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RESEARCH PAPER

Analysis of Factors Affecting Adoption of Vermicomposting Organic Fertilizer and Its Impact on Household's Income in Holeta District, Oromia National Regional State, Ethiopia

Diriba Mehari and Aman Rikitu*

Department of Agricultural Economics, Ambo University, Ambo, Ethiopia

***Corresponding Author:** Email: aman.rikitu@gmail.com*

Abstract

Agriculture remains the backbone of Ethiopia's economy, providing livelihoods for the majority of its population. However, despite its critical importance, the sector is characterized by persistently low productivity. To address this challenge and spur economic growth, the Ethiopian government has prioritized the promotion of value-added compost (VC) organic fertilizer. Nevertheless, the adoption of VC organic fertilizer remains low in many areas, including the Holeta district. This study was conducted to identify the factors influencing the adoption of VC organic fertilizer among farmers in this region. The study utilized both primary and secondary data collected from 174 household head farmers and published and unpublished sources. The analytical framework included descriptive statistics, logistic regression models, and propensity score matching to evaluate the factors influencing adoption and its economic impact. The results revealed that several factors significantly affected farmers' decisions to adopt VC organic fertilizer, including farming experience, farm size, family size, livestock ownership, access to extension services, access to information media, and participation in training programs. Moreover, propensity score matching analysis demonstrated that the adoption of VC organic fertilizer led to an increase in farm income per hectare, ranging from 45,571 ETB to 48,537 ETB. These findings underscore the economic benefits of adopting VC organic fertilizer and highlight the need for targeted interventions. To encourage adoption, the government and other stakeholders need to enhance farmers' access to training, provide robust extension services, and ensure the availability of VC organic fertilizer. Improved access to information about its benefits and usage is also crucial for fostering wider adoption and, ultimately, boosting agricultural productivity and rural incomes.

Keywords: Adoption, Vermicompost, Earthworm, Logit model, and Propensity score matching

Introduction

Agriculture plays a pivotal role in Ethiopia's economy, serving as the backbone of the country's development. It contributes 41.4% of the national GDP, accounts for 83.9% of total exports, and provides employment for 80% of the population (Gebeyanesh *et al*., 2021). Over the past decade, Ethiopia's agricultural sector has grown at an impressive annual rate of about 10%, outpacing population growth. Despite this progress, significant challenges persist, particularly with soil fertility management and sustainable production practices.

The adoption of value-added compost (VC) organic fertilizer offers a promising solution for improving soil fertility, enhancing crop yields, and reducing input costs. VC organic fertilizer contributes to soil health by maintaining fertility, improving soil structure, and reducing reliance on chemical fertilizers, which can harm the environment (Chen *et al*., 2018). Its adoption is seen as critical to addressing food insecurity and poverty while fostering a more sustainable agricultural sector (Kibere and Mwaura, 2022).

VC organic fertilizer also represents a profitable business opportunity. The increasing consumer preference for organic produce, including vegetables and fruits grown without harmful chemicals, has spurred demand (Reddy, 2019). Additionally, the production of VC through the use of earthworms offers a cost-effective and environmentally friendly approach to managing biodegradable solid waste. The end product serves as a high-quality organic fertilizer suitable for agricultural use (Huang *et al*., 2014; Dar and Bhat, 2020).

Despite its potential benefits, challenges such as soil compaction, overuse of chemical fertilizers, and inefficient application techniques have hindered agricultural productivity. Excessive chemical fertilizer use often leads to nitrate accumulation in soil, groundwater contamination, and atmospheric pollution (Nikita and Puneet, 2020). Furthermore, traditional broadcasting methods result in significant nutrient loss due to rain, irrigation, or sublimation by sunlight, exacerbating food insecurity and poverty. Other barriers to sustained agricultural productivity include land degradation, recurrent drought, poor infrastructure, and inadequate nutrient supply (Scotti *et al*., 2015; Tura *et al*., 2017).

Organic fertilizers, including VC, address many of these challenges. They not only enhance soil health but also reduce food production costs by 60-70% while retaining soil moisture, thereby lowering irrigation needs (Adiloglu *et al*., 2018; Yousefi and Sadeghi, 2014). Despite these advantages, the adoption rate of VC organic fertilizer in areas like Wolmera Woreda (Holeta) remains low, with only 48.15% of households using it (WDAO, 2015). This low adoption rate persists despite efforts by the government and development partners to promote the technology.

To address these gaps, this study aimed to evaluate the factors influencing the low adoption of VC organic fertilizer in the Welmera Woreda, Holeta area, and assess its impact on household incomes. By understanding the challenges and opportunities associated with VC adoption, the study provides insights to inform strategies for enhancing agricultural productivity and improving the livelihoods of farming households in the region.

Materials and methods

Description of Study Areas

The study was carried out in Welmera district, West Shewa zone Oromia regional national state Ethiopia. This area is one of the towns of Oromia Regional State which is located 35 km away to the west of Finfinnee. In the north, south, and east the town is bordered by Welmera woreda and in the west by Ejere woreda. Astronomically the city is situated between the latitude of 90 01′ 08″N - 90 06′ 15″N and longitude of 380 26′ 40″E -380 32′46″E. The altitude ranges between 2250-2500m above sea level. The district has eight kebeles with total area coverage of 5550 ha ($55.5km^2$) of which five kebeles are from rural. The district was founded for the purpose of military services in the 1900s and it had the status of a Municipality since 1948 (Welmera Woreda Agricultural Office, 2015). This shows that the district has ample resources for preparing VC organic fertilizer, especially from animal dung which could enable the districts' smallholder and horticulture producers' productivity. Generally, Holeta district is shown below on the map depicted in Figure 1.

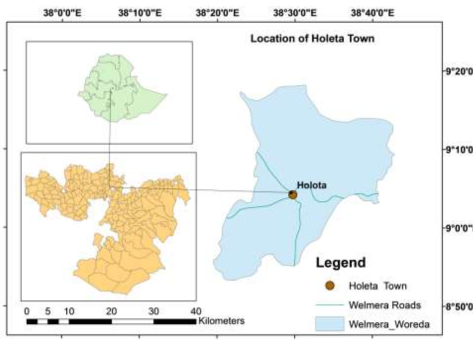

Fig 1. Map of the study area

Types and sources of data

Primary and secondary data sources were used to collect data from primary and secondary sources to describe the characteristics of targeted individuals or groups of horticultural producers.

Sampling procedures and sample size

To achieve the objectives of the study, a multistage sampling technique was employed, combining simple random sampling and stratified sampling methods to identify respondents. In the first stage, a stratified sampling technique was used to select kebeles with relatively higher adoption rates of VC organic fertilizer and those with little to no experience in using it. In the second stage, two kebeles, Birbirsa Siba and Mada Gudina, were randomly selected from the group of kebeles with higher VC adoption rates. In the third stage, respondents from the selected kebeles were further stratified into two groups: adopters and non-adopters of VC organic fertilizer. This stratification ensured balanced selection. Finally, respondents were chosen using simple random sampling, proportional to the population size of each stratified group.

Sample size determination

The study targeted small-scale farmers of horticulture producer heads in the Holeta area of Ethiopia. A total of 174 household head samples were estimated based on the sample size determination formula of Yamane (1967). According to the 2019 Holeta town administration annual bulletin, there are a total of 57,828 populations in this town. The researcher randomly selects two kebeles from eight kebeles in the town. In those two kebeles, there are 1214 Household heads. To determine the sample size, for the study, Yamane's statistical formula was used at a 93% confidence level.

$$n = \frac{N}{1+N(e)2} \qquad (1)$$

Where n= is sample size
N= is the total target population
e=is error margin $(0.07)^2$
1 = is constant
Thus, $n = \frac{1214}{1+1214(0.07)2} = 174$

Therefore, from the total household head population in the two kebeles, 174; were 85; adopters and 89; non-adopters of VC individuals were randomly selected after data was collected. In addition to 174 samples, 16 individuals were selected for Focus Group Discussion (with an arrangement of 1 group containing 8 individuals from each kebeles) and 4 people were used for key informant interview from concerned bodies.

Methods of data collection

A structured and semi-structured questionnaire was used as the data collection instrument, with pre-test interview and final data collection done by trained development agents. Focus group discussion was used to gather large information, with eight employees' heads and 16 household heads participating.

Method of Data Analysis

Descriptive and inferential statistics analysis

The study used descriptive statistics like %age, frequency, mean, standard deviation and economics model by the use of STATA software. The result of the study was presented by table and pi-chart.

Econometrics model analysis

For determining the impact of VC organic fertilizer adoption on farmers' income, the study used propensity score matching (PSM) as the best procedure to determine the impact of VC organic fertilizer usage on farmers' income. This was on the farmers choosing either to adopt or not to adopt a given technology based on expectations, objectives, and observable and unobservable characteristics. This is referred to as self-selection (Chala and Tilahun, 2014). PSM is the best procedure for assessing the effect of agricultural technologies on household income, especially when the dimensions of the covariates are large (Acheampong and Owusu, 2014; Chala and Tilahun, 2014; Awotide *et al*., 2012; Nguezet *et al*., 2011). PSM has the advantage of reducing the dimensionality of matching to a single dimension (Chala and Tilahun, 2014). It is the best possible procedure to evaluate the individual probability of receiving the treatment given the observed covariates (Rubin and Rosenbaum, 1983). It determines the average treatment effect on the VC organic fertilizer adopters and non-adopter farms. The effectiveness of PSM depends on the two below assumptions.

Assumption of Conditional Independence (ACI): This assumption states that the selection into the adoption group is solely based on the observable characteristics. Given the values of some observable covariates, the assumption implies that the value of the outcome variable is independent of the treatment farm income state should be independent. Therefore, the VC organic fertilizer adopter's outcome is independent of the treatment status.

$Y_0, Y_1 \perp A | Z$……………. (2)

$E(Y_1 | P, Ai=1) = E(Y_0 | P, Ai=0)$ ….(3)

Where, P is i^{th} farmer propensity of VC organic fertilizer adoption, Y_1 is outcome (farmers income) of i^{th} farmers when VC organic fertilizer is adopted, Y_0 is outcome of i^{th} farmers when VC organic fertilizer is not adopted, E is expectation operator, and A is the state where i^{th} farmers adopt or not adopt VC organic fertilizer; 1 for a farmer who has adopted VC organic fertilizer and 0 otherwise. Thus, this study used PSM methods to match and compare the impact per hectare farm income between samples of adopters and non-adopters of VC organic fertilizer.

Common Support Assumption (CSA): This assumption states that the average treatment effect for the treated (ATT) is only defined within the region of common support. It also assumes that no explanatory variable predicts the treatment perfectly.

$0 < p(A = 1 | Z) < 1$………………….. (4)

If the above two assumptions are satisfied, then conditional to estimates of propensity scores (p), the observed outcome (average farm income) of VC organic fertilizer adopters can be substituted for the missing average farm income of non-adopters.

Given that the propensity scores are balanced and the above assumptions are satisfied, according to Rosenbaum and Rubin (1983) the parameter of interest which is ATT can be estimated as:

$ATT = E(y_1 - y_0 / A = 1)$

$= E(y_1 / A = 1) - E(y_0 / A = 1)$ …… (5)

Where, y_1 is outcome (farmers income) of i^{th} farmers when VC organic fertilizer is adopted, y_0 is the outcome of i^{th} farmers when VC organic fertilizer is not adopted, E is the expectation operator, and A is the state where ith farmer adopts or not adopt VC organic fertilizer; 1 for a farmer who has adopted VC organic fertilizer and 0 otherwise. In impact evaluation, the interest is not on $E[y_0 / A = 0]$, but on $E[y_0 / A = 1]$. Therefore, PSM uses estimated propensity scores to match the observed mean farm income of the non-adopters who are most similar in observed characteristics with adopters. That is, it uses

$E[y_0 / A = 0]$ to estimate the counterfactual $E[y_0 / A = 1]$. Therefore:

$ATT = E(y_1 - y_0 / A = 1)$

$= E\{E[y_1 - y_0 / A = 1, p(z)]\}$

$= E\{E[y_1 / A = 1, p(z)] - E(y_0 / A = 1, p(z) / A = 1]\}$

$= E\{E[y_1 / A = 1, p(z)] - E(y_0 / A = 0, p(z) / A = 0]\}$……………..……..……...(6)

Where; ATT, E, y_1, y_0, p and A are defined as earlier.

Advantages and limitations of PSM

The Propensity Score Matching (PSM) method offers several advantages in evaluating treatment effects. Firstly, it reduces dimensionality by condensing multiple covariates into a single scalar, the propensity score, simplifying the analysis significantly. Secondly, PSM effectively balances observed characteristics between treated and control groups, thereby minimizing selection bias and ensuring comparability. Additionally, it provides a robust evaluation framework, particularly when treatment effects are influenced by observable covariates. However, PSM also has its limitations. It relies heavily on the assumption that there are no unobservable confounders influencing the treatment or outcome, which may not always hold true. Furthermore, the method requires a sufficient overlap in propensity scores between groups to ensure reliable results and poor overlap can restrict the generalizability of the findings.

This specification of PSM is well-suited for evaluating the impact of VC organic fertilizer adoption on farmers' income in the Holeta area. By addressing selection bias and ensuring robust matching, the model enables a reliable comparison of income outcomes between adopters and non-adopters. However, the study's validity heavily relies on satisfying the CIA and CSA assumptions, as well as the quality of the data used for propensity score estimation.

Results and discussions

Results of descriptive statistics for continuous variables by adoption category

The description was made using mean, minimum, and maximum values as well as, range and standard deviations. In addition, the mean difference for continuous variables and frequencies of discrete variables were tested using T-test and chi-square test respectively.

Results show that the average mean age for the sampled household farmers was 42.5 years Table 1. The mean age of VC organic fertilizer adopters and non-adopters was found to be 38.2 and 46.5 years respectively. These results show that the majority of the households were at productive stages of their lives in terms of the capacity to work. Although the difference was quite low, on average, VC adopters were younger than non-adopters. The result is in line with the study by (Ajewole 2010; Mwangi and Kariuki, 2015; Enete and Igbokwe, 2009).

Education level was measured as the number of years of schooling starting from zero or having no education to university graduate. The average mean years of formal schooling for the sampled farmers were 2.3 years Table 1. Among the VC organic fertilizer adopters, the average mean years of formal schooling was 2.6 while among the non-adopters, it was about 2.1. This shows that more educated farmers were adopters in the study area which might be the result of better education. Education could likely allow farmers to make efficient decisions and be the early adopters who can take advantage of the new technology (Orinda, 2013).

In relation to family size, the overall average mean family size among the respondents was found to be 5.44 Table 1. Among the adopters of VC organic fertilizer, the average family size was about 5.8 whereas it was about 5.04 amongst the non-adopters. On average, the family size was higher among the adopters compared to non-adopters. The fact that VC organic fertilizer is labor intensive compared to the other types of fertilizer supports the results. The t-test result shows that there is a mean difference between adopters and non-adopters of VC organic fertilizers in terms of family size at a 5% statistical significance level. A larger family size may enable one to provide additional labor needed in the use of the VC organic fertilizer (Ajewole, 2010).

The findings suggest that livestock ownership plays a critical role in the adoption of VC organic fertilizer, as livestock provides the raw material (animal manure) necessary for its preparation. The larger average livestock holdings observed among adopters likely facilitated their adoption of organic fertilizer compared to farmers with smaller livestock holdings. Additionally, the t-test results indicate a statistically significant difference in farm size between adopters and non-adopters at the 5% significance level. This highlights that both livestock availability and farm size are influential factors in the adoption of VC organic fertilizers, with larger farm sizes and greater livestock holdings potentially enabling easier integration of this technology into farming practices (Table 1).

The average farm size among the sampled household heads was 2.24 hectares Table 1. On average, the VC organic fertilizer adopters own about 2.6 hectares of the farm size while the non-adopters own about 1.9 hectares of the farm size. The current study predicted that farmers with relatively larger farm sizes are likely to adopt VC organic fertilizer. This could be primarily due to lower marginal costs associated with the adoption of labor-intensive technology on the larger area of the farm size. The results indicated that the households with larger farm sizes were adopters of VC organic fertilizer possibly due to lower marginal costs. Martey *et al*., (2013) argued that an increase in cultivation plots is associated with financial constraints for smallholder farmers in Ghana thus reducing the adoption of chemical fertilizer. Lower use of chemical fertilizer could result in more use of VC organic fertilizer in Ethiopia. The t-test results reveal a statistically significant difference in farm size between adopters and non-adopters of VC organic fertilizers at the 5% level of significance. This suggests that farm size is a distinguishing factor between the two groups, indicating that adopters tend to have either larger or smaller farms compared to non-adopters.

The average total household head agricultural income among the respondents was found to be 94,431.03 ETB per annum Table 1. Amongst the respondents who have adopted VC organic fertilizer, the average agricultural income was about 117,294.1 ETB while the non-adopters of VC organic fertilizer had an average farm income of 72,595.57 ETB. The higher average agricultural income among the adopters may justify that adopters of VC organic fertilizer are more dependent on agricultural activities. The dependency of farmers on agricultural activities makes them more concerned about yield-increasing technologies such as VC organic fertilizer. On the other hand, according to Makokha *et al*., (2001), a household whose income depends on agricultural activities does not have enough capital to use chemical fertilizer in Kenya thus they have the option to use manure to compensate outflow of nutrients. The probability of using household head outcome agricultural income has no significant relationship with VC organic fertilizer adoption decisions.

Table 1. Results of Descriptive statistics for Continuous Variables

	Adopters		Non-adopters			
Characteristics	Mean	SD	Mean	SD	Mean	*t* –value
Age of HH	38.235	9.764	46.561	12.882	42.494	3.0005
Education	2.552	1.096	2.067	1.146	2.304	-3.1862
Family size	5.828	1.400	5.038	1.421	5.442	3.3550**
Livestock	9.105	4.437	7.325	3.560	8.195	-0.9062**
Farm size	2.641	0.811	1.038	0.882	2.237	-3.3630
Outcome effect	117294.1	77485.46	72595.57	79358.47	94431.03	-3.7569

Descriptive results of dummy variables

The results presented in Table 2 show that about 132, or 75.86%, of the households were male-headed, while about 42, or 24.14%, were female-headed. Among the adopters of VC organic fertilizer, about 69, or 81.18%, of the households were male-headed, compared to 16 or 18.82% of the female-headed households. On the other hand, amongst the non-adopters of VC organic fertilizer, about 63, or 70.79%, of the households were male-headed, while the remaining 26, or 29.21%, were female-headed. The results showed that the proportion of male-headed households was higher both among the adopters and non-adopters of VC organic fertilizer compared to that for female-headed households. Among the adopters of VC organic fertilizer, the higher proportion of households headed by a male could be due to the better exposure that the male-headed households have to different technologies and training delivered by extension agents. According to Maria *et al.* (2023), male heads are more likely to attend community meetings and visit demonstration plots or research centers compared to female heads. This could make male-headed households more adopters of VC organic fertilizer.

Extension services refer to demonstrations, training, and advice delivered to farmers mainly by development agents and other agricultural experts. The results indicated that about 89, or 51.15%, of the households' heads had extension service, while about 85, or 48.85%, had no extension service. Approximately 74, or 87.06%, of the household's heads and 11, or 12.76% of the household's heads use VC organic fertilizer. On the other hand, amongst the non-adopters of VC organic fertilizer, about 15 or 16.85% of the households and 74 or 83.15% have no access to extension services, respectively. The findings show that adopters of VC organic fertilizer had better access to extension services on average than non-adopters, implying that better access to extension services may have contributed to VC organic fertilizer adoption. Kassie *et al*., (2009) argued that farmers who have regular contact with agricultural experts are more likely to adopt agricultural technologies. Similarly, Ajewole (2010) claimed that the frequency of extension visits increased the possibility of commercial organic fertilizer adoption in Nigeria. Information can be accessed through different media such as radio, television and social media. The results indicate that about 93 or 53.45% of the sampled households had access to information through radio and television while about 81 or 46.55% did not have access to information media. According to Opara (2010), a higher proportion of households that have had access to information through radio and TV were found to be adopters of VC organic fertilizer. The results indicate that 53.45% of sampled household heads have used VC organic fertilizer, while 81.55% have not. Training users and visits to create awareness are preconditions for them to make decisions to participate in VC organic fertilizer adoption technology. The disparity between the two groups is significant, implying that training and participation of adopters are critical factors in advancing agricultural technology quickly.

According to the findings, approximately 95%, or 54.60%, of the households' head sample had access to VC organic fertilizer input materials, while approximately 81%, or 46.55%, did not. Among the adopters of VC organic fertilizer, about 75, or 88.24%, of the households' head samples had access to VC organic fertilizer, while 10, or 11.76% of the households' head samples did not have access to VC organic fertilizer input materials. In contrast, among non-adopters of VC organic fertilizer, approximately 20 or 22.47% of the household head sample had access to VC organic fertilizer input materials, while approximately 69 or 77.53% of the household head sample did not Table 3. The findings revealed that adopters of VC organic fertilizer had better access to the availability of VC organic fertilizer input materials on average than non-adopters, implying that better access to VC organic fertilizer input materials may have contributed to VC organic fertilizer adoption.

Table 2. Results of dummy variables

Variables		Adopters		Non-adopters		Total		Chi-Square
		Frequency	%	Frequency	%	Frequency	%	
SEX	1	69	81.18	63	70.79	132	75.86	2.0174
	0	16	18.82	26	29.21	42	24.14	
ACC EXT SER	1	74	87.06	15	16.85	89	51.15	34.2032***
	0	11	12.94	74	83.15	85	48.85	
TRAINING	1	73	85.88	21	23.60	94	54.02	47.0863***
	0	12	14.12	68	76.40	80	45.98	
ACC INFO MED	1	75	88.24	18	20.22	93	46.55	16.2712**
	0	10	11.76	71	79.78	81	53.45	
HH HAVE USED	1	72	84.71	21	23.60	93	53.45	22.0498**
VC	0	13	15.29	68	76.40	81	46.55	
ACC VCOFINP	1	75	88.24	20	22.47	95	54.60	25.0477
	0	10	11.76	69	77.53	79	45.40	

Source: results of Chi-square test, **, ***, Significant at 5%, 1% probability level respectively.

Results of propensity score matching for the impact of VC organic fertilizer on income

The logistic regression model used to estimate propensity scores for matching adopter households with non-adopter households was used to compute the impact of VC organic fertilizer adoption on households' farm income. All variables hypothesized to influence adoption decision were included, such as age, sex, family size, education level, total household output farm income, experience, farm size, soil fertility, number of livestock units, access to extension service, access to VC organic fertilizer inputs, access to training, access to information through television, radio and other media.

Before beginning the assessment of impact evaluation, five crucial activity steps need to be completed. These steps are estimation of the propensity score, checking for overlap (common support region), choosing a matching algorithm, checking for balance test, and sensitivity analysis. Graphically, we computed the distribution of the estimated propensity scores matching for both adopters (treated) and non-adopter (control) groups to identify the existence of a common support presented in Figure 5 using kernel density. From the figure, the normal line (the middle line) represents the total sample household head; the long (right below and left upper line) represents the propensity score of the adopters (treated) group, While the short line (left below and right upper line) representing the propensity score of non-adopters (control).

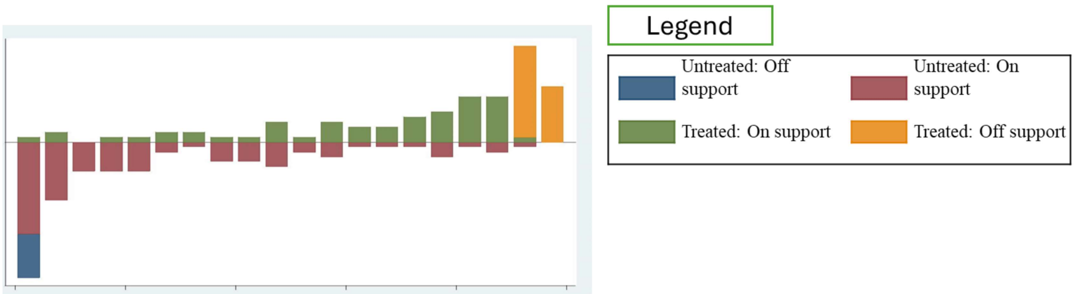

Figure.4 Kernel density of propensity scores of all households before matching

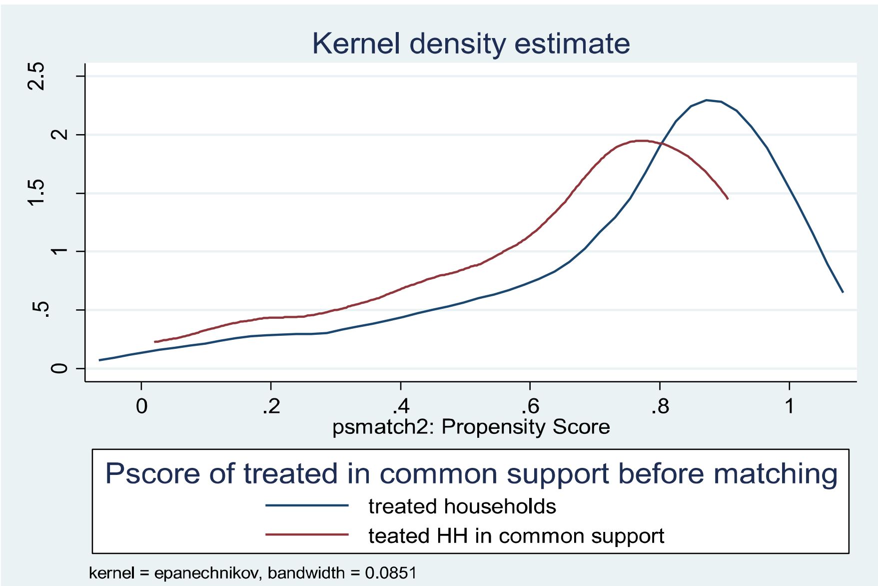

Figure 5: Common support region of propensity scores Source (source: Authors survey data, 2022)

The result accepted that there is a significant overlap in the common support region. As depicted in Figure 4, the distribution of the propensity scores of the treated and untreated individuals in both groups clearly displayed an overlap. The result also indicated that there are individuals out of the common support region. Moreover, there are treated and untreated individuals. Thus, these indicated that there was a sufficient overlap in the propensity score among the adopters and non-adopters household head farmers. Fortunately, one can observe that the upper half of the graph is for the treated or adopters' groups and the bottom half represents the untreated and the non-adopters showing the densities of the scores on the y-axis and the common support regions on the x-axis. As a result of this restriction, 38 household heads (29 from treated and 9 from control households) were dropped from the analysis because their propensity scores fell outside the region of common support. Thus, it seems that the included observations (136 households) were sufficient to predict the impact of VC organic fertilizer on households for this study.

Matching adopters and non-adopters households

Estimation of ATT and ATE are possible only in the region of common support. As shown in Table 3, the estimated value of propensity scores for sample households varies between 0.019 and 0.997 (mean=0.743) for adopter (treated) households and between 0.001 and 0.905 (mean=0.245) for non-adopter (control) households. Thus, the common support assumption is satisfied in the region of 0.019 and 0.997 with a mean of 0.743. This means that households with estimated propensity scores less than 0.019 and greater than 0.905 are not included in the matching exercise. The diagram which shows the matching distribution of propensity scores is presented in Figure 5 below.

Table 3: Distribution of the estimated propensity scores

Categories	Obs	Mean	SD	Min	Max
VCOF treated household	85	0.743	0.244	0.019	0.997
VCOF control household	89	0.245	0.255	0.001	0.905
Total household	174	0.488	0.353	0.001	0.997

Source: Author estimation result, 2022.

Testing the balancing properties of propensity scores and covariates

The balancing test ensures that propensity scores and covariates are similar between adopters and non-adopters after matching, confirming that the matching process creates comparable groups. Nearest Neighbor (3) matching outperformed other methods, achieving the lowest Pseudo R^2 (0.018) and balancing all covariates effectively. Before matching, seven variables exhibited significant differences, but post-matching, no significant differences remained, indicating a high level of covariate balance. The non-significant t-tests and low Pseudo R^2 further validated the matching process. Thus, the matching specification successfully balanced covariates, enabling a reliable comparison of VC organic fertilizer adoption outcomes.

In addition to the above results, the overall (joint) test statistics for the balancing properties showed that Pseudo-R2 was 0.054 for the matched observations which was fairly low. The p-value for the corresponding Pseudo-R2 and likelihood ratio test was insignificant at the conventional probability level ($p > chi2 = 0.998$) confirming that both the treated (adopters of VC organic fertilizer) and control (non-adopters of VC organic fertilizer) groups had the same distribution of covariates after matching. This further shows that the employed model was the most robust and complete therefore allowing comparison average of household's farm income between the adopters and non-adopters per hectare of VC organic fertilizer who share common support in terms of propensity scores. The results of the chi-square test for the joint significance of variables are presented in Table 7.

Table 6: Propensity score and balancing test of the covariates using t-test

Variable	Sample	mean		%bias	%reduction	T-test	
		Treated	control		bias	T	p>|t|
Pscore	Unmatched	0.74334	0.24513	199.2		13.13 ***	0.000
	Matched	0.52707	0.59338	-26.5	86.7	-1.05	0.298
Age	Unmatched	44.565	49.562	-45.5		-3.00	0.003
	Matched	46.727	46.682	0.4	99.1	0.01	0.989
Sex	Unmatched	0.62353	0.51685	21.5		1.42	0.157
	Matched	0.54545	0.59091	-9.2	57.4	-0.33	0.745
Educ	Unmatched	2.247	1.764	48.2		3.19	0.002
	Matched	2.0909	2	9.1	81.2	0.34	0.737
Exp	Unmatched	0.67059	0.31461	75.8		5.00**	0.000
	Matched	0.54545	0.54545	0.0	100.0	0.00	1.000
Farmsiz	Unmatched	2.8292	2.3567	51.2		3.36**	0.001
	Matched	2.6524	2.7909	-15.0	70.7	-0.50	0.621
Famsiz	Unmatched	5.0706	5.7865	-50.9		-3.35**	0.001
	Matched	5.2727	5.3182	-3.2	93.7	-0.10	0.917
Soilfert	Unmatched	1.9176	1.8427	9.7		0.64	0.522
	Matched	1.9697	1.8636	13.7	-41.5	0.47	0.640
Livestockunit	Unmatched	5.9059	5.2809	13.7		0.91**	0.366
	Matched	5.0909	4.7273	8.0	41.8	0.30	0.766
Acctoserv	Unmatched	0.78824	0.34831	98.6		6.49**	
	Matched	0.57576	0.72727	-33.6	65.6	-1.14	0.261
Acctoinfo	Unmatched	0.72941	1.42697	64.0		4.21**	
	Matched	0.57576	0.59091	-3.2	95.0	-0.11	0.913
Acctoorginput	Unmatched	0.69412	0.31461	81.6		5.38	0.000
	Matched	0.54545	0.54545	0.0	100.0	-0.00	1.000
Acctotrain	Unmatched	0.8	0.2809	121.3		7.99**	0.000
	Matched	060606	0.68182	-17.7	85.4	-0.56	0.576

Source: Own estimation result ***and ** means significant at the 1%, and 5% probability levels, respectively

Table 7: Results of Chi-Square test for joint significance of variables

Sample	Pseudo R^2	LR *chi*^{2}	*p-value*
Unmatched	0.430	103.59	0.000***
Matched	0.054	3.98	0.998

Note, *** indicates significance at a 1% probability level

In this section, the study addresses the issue of whether the final evaluation results are sensitive with respect to the choice of the balancing scores. Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. Likewise, sensitivity analysis was undertaken to detect whether the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or whether the estimated ATT is robust to specific failure of the CIA. Also, this section analyses the robustness of the estimated treatment effects. The main purpose of this analysis is to check or estimate the degree to which the estimated treatment effects were free of unobserved covariates. This means, that the estimated impact of VC organic fertilizer adoption on a household's farm income would have been an unobserved confounder that can increase the relative probability of organic fertilizer adoption. Accordingly, the sensitivity analysis was done to check whether the average treatment effect that was estimated using household head farmers VC organic fertilizer was sensitive to unobserved bias using the Rosenbaum bound of gamma values between 1 and 3, by adding 0.25 on 1 and continuing up to 3 (Weiwei *et al.*, 2014).

For all outcome variables estimated at various levels of the critical value of gamma, the p-critical values are significant which further indicates that our impact estimates (ATT) are insensitive to unobserved selection bias and are a pure effect. The result of sensitivity analysis indicates that all important covariates that affect the household head of the estimated average treatment effect on the treated (ATT) reports were insensitive to hidden (unobserved) bias up to (gamma value of 3). This shows that the matching results were almost insensitive to the potential unobservable bias and therefore the estimated ATT were pure effects of VC organic fertilizer adoption. On the other hand, comparing the simulated and baseline ATT, the initial estimates were free of unobserved covariates for the nearest neighbours matching.

Conclusions and recommendation

This study aimed to identify the factors affecting VC organic fertilizer adoption and its impacts on income in the Holeta district of Ethiopia. Data was collected from 174 respondents, of which 85 were adopters and 89 were non-adopters. Descriptive statistics and a logistic regression model were used for analysis. The household heads who have used VC before, farm size, family size, livestock unit (TLU), access to extension service, access to information media, and access to training all played a role in the decision to use VC organic fertilizer. Propensity score matching revealed that the adoption increased farmers' per-hectare farm income by between 45,571 ETB and 48,537 ETB. The sensitivity analysis tested whether the evaluation results of VC organic fertilizer adoption on household farm income were robust to unobserved biases and the conditional independence assumption (CIA). Using Rosenbaum bounds with gamma values ranging from 1 to 3 (incremented by 0.25), the analysis showed significant p-critical values at all levels, confirming that the estimated Average Treatment Effect on the Treated (ATT) was insensitive to unobserved confounders. This indicates that the matching results, particularly under nearest neighbor matching, were free from hidden biases and unobserved covariates, validating the estimated ATT as a pure effect of VC organic fertilizer adoption.

This finding showed that multiple variables have an effect on the adoption of VC organic fertilizer by household head farmers. Therefore, the finding is important to adopt programs to encourage the use of VC organic fertilizer, implement policies in an attempt to adapt the use of VC organic fertilizer in the Wolmera Woreda Holeta area, and critically consider these factors. Household heads who have used VC have higher access to extension visits service, and household heads who have regular contact with agricultural experts, and better information dissemination, are more likely to adopt agricultural technologies and also increase the possibility of commercial VC organic fertilizer adoption. A household head with a lower income prefers to use VC organic fertilizer compared to chemical fertilizer. It was thus concluded that lower costs in relation to the use of VC organic fertilizer on larger farm sizes encouraged farmers to use VC organic fertilizer intensively in the study area. Further, households who had adopted VC organic fertilizer earned a good average per hectare farm income compared to the non-adopters. This implies that the adoption of VC organic fertilizer had a positive impact on households' farm income in the study area encouraged to use VC organic fertilizer. Therefore, NGOs and the government should promote VC organic fertilizer adoption by improving its affordability, especially for low-income farmers, and enhancing extension services to provide regular expert support. They should launch information campaigns to highlight its benefits, implement policies like subsidies to encourage use and support commercialization for broader availability. These efforts will boost adoption, enhance farm productivity, and increase household incomes in areas like Wolmera Woreda Holeta.

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