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Info Note

Creating Wealth from Waste: Resource Use Efficiency in Climate-Smart Agriculture

Findings from interviews with vermiculture farmers in Ha Tinh Province

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Key messages

- Vermiculture as a climate-smart agriculture (CSA) improves resource use efficiency on the farm.
- Integrated resource cycling is directly linked to cost savings on poultry feed, diversified income streams from worm sales, and qualitative agricultural improvements.
- Vermiculture requires minimal investment and can be implemented with little space, hence suitable for backyards and home gardens.
- Vermiculture yields economic and environmental benefits.

Mrs. Bui Thi Luu and Mr. Nguyen Van Thuy are the most successful vermiculture farmers in My Loi Village. They share materials and experiential knowledge with other local farmers. Photo credit: ICRAF/ Hai Van Le

Overview

It is increasingly urgent to support sustainable agroecosystems which optimize symbiotic interactions and productivity. Resources must be used efficiently within the agricultural system to minimize artificial or external inputs and their associated emissions, as well as costs to the farmer. However, past studies indicate that technology alone cannot sufficiently induce farmers to adopt sustainable production systems; additional economic incentives are necessary to foster technological change (Kruseman and Bade 1998).

Climate-Smart Agriculture (CSA) denotes a set of practices developed to increase both productivity and resiliency in the face of a changing climate (FAO 2010). Widespread changes in rainfall and temperature patterns impact agricultural production and farmers' livelihoods (Lipper et al. 2014). CSA practices are developed in partnership with local farmers and communities at risk of extreme weather events due to climate change, and are designed to synergistically address productivity, climate change adaptation and mitigation (Campbell and Dinesh 2017). This integrated approach aims to maximize multiple outcomes of food security, adaptation and mitigation (Lipper et al. 2014).

This study is an attempt to assess the economic and ecological benefits farmers in My Loi experienced from the adoption of vermiculture. Elucidating the quantitative and qualitative benefits of vermiculture can motivate broader adoption and scaling of this climate-smart practice. Using vermiculture as a case study, the multivariate positive benefits yielded from resource cycling within the farm system were explicated. By improving resource cycling on the farm, farmers can maximize efficiency and become more resilient both economically and environmentally.

Vermiculture as a Climate-Smart Practice

Vermiculture is a process in which worms convert manure into compost. Described by Darwin as "intestines of the earth" (Darwin 2002), earthworms and microbes accelerate the decomposition of crop materials and organic waste from livestock to generate vermicompost, a nutritive soil amendment. Earthworms aerate, grind, and mix waste components, in addition secreting enzymes and other chemicals which speed up biochemical degradation processes (Sinha et al. 2002). Vermiculture also functions as a worm production system, yielding outputs which can be sold or used as poultry feed. By utilizing the resources already present on the farm and reducing reliance on external inputs, farmers diversify risks. Resource cycling allows for increased stability and resilience in the context of fluctuating market valuations and weather patterns. The creation of a circular farm metabolism is ecologically restorative, and also yields economic returns for the farmers in direct and indirect ways.

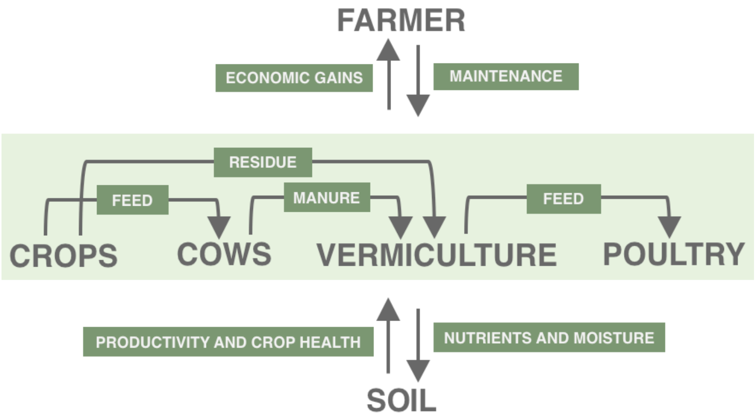

Figure 1. Input and output flows related to vermiculture in an integrated farm system

The vermiculture systems studied used *Perionyx excatatus*, one of the most versatile earthworm species and common in tropical Asia. *Perionyx excavatus* requires warm, moist environments to thrive (Hallatt, Viljoen, and Reinecke 1992), and is particularly well-suited for breaking down organic waste materials (Edwards, Dominguez, and Neuhauser 1998). In particular, cattle and pig manure has been shown to yield the best results for growth and reproduction of this species (Edwards, Dominguez, and Neuhauser 1998).

A CSA approach considers the farm and landscape holistically with the goal of facilitating short and long-term ecological sustainability. Climate-smart practices can synergistically address agricultural productivity, adaptation, and mitigation to improve livelihoods and resilience in the face of a changing climate. Vermiculture has the potential to address each of these CSA pillars.

- Productivity: increased agricultural productivity which results from vermicompost soil enrichment is directly linked with food security, and livelihood benefits result from the economic opportunities of worm sales;

- Adaptation: vermicompost can improve fertility and moisture-holding capacity, which are essential for adaptation. Resource-use efficiency and system integration improve farmers' economic resiliency;

- Mitigation: greenhouse gas emission reductions are achieved through reduced use of fossil fuel-based fertilizers or raw application of manure to fields.

Considering the agricultural production within an ecosystem framework opens up possibilities for cyclical resource analysis and increased efficiency (Fan et al. 2011). This perspective explores the utilization of outputs from one farming practice to become inputs for another, thereby reducing waste as well as external resource dependency. The value of CSA is optimized when multiple practices implemented in tandem, mirroring a symbiotic ecological system. In this way, the resources on the farm are designed to mimic viable ecosystems, yield positive economic and ecological outcomes, and improve the resiliency of the farm system.

These outcomes are particularly aligned with United Nations Sustainable Development Goals (SDGs) 13 and 15. SDG 13 focuses on strengthening adaptive capacity to climate-related hazards and natural disasters, and SDG 15 advocates for sustainable management of soil and water resources (Sustainabledevelopment.un.org 2015).

13 CLIMATE ACTION

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Methodology

A secondary data and literature review was conducted to review ICRAF field notes from previous interactions with farmers, as well as the scope of available material on small-scale vermiculture. Primary economic and qualitative data was collected in My Loi village, Ha Tinh province, Vietnam. A quantitative analysis calculated costs and benefits from the initial year of vermiculture establishment. Initial investments, maintenance, inputs into the vermiculture system, and quantifiable outputs were taken into account. Labor for the farmers was valued at VND 120,000 per day (ICRAF 2003). The weight of each worm was estimated at 0.5 grams, based on available literature (Sinha, Agarwal, et al. 2010). According to interview data, farmers receive VND 10,000 per kilogram of worms with substrate.

This financial breakdown was developed for one hundred chickens, ducks, and geese, in order to compare the value of worm feed for various poultry. However, the majority of farmers interviewed raised a combination of birds. Two farmers managed 4 m^2 worm enclosures, and the third has expanded to 8 m^2 bed since initial adoption two years ago. The initial investment from ICRAF was 50 kg of worms and substrates. Based on previous data collection from ICRAF, worm density in the 4 m^2 bed ranges from 32–48 kg with substrates, and 64–96 kg in the 8 m^2 enclosure.

A qualitative assessment synthesized other benefits associated with vermiculture based on farmer's experiences and available literature. Three farmers were selected for interviews based on their experience practicing vermiculture. Two of the farmers interviewed have been practicing vermiculture for two years, and the other farmer adopted the practice one year ago. One farmer received the initial worms from ICRAF, and the others began practicing vermiculture with worms shared from another farmer. This participant selection was intended to provide data on scaling and farmer-to-farmer social sharing, as well as experience and outcomes for vermiculture in the initial year.

Costs and benefits associated with vermiculture or other CSA practices depend on numerous factors, such as the scale of implementation, farm size, and agricultural practices. The economic values associated with this study are indicative, of the specific conditions for respondents, as farmers' costs vary according to market opportunity, scale, and biophysical features.

Results

Vermiculture practice can yield significant economic returns for farmers in the initial year of implementation and beyond. The fixed costs of vermiculture include initial investment and maintenance of the system, and economic benefits are realized from direct worm sales and worms as a food supplement for animals. Non-economic benefits for agricultural productivity and soil health are other important outcomes of vermiculture practice.

Economic Costs and Benefits

1. Implementation and maintenance

In order to initiate a vermiculture system, a worm enclosure must be built. Construction materials already available on the farm can be used, such as bamboo and palm fronds, hence no additional financial investment is required. In terms of labor, construction takes a half day, which equates to about VND 60,000 in fixed costs. With initial infrastructure in place, the vermiculture system is designed to function continually with consistent maintenance and inputs of manure and crop residue. Though not included in this calculation, water may need to be added if periods of drought ensue to maintain the moisture level of the worm habitat, which is optimum at 76–83% moisture level (Hallatt, Viljoen, and Reinecke 1992). Farmers ensure the appropriate moisture levels by holding the substrate; if too much water runs out, the substrate is too wet, and if it is too dry, the substrate will break apart easily. According to interview data, the upkeep associated with vermiculture requires one hour every other day for turning, watering, and feeding the worms. Maintenance time remains consistent regardless of the enclosure size. This average labor value can be estimated at VND 7,500 per day, or VND 2,737,000 per year.

LOCATION AND CLIMATE ADAPTATION

Worms metabolism rates are optimized between 25–30˚C (Edwards, Dominguez, and Neuhauser 1998), and 76–83% moisture content (Hallatt, Viljoen, and Reinecke 1992). Hence, the location of vermiculture beds must be considered with regards to potential weather events, climate and biophysical conditions.

- Worm enclosures should not be constructed close to ponds, as ponds provide habitat for many worm predator species such as frogs and snakes.
- The shade of home garden trees can help regulate micro-climate variation to keep a stable environment for the worms. Nearby trees and a roof of palm leaves provide shade and protect from rain while maintaining moisture levels. Farmers should be aware of potential breaking trees during storms that may damage the enclosure roof.
- Farmers can add a mulch of palm leaves, cardboard, or other available materials to avoid direct sunshine or winds and associated moisture loss.
- When temperatures dip to between 15˚C or below, worm reproduction significantly slows (Edwards, Dominguez, and Neuhauser 1998).
- During days when temperatures are over 40˚C, the bed can be cooled by watering.
- Positioning the bed on an elevated bed or slope where water can be diverted can help avoid floods.
- Vermiculture systems can also be established under more controlled environments, such as indoors, on cement floors.

2. Poultry Feed

In addition to vermicompost, the vermiculture system produces a growing population of earthworms which can be used for animal feed. Earthworm protein content ranges from 58–71% dry weight, and contains amino acids essential for animal diets (Sabine 1978). Previous studies have cited weight gains and higher survival rates for earthworm-fed quail (Guerrero 1983), indicating that earthworms provide a nutritionally beneficial supplement in animal feed (Sabine 1978). The three farmers interviewed all utilized worms as feed for chickens, ducks, and geese. Tables 1 and 2 break down interview data on how worms were utilized to supplement poultry diets.

ANIMAL	NUMBER	WORMS	OTHER FEED
Chickens	100	250 g	Rice
Chickens	20	300 g	Rice
Ducks	20	300 g	Rice and corn
Geese	15	500 g	Rice
Geese	25	350 g	Rice and corn

Table 1. Daily poultry feed details for each farmer

SUPPLEMENTAL WORM FEED	100 CHICKENS	100 DUCKS	100 GEESE
Number of worms per day	900	1500	2350
Grams of worms per day	450	1175	750

Table 2. Number and average weight of worm feed

The farmers observed many beneficial effects from this additional protein source, including faster growth, smoother feathers, and less prone to disease. All farmers noticed a five percent increase in egg hatching rate after integrating worms into the animal diets. Additionally, the eggs from poultry fed with worms contained larger, darker yolks. The farmers perceived the darker color as indicative of more nutritious eggs, a belief which is also held among consumers in many markets willing to pay a premium for darker yolks (Stadelman 1999). However, yolk color is influenced by a number of other factors and there is no conclusively direct link to nutritional value (Baker and Günther 2004).

3. Worm Sales

Earthworms are hermaphroditic and reproduce rapidly, doubling their population on average every 60-70 days (Sinha, Agarwal, et al. 2010). When the worm populations grow in excess, worms can be sold to other farmers to be used as feed. Of the three farmers interviewed, only two sold worms for additional household income. The farmer who avoided this opportunity cited instability in the worm market. The economic benefits incurred by the other two farmers averaged VND 11,500,000 annually.

INPUTS (VND)	100 CHICKENS	100 DUCKS	100 GEESE
Labor to construct worm bed	60,000	60,000	60,000
Materials to construct bed	0	0	0
Maintenance	2,737,500	2,737,500	2,737,500
Feed for worms	0	0	0
OUTPUTS (VND)			
Worm sales	11,500,000	11,500,000	11,500,000
Supplemental feed	1,642,500	2,737,500	4,288,750
NET INCOME (VND)			
	10,345,000	11,440,000	12,991,250

Table 3. Economic assessment for initial year

Table 3. provides simple economic assessments for vermiculture during the initial year from interviews with farmers with breakdowns for chickens, ducks, and geese. This data assumes that the worm enclosure was constructed in one half day using materials already present on the farm. Maintenance, including feeding, watering, and turning the worm bed is estimated at one hour every two days, which averages out to 30 minutes per day. Inputs to feed the worms comes from livestock manure and crop residues, which are assumed to already be available on the farm. Worm sales occur two times per year, with farmers selling an average of 575 kilograms of worms with substrates per season and charging VND 10,000 per kilogram. The worms used to feed poultry are supplemental to the diets of chickens, ducks, and geese. They provide additional protein, while rice or rice-corn mixtures are the main caloric sources.

Qualitative Benefits for Soil and Productivity

1. Labor Efficiency and Flexibility

Before the farmers began practicing vermiculture, manure from chicken, cows, buffalo, and pigs was used to manage soil fertility. However, this required that farmers plow the soil very carefully before planting. According to previous ICRAF interview data, untreated manure can lead to pests and pathogens, and the high concentrations of urine and minerals in undecomposed manure can damage young roots. With vermicompost, farmers require less time for field application, and can apply at any point in the growing cycle if needed without damaging plants. Through earthworm digestion and microbial activity, a rich compost is generated as agricultural waste and livestock manure are transformed into valuable farm inputs.

2. Soil and Crop Health

Beneficial soil microbes such as nitrogen-fixing bacteria are highly concentrated in vermicompost (Sinha, Herat, et al. 2010), and some research indicates that vermicompost can suppress pathogens in crops and inhibit fungal diseases in soils because of the beneficial microorganisms present in the compost (Arancon, Galvis, and Edwards 2005). Specifically, research has indicated improvements in the intensity and damage of aphids, mealy bugs, and cabbage caterpillars on cabbage plants, and reduced loss in pepper and tomato yields due to vermicompost application (Arancon, Galvis, and Edwards 2005). Plants fertilized with vermicompost were less susceptible to salinity stress than those with conventional compost or synthetic fertilizers (Chaoui, Zibilske, and Ohno 2003).

3. Improved Soil Water Use Efficiency

Farmers also cited improvements in terms of soil moisture, unanimously agreeing that less water was needed after vermicompost application. Changes in soil characteristics were described by all farmers as less sandy and softer after integrating vermicompost. Loamy soil texture is commonly associated with higher water-holding capacity and absorption (Shaxson and Barber 2003), which are critical conditions for drought resilience and therefore adaptation. Studies show that reduced soil moisture is directly linked with nutrient loss and declines in productivity (Pimentel et al. 1995), therefore efforts to improve soil moisture will enhance soil quality and crop yields.

4. Soil Nutrient Improvement

Vermicompost has proven to have beneficial impacts for crop productivity, with farmers noticing that plants grow faster and are greener in color with this soil amendment. One of the farmers interviewed conducted her own experiment on two peanut fields, applying vermicompost to one and only manure to the other. The peanuts fertilized with vermicompost were larger and the yield was higher than those in the field fertilized with manure only. According to a previous study, organic material which had been composted by *Perionyx excavatus* earthworms yielded a significant increase in N, P, and K elements – three essential fertilizer components (Suthar 2007). This is because earthworms are able to mineralize the nitrogen, phosphorous, and potassium found in organic waste and make these nutrients bio-available to plants (Sinha, Herat, et al. 2010).

After successive years of application, vermicompost can improve texture, build up the nutrients, and increase the populations of beneficial microbes in agricultural soil, thereby improving its natural fertility and resilience. Vermicompost provides a beneficial alternative to direct application of manure on agricultural fields. Additionally, for farmers currently reliant on synthetic fertilizers, vermicompost could be one option to reduce or replace fossil fuel-based fertilizer inputs.

5. Organic Waste Management

All farmers interviewed indicated that vermiculture practice has eliminated the smell previously associated with manure. This odor reduction is due to the anaerobic conditions created by earthworm burrowing which inhibits anaerobic microorganisms associated with noxious gases (Mitchell, Hornor, and Abrams 1980). Additionally, the coelomic fluids from earthworms have anti-bacterial properties which kill pathogens and reduce odors (Sinha et al. 2002). Some studies have shown that vermiculture also reduces methane emissions compared with the current practice of spreading raw manure applied on fields (Sinha et al. 2014). Because the worms must be covered to avoid direct sunlight, emissions are reduced compared to raw manure application. Additionally, home vermicompost bins have lower emissions of nitrous oxide than other small-scale composting methods (Sinha et al. 2014; Chan, Sinha, and Wang 2011), a greenhouse gas which is particularly damaging to the ozone. By decreasing the proportion of anaerobic to aerobic decomposition, emissions are lowered (Sinha, Herat, et al. 2010; Sinha et al. 2014).

In terms of waste treatment, earthworms release coelomic fluids which have been shown to contain antibacterial properties, thereby destroying many pathogens from manure (Valembois et al. 1982) in the digestive process. One experiment showed that *Escherichia coli* (*E. coli*) in organic waste was eliminated through vermicomposting in 4–5 months (Bajsa et al. 2004). In 2010, 28.7 million cases of diarrhea were attributed to *E. coli* in Southeast Asia (Nsubuga et al. 2010).

Scaling and Social Sharing

The potential to scale out vermiculture practice is significant, as the three farmers interviewed have shared worms with 20 other individuals combined. Providing 30–50 kg of worms per farmer, other farmers were able to initiate their own vermiculture systems and multiply the worms for use in feeding poultry, selling, and creating vermicomposting for field application.

The farmers interviewed also articulated their participation in an array of social sharing methods. For example, they discussed vermiculture practice in passing or at the market, often conferring about technical worm-raising questions or other beneficial outcomes of the practice in person. Additionally, ICRAF has facilitated farmer-to-farmer interest groups on livestock, forestry, intercropping, and homegardens. The relevance of vermiculture spans these various topics, and farmer groups present an ideal opportunity for disseminating information about vermiculture practice. As has been detailed in a recent ICRAF gender analysis, differences between men and women manifest in different sharing and communication networks (Minh DT 2017). Social norms should be taken into account to maximize social sharing and facilitate support systems for farmers interested in beginning vermiculture practice. All farmers in this study recommend vermiculture to fellow farmers because it is easy to implement and maintain, and leads to a host of economic benefits. Vermiculture is an appropriate technology with numerous benefits, making it particularly suitable for broader adoption and scaling.

Conclusion

With minimal initial investment and maintenance, vermiculture yields many benefits, both economic and qualitative. Nutrient-rich vermicompost can be generated from waste and used as a soil amendment to improve soil structure, water filtration, and overall farm productivity which manifests as economic returns for the farmer. Inedible crop residues and livestock waste are recycled back into the system to reduce agricultural waste. The worms themselves are a renewable resource, with worm biomass functioning as a supplemental protein and food source for poultry, or a valuable product for farmers to sell. Integration of worms into the diets of the birds leads to faster growth, higher hatching rates, and improved overall health. This interconnected network of farm resources is directly linked with soil health, agricultural productivity and system resiliency.

Recommendations

1. Practitioners

Due to the low initial capital required to establish a vermiculture system, this practice could be scaled widely among farmers. An aggregation of vermiculture farmers in a cooperative model could enhance market stability and offer increased opportunities for income.

2. Policy Makers

Vermiculture is particularly cost-effective and suitable to integrate with development funds for economic and environmental returns. Scaling efforts for CSA practices could be enhanced by inclusion in socio-economic, agricultural, and rural development plans.

3. Further Research

Initial studies in the Philippine uplands indicate potential for vermijuice, the liquid component of vermiculture, as a natural pesticide (Weidner et al. 2011). More research is necessary to identify details on application methods and effectiveness for specific crops.

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