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ECONOMIC ANALYSIS OF APPLYING VERMICOMPOST FOR VEGETABLE CULTIVATION: AN EXPERIMENTAL CASE STUDY FROM AN EMERGING ECONOMY

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Abstract

While various low-synthetic input agricultural cultivation practices are available, they have not been widely applied by farmers in developing countries since many farmers have not had concrete evidence on the economic viability of these practices. This study provides such evidence by analyzing collected information and data from: in-depth interviews with farmers and agricultural experts; an experiment in one vegetable farm in Northern Viet Nam, where the treated plots use vermicompost and the control plots use synthetic fertilizers; and records of the farmer's self-production of vermicompost. The results show that it is more profitable to cultivate vegetables using vermicompost than usual synthetic fertilizers, holding other conditions constant. Findings from this study suggest that government support is needed to reveal the economic viability of low-synthetic input agricultural cultivation to motivate farmers in developing countries towards sustainable agricultural cultivation.

Keywords: Vermicompost, Vegetable cultivation, Experiment, Case study, Viet Nam

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1. Introduction

Agricultural production has been increasingly intensified to meet the growing demand for food and agricultural products (FAO et al., 2017). Therefore, farmers have become more heavily dependent on chemical inputs in intensified agricultural cultivation. For example, Yousaf et al. (2017) demonstrate that synthetic fertilizers have contributed to at least 50% of the increase in crop yields during the 20th century. The excessive usage of synthetic fertilizers, pesticides, and feed in farming has led to increased agricultural waste, environmental pollution, loss of agrobiodiversity, and adverse health effects (Lee et al., 2019; Xia et al., 2020).

As the income of local people in developing countries becomes higher and more products are exported to developed countries, where safe and high-quality agricultural products are required, demand for low-synthetic input agricultural products has been rising worldwide (Kumar et al., 2017). As a result, low-synthetic inputs in agricultural cultivation have been adopted (Anh et al., 2024). Nevertheless, the application of low-synthetic inputs has not been widespread due to concerns such as reduced yields or increasing costs (Aertsens et al., 2009; Anh et al., 2024). It is also not ensured that products from low-synthetic input agricultural cultivation can be sold at a higher price than conventional products (Aertsens et al., 2009). Moreover, farmers' awareness and information about low-synthetic input agricultural cultivation is limited, particularly in developing countries (Coman et al., 2020). One of the key concerns is that there is limited evidence to convince farmers in developing countries to switch to low-synthetic input agricultural cultivation (Reganold & Wachter, 2016).

This study was conducted in Viet Nam with the aim of addressing the concern mentioned above. Viet Nam provides an ideal context for this study as Viet Nam produces and exports a wide variety of agricultural products (Vietnam Briefing, 2023). Among them, vegetables are important (Ly et al., 2014). The rapid increase in per capita income in Viet Nam has resulted in an increasing demand for organic vegetables (Schreinemachers et al., 2018). Many of the exported vegetables from Viet Nam are also organic (Vietnam Briefing, 2023). Therefore, helping farmers switch to low-synthetic input agricultural cultivation should be one of the first actions to increase organic vegetable production in Viet Nam (Le & Nguyen, 2019).

Previous studies in the literature suggest that supporting farmers to replace synthetic fertilizers with organic fertilizers should be an important step to switch to low-synthetic input agricultural cultivation. Among the available organic fertilizers, vermicompost is widely applied (Lim et al., 2015). It is documented that vermicompost can promote the growth of plants (Joshi et al., 2015; Lim et al., 2015). Tran et al. (2023) find that applying vermicompost in Viet Nam increased dwarf green bean yield by 14.6% compared to NPK fertilizer alone, even under saline irrigation conditions. Similarly, Thu et al. (2021) report that organic fertilizers, including vermicompost, improved okra fruit quality and yields compared to synthetic fertilizers. Nevertheless, there remain concerns about applying vermicompost in agricultural cultivation, particularly among farmers in developing countries (Hussain et al., 2016). Limited concrete evidence on the effectiveness and cost of vermicompost application in developing countries is available (Lim et al., 2015).

This study is based on qualitative information collected from in-depth interviews with 10 vegetable farmers and agricultural experts and quantitative data from an experimental case study in a province in Northern Viet Nam. Data on costs, sales revenue, and profit were collected from a farm with both treated plots and control plots, which have similar soil, weather, water, growing processes, seeds, and pesticides. While the treated plots were applied with vermicompost, the control plots were cultivated with chemical fertilizers. We conducted the test with two types of vegetables, which are gourd and brassica integrifolia.

Findings from this study present evidence on the economic viability of using vermicompost for agricultural cultivation. It is found that even though the use of vermicompost is costly, it helps reduce other costs. The cultivation of vegetables is, thus, profitable. This finding confirms that vermicompost can replace synthetic fertilizers for vegetable cultivation. Furthermore, the use of vermicompost helps improve the health of plants and, consequently, reduces the use of synthetic pesticides. These dual effects lead to a considerable reduction in the use of synthetic inputs, which is critical to preserving agrobiodiversity and obtaining sustainable agricultural production in developing countries. Our study reveals that farmers' lack of knowledge and awareness of using non-synthetic inputs is the main bottleneck for promoting low-synthetic input agricultural cultivation.

This paper is structured in six sections. After the introduction, Section 2 presents a literature review. Section 3 describes the context of agricultural cultivation in Viet Nam. The methodology and data are presented in Section 4. Section 5 discusses the findings. Finally, concluding remarks are presented in Section 6.

2. Literature review

2.1. Low synthetic input agricultural cultivation

Many agricultural cultivation practices such as organic farming or low-synthetic input cultivation have been proposed to ensure agrobiodiversity, the health of people, and sustainable development of agricultural production (Gemiero et al., 2011; Seufert & Ramankutty, 2017). Organic farming refers to a system that bans agrochemicals such as synthetic fertilizers and pesticides, genetically modified organisms (GMO), and synthetic compounds used as food additives such as preservatives and coloring (IFOAM, 2008; 2010). According to Gomiero et al. (2011), organic farming enhances soil fertility, reduces soil erosion, increases soil organic matter content, and improves biodiversity and energy efficiency. Nevertheless, yields of organic farming are generally lower. There exists a big gap in yields between organic and intensive conventional farming (Ponisio et al., 2015).

For small-scale producers, there are various challenges to conducting organic farming. For example, it is more complex and costly to ensure adequate nutrient supply for crops through organic sources such as manure and compost than through synthetic fertilizers (Reganold & Wachter, 2016). In organic farming, dealing with organic weeds, pests, and diseases requires more intensive management and knowledge compared to conventional cultivation using synthetic pesticides (Bàrberi, 2019). Economic and logistical barriers are also high for small farmers to carry out the organic certification process and marketing of organic products (Seufert & Ramankutty, 2017).

Another approach to organic farming is the low-synthetic input model of agricultural production. This model aims to reduce the reliance on synthetic inputs, such as synthetic fertilizers and pesticides, while maintaining the productivity and profitability of agricultural production. The low-synthetic input model is also named low-input agriculture or low external-input agriculture. Low-input agriculture is described as "a farming system that uses on-farm resources efficiently, minimizes the use of external, purchased inputs, and relies on natural, biological processes to improve soil fertility and control pests and diseases" (Katarzyna et al., 2008). In developing countries, low-external input agriculture has been widely accepted and promoted in the context of sustainable agriculture for several decades (Reijntjes et al., 1992). The key principles and practices of low-external input agriculture (LEIA) include integrated nutrient management using organic amendments such as compost, manure, and biological nitrogen fixation. LEIA also refers to diversified cropping systems, crop rotations, and biological pest and weed control using natural predators, botanical pesticides, and manual/mechanical methods. Moreover, LEIA covers integration of crop and livestock production to enable nutrient cycling and prudent water management and conservation practices.

2.2. Challenges of low synthetic fertilizer agricultural cultivation

In the approach to low synthetic input agricultural cultivation, organic fertilizers are used to replace synthetic fertilizers. Organic fertilizers are composed of natural, plant-based, or animal-derived materials such as compost, animal manures, bone meal, blood meal, seaweed extracts, and plant-based meals (Reeve et al., 2016). Organic fertilizers improve soil health by increasing organic matter and through microbial activities, rather than simply providing a quick burst of nutrients like their synthetic counterparts

The application of low-synthetic fertilizers in agricultural cultivation has become widespread in developing countries due to growing consumers' demand for high-quality, safe, and environmentally friendly agricultural products (Seufert & Ramankutty, 2017). The application of low-synthetic fertilizers is a must to meet international standards and certification systems for export. Therefore, low-synthetic fertilizer agricultural cultivation has been increasingly adopted by farmers in developing countries (Reganold & Wachter, 2016).

Nevertheless, the application of low-synthetic fertilizers in agricultural cultivation in developing countries encounters many challenges. One of them is the limited supply leading to a higher cost of organic fertilizers. In addition, organic fertilizers are often applied in a larger amount to achieve similar effects on agricultural yields as synthetic fertilizers. Therefore, the application of organic fertilizers requires higher labor costs (Vanlauwe et al., 2014). Another challenge comes from the gradual and lagged effects of organic fertilizers while farmers prefer the immediate effects from synthetic fertilizers (Marenya & Barrett, 2007). Indeed, farmers' limited knowledge and perception gap of low-synthetic fertilizers is a crucial constraint, leading to their reluctance to adopt low-synthetic fertilizers (Blanco-Canqui & Lal, 2009). This constraint comes from the fact that limited evidence on the economic effects of low-synthetic fertilizers has been demonstrated to farmers in developing countries (Blanco-Canqui & Lal, 2009).

2.3. Agricultural cultivation with vermicompost

Among organic fertilizers, vermicompost is often referred to (Kallas et al, 2020). Vermicompost is a nutrient-rich organic fertilizer, which is produced by decomposing organic matter by earthworms (Hossain et al., 2016). Vermicomposting is a process of using earthworms to transform organic waste into a nutrient-rich soil amendment. Vermicompost contains essential macro- and micro-nutrients, growth hormones, and beneficial enzymes that continue to break down organic matter even after excretion (Olle, 2019). Compared to synthetic fertilizers, the nutrients from vermicompost are released more slowly into the soil. One feature that is unknown to many farmers is that vermicompost has pesticidal properties. Hence, the application of vermicompost helps reduce synthetic pesticides (Kalika-Singh et al., 2022).

Vermicompost is an effective source of plant nutrients, microbial activities, and humic substances that improve soil quality, enhance crop yield and growth, and support sustainable farming (Vennila et al., 2012; Olle, 2019). Its use in agriculture reduces water consumption, pest attacks, and weed growth. Also, it promotes faster seed germination and increases fruit and seed production (Olle, 2019). Vermicompost is, thus, important to maintain soil health and ecosystem sustainability (Singh et al., 2020).

Despite these benefits, there are great challenges to the application of vermicompost. One primary challenge is the variability in quality and nutrient composition. The nutrient content and properties of vermicompost vary depending on the feedstock used, species of earthworms, and the environmental conditions during the composting process (Bhat et al., 2017). This heterogeneity makes it difficult to standardize the application rates and to ensure consistent crop responses (Alkobaisy et al., 2021). Another challenge is the limited availability and scalability of vermicompost production. The production of vermicompost is often constrained by the availability of suitable organic waste feedstocks, making it hard to meet the growing demand for large-scale agricultural cultivation (Pereira et al., 2014). Moreover, many farmers in developing countries have limited information about the cost-effectiveness and productivity gains from using vermicompost compared to synthetic fertilizers. Indeed, Suthar (2009) notes that providing training and demonstrating the benefits of vermicompost can help increase awareness and uptake among farmers.

More importantly, there are few concrete studies and field experiments to demonstrate the effects of vermicompost in improving crop yields, product quality, and soil health in developing countries. More local research is, thus, needed to generate new evidence, which is tailored to the local contexts. Devi and Rawat (2018) emphasize the need for further research to establish the economic viability of vermicompost compared to synthetic fertilizers to upscale the adoption of vermicompost in developing countries. Addressing this research gap helps promote the application of vermicompost in agricultural production in the developing world (Devi and Rawat, 2018).

3. Context of agricultural cultivation in Vietnam

About 40% of Viet Nam’s land is utilized for agricultural cultivation, which supports the livelihood of more than half of the population (Nguyen, 2020). Agricultural output contributes to approximately 20% of GDP. Viet Nam’s plant-based agriculture has undergone a remarkable transformation to become one of the world’s large agricultural exporters and key players in global agriculture (Vietnam Briefing, 2023). Agriculture plays an important role in creating jobs and income (Nguyen, 2020).

In the agricultural sector in Viet Nam, fruit and vegetable cultivation is important because Viet Nam has ideal natural conditions, including a climate and year-round availability of certain temperate vegetables (Ly et al., 2014). The scale and structure of fruit and vegetable cultivation have advanced significantly in recent years since they have an important role in the local people’s diet. It is the second most important foodstuff after rice. According to FAO (2018), domestic consumption of vegetables accounts for 85% of the total production.

Among vegetable farmers in Viet Nam, about 90% of them are small and family-type. There is a small number of large-scale farms and farmer cooperatives. More than 65% of the vegetable farmers are located in rural areas (FAO, 2018). There exist various difficulties for small family-type vegetable farmers due to their limited access to capital, technology, and market information. Small vegetable farmers do not have a brand or bargaining power in the market. They often have to sell vegetables through traders at a lower price. Moreover, due to the lack of large-scale processing and storage facilities, vegetables harvested from small farms cannot be processed properly and quickly deteriorate. Thus, small farmers mainly sell vegetables through traders or directly in open-air markets.

Farmers in Viet Nam have frequently used synthetic inputs in agricultural cultivation. The availability of imported synthetic inputs has increased. Synthetic inputs are applied widely because of their immediate effects on yields. The usage of synthetic fertilizers and pesticides in large amounts has resulted in water pollution, air pollution, deteriorated soil, and other health problems (MOH, 2022). In recent years, under market pressure, farmers in Viet Nam have gradually shifted to using less synthetic fertilizers and pesticides. Nevertheless, there have been obstacles to this transition. Organic fertilizers such as cow, pig, chicken, and buffalo manure are not enough for expanding vegetable cultivation. Other organic inputs are also not widely applied. For example, while vermicompost is prevalent in developed countries with large-scale farms (Kallas et al., 2020; Michelson, 2023), it is not widespread in Viet Nam (Tran et al., 2023; Thu et al., 2021). An important reason is that information and evidence on the effectiveness of organic fertilizers such as vermicompost is not yet available (Huynh et al., 2023). Hence, most of the farmers in Viet Nam still depend on synthetic fertilizers, which are readily available, inexpensive, and offer an immediate effect.

From the demand side, the increase in per capita income in Viet Nam and the export of agricultural products have led to a rising demand of customers for higher-quality and safe vegetables (Le & Nguyen, 2019; Xuan, 2021). The rising income allows local customers to accept higher prices of organic vegetables, which are mainly sold in supermarkets and organic vegetable shops. At the same time, the export of vegetables has been expanded in terms of both value and markets. The value of fruit and vegetable exports set a record high of nearly 5.6 billion USD in 2023. It is forecasted to reach 6.5 billion USD in 2024 (Viet Nam Pictorial, 2024).

4. Methodology and data

4.1. Methodology

This study employed both qualitative and quantitative methods to investigate the impact of vermicompost on vegetable farming in Viet Nam. Information on the use of vermicompost and vegetable cultivation including costs and outputs, socioeconomic characteristics of farmers, their awareness of vermicompost, and their farming practices was collected.

For the qualitative analysis, in-depth interviews were carried out with ten respondents including six owners of vegetable farms who have not used vermicompost (Farmers A, B, C, D, E, and F), one owner of a vegetable farm who has used vermicompost bought from the local market (Farmer G), two Vietnamese experts in vegetable cultivation (Experts A and B), and one expert of vermicompost from Madagascar (Expert C). This expert from Madagascar has expertise in culturing earthworms and producing vermicompost. She was conducting another similar project in Madagascar. While she was visiting Viet Nam, we had an in-depth interview with her.

We conducted the in-depth interviews in Hanoi, which is the capital city of Viet Nam, following ethical procedures. The identities of the respondents are kept confidential and anonymous. The in-depth interview with each respondent was conducted for about sixty minutes. During the in-depth interviews, we were interested in farmers' awareness of earthworms and vermicompost, existing support for their culture of earthworms and use of vermicompost, and their assessment of using vermicompost for vegetable cultivation. Through the interviews, we captured specific narratives of earthworms and vermicompost in agrobiodiversity. We recorded and transcribed all of the in-depth interviews. We then prepared the information collected from the in-depth interviews for our qualitative analysis using the NVivo coding software. The in-depth interviews were carried out in Vietnamese. The transcripts were translated into English. We have a bilingual researcher assisting us with reverse translation to prevent bias.

In addition to the qualitative analysis, we are interested in examining the economic benefit of using vermicompost in growing vegetables. Therefore, we conducted an experiment with a vegetable farm in Viet Nam. To test the impact of vermicompost on vegetable cultivation, we designed an experiment with a farm for two vegetable products: gourd and brassica integrifolia. These products are among the most popular vegetables sold in Viet Nam (Muriel & CIRAD, 2023). The gourd is for fruits and the brassica integrifolia is for edible leaves. It is noted that these two products are different in terms of the number of harvesting times in one cycle. While the gourd can be harvested several times, the brassica integrifolia can be harvested only once during one cycle. This vegetable selection ensures that the heterogeneity in harvesting times is controlled for when the effects of vermicompost on vegetable cultivation are evaluated.

For each of these products, we have one plot using vermicompost (the treated plot) and the other using normal synthetic fertilizers (the control plot). The cultivation of the two vegetables was carried out during the same winter season in 2023. Other conditions, i.e., land fertility, seeds, application of machines and tools, and use of other inputs, are held constant. The vegetable products were sold during the same period to minimize any difference in prices. This setting allows us to compare costs, output, sales revenue, and profit between the treated and the control plots, thus separating the effects of applying vermicompost on vegetable cultivation.

Moreover, we were successful in convincing the farmer to invest in facilities and start producing vermicompost, which was used for the treatment during our study. We are, therefore, interested in exploring if the cost of self-produced vermicompost is lower than the market price.

4.2. Data

We conducted in-depth interviews with ten respondents in the middle of 2023 to collect information for the qualitative analysis. Regarding the selection of seven farmers for the interviews, we first picked up one district with the largest vegetable cultivation in Hanoi, which is one of the main areas of vegetable cultivation in Viet Nam (Ngo et al., 2019). We then randomly selected one commune in that district. Six farmers without using vermicompost in a farmer list provided by the commune government were randomly chosen. One farmer who has used vermicompost was suggested by the commune government. We also got the names of two experts in vegetable cultivation in Viet Nam, who were introduced by a governmental agency in vegetable cultivation. The expert in vermicompost production from Madagascar was introduced by the Global Development Network. The ages of the ten respondents range from 36 to 55. The gender distribution of the respondents was 50% male and 50% female.

To collect data on costs, output, sales revenue, and profits of the treated and control plots for both products and the earthworm production, we requested the female farm owner to keep detailed written records of the vegetable and earthworm production of one cycle during the winter season. She has an accounting staff, who helps her to enter all data into an Excel file on her computer. During the production in the winter season in 2023, we visited the farm several times to observe the progress of the experiment. In early April 2024, we came to collect the data for the first time. After checking the data, we revisited the farm in June 2024 to verify the data.

The start of the experiment, i.e., gourd and brassica integrifolia cultivation, was in mid-July 2023. The total area for the gourd cultivation was 720m^2, of which 480m^2 was for the treated plot (using earthworms) and 240m^2 was selected for the control plot (using usual synthetic fertilizers). It took the gourd 60 days to be harvested. In the control plot, the harvesting period was 60 days until mid-November 2023. In the treated plot, the harvesting period was 120 days until mid-January 2024. According to our interview with the farmer, she discovered that the harvesting time of the gourd with earthworms in the treated plot was longer lasting than usual as the gourd was stronger and more productive.

The total area for the brassica integrifolia cultivation was 600m^2, of which 240m^2 was for the treated plot and 360m^2 was for the control plot. The farm began planting seeds in late September 2023. The brassica integrifolia in the control plot was harvested after 45 days, in around mid-November 2023. The brassica integrifolia in the treated plot was harvested after 30 days, in late October 2023. The growing duration of brassica integrifolia using synthetic fertilizer in the control group was almost 1.5 times longer than that using vermicompost in the treated group.

Regarding the vermicompost production, the farmer began producing vermicompost in early July 2023. The area of vermicompost production was 300m^2. The average cycle of vermicompost production was about 40-45 days.

For the gourd and the brassica integrifolia cultivation on both treated and control plots, we collected data on costs, sales revenue, and profits of the plots for one cycle. The total cost consists of direct and indirect costs (Conner & Rangarajan, 2009; Chamberlain, 2012). Direct costs of vegetable cultivation include the cost of seeds, basal fertilizers, main fertilizers, additional fertilizers, pesticides including insecticides and fungicides, electricity and water, and labor for seeding, tillage, fertilizing, pesticide spraying, and harvesting. Indirect costs include the cost of trellis, netting, land rental, and management.

Regarding vermicompost production, direct costs include the cost of earthworms, bags, electricity, labor, and feed materials. Indirect costs consist of the cost of infrastructure, nets to prevent earthworms from escaping to the ground, covering nets, canvas, a shelter frame, a watering system, land rental, and management.

Sales revenue was calculated as the quantity produced of each product times its market price. Profit was calculated as sales revenue minus total cost. To make the comparison across plots possible, we standardized costs, sales revenue, and profit by measuring these indicators per one Vietnamese acre, which is 360m^2.

5. Findings

5.1. Awareness of and barriers to use vermicompost: a qualitative analysis

During our in-depth interviews with the farmers who have not used vermicompost, it was revealed that they are aware of the role of earthworms in improving soil fertility and productivity. This finding supports the result of Ebewore and Ovharhe (2016), which addresses the improvement of soil fertility and the nutrient cycling process in the ecosystem through earthworms. Most of the farmers are, however, not fully aware of the benefits of vermicompost and how to produce vermicompost. This finding is also in line with the literature. For example, Gebrehana et al. (2022) reveal that farmers in Ethiopia disagree on earthworms' potential to degrade organic wastes. Birang et al. (2003) find that farmers had limited interest in vermicompost since they did not believe that vermicompost affects crop production.

I am using cow and chicken manure as fertilizer because it is not expensive. It is suitable for my small farm (Farmers A, B, and E).

I know earthworms and why they are important for vegetable cultivation (Farmers A, B, C, D, E, and F). I also add earthworms to make my soil more fertile and plants healthier (Farmers A, C, and F).

I am not sure if vermicompost works for my cultivation. I have no idea about producing vermicompost (Farmers A, B, C, D, E, and F).

During our interview with the farmer who has already used vermicompost in their vegetable farm cultivation, it was reported that the use of vermicompost produces high-quality vegetables, leading to a high crop yield. Vegetable buyers such as grocery shops or supermarkets are willing to buy them at a higher price. Rastegari et al. (2023) also agree that the conversion of agricultural waste into organic fertilizer through vermicomposting is not only a sustainable waste management solution but also an additional income source for farmers. Vermicompost is useful to increase the defensive capacity of plants (Rehman et al., 2023; Yatoo et al., 2021).

Last year, I tried to use vermicompost once. I could harvest a larger quantity of higher-quality vegetables. The time of cultivation with vermicompost was shorter. However, the cost of vermicompost was high. Two supermarkets showed their interest in paying a higher price for our vegetables. However, they eventually did not buy our vegetables for an unknown reason (Farmer G).

There are, however, certain barriers for farmers to apply vermicompost in vegetable cultivation in Viet Nam. Limited understanding and experience in using vermicompost make farmers hesitant to apply it in vegetable cultivation. Fears of losing crops and income when synthetic fertilizer is not used exist among farmers. A relatively high price of vermicompost compared to that of synthetic fertilizers also prevents farmers from purchasing vermicompost. These barriers are similar to what are suggested by Rastegari et al. (2023) and Pierre-Louis et al. (2021). According to these studies, there are financial and market, political, and informational and behavioral barriers. The lack of a high-quality local workforce is also another barrier.

In Viet Nam, vermicompost is not well known among farmers. Synthetic fertilizer is available at a reasonable price. Many farmers do not know how efficient vermicompost is for vegetable cultivation (Experts A and B). In Madagascar, vermicompost is, however, popular as many farmers know how efficient it is for crop cultivation (Expert C).

I found vermicompost available in the market. However, its price is high. Moreover, I do not know if it is really efficient to use vermicompost in vegetable cultivation (Farmers A, B, C, D, E, and F).

In Viet Nam, few farmers could produce vermicompost by themselves (Experts A and B). In Madagascar, some farmers have started producing vermicompost by themselves. Even though the production is on a small scale, the cost is low (Expert C).

To motivate farmers to use vermicompost in vegetable cultivation, there are several recommendations from interviewed experts. Firstly, a pilot-scale project for vermicompost application is important as it has a demonstration effect for many farmers (Katiyar et al., 2023; Hu et al., 2021). During our interviews, three experts also agreed that support from the government for a pilot project to use vermicompost in vegetable cultivation is needed. The pilot project shall reveal the economic benefits of applying vermicompost in vegetable cultivation. Information of these economic benefits should be made available to as many farmers as possible. With concrete evidence, vegetable farmers are motivated and willing to adopt vermicompost. Secondly, Dhanushkodi and Porkodi (2018) demonstrate that farmers can learn vermicomposting technology through hands-on training and take it up as a venture for additional income. Nevertheless, producing vermicompost at a low cost is challenging for small-scale farmers. Therefore, training and technical support for farmers to produce vermicompost is warranted (Suzuki et al., 2014; Vu et al., 2021).

If vermicompost can be self-produced by farmers at a certain scale, it is cheaper than buying from the market (Experts A and B). In Madagascar, we organized workshops for small farmers and sent technicians to help them produce vermicompost. They can afford to produce vermicompost for their farming (Expert C).

5.2. Quantitative analysis of vegetable cultivation using vermicompost

The qualitative analysis shows that farmers are afraid of losing their crops and income if they change from synthetic fertilizers to vermicompost. They also observe a high price of vermicompost in the market given the availability of synthetic fertilizers. In this section, we aim at providing quantitative evidence on the economic benefits of using vermicompost in vegetable cultivation in comparison with vegetable cultivation using usual synthetic fertilizers.

In this section, all the costs are measured in Viet Nam Dong (VND) at the current price in the winter of 2023. To compare costs between the treated and the control plots, costs are standardized using the same unit of analysis, which is one cycle per one Vietnamese acre. One Vietnamese acre is equivalent to 360m^2.

5.2.1. Gourd cultivation

Table 1 provides the details of the costs associated with gourd cultivation in two plots: the treated one using vermicompost versus the control one using synthetic fertilizers. The last row of Table 1 shows that the total cost for one cycle per one Vietnamese acre of gourd in the control plot, i.e., using synthetic fertilizers, is 4,629,334 VND. The total cost in the treated plot, i.e., using vermicompost, is 5,948,000 VND, which is 28.5% higher than that in the control plot. Higher costs in the treated plot are mainly due to the application of vermicompost, which accounts for 31.5% of the total cost. It is noted that the farmer could produce enough vermicompost for her use in the treated plot. She did not have to buy from the market. For a comparison with the control plot, the cost of vermicompost is calculated by multiplying the amount used in the treated plot and the market price. As the quantity of vermicompost used in the treated plot and the price of vermicompost are higher than the usual levels in the control plot, the total cost for fertilizers is higher in the treated plot. This finding confirms the worries of many farmers about costly vermicompost during our in-depth interviews. This finding also indicates that vermicompost can replace conventional fertilizers such as microbial and NPK fertilizers in vegetable cultivation.

In addition, Table 1 shows that the cost of harvesting in the treated plot is higher because the farmer had to collect a larger quantity of output. The costs of rental land and management differ between the two plots. In the treated plot using vermicompost, these costs are higher than in the control plot. This increase in rental land and management costs is due to the extended harvesting period of the gourd in the treated plot from 4 to 6 months with a higher yield.

Table 1. Costs of gourd cultivation in treated and control plots

	Quantity		**Cost (VND)**	
	Treated	**Control**	**Treated**	**Control**
Seeds	500 grams	500 grams	150,000	150,000
Basal fertilizers (chicken manure)	250 kg	250 kg	200,000	200,000
Fertilizers				
Vermicompost	375 kg	0	1,875,000	0
Microbial fertilizer	0	2 packs	0	360,000
NPK fertilizer	0	10 kg	0	125,000
Additional fertilizer	0	30 kg	0	375,000
Pesticides				
Insecticide	3.75 tanks	15 tanks	150,000	600,000
Fungicide	3.75 tanks	15 tanks	37,500	150,000
Nylon	0.5 pack	0.5 pack	190,000	190,000
Electricity and water	-	-	50,000	50,000
Labor				
Seeding labor	-	-	150,000	150,000
Tillaging labor	-	-	250,000	250,000
Basally fertilizing labor	-	-	195,000	120,000
Pesticide spraying labor	9 tanks	18 tanks	63,000	126,000
Additionally fertilizing labor	0	-	0	135,000
Harvesting labor	-	-	1,177,500	675,000
Trellis, net (a 15-year amortization)	1 net	1 net	400,000	266,667

Land rental	1 acre	1 acre	250,000	166,667
Management				
Remuneration for Board of Cooperative	3 persons/6 months	3 persons/4 months	405,000	270,000
Accounting	2 persons/6 months	2 persons/4 months	405,000	270,000
Total costs			5,948,000	4,629,334

Source: Authors' compilation and calculation

It is, however, noted in Table 1 that the cost of pesticides is lower in the treated plot. Correspondingly, the labor cost for applying pesticides is lower in the treated plot. The farmer reported that the gourd cultivated with vermicompost is stronger and more resistant to diseases. As a result, she had to apply fewer pesticides. In fact, the farmer did not expect this from the beginning. Hence, she was happy to discover this feature of vermicompost. This remarkable difference reflects the findings from Olle (2019), which highlight the advantages of vermicompost in agricultural cultivation, including decreased water usage for irrigation and reduced pest and termite infestations. These benefits contribute to environmental protection (Pretty & Bharucha, 2014) and result in safer products for consumers (Reganold & Wachter, 2016). The use of vermicompost leading to reduced application of synthetic fertilizers and pesticides offers potential long-term benefits for farmers in terms of well-maintained soil quality and increased crop health (Aslam et al., 2019; Chatterjee et al., 2020).

These findings are in line with previous research indicating that organic farming requires more labor than conventional farming as synthetic inputs are replaced by innovative processes, increased labor, capital investment, and enhanced management expertise (Sørensen, 2005). It is reported in Table 1 that the harvesting cost in the treated plot was 1,177,500 VND, which substantially exceeded that in the control plot with 675,000 VND, due to a higher quantity of output in the treated plot. Adding other labor costs, the total labor cost in the treated plot was approximately 1.3 times higher than that in the control plot.

Table 2. Output, sales revenue, and profit of gourd cultivation in treated and control plots

	Treated	**Control**
Output in one cycle (kg)	1,178	675
Price (VND/kg)	10,000	10,000
Sales revenue in one cycle (VND)	11,775,000	6,750,000
Profit in one cycle (VND)	5,827,000	2,120,667
Profit in one year (VDN)	11,654,000	6,362,000

Source: Authors' compilation and calculation

Table 2 presents a comparison of output, sales revenue, and profit of cultivating gourd in both treated and control plots. It is noted that the gourd cultivated from the treated plot was not offered a higher price since it is not an organic vegetable. The statistics in Table 2 show remarkably better results of cultivating gourd using vermicompost than using synthetic fertilizers. The total amount of gourd harvested in one cycle from the treated plot is 1.7 times higher than that in the control plot. This finding is in line with the previous studies (Kalika-Singh et al., 2022). This difference in the amount of output leads to a considerable disparity in sales revenue. Despite incurring a higher total cost, the gourd cultivation in the treated plot generates higher profit. The profit gained from the treated plot in one cycle is 2.8 times higher than that in the control plot. The profit gained from the treated plot in one year is 1.8 times higher than that in the control plot. This substantial profit difference underscores the economic viability of adopting vermicompost in gourd cultivation.

5.2.2. Brassica integrifolia cultivation

Table 3 presents a comparison of costs for brassica integrifolia cultivation in the treated plot using vermicompost and in the control plot using synthetic fertilizers.

Table 3. Costs of brassica integrifolia cultivation in treated and control plots

	Quantity		Cost (VND)	
	Treated	**Control**	**Treated**	**Control**
Seeds	300 grams	300 grams	120,000	120,000
Basal fertilizers (chicken manure)	15 packs	15 packs	300,000	300,000
Fertilizers				
Vermicompost	7.5 packs	0	937,500	0
Microbial fertilizer	3 packs	3 packs	180,000	180,000
NPK fertilizer	0	10 packs	0	130,000
Additional fertilizer	0	1 bottle	0	80,000
Pesticides				
Insecticide	1.5 tanks	5 tanks	90,000	300,000
Fungicide	1.5 tanks	5 tanks	90,000	50,000
Seed booster	0	1 bottle	0	50,000
Netting	1 acre	1 acre	15,000	15,000
Electricity and water	-	-	30,000	45,000
Labor				
Tillaging labor	-	-	250,000	250,000
Basally fertilizing labor	-	-	198,900	130,000
Seeding labor	-	-	600,000	600,000
Watering labor	-	-	300,000	450,000

Pesticide spraying labor	-	-	21,000	70,000
Weeding labor	-	-	250,000	250,000
Harvesting labor	-	-	1,342,500	1,000,000
Land rental	1 acre	1 acre	41,667	62,500
Management				
Remuneration for Board of Cooperative	3 persons/1 month	3 persons/1.5 months	67,500	101,250
Accounting	2 persons/1 month	2 persons/1.5 months	67,500	101,250
Total cost			4,901,567	4,285,000

Source: Authors' compilation and calculation

Similar to the findings in Table 1, the total cost of brassica integrifolia cultivation in the treated plot is 14.4% higher than that in the control plot. The difference in the total cost between the two plots of brassica integrifolia cultivation is, however, smaller than that of gourd cultivation. This higher total cost in the treated plot is also mainly due to the purchase of vermicompost, which accounted for 19.1% of the total cost. Again, we assumed the farmer had bought the vermicompost at the market price. The higher total cost is partly due to the higher cost of harvesting labor as the output is higher in the treated plot.

The increase in total cost in the treated plot is, however, mitigated by a reduction in the cost of pesticides (Table 3). Similar to the gourd cultivation, the brassica integrifolia cultivation using vermicompost in the treated plot saves pesticide cost as vermicompost helps the vegetable better resist to diseases. This reduction in pesticide use is essential for both labor safety and the farmer's health as previous studies have highlighted the health risks associated with extensive pesticide use in agriculture. Farmers who rely heavily on pesticides often face numerous health issues (Chatzimichael, 2022), including headaches, nausea, and skin problems (Qiao et al., 2012). Paradoxically, the study by Athukorala et al. (2023) suggests that despite these risks, the reduction in pesticide use is not always realized.

One of the important advantages of brassica integrifolia cultivation using vermicompost is that it helps shorten the cultivation time. The duration for the cultivation of brassica integrifolia using vermicompost was reduced to 30 days from 45 days for the cultivation of brassica integrifolia using synthetic fertilizers. As a result of the reduced cultivation time in the treated plot, the indirect costs such as land rental, remuneration for board members of the cooperative, and accounting were lower than those in the control plot. Additionally, the cultivation of brassica integrifolia using vermicompost costs less electricity and water. This observation can be attributed to better water use, improved soil health, and enhanced water-holding capacity associated with vermicompost use (Moreno-Reséndez et al., 2013; Saha et al., 2022).

Table 4. Output, sales revenue, and profit of brassica integrifolia cultivation in treated and control plots

Category	Treated	Control
Output in one cycle (kg)	1,074	800
Price (VND/kg)	10,000	10,000
Sales revenue in one cycle (VND)	10,740,000	8,000,000
Profit in one cycle (VND)	5,838,433	3,715,000
Profit in one year (VND)	46,707,467	19,813,333

Source: Authors' compilation and calculation

Table 4 compares the output, sales revenue, and profit of brassica integrifolia cultivation in both treated and control plots. In the treated plot, the output and sales revenue were 34.3% higher than those in the control plot. The profit of brassica integrifolia cultivation in the treated plot in one cycle was 1.6 times higher than in the control plot. The profit of brassica integrifolia cultivation in the treated plot in one year was 2.4 times higher than in the control plot. The use of vermicompost in vegetable cultivation, hence, presents a feasible path to economically viable agriculture. These results challenge the argument that in low-income countries farmers have to produce vermicompost to make a profit in agricultural production (de Souza et al., 2022; Ananno et al., 2021).

The use of vermicompost may incur a higher initial investment. Its benefits far outweigh its costs. Hsing vermicompost not only results in a higher yield and profit but also has the potential to deliver long-term benefits in soil quality and crop health, contributing to a more sustainable agricultural system. These findings support Kavitha's arguments (2022) that farmers are not well aware of the economic benefits of using vermicompost in agricultural production.

5.3. Vermicompost production

We were successful in persuading the farmer to invest in the cultivation of earthworms and the production of vermicompost. Then, we collected detailed information on the costs of vermicompost production, which is presented in Table 5.

Table 5. Costs of vermicompost production

	Variable and fixed cost (initial price) (VND)	Amortization (years)	Amount (VND)
Breed of earthworms	20,625,000	20	128,906
Bags	96,000		96,000
Electricity	25,000		25,000
Labor			
Composting	150,000		150,000
Harvesting	312		748,800
Logistics	300,000		300,000
Feeding materials			
Cow manure	3,000,000		3,000,000
Other materials	240,000		240,000
Fermenter	96,000		96,000
Infrastructure (floor, tanks…)	126,039,000	20	787,744
Net (preventing earthworms from escaping)	1,500,000	20	9,375
Cover netting	540,000	10	6,750
Canvas	1,080,000	3	45,000
Steel frame	40,000,000	20	250,000
Nylon frame	8,000,000	7	142,857
Water pipeline system	7,000,000	15	58,333
Water pump	800,000	10	10,000
Total cost			6,094,765
Cost per one kilogram of vermicompost			2,539

Source: Authors' compilation and calculation

The previous sections suggest that the vermicompost cost accounts for a large share of the total cost, thus being the main source of the higher total cost of both gourd and brassica integrifolia cultivation in the treated plot. This finding explains why many farmers showed their concerns about costly vermicompost during our in-depth interviews. In this study, we have gone further than the two experiments with gourd and brassica integrifolia cultivation of earthworms. As can be seen in Table 5, the total production cost in one cycle of vermicompost production amounted to 6,094,765 VND. The cost structure encompasses both direct and indirect costs, providing a holistic view of vermicompost production (Devkota et al., 2014). The direct costs accounted for the largest share of the total cost, including breeding material, bags, electricity, labor costs, and feeding ingredients. Cow manure cost accounted for nearly half of the total cost.

Cow manure is crucial for vermicompost production (Wang et al., 2022) as it demonstrates high efficiency in organic matter conversion (Suthar, 2009). The second largest share of the cost was for labor. The indirect costs include the initial investments to establish a vermicompost production base, including infrastructure such as the floor, earthworm tanks, compost tanks, a netting to prevent earthworms from escaping, a canvas for protection, and a watering system. These indirect costs underscore the importance of long-term planning and investment in vermicompost production.

For one cycle, the farmer could harvest 2,400 kg of vermicompost. Therefore, the unit cost of vermicompost was 2,539 VND per kilogram. We interviewed the farmer and obtained information of the market price of vermicompost (Table 6). The price of vermicompost depends on the humidity contained in the vermicompost. Our analysis shows that the farmer could produce vermicompost at a cost which is lower than the market price. This finding has two implications. First, since we used the market price of vermicompost in calculating costs, the total cost of gourd and brassica integrifolia cultivation was actually lower and the profit was actually higher than the corresponding levels calculated in Sections 5.1 and 5.2. This finding indicates that the gourd and brassica integrifolia cultivation is more profitable than what is presented in Sections 5.1 and 5.2. Second, the production of vermicompost is a potentially profitable business for farmers in Viet Nam. Hence, this analysis provides a solid basis for economic evaluation and decision-making in sustainable vegetable cultivation.

Table 6. Market price and sales revenue of vermicompost

	Market price (VND)	Sales revenue (VND)	Profit (VND)
Humidity (60%)	-	-	-
Humidity (70%)	5,000/kg	12,000,000	5,905,235
Humidity (80%)	4,000/kg	9,600,000	3,505,235

Source: Authors' compilation and calculation

The farmer reported that she has not had any equipment to measure the humidity of her vermicompost. She was, however, confident that her vermicompost contains 60% of humidity. In fact, there is not vermicompost that contains 60% of humidity in the market since the demand for that vermicompost is not high. Its price is, thus, not available. We used the prices of the other vermicompost types, i.e., containing 70% and 80% humidity, to calculate sales revenue and profit of vermicompost production. The results reported in Table 6 show that the production of vermicompost is profitable, suggesting an opportunity for a new business for vegetable farmers in Viet Nam. These results also indicate that small farmers can potentially participate in the high-end segment of the vermicompost market. These results also suggest implications for the implementation of a circular economy in developing countries.

6. Concluding remarks

6.1. Theoretical contribution

Our study is based on the qualitative analysis of information from in-depth interviews with farmers and experts in agriculture and an experimental case study of a farmer in Northern Viet Nam. In this experiment of vegetable cultivation, vermicompost was applied in the treated plots while synthetic fertilizers were used in the control plots. By holding other conditions constant, we could evaluate the impact of vermicompost on the economic viability of vegetable cultivation. Our study has several contributions to the literature.

First, our study provides evidence on the economic viability of using vermicompost for profitable agricultural production, which challenges a widely accepted argument that farmers need to produce vermicompost by themselves to make a profit (de Souza et al., 2022; Ananno et al., 2021). Our study shows that even though the use of vermicompost purchased from the market is costly due to high price and more labor required, it helps reduce other costs. As a result, the cultivation of vegetables is profitable without having any price premium for improved-quality vegetables.

Second, vermicompost can replace synthetic fertilizers for vegetable cultivation. Moreover, the use of vermicompost helps improve the health of plants and, consequently, reduces the use of synthetic pesticides. These dual effects lead to a considerable reduction in the use of synthetic inputs, which is critical to preserving agrobiodiversity and obtaining sustainable agricultural production in developing countries. Our study indicates that the promotion of low use of synthetic inputs has a profound impact on sustainable agricultural production from perspectives of both farmers' livelihood and agrobiodiversity.

Third, above all our study reveals challenges in promoting agricultural production with low use of synthetic inputs. The most critical one is famers' lack of knowledge and awareness of using non-synthetic inputs.

6.2. Practical implications

From the qualitative analysis and experimental case study results, our study has several practical implications. First, governments should break the constraints in famers' lack of knowledge and awareness of using non-synthetic inputs by providing farmers with adequate and updated information on the economic viability of non-synthetic inputs such as vermicompost. Such information updates could be provided through seminars or workshops for demonstration to farmers. Generating opportunities for farmers to experience low-synthetic input agricultural production should also be effective.

Second, support from the government such as tax incentives, credit access, new technology, and high-quality human resources should be provided to farmers to motivate their production of non-synthetic inputs such as vermicompost (Vu et al., 2021; Nam & Luu, 2022).

Third, information on successful cases of using and producing vermicompost should be disseminated by the government to various stakeholders in the value chain of agricultural production (Vu et al., 2022). This information will make replication possible.

Fourth, promoting agricultural production using vermicompost should be used as an important policy to enhance the circular economy. Practical training of farmers on vermicompost use and production should be part of the organic production policy in agricultural production.

Additionally, public testing labs should be provided so that the quality of the vermicompost produced by farmers is revealed and ensured.

6.3. Limitations

Our study has several limitations. First, we only selected one farm in one particular province to conduct the experiment. This farm selection could lead to some potential bias. Future research should be conducted with more farms to control the heterogeneity among farms and locations. Second, we have not been able to provide any empirical evidence. A survey of a large number of farms should allow for this empirical study and provide more rigorous results.

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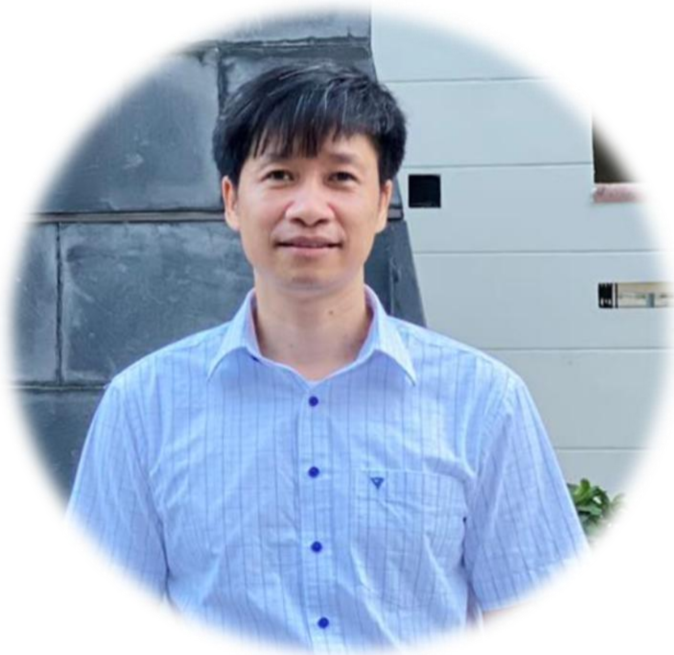

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