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THE ECONOMIC VIABILITY AND SOCIAL ACCEPTABILITY OF BLACK SOLDIER FLY LARVAE FRASS AS A SUBSTITUTE FOR CHEMICAL FERTILISER IN AGRICULTURE IN CAMEROON

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ABSTRACT: *The global adoption and recognition of eco-friendly black soldier fly larvae frass as a sustainable substitute for inorganic fertiliser is increasing rapidly, particularly in sub-Saharan Africa, showcasing its innovation. This study aimed to assess the economic feasibility of substituting synthetic fertiliser with black soldier fly larvae (BSFL) frass, as well as to examine the attitudes of urban farmers towards the usage of BSFL frass. The economic data was collected through a cost-benefit ratio analysis and return on investment research. A total of 150 questionnaires were distributed to selected urban farmers in the central region of Cameroon in order to collect social data. The findings revealed that the utilisation of black soldier fly larvae frass yielded the greatest Return on Investment, profit margin, and Cost-Benefit ratio in comparison to commonly used inorganic fertilisers such as NPK, Urea, Yara, and surface fertilisers. The idea of using frass as a replacement was considered acceptable, while there are some worries that can be gradually eliminated via awareness and further investigation into the ability of crops grown on frass to transmit plant diseases. This study confirms the effectiveness of using Black Soldier Fly Larvae (BSFL) as a sustainable method for managing waste. The products derived from BSFL, such as protein, biodiesel, and manure, are environmentally friendly, economically feasible, and socially acceptable for use in Cameroon and Sub-Saharan Africa as a whole.*

KEYWORDS: Waste valorisation; Black Soldier Fly Larvae frass; Economic Viability; Social acceptance; Urban Farming sustainability.

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INTRODUCTION

Urbanisation (or urbanisation) refers to the population shift from rural to urban regions, the decline in the proportion of people living in rural areas, and how societies adjust to this change. It is primarily the process by which towns and cities develop and grow as more people move to urban centres to live and work. In 2019, the United Nations forecasted that more than half of the world's population (4.2 billion people) lives in urban areas; by 2041, this number is expected to reach 6 billion (United Nations. World urbanisation prospects. New York; 2019.). Urban existence is the cornerstone of today's human ecology. Over the past two centuries, cities have swiftly developed and spread around the globe. Cities are sources of innovation and innovation, as well as engines of economic progress (McMichael, 2000). Despite the benefits of urbanisation, migration from rural to urban areas reflects a number of serious issues, such as malnutrition, pollution-related health disorders and infectious diseases, insufficient sanitation and housing conditions, and linked health issues (Kuddus et al., 2020), including the onset of industrialisation, uncertainty regarding the availability of food in rural areas, and environmental degradation (Mcmichael, 2000). Africa is currently the least urbanised major region globally, as the correlation between economic development and urbanisation is weaker than in other regions. However, it is also the region with the most significant rapid urbanisation (Brennan EM, 1999). The yearly urban growth rate in Sub-Saharan Africa is 4.1%, over double the global average (World Bank, 2017; Saghir & Santoro, 2018).

The Urbanisation Problem

Urbanisation is currently a worldwide phenomenon, but its effects are most pronounced in developing nations (Vij, D 2012). The rapid urban population growth in sub-Saharan Africa is mostly attributable to emigration from rural poverty and high urban fertility rates. In addition to its socioeconomic effects, this fast urbanisation poses significant problems to environmental protection, like heavy use of natural resources (Wang et al., 2020), pollution (air pollution, water pollution, land pollution, and soil pollution) (Liang & Yang, 2019), and waste generation (municipal solid waste, industrial waste, agricultural waste) (Yiougo et al., 2013) are a few of the issues that plague the region. and the provision of enough, food, water, and sanitation (UNFPA 2007; Drechsel & Dongus, 2010).

Waste generation

Several socioeconomic factors, such as education, occupation, and family composition, have been found to affect the rate of MSW generation and to be linked with MSW generation (Bandara et al., 2007). Similarly, several indicators of urbanisation are linked with MSW generation (Ho et al., 2017) as well. Urbanisation is causing waste generation to increase at a rate that exceeds urbanisation itself (Hoornweg, D., Bhada-Tata, P., 2012).

Food Insecurity

Urbanisation is a fundamental factor influencing the viability of agricultural development and the character of global food security (Vasylieva et al., 2021). Urbanisation brings major changes in demand for agricultural products both from increases in urban populations and from changes in their diets and demands. This has brought and continues to bring major changes in how needs are met and in the farmers, companies, corporations, and local and national economies who benefit (and who lose out). It can also bring major challenges for urban and rural food security (Satterthwaite et al., 2010). Urbanisation poses a threat to food availability

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in terms of shifting consumption patterns, food production and distribution methods (Szabo, 2016).

As a response to the increase in waste generated as a result of urbanisation, research to propose sustainable solutions has gravitated toward the valorisation of said waste through the use of Black Soldier Fly larvae, whose ability to feed on various types of organic waste veraciously makes them suitable for converting and reducing the waste generated to a significant degree (Diener et al., 2009; Singh & Kumari, 2019). Urban agriculture (UA) is roughly defined as the cultivation, processing, and distribution of foodstuffs from crop and animal production within and around urban areas, being found to be the solution to urban food demands (Mougeot, 2000). On the one hand, UA is frequently viewed as a solution to some of the social, economic, and environmental difficulties in urban areas (Davies et al., 2021; Miccoli et al., 2016; Nkrumah, 2018). A solution to environmental issues like waste generation is through the recycling of organic waste on agricultural land as a way to improve its quality (Alvarenga et al., 2017). Several advantages accrue from the social aspect of urban agriculture. Physical activity enhancement: In cultures where obesity is an issue, urban gardens offer residents the chance to boost their physical activity via gardening. In addition to being viewed as a form of therapy, landscape renewal is supported by psychological studies demonstrating that its impacts hasten a person's health improvement (Marzieh Rezaei Ghaleh, 2019). Last but not least, the economic benefits of agriculture through creating jobs and empowering the urban population through training in urban agriculture (Golden, 2013). On the other hand, experts have highlighted the challenges to UA, citing numerous instances in which UA practices in Sub-Sahara Africa have been proven to be unsustainable. Traditional farming methods in sub-Sahara Africa (SSA) have resulted in significant nutrient depletion and low crop yields (Chianu et al., 2012). Due to increasing demand and limited land availability, farmers have increased their use of nitrogen fertilisers to boost agricultural productivity. However, nitrogen fertilisers can cause soil acidification, heavy metal pollution, soil compaction, and microbiota alterations (Lin et al., 2019). UA has shown to be an ineffective source of revenue for low-income urban households that rely mostly on cash income to meet their basic requirements. UA has proven to be an inefficient source of income for low-income urban households that rely primarily on cash income to cover their basic needs (Crush et al., 2011; White & Hamm, 2014), especially when compared to the input (economic value/cost) involved in urban farming. As a result, the global community has advocated for sustainable urban agriculture, particularly in Sub-Saharan Africa, which is afflicted by insufficient understanding of the use of fertilisers among farmers, low farmer literacy, and declining soil scientific ability, among other problems. (Chianu et al., 2012). For resource-poor farmers, the cost and availability of synthetic fertilisers, along with inherently low soil fertility, is a significant barrier to increasing crop yields (Reynolds et al., 2015). Consequently, developing sustainable 'on-farm' strategies is essential to enhancing crop nutrient use efficiency (Quilliam et al., 2020). One of the goals of Sustainable urban agriculture is to increase environmental flexibility, sustainability and economic viability of urban farming. Researchers have determined that boosting organic farming over the use of inorganic fertiliser may enhance the environmental resilience and economic feasibility of urban agricultural systems (Sandeepani & Samaraweera, 2022). Unlike the use of vermicompost as a substitute for inorganic fertiliser in the majority of agricultural practices and its plethora of benefits, such as its ability to act as biofertiliser, restore soil nutrients, stabilise soil, and increase soil fertility over a long period of time (Kayabasi & Yilmaz, 2021), which have been widely demonstrated and documented, the use of Black soldier fly larvae frass as a substitute for inorganic fertiliser is a novel practice. The use of the Black Soldier larvae Frass ("Frass" refers to the castings

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(poop), leftover food, and exoskeletons remaining in a compost pile after all the larvae have been removed) as a biofertiliser and soil conditioner (Quilliam et al., 2020) though the novel has also been proven to have other environmental benefits like the biostimulant properties of insect byproducts in the frass conclusively showing to improve plant resistance to pests, then the reduction in the reliance on pesticides which could inherently have important consequences for biodiversity (Schmitt & de Vries, 2020). Various life cycle assessments of the performance of black soldier fly The role of black soldier fly larvae in promoting sustainability is being thoroughly researched. Its contribution to the environmental dimension of sustainability has been shown to be beneficial, for example, through its role in sustainable waste management by reducing significant amounts of organic waste. The economic aspect of the role played by the BSFL, particularly the viability of its frass to be used as an organic fertiliser and soil conditioner, thereby promoting sustainable urban agriculture, is still being researched, particularly in Sub-Saharan Africa, where the farming system is primarily dependent on family capital (Shimeles et al., 2018). This study aims to establish the economic viability through performing an Environmental cost-benefit analysis (which is the application of CBA to projects or policies with the intention of improving the natural environment or to acts that indirectly influence the natural environment (OECD, 2018) and social acceptability of BSFL frass use in urban agriculture in the cultivation of maize in the urban town of Yaoundé Cameroon. Which will serve to establish the role such alternative technologies play in sustainable development.

LITERATURE REVIEW

Globally, the rate of waste production is increasing. In 2020, it was estimated that the world would generate 2.24 billion tonnes of solid waste or 0.79 kilogrammes per person per day. Rapid population growth and urbanisation are expected to increase annual waste generation by 73% from 2020 levels to 3.88 billion tonnes in 2050 (Wynants et al., 2019). Compared to residents of developed nations, residents of developing countries, particularly urban ones, are more severely impacted by improper waste management. Proper waste management is essential for constructing sustainable and habitable cities, but many developing countries and municipalities continue to struggle with this issue. The cost of effective waste management is high. It has been reported by Shimeles et al. (2018) that in 2025, solid waste management costs will increase from the current annual level of $205.4 billion to approximately $375.5 billion. Cost increases will be most severe in low-income and lower-middle-income countries (increases of more than fivefold and fourfold, respectively). Cameroon ranks sixth in Africa and second among low-middle-income countries worldwide in terms of waste generation (Shimeles et al., 2018). With a huge portion of the waste generated being organic waste, it is therefore imperative that Integrated solid waste management (ISWM) systems be the norm in this nation. ISWM reflects the need to approach solid waste comprehensively, with careful selection and sustained application of appropriate techniques, and establishment of a social licence' between the community and designated waste management authorities (typically local government), as well as considering the value of waste streams, the actors involved, and potential implementation constraints. With such a waste management scheme, the social, economic, and environmental, thus promoting sustainable development (Hoornweg D Bhada-Tata 2012). In the implementation of ISMW, researchers have pursued techniques suitable for developing nations, and from numerous studies, they proposed the Fly larvae composting process using the Black soldier fly larvae (Golden, 2013; Chianu et al., 2012; Lin et al., 2019). The black soldier fly is well-known for its characteristic of being a voracious feeder that feeds

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on various types of organic waste (Crush et al., 2011; White & Hamm, 2014; Reynolds et al., 2015) and its performance in organic waste valorisation into multiple products, such as alternative protein sources for livestock feed (da Silva et al., 2020; Sprangers et al., 2017; Fawole et al., 2019), biodiesel (Gligorescu et al., 2020; Arancone et al., 2013), and most recently organic fertiliser (Li et al., 2011; Bortolini et al., 2020; Liu et al, 2022). In the developed world, the use of BSFL in waste management and subsequent use as a protein source and biodiesel production is widely encouraged. It has been shown to meet one of the dimensions of sustainable development, namely the environmental aspect because its negative environmental impacts are significantly lower than those of other waste management techniques (Beesigamukama et al., 2020; Boakye et al., 2022). Its economic viability and social acceptability (Jaza, 2017; Sumbule et al., 2021) are somewhat researched and documented. In Sub-Saharan Africa and Africa as a whole, researchers are warming up to the use of BSFL in waste management and focusing on its protein-providing and biodiesel properties (Sprangers et al., 2017; Waithaka et al., 2022). However, the use of BSFL frass, particularly in urban agriculture, is hesitant because its economic viability and social acceptability are not adequately well-known. These factors are equally crucial to sustainable development (Sprangers et al., 2017) as environmental sustainability, as they enable policymakers to make informed decisions regarding refuse management.

METHODOLOGY

The research was conducted in Cameroon's central region (Fig 1). The physical location of the region is 4.6298° North latitude and Longitude 11.7068° E. This region is pertinent for investigating the acceptability of BSFL frass as an organic fertiliser and soil conditioner because it is characterised by a significant proportion of urban farming households. Urban and peri-urban agriculture in Cameroon's central region and capital, Yaoundé, is a rising activity in the survival economy and contributes to the population's access to seasonal fruits and vegetables and grains (maize in the case of this study maize, *Zea mays*) (Sogang & Monkouop, 2022).

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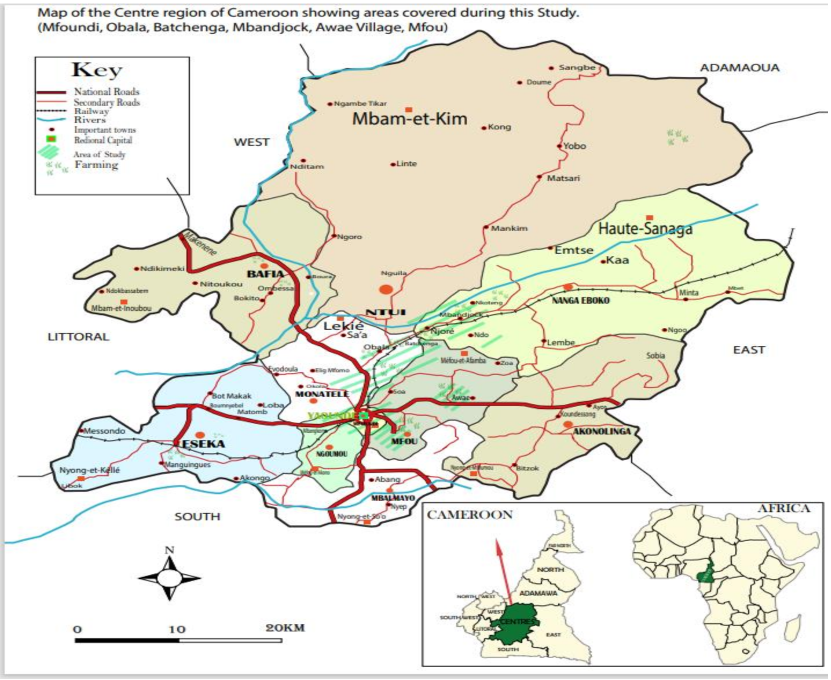

Fig 1: Study Area

A financial analysis of the BSFL Frass

An experimental design was constructed to determine the economic feasibility of using the suggested organic fertiliser made from Black Soldier Fly Larvae Frass (BSFLf). The study involved a control group and an experimental design. The experimental design involves cultivating maize in open-field agriculture and applying several formulations of soil conditioner to maize plants growing in ultisol soil. Ultisols are reddish, clay-rich, acidic soils that support mixed forest vegetation prior to cultivation. The studies comprised treatments that included the essential component of the BSF frass, along with four replications. The control group cultivated their maize using four regularly utilised synthetic fertilisers in Cameroon, namely NPK, UREA, YARA, and Surface. Each trial utilised a land area of 300 square metres, and the corn yield was determined using a corn yield calculator (Michałowska, 2023).

Return on investment (RoI) and cost-benefit ratio (CBR) (Chia et al., 2019; Sumbule et al., 2021) were used to examine the economic significance of substituting BSFL frass for inorganic fertiliser in maize cultivation. As an indicator in CBA, the cost-benefit ratio (CBR) was employed to summarise the economic worth of replacing inorganic fertiliser with BSFLf. Four distinct inorganic fertilisers were supplied in Cameroon, and the price of BSFL used in waste treatment was utilised to compute fertiliser expenses. The anticipated yield per parcel of land (land size) cultivated on each fertiliser was used to calculate the overall revenue from maize production. This yield was supposed to represent all the benefits derived from the production. The CBR represents the ratio between production income and production cost. A BCR value greater than 1 indicates that the production's benefits outweighed its costs and vice versa. ROI measures the profit or loss generated by an investment relative to the amount of capital invested. The greater the ROI value, the greater the returns of the proposed project (Onsongo et al., 2018). Economic performance was determined by the gross profit, gross profit margin, –benefit-cost ratio (BCR), and return on investment (RoI).

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The following formulas were utilised, which were adapted from (Waithaka et al., 2022).

$$Total\ revenue = Unitary\ price \times total\ yield$$

$$Gross\ profit = total\ revenue - total\ production\ cost.$$

$$Gross\ profit\ margin = gross\ profit / total\ revenue$$

$$Net\ profit = Gross\ profit - total\ cost$$

$$CBR = Gross\ profit\ /\ total\ production\ cost \times 100$$

$$ROI = net\ profit / total\ production\ cost$$

Accessing Social Acceptance of BSFLf

This study was undertaken in the urban zone of the central region, Cameroon, where urban farming is a vital sector for sustaining livelihoods and many culinary cultures exist. A systematic questionnaire was used to conduct interviews with 150 people who practice urban agriculture. With both open-ended and closed-ended questions, the questionnaire gathered information on farmer gender, attitudes toward employing black soldier fly larvae frass, etc. Farmers were chosen at random. To qualify for inclusion in the study, farmers had to have been involved in urban agriculture and be regular users of inorganic fertiliser. The questions will be self-administered based on the language of the participants (French or English). The study questionnaire will be divided into four sections. The first aimed at collecting demographic and socioeconomic information, such as age, gender, marital status, religion, occupation, etc., about the participants. In section 2, participants were asked how they felt about using BSFL frass as an organic fertiliser as opposed to conventional fertiliser. This was determined using a five-point semantic differential scale: 1 = strongly acceptable; 2 = acceptable with some reservations; 3 = neutral; 4 = unacceptable; and 5 = severely unacceptable. Thirdly (section 3), participants were asked their opinions on the potential advantages of employing BSFL frass as an organic fertiliser as opposed to the traditional. On a five-point Likert scale, 1 represents strong agreement, 2 represents agreement, 3 represents neither agreement nor disagreement, 4 represents disagreement, and 5 represents severe disagreement. In Section 4, using the same Likert scale-based options as described previously, participants were asked their opinions on the potential dangers associated with utilising BSFL frass as an organic fertiliser instead of conventional fertilisers. The analysis of data was performed using IBM SPSS Statistic 21. To analyse the demographic and socioeconomic status of respondents/farmers, frequencies were employed. Robust Tests of Equality of Means were used to determine the equality of means.

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RESULTS AND DISCUSSION

Economic performance

The total production was calculated based on the specified parameters and their corresponding costs, as shown in Table 2. The cost of fertiliser is the sole factor that affects and is considered in the calculation of production cost. This is based on the assumption that the costs of raw materials (such as land, maize seeds, and water), direct labour (with a labour force of 3), and overhead costs remain constant for maize production. The disparity in overall corn production among the several experiments, as determined by the corn yield calculator (Michałowska, 2023), was minimal (with the yield of corn grown on BSFL frass being the highest, thus exhibiting the potential of BsflFrass to increase corn yield), as illustrated in table 1. Therefore, the overall output was not taken into account when determining the production cost, resulting in the subsequent calculation of the cost-benefit ratio and return on investment.

Table 1: Total Yield (per 300m^2)

Parameters	BSFL frass				NPK				UREA				YARA				SURFACE			
Replications	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Kernels per ear	480	473	502	511	488	501	507	493	422	383	485	506	380	500	412	496	412	488	387	500
Ears in sample	50				50				50				50				50			
Size of field	300m2				300m2				300m2				300m2				300m2			
Size of kernels	L	L	L	M	L	M	M	M	L	L	L	M	L	M	M	L	L	M	L	M
Total yield (Bushels)	22.24	21.91	23.26	21.04	22.61	20.63	20.88	20.30	19.65	17.75	22.47	20.8	17.06	20.59	16.96	22.98	19.09	20.09	17.93	20.59
Average total yield	22.11				21.10				20.16				19.39				19.42			

The total production was determined using the following defined parameters and their respective cost**.** The cost of fertiliser is the single parameter contributing to and taken into account when considering production cost the production cost, given that the cost of raw materials (including land, maize seeds, and water), direct labour (labour force =3), and overhead costs were assumed to be the same for the production of maize. The 300m^2 choice of land was based on the average surface area of land used for urban agriculture per agriculturalist in Cameroon, as reported by (Bopda et al., 2010).

Table 2: Production cost

Parameters	Cost ($)
Land (300m^2)	7500
Work equipment	45
Water	--
fertiliser	4.8
Seedlings (0.54kg×605)	1.008
Production cost	5.808
Overhead cost	16.67
Total cost	22.48

Exchange rate 1USD= 600XAF

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The calculation of production costs did not include fixed costs (land, work equipment) because they cannot be recovered in a single planting season and must be amortised over multiple planting seasons and years. Since urban farming, especially over 300m^2, conducted by an individual will be performed by the owner, no compensation (income) will be paid. Thus, it was not included either. Hence, production is obtained by adding the costs of fertilisers and seedlings. The quantity of seedlings utilised was determined and adapted from (Omoigui et al., 2020), and the price of maize seeds was determined and adapted from (Jaza Folefack, 2017).

In this study, the BSFL frass had no effect on the total cost of production in terms of frass production, as it is presumed that the BSF was attracted from the wild (Ewusie et al., 2019). After reproduction, the larvae were fed different types of waste. Hence, the cost of frass was not allocated.

Table 3 and Figure 2 display the results of the return on investment (ROI) and benefit-cost ratio (CBR). CBR and RoI were also found to differ between synthetic and frass-based fertilisers. The most expensive growing medium was NPK (widely used in Cameroon), Urea, and Yara, whereas BSFL was the least expensive, with the same yield as the rest. The most significant gross profit margin was obtained when BSFL frass was utilised. The return on investment increased when inorganic fertiliser was substituted with BSFL frass (Table 2).

Table 3: Economic analysis of substituting inorganic fertiliser with BSFLfrass in maize (*Zea mays*) cultivation.

Parameters	Fertiliser/per utilisation				
	NPK	Urea	Yara	Surface	Bsfl frass
Cost of fertiliser ($/300m^2)	4.8	4.8	4.8	3.3	--
Production cost	5.808	5.808	5.808	4.308	1.008
Yield (kg/300m^2)	187.5	187.5	187.5	187.5	187.5
Price $(per kg)	0.53	0.53	0.53	0.53	0.53
Total yield or revenue ($)/	99.38	99.38	99.38	99.38	99.38
Gross profit	93.57	93.57	93.57	95.07	98.37
Gross profit margin	0.94	0.94	0.94	0.96	0.99
Total cost	22.48	22.48	22.48	20.96	17.68
Net profit	71.09	71.09	71.09	74.11	80.69
CBR	16.11	16.11	16.11	22.07	97.59
RIO	3.16	3.16	3.16	3.54	4.56

Inorganic or synthetic fertilisers had the lowest gross profit margin, CBR, and return on investment when compared to BSFL frass. The BSFL frass has been proven to be more cost-effective than typical inorganic/synthetic fertiliser, whose prices are continually rising as the majority of fertiliser sold in Cameroon is imported. The low cost of Bsfl frass is reflected in enhanced profitability, CBR, and RoI when compared to inorganic/synthetic fertilisers.

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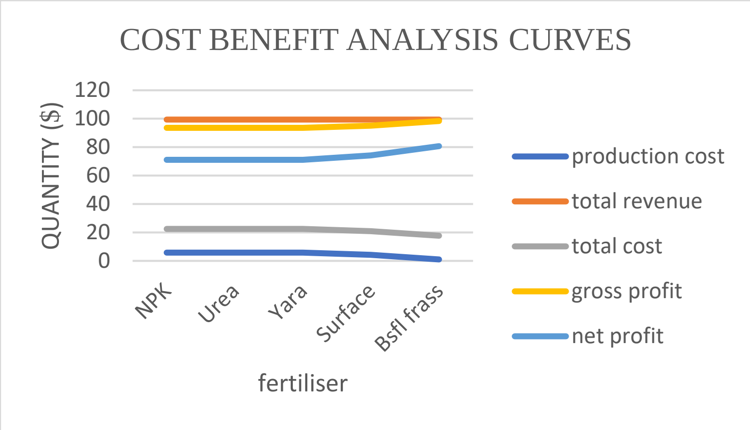

Fig 2: Cost-benefit analysis curves

Social attitude perceptions and acceptability of BSFL frass.

The majority of participants in this study were over 30 years old (40%) and female (51,33%). 48% and 60% of the population were married and Christian, respectively. The majority of participants (68%) are engaged in urban farming as a primary or secondary source of income and have been doing so for at least six to ten years (40%), as depicted in Table 4.

Table 4: Farmers' demographic characteristics

Terms	Status	Frequency	Percentage
Age (years)	21 - 30	53	35.0
	31 -40	60	40.0
	41-50	29	19.0
	51-60	5	3.0
	Above 60	3	2.0
	Total	150	100
Gender	Male	73	48.67
	female	77	51.33
	Total	150	100.0
Religion	Christian	90	60.0
	Muslim	11	7.0
	Traditionalist	15	10.0
	Other	34	22.0
	Total	150	100.0
Marital status	Single	51	34.0
	Married	73	48.0
	Divorced	7	4.0
	Widowed	7	4.0
	Never married	12	8.0
	Total	150	100.0
	No formal education	36	24.0
	Primary	12	8.0

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Educational level	Secondary	54	36.0
	Tertiary	28	18.0
	Technical/vocational	20	13.0
	Total	150	100.0
Occupation	Farming	103	68.0
	Animal husbandry	3	2.0
	Both	44	29.0
	Total	150	100.0
Working years	Less than 1	2	1.0
	1-5	57	38.0
	6-10	60	40.0
	Above 10	31	20.0
	Total	150	100.0

Perceptions and attitudes of farmers towards the usage of BSFL frass as an organic fertiliser as opposed to the extensively utilised inorganic fertiliser in agriculture.

Table 5 presents the opinions of farmers regarding the usage of BSFL frass as an organic fertiliser as opposed to the widely used inorganic fertiliser in agriculture. The majority of women regarded the concept to be highly acceptable, although men expressed some reservations. When asked about an organic waste-based fertiliser containing larvae excrement and exoskeleton, its use in agriculture, and how they feel about consuming food grown on such a fertiliser, the women scored an average of 1.000, while men scored an average range of 2.000-2.0274, indicating that the average female respondent finds the idea strongly acceptable, while the average male respondent finds the idea acceptable with some reservations.

Table 5: Perceptions and attitudes of farmers towards the usage of BSFLfrass

	Pooled sample	Type of respondent		Standard error	P-value
		Male	Female		
What are your thoughts on the idea of producing organic waste-based fertiliser over the use of inorganic fertiliser?	1.0000	2.0274	1.0000	.08232	.034
What are your thoughts on the idea of producing organic waste-based fertiliser over the use of inorganic fertiliser?	2.0267	2.0000	1.0000	.08135	.033
What are your thoughts on the use of BSFL frass in agriculture?	2.0067	2.0000	1.0000	.08054	.025
How do you feel about consuming agricultural products grown on all types of organic wastes	1.0000	2.0000	1.0000	.07469	.017

1 Scale: 1 (strongly agree) to 5 (strongly disagree).

2 Mean within the same row with $P < 0.05$ are statistically significant and imply equality of mean, and $P > 0.050$ implies a significant difference of mean.

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Perception of potential benefits of using BSFL frass-based fertilisers in agriculture.

The results of this study suggested a favourable attitude towards the potential benefits of substituting BSFL frass for inorganic fertiliser in urban agriculture (Table 6). Farmers had the most favourable attitude towards waste management and the environmental sustainability benefits that result from it. Youth farmers, however, rejected this notion. The weakly perceived advantage was that the use of BSFL frass-based fertiliser created competition in the fertiliser market, resulting in a decrease in the price of synthetic fertiliser and so making urban farming more affordable.

Table 6: Perception of potential benefits of using BSFL frass-based fertiliser

	Pooled sample	Type of respondent		Standard error	P-value
		Male	Female		
The use of BSFL frass fertiliser reduces your reliance on conventional inorganic fertiliser.	2.0000	2.0000	2.0000	.08097	.000
The use of BSFLfrass-based fertiliser enhances the value of organic waste, thus creating a cleaner environment	1.0000	1.0000	1.0000	.06956	.000
The use of BSFL frass-based fertiliser will create competition and can lead to the reduction of inorganic fertiliser.	2.0000	2.0000	2.0390	.07246	.000
The use of BSFLfrass-based fertiliser will enhance urban agriculture sustainability	2.0333	2.0000	1.0000	.07994	.024

1 Scale: 1 (strongly agree) to 5 (strongly disagree).

2 Mean within the same row with P < 0.05 are statistically significant and imply equality of mean, and P > 0.050 implies a significant difference of mean.

Perception of potential dangers associated with the usage of BSFL-based fertilisers in agriculture.

Table 7 displays farmers' perceptions of potential risks related to the use of BSFL-based fertilisers in agriculture. When asked about their views on the many alleged concerns associated with the usage of BSFL frass, farmers were beset by indecision. To the possibilities of cross microbial contamination from BSFL frass to food products, reduced consumption of products by the public in response to knowledge of the type of fertiliser used, reduced yield and malformation of farm products, the allergenic potential of the frass on the crops and consumers, and finally, the loss of crops caused by the use of frass, farmers on average were neither in agreement nor disagreement regarding the perceived dangers.

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Table 7: Perception of potential dangers associated with the usage of BSFL-based

	Pooled sample	Type of respondent		Standard error	P-value
		Male	Female		
The use of BSFL frass-based fertiliser could lead to the introduction of microbiology and food contamination.	3.0000	3.0000	3.0000	.08059	.000
The use of BSFL frass-based fertiliser could lead to low consumer acceptance of agricultural products.	3.0000	3.0000	3.0000	.08124	.000
The use of BSFLfrass-based fertiliser could result in low yield and/or malformation of certain farm products	3.0000	3.0000	3.0000	.08341	.000
Crops grown on BSFL frass-based fertiliser could cause allergic reactions in humans when consumed.	3.0000	3.0000	3.0000	.08215	.000
The use of BSFLfrass-based fertiliser could cause death to crops	3.0000	3.0000	3.0000	.08375	.000

1 Scale: 1 (strongly agree) to 5 (strongly disagree).

2 Mean within the same row with $P < 0.05$ are statistically significant and imply equality of mean, and $P > 0.050$ imply a significant difference of mean.

Internationally, the use of BSFL frass as a substitute for inorganic fertiliser has garnered increasing attention, although it is still a novel practice in sub-Saharan Africa. As a result, information regarding its economic viability and the attitude of farmers towards the use of BSFL frass is still restricted, a factor that, along with environmental sustainability, contributes to sustainable development. In this study, it was discovered that using BSFL frass in urban farming yields a higher return on investment and profit margin than synthetic fertilisers, which is in accordance with the findings of (Beesigamukama et al., 2022). Farmers supported the concept of substituting BSFL frass for inorganic fertiliser in urban agriculture, indicating that the average responder viewed the concept as 'appropriate. The majority of male farmers had doubts, which may be related to their uncertainty as to whether or not the final yield of the product would be equivalent to or the same as that cultivated with chemical fertiliser. They did not see the need to treat organic waste, particularly animal manure, because it could be spread straight to farms. When told, women recognised the detrimental effects of animal manure (Malomo et al., 2018). In addition, women were more receptive to the concept because they predominate in urban agriculture (Ngome & Foeken, 2012) and efficiently adapt to the changes required to sustain a robust and dynamic agricultural sector. It was determined that the consumption of crops cultivated on BSFLfrass was neither acceptable nor undesirable, as were the threats to crops posed by crop death and crop mortality. Although they were informed otherwise (Basri et al., 2022; Gebremikael et al., 2022; Quilliam et al., 2020), the respondents were not fully persuaded that frass would not have any detrimental impacts on either human health or crop health. Farmers adopted the concept of employing BSFL frass as organic fertiliser and soil conditioner, thereby decreasing their reliance on synthetic fertiliser. This is in agreement with a previous study which found that the use of frass can reduce the urban farmer's reliance on increasingly environmentally detrimental, expensive and less accessible foreign synthetic fertilisers (Ousman Gajigo, 2022) and enable the valorisation of organic

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waste. Organic waste poses a significant threat to our living environment. Therefore, efficient waste management is crucial for the preservation of the ecosystem. BSFL has been described as a solution for waste management (Amrul et al., 2022; Kim et al., 2021; Liu et al., 2018) by transforming garbage into precious wealth (Alagappan et al., 2022; Choi & Hassanzadeh, 2019; Dzepe et al., 2021; Fawole et al., 2020; Jung et al., 2022) through the composting of fly larvae. According to (Siddiqui et al., 2022), the use of BSFL in waste valorisation is one of the most feasible and environmentally friendly techniques for the bioconversion of waste into useful and high-quality products (protein source and biodiesel) for developing nations and recent studies have shown that combining the production of BSFL protein and biodiesel with organic fertiliser production through BSFL waste valorisation could increase the economic value of organic waste which is in accordance with the findings reported by (Handayani et al., 2021; Thuriès et al., 2019). According to our findings, farmers approved adopting BSFL to enhance organic waste as it is becoming a nuisance. There are hazards linked to the usage of BSFL frass despite its tremendous advantages. Major considerations include customer acceptance of end-products and safety concerns associated with the introduction of microorganisms in plants and insects' excretory matter, exoskeleton, dead larvae, etc., which can cause allergic reactions (Amrul et al., 2022; Kawasaki et al., 2020; Surendra et al., 2020; Wynants et al., 2019). Little data exist on the allergenic dangers of the use of frass. Kawasaki et al. (2020) discovered a low level of Escherichia coli in BSFL frass and a disease-causing bacterium in Xanthomonadaceae plants. Even though it is stated that these bacteria cause damage to crops (Costa et al., 2021), nothing is known about allergies caused by the consumption of crops grown on frass insects. Moreover, they represent a modest threat of transmitting phytotoxic diseases.

FUTURE DIRECTION OF RESEARCH

Future research should assess the impact of using frass in agriculture on human health.

CONCLUSION

The use of BSFL in the valorisation of organic waste has been thoroughly documented throughout the years, as have its environmental benefits. Poor nations favour this waste valorisation method because of its low cost and ease of implementation compared to other ecologically friendly organic waste management methods. In addition to the BSFL trait of being voracious feeders and its affinity for organic waste, the BSFL products of Protein, biodiesel, and BSFL frass are widely used to address sustainability and environmental issues by providing alternatives to protein sources for animal feed, fuel, and synthetic fertilisers. Frass, which is a novel approach, has been proven to be more cost-effective than the most commonly used synthetic fertiliser and is deemed suitable for use by urban farmers in Cameroon, thereby confirming that BSFLfrass meets all the sustainability criteria (environmentally sustainable, economically viable and socially acceptable).

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Declaration of Interest Statement

Manuscript Title: **THE ECONOMIC VIABILITY AND SOCIAL ACCEPTABILITY OF BLACK SOLDIER FLY LARVAE FRASS AS A SUBSTITUTE FOR CHEMICAL fertiliser IN AGRICULTURE IN CAMEROON**

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Data Availability statement

The supporting data for the conclusions of this study can be obtained by contacting the corresponding author upon request.

Author Contribution statement

The idea was conceived by T.A.Mk. T.A.Mk formulated the theory and conducted the calculations. T.A.Mk, O.T, and K.MA confirmed the validity of the methodology. O.T. and K.MA reviewed the findings of this study. Every author engaged in a discussion about the outcomes and made contributions to the ultimate manuscript.

Data Availability statement

The supporting data for the conclusions of this study can be obtained by contacting the corresponding author upon request.

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