribution to GHG emission is through production and related activities, and through waste disposal (Tubiello et al., 2021), with Africa having the largest share of GHGs from Agriculture (FAO, 2020a, 2020b). A further synthesis by FAO (2020b) on individual contributions to non-CO_2 agriculture-related emissions, for example, revealed a 20% contribution from livestock manure, 4% from crop residues, and 6% from manure management. Although data on Uganda's emissions from crops, animals, and other organic wastes are scarce, the quantity of waste generated indicates a significant contribution to climate change catastrophe. A precise estimate, though not very current, revealed that every individual in Uganda generates 0.55 kg of wastes per day (Okot-Okumu & Nyenje, 2011). Among these, the authors reported that over 0.4 kg are biodegradable. In Kampala, Uganda's capital, an even higher waste generation of food wastes alone was reported at 0.75 kg/capita/day (Ojok et al., 2013). Although uncategorised, the above waste generation data provide a snapshot of the potential climate change effects accruing from Uganda's waste generation. In addition, because waste generation increases with an increase in population, it is most likely that the current quantities could be almost twice the above figures.

Uganda's waste collection and management system is very inefficient due to limited financing (GIZ, 2023) and a low level of community awareness of the importance of managing waste (Mugambe et al., 2022). The study by Mugambe et al. (2022), assessing the behavior of individuals on segregating wastes, realized that this depends on the availability of segregation containers in close proximity to the individuals. However, even with segregation, the inefficiency in collection by the responsible bodies might not achieve the desired waste management level.

How BSF rearing could contribute to reducing climate change processes

In search of innovative waste management practices, Ahmad et al. (2023) developed a BSFL bin. This is placed in the open and allows for BSF from the wild to lay eggs, which on hatching into larvae, will grow on the waste, turning them to frass, while the larvae can be harvested for use in animal feeds. Fortunately, the bin can be fabricated locally. Since individuals opt to segregate waste when expecting incentives (Mugambe et al., 2022), the income from the sale of frass and larvae could be an incentive to let farmers segregate waste. Embracing this initiative could possibly lead individuals to recycle organic waste at will. In assessing the potential use of BSFL as a waste management initiative among rural housewives, Nadeak (2023) reported that economic and social benefits attached to the initiative would be pivotal in influencing its uptake. For example, the benefits of either direct use or sale of frass and larvae as animal feed could influence the uptake of BSFL bins if introduced to communities. This could be a strategy to manage waste and thus reduce climate change processes owing to poor waste handling.

Concerning the environmental effects of waste biodegradation using BSFL, Panget al. (2020a) reported a significant reduction in CH_4 and N_2O emissions from food waste. When compared with aerobic microbial biodegradation, Perednia et al. (2017) realized that degradation by BSFL emitted 28.5% of the carbon in the atmosphere, as opposed to the 48.6% emission when aerobic microbes were used (Table 1). Pretreatment of fruit and vegetable wastes with ammonia prior to BSFL bioconversion was found to further reduce CH_4 and N_2O emissions during the process (Lindberg et al., 2022). A more critical assessment of GHG emissions from BSFL bioconversion by Parodi et al. (2020) reported relatively higher values than those reported in previous studies. However, the study acknowledged higher moisture losses from the substrates during rearing and realized that with optimal moisture content, a lower level of GHG emissions could be realized. In addition, because the carbon-to-nitrogen ratio (C/N) influences BSFL growth, Panget al. (2020b) found that the same influences the level of GHG emissions from BSFL bioconversion. In addition, balancing the C/N ratio in the substrate is important when using BSFL to biodegrade organic wastes. Chen et al. (2019) also reported a positive correlation between the CH_4 emissions and moisture content. Thus, providing the optimal moisture content for BSFL bioconversion would reduce the level of GHG emissions. Notwithstanding the reported variations in findings, BSFL presents a more environment-friendly alternative to organic waste management and a higher global warming potential reduction (Mertenat et al., 2019).

Potential limitations to the contribution of BSF towards SGD attainment

Even with insects that are considered edible among insectivorous communities of Uganda, there is still some level of neophobia against these species (Olum et al., 2021). Therefore, there is also a high likelihood that the use of these '*maggots*' as they are always referred to- and rightly so- in some products might be hindered by neophobia against consumption of products raised from them. Despite several studies reporting higher consumer preference and willingness-to-pay for bakery products with BSFL as one of the ingredients (Delicato et al., 2020), eggs from chickens fed BSFL-based diets (Khaemba et al., 2022), organic fertilizer from BSFL bioconversion of waste (Kragt et al., 2023) and crops produced using BSFL frass (Traore et al., 2024), their direct consumption as food for humans has gained minimal acceptance (Higa et al., 2021). Concerning the acceptance of bakery products containing BSFL, localized studies should be conducted; otherwise, it is inappropriate to generalize the findings to all countries. This is because some studies have reported that some consumers still take BSFL as a yucky organism (Adetunmbi, 2023), which might hinder their acceptance, especially as food for humans in the developing world.

Policy implications

Although the above attributes put BSF rearing at the forefront in sustainable development efforts, policymakers need to strike a compromise between benefits and public acceptance. Thus, a well-thought and informed decision-making process should be employed, involving all stakeholders in decisions regarding the use of BSF and their products as food for humans or in the production of human food from animals and/or crops. Individual countries should establish what their citizens would primarily accept from the BSF and promote economic development in their economies. Otherwise, generalized information might not yield a unified outcome when using insects in development efforts.

With regards to Uganda, the use of BSF products is still unregulated. This puts the consumers of foods produced using BSF products at stake. We recommend the formulation of policies to guide the use of these products in the food system. Particularly, policies to guide production of feed-grade BSFL and frass will contribute to realisation of premium markets for these products locally and internationally. This would enhance the incomes of farmers and other actors within the BSF value chain. It will also protect the lives of consumers of food products produced using BSFL and frass.

Need for regulations

Despite its potential to lead the way to better economies in the developing world, unregulated use of BSFL could predispose the population to health risks. As they degrade organic matter, the BSFL accumulate microorganisms that can enter the food chain with insufficient postharvest treatment (Bessa et al., 2021). A study by Grisendi et al. (2022) showed that, although BSFL reduced the concentration of *Salmonella typhimurium* in contaminated wastes, the larvae did not completely eliminate them and also appeared in the larvae tissue. Furthermore, BSFL can thrive within living vertebrates if either consumed alive or through openings such as wounds (Rojo, 2024). Many farmers are unaware of this and give live larvae to their animals, predisposing the animals to the risk of death as the larvae feed on animal tissues. In addition, the potential of the larvae to bioaccumulate heavy metals such as Cd and Pb within the tissues (Purschke et al., 2017) also predisposes consumers of BSFL-based products to health risks. To this end, the Uganda National Bureau of Standards should establish standards to regulate the use of BSFL-based products. This should also align with existing standards, for example, the minimum acceptable concentration of heavy metals and microbial load for products to be included in human diets, livestock feeds, and fertilizer use.

Limitations to this review

Due to inconsistencies and the scarcity of reliable data on the current volumes of organic wastes generated in Uganda, we could not precisely and statistically extrapolate the contribution of BSF to the achievement of the SDGs discussed here. This is particularly true because the success of any BSF operation is largely dependent on organic waste generation. Thus, our review provides a starting point to simulate the potential contribution of BSF to the attainment of SDGs in case the data on waste generation is available. Furthermore, we are aware that the success of these innovations partly depends on the will of policymakers in the developing world. Thus, although our study might theoretically portray BSF rearing as actually '*forerunner*' to the attainment of the discussed SDGs, policymakers must weigh and ensure that if this is a feasible option, it is put into practice. To allow for a precise estimate of the potential contribution of BSF rearing to achieving the SDGs discussed, we recommend periodical update of the volumes of organic wastes produced in the different parts of the country. For the case of wastes from crop production systems, for example, this could be done by tracking losses along the different value chains, right from production to the final consumer.

Conclusion

This review highlights the significant potential of integrating BSF into strategies aimed at contributing to the achievement of SDGs 1, 2, 3, 7, and 13 in the context of developing countries. With a decline in funding from the developed world to developing economies, the individual efforts of the developing countries will be pivotal in attaining the SDGs. It is important for the developing world to invest in cost-effective innovations that could contribute to efforts to attain SDGs. Herein, we review the potential of BSF as a cost-effective initiative to contribute directly to the attainment of the selected SDGs using BSFL in organic waste management. Although we have only discussed the above SDGs, we are sure that since no SDG is independent of the other, embracing BSF rearing has the potential to contribute to the attainment of other SDGs indirectly. Nonetheless, policymakers will be pivotal in the pursuit of embracing BSF rearing as a tool for economic development in developing countries. Once reliable data on organic waste generation is available, we recommend further research to establish the feasibility of the proposed intervention in the face of factors such as policy, consumer behavior, and seasonal variations. Since BSF rearing is still in its infancy in Uganda and other developing countries, we also recommend that farmers and other actors along the BSF value chain be trained in production (rearing) and processing into different products.

Acknowledgements

We are indebted to all authors whose work has been cited herein. Without this, this review would be an impossible task.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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All authors confirm their contribution to the paper as follows: study conception and design, and draft manuscript preparation: Kasima JS; review of draft manuscript: Kasima JS, Mugonola B, Menya E, Ndaula S, and Ndyomugyenyi EK. All authors agree with the content of the final version of the manuscript.

Data availability statement

All data related to this review have been presented in this paper.

References

Abro, Z., Macharia, I., Mulungu, K., Subramanian, S., Tanga, C. M., & Kassie, M. (2022). The potential economic benefits of insect-based feed in Uganda. *Frontiers in Insect Science*, *2*(2022), 1–14. https://doi.org/10.3389/finsc.2022.968042

Addeo, N. F., Vozzo, S., Secci, G., Mastellone, V., Piccolo, G., Lombardi, P., Parisi, G., Asiry, K. A., Attia, Y. A., & Bovera, F. (2021). Different combinations of butchery and vegetable wastes on growth performance, chemical-nutritional characteristics and oxidative status of black soldier fly growing larvae. *Animals*, *11*(12), 1–12. https://doi.org/10.3390/ani11123515

Adetunmbi, T. (2023). The potential of insects as alternative animal protein source for livestock feeding. *Global Journal of Agricultural Sciences*, *22*(2023), 47–61. https://doi.org/10.4314/gjass.v22i1.6

Ahimbisibwe, K. F., & Kontinen, T. (2021). Localising SDGs in rural Uganda: Learning active citizenship through the *saemaul undong* model. In G. Nhamo, M. Togo, & K. Dube (Eds.), *Sustainable development goals for society vol. 1. Sustainable development goals series*. Springer. https://doi.org/10.1007/978-3-030-70948-8_3

Ahmad, I. K., Mohamed, Z. S., Amrul, N. F., Quan, C. W., Jalil, N. A. A., Basri, N. E. A., & Azmi, M. R. (2021). Composting fruit and vegetable waste using black soldier fly larvae. *Jurnal Kejuruteraan*, *33*(4), 837–843. https://doi.org/10.17576/jkukm-2021-33(4)-06

Ahmad, I. K., Peng, N. T., Amrul, N. F., Basri, N. E. A., Jalil, N. A. A., & Azman, N. A. (2023). Potential application of black soldier fly larva bins in treating food waste. *Insects*, *14*(5), 1–15. https://doi.org/10.3390/insects14050434

Annan-Aggrey, E., Bandauko, E., & Arku, G. (2021). Localising the sustainable development goals in Africa: Implementation challenges and opportunities. *Common Wealth Journal of Local Governance*, *2021*(24), 4–23. https://doi.org/10.5130/cjlg.vi24.7739

Apollo, A., & Mbah, M. F. (2021). Challenges and opportunities for climate change education (Cce) in East Africa:

A critical review. *Climate*, *9*(6), 1–16. https://doi.org/10.3390/cli9060093

Arabzadeh, G., Delisle-Houde, M., Tweddell, R. J., Deschamps, M. H., Dorais, M., Lebeuf, Y., Derome, N., & Vandenberg, G. (2022). Diet composition influences growth performance, bioconversion of black soldier fly larvae: Agronomic value and in vitro biofungicidal activity of derived frass. *Agronomy*, *12*(8), 1–19. https://doi.org/10.3390/agronomy12081765

Arabzadeh, G., Delisle-Houde, M., Vandenberg, G. W., Deschamps, M. H., Dorais, M., Derome, N., & Tweddell, R. J. (2024). Suppressive effect of black soldier fly larvae frass on fusarium wilt disease in tomato plants. *Insects*, *15*(8), 1–6. https://doi.org/10.3390/insects15080613

Arora, R. U., & Sarker, T. (2023). Financing for sustainable development goals (SDGs) in the era of COVID-19 and beyond. *European Journal of Development Research*, *35*(1), 1–19. https://doi.org/10.1057/s41287-022-00571-9

Aryampa, S., Maheshwari, B., Sabiiti, E., Bateganya, N. L., & Bukenya, B. (2019). Status of waste management in the East African cities: Understanding the drivers of waste generation, collection and disposal and their impacts on Kampala City's sustainability. *Sustainability*, *11*(19), 1–16. https://doi.org/10.3390/su11195523

Attiogbe, F. K., Ayim, N. Y. K., & Martey, J. (2019). Effectiveness of black soldier fly larvae in composting mercury contaminated organic waste. *Scientific African*, *6*(2019), 1–10. https://doi.org/10.1016/j.sciaf.2019.e00205

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture & Food Security*, *10*(1), 1–14. https://doi.org/10.1186/s40066-020-00279-1

Ayoo, C. (2022). Poverty reduction strategies in developing countries. *Rural Development-Education, Sustainability, Multifunctionality*, 1–19. https://doi.org/10.5772/intechopen.101472

Azzarri, C., Zezza, A., Haile, B., & Cross, E. (2015). Does livestock ownership affect animal source foods consumption and child nutritional status? Evidence from rural Uganda. *The Journal of Development Studies*, *51*(8), 1034–1059. https://doi.org/10.1080/00220388.2015.1018905

Barbier, E. B., & Burgess, J. C. (2023). Natural capital, institutional quality and SDG progress in emerging market and developing economies. *Sustainability*, *15*(4), 1–19. https://doi.org/10.3390/su15043055

Barua, S. (2020). Financing sustainable development goals: A review of challenges and mitigation strategies. *Business Strategy & Development*, *3*(3), 277–293. https://doi.org/10.1002/bsd2.94

Basri, N. E. A., Azman, N. A., Ahmad, I. K., Suja, F., Jalil, N. A. A., & Amrul, N. F. (2022). Potential applications of frass derived from black soldier fly larvae treatment of food waste: A review. *Foods*, *11*(17), 1–19. https://doi.org/10.3390/foods11172664

Bede Ojimadu, O., & Orisakwe, O. E. (2020). Exposure to wood smoke and associated health effects in Sub-Saharan Africa: A systematic review. *Annals of Global Health*, *86*(1), 1–27. https://doi.org/10.5334/aogh.2725

Bessa, L. W., Pieterse, E., Marais, J., Dhanani, K., & Hoffman, L. C. (2021). Food safety of consuming black soldier fly (*Hermetia illucens*) larvae: Microbial, heavy metal and cross-reactive allergen risks. *Foods*, *10*(8), 1–20. https://doi.org/10.3390/foods10081934

Bessa, L. W., Pieterse, E., Marais, J., & Hoffman, L. C. (2020). Why for feed and not for human consumption? The black soldier fly larvae. *Comprehensive Reviews in Food Science and Food Safety*, *19*(5), 2747–2763. https://doi.org/10.1111/1541-4337.12609

Biasato, I., Renna, M., Gai, F., Dabbou, S., Meneguz, M., Perona, G., Martinez, S., Lajusticia, A. C. B., Bergagna, S., Sardi, L., Capucchio, M. T., Bressan, E., Dama, A., Schiavone, A., & Gasco, L. (2019). Partially defatted black soldier fly larva meal inclusion in piglet diets: Effects on the growth performance, nutrient digestibility, blood profile, gut morphology and histological features. *Journal of Animal Science and Biotechnology*, *10*(1), 2–11. https://doi.org/10.1186/s40104-019-0325-x

Castellani, P., Ferronato, N., & Torretta, V. (2022). Setting priorities to achieve sustainable development goals through appropriate waste management systems in Uganda. *Environmental Development*, *44*, 100764. https://doi.org/10.1016/j.envdev.2022.100764

Chaparro-Banegas, N., Ibañez Escribano, A. M., Mas-Tur, A., & Roig-Tierno, N. (2024). Innovation facilitators and sustainable development: A country comparative approach. *Environment, Development, and Sustainability*, *26*(4), 8467–8495. https://doi.org/10.1007/s10668-023-03055-w

Chen, J., Hou, D., Pang, W., Nowar, E. E., Tomberlin, J. K., Hu, R., Chen, H., Xie, J., Zhang, J., Yu, Z., & Li, Q. (2019). Effect of moisture content on greenhouse gas and NH3 emissions from pig manure converted by black soldier fly. *Science of the Total Environment*, *697*(2019), 133840. https://doi.org/10.1016/j.scitotenv.2019.133840

Chia, S. Y., Macharia, J., Diiro, G. M., Kassie, M., Ekesi, S., van Loon, J. J., Dicke, M., & Tanga, C. M. (2020). Smallholder farmers' knowledge and willingness to pay for insect-based feeds in Kenya. *PLOS ONE*, *15*(3), 1–25. https://doi.org/10.1371/journal.pone.0230552

Crosbie, M., Zhu, C., Shoveller, A. K., & Huber, L. (2020). Standardized ileal digestible amino acids and net energy contents in full fat and defatted black soldier fly larvae meals (*Hermetia illucens*) fed to growing pigs. *Translational Animal Science*, *4*(3), 1–10. https://doi.org/10.1093/tas/txaa104

Danladi, S., Prasad, M. S. V., Modibbo, U. M., Ahmadi, S. A., & Ghasemi, P. (2023). Attaining sustainable development goals through financial inclusion: Exploring collaborative approaches to Fintech adoption in developing economies. *Sustainability*, *15*(17), 1–14. https://doi.org/10.3390/su151713039

Davies, I. E. E., Nwankwo, C. O., Olofinnade, O. M., & Michaels, T. A. (2019). Insight review on impact of infrastructural development in driving the SDGs in developing nations: A case study of Nigeria. *IOP Conference Series*, *640*(1), 1–9. https://doi.org/10.1088/1757-899X/640/1/012112

Delicato, C., Schouteten, J. J., Dewettinck, K., Gellynck, X., & Tzompa-Sosa, D. A. (2020). Consumers' perception of bakery products with insect fat as partial butter replacement. *Food Quality and Preference*, *79*(2020), 103755. https://doi.org/10.1016/j.foodqual.2019.103755

FAO. (2020a). *The share of agriculture in total greenhouse gas emissions. Global, regional and country trends: 1990-2017. FAOSTAT analytical brief series No 1*, 6. Retrieved September 14, 2024, from https://openknowledge.fao.org/server/api/core/bitstreams/7fe33d41-3969-4f87-95c5-4b897229350b/content .

FAO. (2020b). *Emissions due to agriculture. Global, regional and country trends 2000-2018. FAOSTAT analytical brief series no 18*. Retrieved September 14, 2024, from https://openknowledge.fao.org/server/api/core/bitstreams/cc09fbbc-eb1d-436b-a88a-bed42a1f12f3/content

FAO. (2022). *The state of world fisheries and aquaculture 2022. Towards blue transformation*. https://doi.org/10.4060/cc0461en

Fashina, A., Mundu, M., Akiyode, O., Abdullah, L., Sanni, D., & Ounyesiga, L. (2018). The drivers and barriers of renewable energy applications and development in Uganda: A review. *Clean Technologies*, *1*(1), 9–39. https://doi.org/10.3390/cleantechnol1010003

Food Rights Alliance. (2020, September). *Observance and awareness creation. Briefing paper food loss and waste*, 8. Retrieved September 9, 2024, from https://fra.ug/wp-content/uploads/2021/03/FOOD-LOSS-WASTE-1.pdf

Gärttling, D., & Schulz, H. (2022). Compilation of black soldier fly frass analyses. *Journal of Soil Science and Plant Nutrition*, *22*(1), 937–943. https://doi.org/10.1007/s42729-021-00703-w

Gebremikael, M. T., Wickeren, N. V., Hosseini, P. S., & De Neve, S. (2022). The impacts of black soldier fly frass on nitrogen availability, microbial activities, C sequestration, and plant growth. *Frontiers in Sustainable Food Systems*, *6*(2022), 1–13. https://doi.org/10.3389/fsufs.2022.795950

Gebru, B., & Elofsson, K. (2023). The role of forest status in households' fuel choice in Uganda. *Energy Policy*, *173* (2023), 1–14. https://doi.org/10.1016/j.enpol.2022.113390

Geng, W., Zhao, Y., Mao, Z., Wang, X., Wu, N., & Xu, X. (2022). The effects of combined use of black soldier fly larvae frass fertilizer with exogenous selenium on rice growth and accumulation of heavy metals. *Journal of Soil Science and Plant Nutrition*, *22*(4), 5133–5143. https://doi.org/10.1007/s42729-022-00989-4

GIZ. (2023). *Sector brief Uganda*: Renewable energy, 8. Retrieved September 14, 2024, from https://www.giz.de/de/downloads/giz2023-en-sectorbrief-uganda-waste.pdf

Gołasa, P., Wysokiński, M., Bieńkowska-Gołasa, W., Gradziuk, P., Golonko, M., Gradziuk, B., Siedlecka, A., & Gromada, A. (2021). Sources of greenhouse gas emissions in agriculture, with particular emphasis on emissions from energy used. *Energies*, *14*(13), 1–20. https://doi.org/10.3390/en14133784

Gold, M., Tomberlin, J. K., Diener, S., Zurbrügg, C., & Mathys, A. (2018). Decomposition of biowaste macronutrients, microbes, and chemicals in black soldier fly larval treatment: A review. *Waste Management*, *82*(2018), 302–318. https://doi.org/10.1016/j.wasman.2018.10.022

Gonzalez, C. G., & Ebbesson, J. (2021). SDG 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. In E. Hey (Ed.), *The cambridge handbook on the SustainableDevelopment goals and international law* (pp. 1–26). Cambridge University Press. https://ssrn.com/abstract=3976582

Grisendi, A., Defilippo, F., Lucchetti, C., Listorti, V., Ottoboni, M., Dottori, M., Serraino A., Pinotti L., & Bonilauri, P. (2022). Fate of Salmonella enterica Typhimurium and Listeria monocytogenes in black soldier fly (*Hermetia illucens*) larvae reared on two artificial diets. *Foods*, *11*(15), 1–13. https://doi.org/10.3390/foods11152208

Guerrero-Ruiz, A., Sachin, K., & Schnatz, J. (2021). *Aligning development co-operation to the SDGs in least developed countries: A case study of Uganda. OECD development Co-operation working papers, No. 102*, 71. OECD Publishing.

Halisçelik, E., & Soytas, M. A. (2018). Sustainable development from millennium 2015 to sustainable development goals 2030. *Sustainable Development*, *27*(4), 545–572. https://doi.org/10.1002/sd.1921

Hetherington, J. B., Wiethoelter, A. K., Negin, J., & Mor, S. M. (2017). Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agriculture & Food Security*, *6*(1), 1–11. https://doi.org/10.1186/s40066-016-0079-z

Hickmann, T., Biermann, F., Spinazzola, M., Ballard, C., Bogers, M., Forestier, O., Kalfagianni, A., Kim, R. E., Montesano, F. S., Peek, T., Sénit, C.-A., van Driel, M., Vijge, M. J., & Yunita, A. (2023). Success factors of global goal-setting for sustainable development: Learning from the Millennium development goals. *Sustainable Development*, *31* (3), 1214–1225. https://doi.org/10.1002/sd.2461

Higa, J. E., Ruby, M. B., & Rozin, P. (2021). Americans' acceptance of black soldier fly larvae as food for themselves, their dogs, and farmed animals. *Food Quality and Preference*, *90*(2021), 104119. https://doi.org/10.1016/j.foodqual.2020.104119

Hinson, R., Lensink, R., & Mueller, A. (2019). Transforming agribusiness in developing countries: SDGs and the role of FinTech. *Current Opinion in Environmental Sustainability*, *41*(2019), 1–9. https://doi.org/10.1016/j.cosust.2019.07.002

Hlongwane, Z. T., Slotow, R., & Munyai, T. C. (2021). The role of edible insects in rural livelihoods, and identified challenges in Vhembe District, Limpopo, South Africa. *Resources (Basel, Switzerland)*, *10*(12), 1–14. https://doi.org/10.3390/resources10120123

Hong, J., & Kim, Y. Y. (2022). Insect as feed ingredients for pigs. *Animal Bioscience*, *35*(2), 347–355.

Houssam, N., Ibrahiem, D. M., Sucharita, S., El-Aasar, K. M., Esily, R. R., & Sethi, N. (2023). Assessing the role of green economy on sustainable development in developing countries. *Heliyon*, *9*(6), 1–15. https://doi.org/10.1016/j.heliyon.2023.e17306

Hoy, C. Can developing countries afford the SDGs. *Development Policy Centre*, *2016*(2016), 1–4. Retrieved September 9, 2024, from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=SDGs+in+the+developing+world&btnG=#d=gs_cit&t=1725443681525&u=%2Fscholar%3Fq%3Dinfo%3A82-nxd9DL7UJ%3Ascholar.google.com%2F%26output%3Dcite%26scirp%3D0%26hl%3Den

IEA, IRENA, UNSD World Bank and WHO. (2024). *Tracking SDG 7: The energy progress report. World Bank, Washington DC. © World Bank*, 179. Retrieved September 14, 2024, from https://www.seforall.org/system/files/2024-06/Tracking%20SDG7%20-%20final%20report.pdf.

Indiana, F., & Pahlevi, R. W. (2023). A bibliometric approach to sustainable development goals (SDGs) systematic analysis. *Cogent Business & Management*, *10*(2), 1–12. https://doi.org/10.1080/23311975.2023.2224174

Ishak, S., & Kamari, A. (2019). Biodiesel from black soldier fly larvae grown on restaurant kitchen waste. *Environmental Chemistry Letters*, *17*(2019), 1143–1150. https://doi.org/10.1007/s10311-018-00844-y

Ishak, S., Kamari, A., Yusoff, S. N. M., & Halim, A. L. A. (2018, September). Optimisation of biodiesel production of black soldier fly larvae rearing on restaurant kitchen waste. *Journal of Physics: Conference Series*, *1097*(12052), 1–8. https://doi.org/10.1088/1742-6596/1097/1/012052

Jakovac, C. C., Junqueira, A. B., Crouzeilles, R., Peña-Claros, M., Mesquita, R. C., & Bongers, F. (2021). The role of land-use history in driving successional pathways and its implications for the restoration of tropical forests. *Biological Reviews*, *96*(4), 1114–1134. https://doi.org/10.1111/brv.12694

Jung, S., Jung, J. M., Tsang, Y. F., Bhatnagar, A., Chen, W. H., Lin, K. Y. A., & Kwon, E. E. (2022). Biodiesel production from black soldier fly larvae derived from food waste by non-catalytic transesterification. *Energy*, *238*(2022), 121700. https://doi.org/10.1016/j.energy.2021.121700

Kaczor, M., Bulak, P., Proc-Pietrycha, K., Kirichenko-Babko, M., & Bieganowski, A. (2022). The variety of applications of Hermetia illucens in industrial and agricultural areas. *Biology*, *12*(1), 1–36. https://doi.org/10.3390/biology12010025

Kasozi, K. I., Otim, E. O., Ninsiima, H. I., Zirintunda, G., Tamale, A., Ekou, J., Otim, E. O., Musoke, G. H., Muyinda, R., Matama, K., Mujinya, R., Matovu, H., Ssempijja, F., Eze, E. D., Atino, M., Udechukwu, B., Kayima, R., Etiang, P., Batiha, G. E. S., … Otim, O. (2021). An analysis of heavy metals contamination and estimating the daily intakes of vegetables from Uganda. *Toxicology Research and Application*, *5*(2021), 1–15. https://doi.org/10.1177/2397847320985255

Katutsi, V., Dickson, T., & Migisha, A. G. (2020). Drivers of fuel choice for cooking among Uganda's households. *Open Journal of Energy Efficiency*, *9*(3), 111–129. https://doi.org/10.4236/ojee.2020.93008

Khaemba, C. N., Kidoido, M. M., Owuor, G., & Tanga, C. M. (2022). Consumers' perception towards eggs from laying hens fed commercial black soldier fly (Hermetia illucens) larvae meal-based feeds. *Poultry Science*, *101*(3), 1–10. https://doi.org/10.1016/j.psj.2021.101645

Klammsteiner, T., Turan, V., Fernández-Delgado Juárez, M., Oberegger, S., & Insam, H. (2020). Suitability of black soldier fly frass as soil amendment and implication for organic waste hygienization. *Agronomy*, *10*(10), 1–12. https://doi.org/10.3390/agronomy10101578

Koch, F., & Krellenberg, K. (2018). How to contextualize SDG 11? looking at indicators for sustainable urban development in Germany. *International Journal of Geo-Information*, *7*(12), 1–16. https://doi.org/10.3390/ijgi7120464

Kovbasenko, S. V., & Simonenko, V. V. (2023). Research of diesel bus performances under diesel biofuel operation conditions. *Bulletin of the Kharkiv National Automobile and Road University*, *2*(101), 104–109. https://doi.org/10.30977/BUL.2219-5548.2023.101.2.104-109

Koyunoğlu, C. (2024). Biofuel production utilizing black soldier fly (Hermetia illucens): A sustainable approach for organic waste management. *International Journal of Thermofluids*, *23*(2024), 1–14. https://doi.org/10.1016/j.ijft.2024.100754

Kragt, M. E., Dempster, F., & Subroy, V. (2023). Black soldier fly fertilisers by bioconversion of livestock waste: Farmers' perceptions and willingness-to-pay. *Journal of Cleaner Production*, *411*(2023), 1–11. https://doi.org/10.1016/j.jclepro.2023.137271

Leal-Filho, W., Tripathi, S. K., Guerra, J. B. S. O. D. A., Giné-Garriga, R., Lovren, V. O., & Willats, J. (2019). Using the sustainable development goals towards a better understanding of sustainability challenges. *International Journal of Sustainable Development & World Ecology*, *26*(2), 179–190. https://doi.org/10.1080/13504509.2018.1505674

Leal-Filho, W., Wolf, F., Lange Salvia, A., Beynaghi, A., Shulla, K., Kovaleva, M., & Vasconcelos, C. R. (2020). Heading towards an unsustainable world: Some of the implications of not achieving the SDGs. *Discover Sustainability*, *1*(1), 1–11. https://doi.org/10.1007/s43621-020-00002-x

Liew, C. S., Mong, G. R., Lim, J. W., Raksasat, R., Rawindran, H., Hassan, M. A., Lam, M. K., Khoo, K. S., & Zango, Z. U. (2023a). Low-temperature thermal pre-treated sewage sludge for feeding of black soldier fly (Hermetia illucens) larvae: Protein, lipid and biodiesel profile and characterization. *Renewable and Sustainable Energy Reviews*, *178*(2023), 113241. https://doi.org/10.1016/j.rser.2023.113241

Liew, C. S., Mong, G. R., Lim, J. W., Raksasat, R., Rawindran, H., Leong, W. H., Devendran Manogaran, M., Ho Chai, Y., Chia Ho, Y., Ur Rahmah, A., Lin, C., Shiong Khoo, K., & Kiatkittipong, W. (2023b). Life cycle assessment: Sustainability of biodiesel production from black soldier fly larvae feeding on thermally pre-treated sewage sludge under a tropical country setting. *Waste Management*, *164*(2023), 238–249. https://doi.org/10.1016/j.wasman.2023.04.013

Lindberg, L., Ermolaev, E., Vinnerås, B., & Lalander, C. (2022). Process efficiency and greenhouse gas emissions in black soldier fly larvae composting of fruit and vegetable waste with and without pre-treatment. *Journal of Cleaner Production*, *338*(2022), 1–10. https://doi.org/10.1016/j.jclepro.2022.130552

Lopes, I. G., Yong, J. W., & Lalander, C. (2022). Frass derived from black soldier fly larvae treatment of biodegradable wastes. A critical review and future perspectives. *Waste Management*, *142*(2022), 65–76. https://doi.org/10.1016/j.wasman.2022.02.007

Lv, J., Lv, X., Ma, M., Oh, D. H., Jiang, Z., & Fu, X. (2023). Chitin and chitin-based biomaterials: A review of advances in processing and food applications. *Carbohydrate Polymers*, *299*(2023), 120142. https://doi.org/10.1016/j.carbpol.2022.120142

Mainimo, E. N., Okello, D. M., Mambo, W., & Mugonola, B. (2022). Drivers of household demand for cooking energy: A case of Central Uganda. *Heliyon*, *8*(3), 1–7. https://doi.org/10.1016/j.heliyon.2022.e09118

Masereka, J., Byamugisha, D., & Adaku, C. (2022). Heavy metal accumulation in vegetables grown in rock soils of kilembe copper mine, Kasese, Western Uganda. *Asian Journal of Applied Chemistry Research*, *12*(1), 30–40. https://doi.org/10.9734/AJACR/2022/v12i1213

Mayanja, C. S., & Nkata, J. L. (2019). Pursuing sustainable development goals in Uganda: Do anti-corruption strategies of management development institutes matter? *Journal* *of Public Administration and Policy Research*, *11*(4), 38–47. https://doi.org/10.5897/JPAPR2019.0457

Medina-Hernández, E. J., Guzmán-Aguilar, D. S., Muñiz-Olite, J. L., & Siado-Castañeda, R. L. (2023). The current status of the sustainable development goals in the world. *Development Studies Research*, *10*(1), 1–13. https://doi.org/10.1080/21665095.2022.2163677

Mertenat, A., Diener, S., & Zurbrügg, C. (2019). Black soldier fly biowaste treatment-assessment of global warming potential. *Waste Management*, *84*(2019), 173–181. https://doi.org/10.1016/j.wasman.2018.11.040

Mitra, S., Chakraborty, A. J., Tareq, A. M., Emran, T. B., Nainu, F., Khusro, A., Idris, A. M., Khandaker, M. U., Osman, H., Alhumaydhi, F. A., & Simal-Gandara, J. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity. *Journal of King Saud University-Science*, *34*(3), 1–23. https://doi.org/10.1016/j.jksus.2022.101865

Mohan, K., Sathishkumar, P., Rajan, D. K., Rajarajeswaran, J., & Ganesan, A. R. (2023). Black soldier fly (Hermetia illucens) larvae as potential feedstock for the biodiesel production: Recent advances and challenges. *Science of the Total Environment*, *859*, 160235. https://doi.org/10.1016/j.scitotenv.2022.160235

Mongi, R., & Chove, L. (2020). Heavy metal contamination in cocoyam crops and soils in countries around the Lake Victoria basin (Tanzania, Uganda and Kenya). *Tanzania Journal of Agricultural Sciences*, *19*(2), 148–160. https://www.ajol.info/index.php/tjags/article/view/205084

Mpewo, M., Kizza-Nkambwe, S., & Kasima, J. S. (2023). Heavy metal and metalloid concentrations in agricultural communities around steel and iron industries in Uganda: Implications for future food systems. *Environmental Pollutants and Bioavailability*, *35*(1), 1–12. https://doi.org/10.1080/26395940.2023.2226344

Mpuuga, D. (2023). *Threats to Uganda's food security in 2023. Economic Policy Research Centre*. Retrieved September 10, 2024, from https://eprcug.org/eprc-highlights/threats-to-ugandas-food-security-in-2023/ ,

Mugambe, P., & Avogo, F. A. (2024). Prioritizing sustainable development goals in Africa: Perspectives from academia in Ghana and Uganda. *European Journal of Sustainable Development Research*, *8*(3), em0263. https://doi.org/10.29333/ejosdr/14783

Mugambe, R. K., Nuwematsiko, R., Ssekamatte, T., Nkurunziza, A. G., Wagaba, B., Isunju, J. B., Wafula, S. T., Nabaasa, H., Katongole, C. B., Atuyambe, L. M., & Buregyeya, E. (2022). Drivers of solid waste segregation and recycling in Kampala slums, Uganda: A qualitative exploration using the behavior centered design model. *International Journal of Environmental Research and Public Health*, *19*(17), 1–18. https://doi.org/10.3390/ijerph191710947

Mwangu, A. R. (2023). SDG localization in Uganda: Prospects for climate change mitigation. In W. Leal Filho, I. R. Abubakar, I. da Silva, R. Pretorius, & K. Tarabieh (Eds.), *SDGs in Africa and the Middle East region. Implementing the UN sustainable development goals - regional perspectives*. Springer. https://doi.org/10.1007/978-3-030-91260-4_31-1

Nabyonga, L., Basamba, T. A., Nyakoojo, C., & Ssenku, J. E. (2022). Impediments to agricultural production in Uganda and measures to enhance soil fertility utilizing organic soil amendments: A review. *Cogent Food & Agriculture*, *8*(1), 1–13. https://doi.org/10.1080/23311932.2022.2113051

Nadeak, E. S. M. (2023). Housewives' perceptions toward the use of black soldier fly technology in managing household organic waste in rural areas. *International Journal of Social Science*, *3*(4), 429–436. https://doi.org/10.53625/ijss.v3i4.6992

Nampijja, Z., Kiggundu, M., Kigozi, A., Lugya, A., Magala, H., Ssepuuya, G., Nakimbugwe, D., Walusimbi, S. S., & Mugerwa, S. (2023). Optimal substitution of black soldier fly larvae for fish in broiler chicken diets. *Scientific African*, *20*(2023), 1–12. https://doi.org/10.1016/j.sciaf.2023.e01636

Obubu, J. P., Mengistou, S., Fetahi, T., Alamirew, T., Odong, R., & Ekwacu, S. (2021). Recent climate change in the Lake Kyoga basin, Uganda: An analysis using short-term and long-term data with standardized precipitation and anomaly indexes. *Climate*, *9*(12), 1–27. https://doi.org/10.3390/cli9120179

Oburu, O. M. O. (2023). Poverty eradication programmes and the economic security of police officers: A case study of operation wealth creation Kampala metropolitan region south. *Police College Journal of Law Enforcement and Crime*, *6*(2023), 41–81. https://www.researchgate.net/profile/Muganzi-Edson-Rusetuka/publication/378766144_Police_College_Journal_of_Law_Enforcement_and_Crime_i_POLICE_COLLEGE_JOURNAL_OF_LAW_ENFORCEMENT_AND_CRIME_Volume_6/links/65e875f2c3b52a11701b7d7e/Police-College-Journal-of-Law-Enforcement-and-Crime-i-POLICE-COLLEGE-JOURNAL-OF-LAW-ENFORCEMENT-AND-CRIME-Volume-6.pdf#page=45

Office of the Prime Minister. (2024a). *SDG/VNR factsheet 2024*, 44. The SDG Secretariat. Retrieved September 7, 2024, from https://sdgs.opm.go.ug/wp-content/uploads/2024/07/SDG-VNR-FACT-SHEET-2024-PV.pdf,

Office of the Prime Minister. (2024b). *Assessment of leave no one behind (LNOB) in development and humanitarian contexts in Uganda*, 88. SDG Secretariat, OPM & UN WOMEN. Retrieved September 7, 2024, from https://sdgs.opm.go.ug/wp-content/uploads/2024/07/Ugandas-Leave-No-One-Behind-Report-2024-Web-Verseion.pdf,

Ojok, J., Koech, M. K., Tole, M., & OkotOkumu, J. (2013). Rate and quantities of household solid waste generated in Kampala City, Uganda. *Science Journal of Environmental Engineering Research*, *2013*(237), 1–6. https://doi.org/10.7237/sjeer/237

Okot-Okumu, J., & Nyenje, R. (2011). Municipal solid waste management under decentralisation in Uganda. *Habitat International*, *35*(4), 537–543. https://doi.org/10.1016/j.habitatint.2011.03.003

Olum, S., Wesana, J., Mawadri, J., Nakiranda, J. K., & Odongo, W. (2021). Insects as food: Illuminating the food neophobia and socio-cultural dynamics of insect consumption in Uganda. *International Journal of Tropical Insect Science*, *41*(3), 1–10. https://doi.org/10.1007/s42690-020-00309-2

Olza, S., Salaberria, A. M., Alonso-Varona, A., Samanta, A., & Fernandes, S. C. (2023). The role of nanochitin in biologically-active matrices for tissue engineering-where do we stand? *Journal of Materials Chemistry B*, *11*(25), 5630–5649. https://doi.org/10.1039/D3TB00583F

Onen, O. W. (2023). Poverty eradication: Innovative approach to accelerate poverty alleviation in Uganda, Africa. In W. Leal Filho, I. R. Abubakar, I. da Silva,

R. Pretorius, & K. Tarabieh (Eds.), *SDGs in Africa and the Middle East Region. Implementing the UN sustainable development goals - regional perspectives*. Springer. https://doi.org/10.1007/978-3-030-91260-4_14-1

Ortiz, A. M. D., Outhwaite, C. L., Dalin, C., & Newbold, T. (2021). A review of the interactions between biodiversity, agriculture, climate change, and international trade: Research and policy priorities. *One Earth*, *4*(1), 88–101. https://doi.org/10.1016/j.oneear.2020.12.008

Oteu, O. J., Nkambwe, S. K., Kasima, J. S., Mpewo, M., & Agunyo, M. F. (2024). Evaluation of agricultural waste-based briquettes as an alternative biomass fuel for cooking in Uganda. *African Journal of Climate Change and Resource Sustainability*, *3*(1), 49–62. https://doi.org/10.37284/ajccrs.3.1.1763

Palinkas, L. A., & Wong, M. (2020). Global climate change and mental health. *Current Opinion in Psychology*, *32* (2020), 12–16. https://doi.org/10.1016/j.copsyc.2019.06.023

Pallegedara, A., & Kumara, A. S. (2022). Impacts of firewood burning for cooking on respiratory health and healthcare utilisation: Empirical evidence from Sri Lankan micro-data. *The International Journal of Health Planning and Management*, *37*(1), 465–485. https://doi.org/10.1002/hpm.3350

Pang, W., Hou, D., Chen, J., Nowar, E. E., Li, Z., Hu, R., Tomberlin, J. K., Yu, Z., Li, Q., & Wang, S. (2020a). Reducing greenhouse gas emissions and enhancing carbon and nitrogen conversion in food wastes by the black soldier fly. *Journal of Environmental Management*, *260*, 110066. https://doi.org/10.1016/j.jenvman.2020.110066

Pang, W., Hou, D., Nowar, E. E., Chen, H., Zhang, J., Zhang, G., Li, Q., & Wang, S. (2020b). The influence on carbon, nitrogen recycling, and greenhouse gas emissions under different C/N ratios by black soldier fly. *Environmental Science and Pollution Research*, *27*(34), 42767–42777. https://doi.org/10.1007/s11356-020-09909-4

Paprotny, D. (2021). Convergence between developed and developing countries: A centennial perspective. *Social Indicators Research*, *153*(1), 193–225. https://doi.org/10.1007/s11205-020-02488-4

Park, J. Y., Jung, S., Na, Y. G., Jeon, C. H., Cheon, H. Y., Yun, E. Y., Lee, S.-H., Kwon, E. E., & Kim, J. K. (2022). Biodiesel production from the black soldier fly larvae grown on food waste and its fuel property characterization as a potential transportation fuel. *Environmental Engineering Research*, *27*(3), 200704–0. https://doi.org/10.4491/eer.2020.704

Parodi, A., De Boer, I. J., Gerrits, W. J., Van Loon, J. J., Heetkamp, M. J., Van Schelt, J., Bolhuis, J. E., & Van Zanten, H. H. (2020). Bioconversion efficiencies, greenhouse gas and ammonia emissions during black soldier fly rearing – A mass balance approach. *Journal of Cleaner Production*, *271*(2020), 1–9. https://doi.org/10.1016/j.jclepro.2020.122488

Perednia, D. A., Anderson, J., & Rice, A. (2017). A comparison of the greenhouse gas production of black soldier fly larvae versus aerobic microbial decomposition of an organic feed material. *Research & Reviews: Journal of Ecology and Environmental Sciences*, *5*(3), 10–16. Retrieved September 14, 2024 at https://www.researchgate.net/profile/Douglas-Perednia/publication/320865818_A_Comparison_of_the_Greenhouse_Gas_Production_of_Black_Soldier_Fly_Larvae_versus_Aerobic_Microbial_Decomposition_of_an_Organic_Feed_Material/links/59ff6713458515d0706d6f78/A-Comparison-of-the-Greenhouse-Gas-Production-of-Black-Soldier-Fly-Larvae-versus-Aerobic-Microbial-Decomposition-of-an-Organic-Feed-Material.pdf

Perkins, J. M., Nyakato, V. N., Kakuhikire, B., Tsai, A. C., Subramanian, S. V., Bangsberg, D. R., & Christakis, N. A. (2018). Food insecurity, social networks and symptoms of depression among men and women in rural Uganda: A cross-sectional, population-based study. *Public Health Nutrition*, *21*(5), 838–848. https://doi.org/10.1017/S1368980017002154

Popa, R., & Green, T. R. (2012). Using black soldier fly larvae for processing organic leachates. *Journal of Economic Entomology*, *105*(2), 374–378. https://doi.org/10.1603/EC11192

Purschke, B., Scheibelberger, R., Axmann, S., Adler, A., & Jäger, H. (2017). Impact of substrate contamination with mycotoxins, heavy metals and pesticides on the growth performance and composition of black soldier fly larvae (*Hermetia illucens*) for use in the feed and food value chain. *Food Additives & Contaminants: Part A*, *34*(8), 1410–1420. https://doi.org/10.1080/19440049.2017.1299946

Quilliam, R. S., Nuku-Adeku, C., Maquart, P., Little, D., Newton, R., & Murray, F. (2020). Integrating insect frass biofertilisers into sustainable peri-urban agro-food systems. *Journal of Insects as Food and Feed*, *6*(3), 315–322. https://doi.org/10.3920/JIFF2019.0049

Raman, S. S., Stringer, L. C., Bruce, N. C., & Chong, C. S. (2022). Opportunities, challenges and solutions for black soldier fly larvae-based animal feed production. *Journal of Cleaner Production*, *373*(2022), 1–18. https://doi.org/10.1016/j.jclepro.2022.133802

Republic of Uganda. (2024, July). *Uganda's 3rd voluntary national review report on the implementation of the 2030 agenda for sustainable development*. (88. SDG Secretariat-Office of the Prime Minister. https://sdgs.opm.go.ug/wp-content/plugins/download-attachments/includes/download.php?id=1997,

Rocque, R. J., Beaudoin, C., Ndjaboue, R., Cameron, L., Poirier-Bergeron, L., Poulin-Rheault, R. A., Fallon C., Tricco A. C., & Witteman, H. O. (2021). Health effects of climate change: An overview of systematic reviews. *BMJ Open*, *11*(6), 1–14. https://doi.org/10.1136/bmjopen-2020-046333

Rojo, S. (2024). Parasitoids of the black soldier fly (*Hermetia illucens*)-a minor problem or the tip of the iceberg? *Journal of Insects as Food and Feed*, *10*(9), 1505–1514. https://doi.org/10.1163/23524588-100901ED

Salomone, R., Saija, G., Mondello, G., Giannetto, A., Fasulo, S., & Savastano, D. (2017). Environmental impact of food waste bioconversion by insects: Application of life cycle assessment to process using Hermetia illucens. *Journal of Cleaner Production*, *140*(2017), 890–905. https://doi.org/10.1016/j.jclepro.2016.06.154

SDG Knowledge Hub. (2022). *UNECA launches Africa SDGs progress dashboard*. Retrieved September 3, 2024 at https://sdg.iisd.org/news/uneca-launches-africa-sdgs-progress-dashboard/#:~:text=On%20the%20current%20status%20of,(partnerships%20for%20the%20Goals)

Selaledi, L., Hassan, Z., Manyelo, T. G., & Mabelebele, M. (2021). Insects' production, consumption, policy, and sustainability: What have we learned from the indigenous knowledge systems? *Insects*, *12*(5), 1–18. https://doi.org/10.3390/insects12050432

Shulla, K., & Leal-Filho, W. (2023). *Achieving the UN agenda, 2030: Overall actions for the successful implementation of the sustainable development goals before and after the 2030 deadline*. European Union Parliament: In-depth analysis. (64. https://www.agenda-2030.fr/IMG/pdf/expo_ida_2022_702576_en.pdf

Siddiqui, S. A., Ristow, B., Rahayu, T., Putra, N. S., Yuwono, N. W., Mategeko, B., Mategeko, B., Smetana, S., Saki, M., Nawaz, A., & Nagdalian, A. (2022). Black soldier fly larvae (BSFL) and their affinity for organic waste processing. *Waste Management*, *140*(2022), 1–13. https://doi.org/10.1016/j.wasman.2021.12.044

Singh, A., & Kumari, K. (2019). An inclusive approach for organic waste treatment and valorisation using black soldier fly larvae: A review. *Journal of Environmental Management*, *251*(2019), 109569. https://doi.org/10.1016/j.jenvman.2019.109569

Sogari, G., Amato, M., Biasato, I., Chiesa, S., & Gasco, L. (2019). The potential role of insects as feed: A multi-perspective review. *Animals*, *9*(4), 1–13. https://doi.org/10.3390/ani9040119

Strong, K., Noor, A., Aponte, J., Banerjee, A., Cibulskis, R., Diaz, T., Ghys, P., Glaziou, P., Hereward, M., Hug, L., Kantorova, V., Mahy, M., Moller, A.-B., Requejo, J., Riley, L., Say, L., & You, D. (2020). Monitoring the status of selected health related sustainable development goals: Methods and projections to 2030. *Global Health Action*, *13*(1), 1–14. https://doi.org/10.1080/16549716.2020.1846903

Susilo, H., Nurmayulis, N., Syahbana, M. A., & Sodiq, A. H. (2024). The potential of frass BSF as an organic fertilizer for making sustainable agriculture a reality. *Jurnal Biologi Tropis*, *24*(2), 209–217. https://doi.org/10.29303/jbt.v24i2.6782

Tagumira, A., Biira, S., & Amabayo, E. B. (2022). Concentrations and human health risk assessment of selected heavy metals in soils and food crops around Osukuru phosphate mine, Tororo District, Uganda. *Toxicology Reports*, *9*(2022), 2042–2049. https://doi.org/10.1016/j.toxrep.2022.11.007

Taufiq, K., & Ismail, S. (2020). Food insecurity in relation to governance in Uganda. *Journal of Advanced Research in Social Sciences & Humanities*, *5*(5), 164–171. https://doi.org/10.26500/JARSSH-05-2020-0501

Tibesigwa, T., Olupot, P. W., & Kirabira, J. B. (2023). Assessment of the techno-economic viability of B10 synthesis from second-generation biodiesel feedstocks in Uganda. *International Journal of Sustainable Energy*, *42*(1), 351–373. https://doi.org/10.1080/14786451.2023.2191144

Traore, O., Zaato, P. A., Baidoo, J. K., Feleke, S., Manyong, V., Abdoulaye, T., Djouaka, R., Schreinemachers, P., & Ba, M. N. (2024). Willingness of West African consumers to buy food produced using black soldier fly larvae and frass. *Foods*, *13*(17), 1–15. https://doi.org/10.3390/foods13172825

Tubiello, F. N., Rosenzweig, C., Conchedda, G., Karl, K., Gütschow, J., Xueyao, P., Obli-Laryea, G., Wanner, N., Qiu, S. Y., Barros, J. D., Flammini, A., Mencos-Contreras, E., Souza, L., Quadrelli, R., Heiðarsdóttir, H. H., Benoit, P., Hayek, M., & Sandalow, D. (2021). Greenhouse gas emissions from food systems: Building the evidence base. *Environmental Research Letters*, *16*(6), 1–13. https://doi.org/10.1088/1748-9326/ac018e

Twinomuhangi, R., Sseviiri, H., Mulinde, C., Mukwaya, P. I., Nimusiima, A., & Kato, A. M. (2021). Perceptions and vulnerability to climate change among the urban poor in Kampala City, Uganda. *Regional Environmental Change*, *21*(2), 1–13. https://doi.org/10.1007/s10113-021-01771-5

United Nations. (2024). *The sustainable development goals report 2024*. (51). Retrieved September 7, 2024, from https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf

United Nations Department of Economic and Social Affairs. (2020). *The 2020 Uganda VNR process: A leadership journey in the implementation of the SDGs in Uganda*. Retrieved September 7, 2024, from https://sdgs.un.org/events/2020-uganda-vnr-process-leadership-journey-implementation-sdgs-uganda-27329

Urrutia, R. I., Jesser, E. N., Gutierrez, V. S., Rodriguez, S., Gumilar, F., Murray, A. P., Volpe, M. A., & Werdin-González, J. O. (2023). From waste to food and bioinsecticides: An innovative system integrating Tenebrio molitor bioconversion and pyrolysis bio-oil production. *Chemosphere*, *340*(2023), 139847. https://doi.org/10.1016/j.chemosphere.2023.139847

Visvini, L., Latifah, O., Ahmed, O. H., & Kurk, W. J. (2022, April). Frass production from black soldier fly larvae reared on palm oil wastes. *IOP Conference Series Earth and Environmental Science*, *995*(1), 012012–6. https://doi.org/10.1088/1755-1315/995/1/012012

Wang, H., Ur Rehman, K., Feng, W., Yang, D., Ur Rehman, R., Cai, M., Zhang, J., Yu, Z., & Zheng, L. (2020). Physicochemical structure of chitin in the developing stages of black soldier fly. *International Journal of Biological Macromolecules*, *149*(2020), 901–907. https://doi.org/10.1016/j.ijbiomac.2020.01.293

Wang, Y. S., & Shelomi, M. (2017). Review of black soldier fly (*Hermetia illucens*) as animal feed and human food. *Foods*, *6*(10), 1–23. https://doi.org/10.3390/foods6100091

Wanyana, I., Helldén, D., Ndejjo, R., Murzabekov, M., Alfven, T., Wanyenze, R. K., & Viberg, N. (2024). Finding linkages between the sustainable development goals in Uganda: A key to attain health and well-being for all. *BMJ Public Health*, *2*(2), 1–9. https://doi.org/10.1136/bmjph-2023-000529

Wong, C. Y., Rosli, S. S., Uemura, Y., Ho, Y. C., Leejeerajumnean, A., Kiatkittipong, W., Cheng, C.-K., Lam, M.-K., & Lim, J. W. (2019). Potential protein and biodiesel sources from black soldier fly larvae: Insights of larval harvesting instar and fermented feeding medium. *Energies*, *12*(8), 1–15. https://doi.org/10.3390/en12081570