Farmers perceive that the application of vermicompost enhances plant growth and strengthens resistance to diseases

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ABSTRACT

Objective: To identify the factors influencing growers in the municipalities of Fresnillo, Río Grande, and Zacatecas to either incorporate or refrain from incorporating available cattle manure into vermicompost production, trade, and use.

Design/methodology/approach: A questionnaire comprising 59 items was designed to assess human, social, physical, and economic factors related to vermicompost use in agricultural plots. The questionnaire was administered to 30 growers. The resulting dataset was analyzed using Principal Component Analysis (PCA) and Cluster Analysis (CA) to identify dominant factors and to classify growers.

Results: Both PCA and CA enabled the identification of key factors within each domain and facilitated the classification of growers.

Limitations on study/implications: The sample size is relatively small due to the limited number of growers using vermicompost in the study region.

Findings/conclusions: Among growers using vermicompost, three distinct groups were identified: the first group (10 growers) perceives improvements in soil fertility and contamination reduction; the second group (9 growers) values enhanced plant nutrition and increased soil microorganism activity; and the third group (11 growers) reports better plant growth and greater disease resistance.

Keywords: Human capital, Social capital, Physical capital, Economic capital.

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INTRODUCTION

The increase in agricultural production has driven the adoption of improved seeds and the intensive use of agrochemical products (Deepak, 2019). As a result, farmers have faced declining profits and rising input costs (Deepak, 2019). In response to this situation, they have sought to incorporate treated organic materials to produce environmentally friendly fertilizers (Enebe & Erasmus, 2023), such as vermicompost-derived products. Vermicomposting is a viable alternative due to its simple production techniques and the ecological and economic benefits it offers (Deepak, 2019).

Vermicomposting is a biological process in which earthworms decompose organic matter, transforming it into a nutrient-rich (Thirunavukkarasu *et al.*, 2022) and microbe-enriched fertilizer (Enebe & Erasmus, 2023). The resulting product, known as vermicompost, contains essential nutrients such as carbon, nitrogen (N), phosphorus (P), and potassium (K), as well as microorganisms, enzymes, plant growth regulators, and hormones (Gupta & Garg, 2008). Various sources of organic waste can be used in the vermicomposting process, including animal manure, sewage sludge, food production waste, kitchen waste, and horticultural residues, among others (Thirunavukkarasu *et al.*, 2022).

The potential benefits of using vermicompost include stimulating plant growth, reducing the incidence of diseases, and increasing soil porosity and microbial activity (Padilla *et al.*, 2021). In other words, vermicompost promotes soil biology improvement, which leads to enhanced crop productivity (Enebe & Erasmus, 2023), including nutrient absorption and plant growth. Recently, Keskin *et al.* (2025) reported that vermicompost induces increases in root biomass and leaf area. These effects can be attributed to the role of vermicompost in increasing organic carbon in the soil, as well as its capacity to improve soil water retention, aeration, and porosity (Haque & Biswas, 2021; Liu *et al.*, 2020; Wang *et al.*, 2018).

The use of vermicompost produced from bovine manure has generated growing interest in the dairy industry (Padilla *et al.*, 2021); however, dairy farmers face several issues regarding manure management (Padilla *et al.*, 2021); this implies the need for guidance on the proper management and use of vermicompost through the organization of various training and outreach activities (Sharma & Garg, 2019).

In the case of the state of Zacatecas, Mexico, some farmers and companies produce and market vermicompost. However, the evident issue is the lack of information regarding production systems, products (vermicomposts and leachates), as well as their composition, quality, storage, packaging, transportation, and distribution. In this context, the municipalities of Fresnillo (16,890.80 thousand liters), Río Grande (15,226.20 thousand liters), and Miguel Auza (23,014.70 thousand liters) are the top producers of cow's milk (SIAP, 2021); this implies that these municipalities have the highest number of dairy cattle farms and greater manure production due to the confinement of the animals.

Therefore, it is essential to understand the challenges, issues, and problems faced by farmers who have access to dairy cattle manure in adopting vermicomposting technology (Padilla *et al.*, 2021). Thus, the objective of this research was to identify the reasons why farmers with access to bovine manure in the municipalities of Fresnillo, Río Grande, and Miguel Auza, Zacatecas either incorporate or do not incorporate this raw material for the production, marketing, and use of vermicompost.

MATERIALS AND METHODS

A data generation/collection instrument was designed with semi-structured statements, considering a first section about the respondent's data, such as the production unit profile, infrastructure, equipment, and input acquisition. The second section of the instrument included 59 items based on the Likert scale. These items addressed technical and productive aspects within the human (14 items), social (19 items), physical (15 items), and economic (11 items) domains, in accordance with the Mexico's Sustainable Rural Development Law (DOF, 2019). The response scale consisted of five agreement categories. The categories were: Disagree, Partially Disagree, Neither Agree nor Disagree, Agree, and Strongly Agree (Likert, 1932). The information generated through the application of semi-structured questionnaires can be useful for estimating their reliability using the Cronbach's alpha statistic (Añorve-Guillén, 1991).

The application of the semi-structured questionnaire was carried out from November 2022 to May 2023. The instrument was administered to farmers in the municipalities of Fresnillo, Río Grande, and Miguel Auza, Zacatecas. Visits to the involved farmers were conducted to inform them about the study and obtain their consent as informants. Once consent was obtained, the questionnaire was provided to them in printed form so they could answer it at their convenience, ensuring their responses were not influenced.

Data Collection and Analysis

The data collected from the surveys were entered into a Microsoft Excel® spreadsheet, classified by human, social, physical, and economic capitals. Values from 1 to 5 were assigned to the Likert scale levels. This approach made it possible to calculate basic statistical estimators and verify whether the sample (n=30) was representative. The reliability of the questionnaire was confirmed through Cronbach's alpha coefficient (α). This statistical estimator evaluates the internal consistency of a set of items. The α is used to determine the reliability of a survey that uses a measurement scale, as it reflects the correlations between the variables. The higher the α value, the greater the internal consistency of the questionnaire.

A principal component analysis (PCA) was carried out with the aim of identifying the items that explain the largest portion of the variance in the data matrix. The principal components (PCs) allowed for the identification of the variables (items) that best describe the structure of each component, thus facilitating the ordination of the involved farmers. Additionally, a multivariate cluster analysis (CA) was performed to classify the farmers based on the structure of the Principal Components (*i.e.*, the coefficients of the Principal Components) that together explained >60% of the total variation. Overall, this analysis confirmed the groups identified through the PCA. The statistical analyses were performed using MINITAB 16® software.

RESULTS

All the farmers who participated in answering the questionnaire were men (n=30) (Table 1). The sample was found to be representative. Regarding age distribution, 40% of the respondents are 60 years or older; 30% are between 50 and 59 years old; 23.33% are between 40 and 49 years old; and 6.67% are between 30 and 39 years old. Concerning educational level, 86.67% of the farmers completed only basic education (primary and secondary), while 13.33% reached higher secondary education. Additionally, 66.67% of the farmers reported using vermicompost.

Table 1. Statistical Estimators of the Farmers (n=30) who answered the questionnaires in the municipalities of Fresnillo, Río Grande, and Miguel Auza, Zacatecas, Mexico.

Age class	Percentage	
18 to 29 years	DNA[1]	
30 to 39 years	2	6.67
40 to 49 years	7	23.33
50 to 59 years	9	30
>60 years	12	40
Schooling		
Elementary	15	50
Secondary	11	36.67
High	4	13.33
Bachelor	NA	NA
Other	NA	NA
Use Vermicompost		
Yes	20	66.67
No	10	33.33

[1]DNA: Does not apply.

Reliability of the Questionnaire

The Cronbach's Alpha values for the Human Capital (α=0.819), Social Capital (α=0.826), and Physical Capital (α=0.802) indicate good reliability. Additionally, the value of this coefficient for Economic Capital (α=0.935) suggests excellent internal consistency. Therefore, the information generated through the application of the questionnaire is sufficiently reliable. For example, the error associated with the information about the Human Capital of the farmers is 0.329 (*i.e.*, 0.819*0.819=0.670; 1−0.670=0.329).

Human Capital

The PCA conducted based on 14 items about Human Capital showed that the first four components explain 67% of the total variance (Table 2). CP1 (31%) reflects the farmers' perception of soil improvement and the importance of training. CP2 (15.6%) focuses on knowledge about plant nutrition and the vermicomposting process. CP3 (12.3%) highlights the use of leachate as a fertilizer and plant disease resistance, while CP4 (8.1%) is based on ease of use and improvements in seed germination and soil aeration.

Table 2. Eigenvalues, proportions of explained variance, and cumulative variance associated with the first four principal components (PCs) corresponding to 14 items on Human Capital regarding the use of vermicompost based on the perceptions of 30 surveyed farmers.

	PC1	PC2	PC3	PC4
Eigenvalue	4.3422	2.1792	1.7150	1.1387
Proportion of variance	0.310	0.156	0.123	0.081
Accumulated variance	0.310	0.466	0.588	0.670

Both the PCA results (Figure 1) and CA results through the Euclidean Distance$=-62.87$ (Figure 2) identify two groups of farmers. The first group (farmers 2, 11, 14, 17, 22, 23, 25, 26, and 30) agrees that vermicompost is easy to apply, improves plant nutrition and disease resistance, and uses technical instructions; the second group (remaining farmers) highlighted improvements in germination, roots, and soil aeration, and considers training to be important.

Social Capital

The Principal Component Analysis (PCA) on Social Capital (19 items) showed that the first five principal components explained 61.6% of the total variability. CP1 (25.5%)

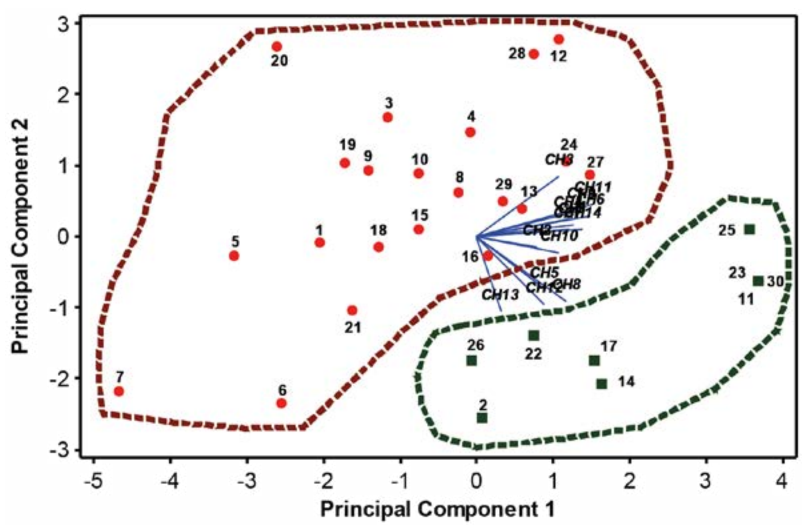

Figure 1. Position of the 30 farmers according to their perception, considering 14 items on Human Capital regarding the use of vermicompost in the orthogonal plane defined by the first two Principal Components.

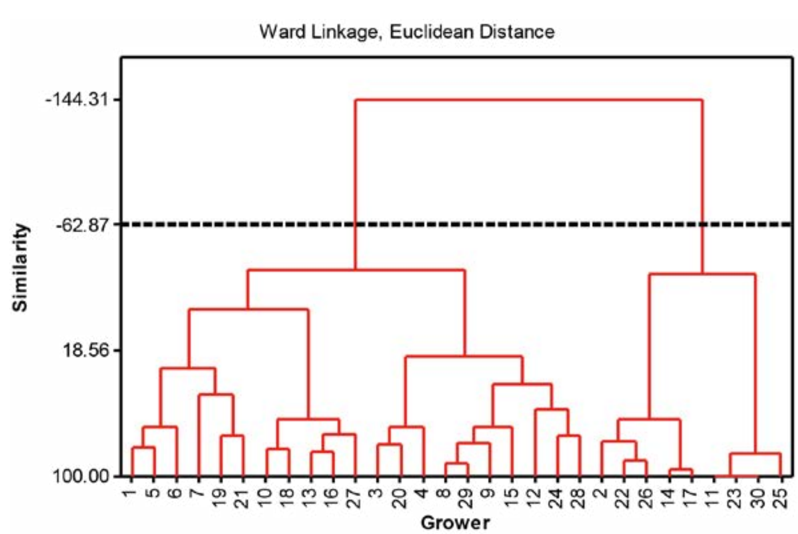

Figure 2. Dendrogram of 30 farmers based on their perception, considering 14 items on Human Capital regarding the use of vermicompost as variables.

is related to recommendations from suppliers to improve soil fertility; CP2 (10.3%) is associated with the reduction of chemical fertilization and technical support; CP3 (10%) is linked to soil aeration and plant tolerance to stress; CP4 (9%) is associated with germination and yield; and CP5 (6.8%) is related to plant nutrition and root growth.

Three groups of farmers were identified based on their perception of vermicompost usage recommendations (Figure 3). The multivariate cluster analysis (CA) confirmed these groups through Ward's method and Euclidean Distance=−10.46.

Physical Capital

The PCA on Physical Capital, based on the perception of 30 farmers, revealed that the first four components explain 68.3% of the total variation. CP1 emphasizes soil fertility and nutrition. CP2 is more related to plant growth improvement and soil aeration. CP3 highlights that fertility and photosynthesis are enhanced. CP4 refers to how vermicompost facilitates germination and induces stress tolerance. In the plane defined by CP2 *vs.* CP1, three groups of farmers were identified (not shown). The first group perceives improvements in soil fertility and reduced pollution; the second values soil nutrition and microorganisms; and the third observes plant growth and resistance. The hierarchical cluster analysis confirmed these groups through a Euclidean Distance=−40.24 (Figure 4).

Economic Capital

The PCA of 11 items on Economic Capital, based on the perceptions of 30 farmers, showed that the first two components explain 87.8% of the total variation. CP1 highlights the reduction of costs in fertilizers, root growth enhancers, plant nutrition, and pest control, while CP2 emphasizes the use of machinery and specialized labor, as well as the reduction in chemical fertilizer quantities and increased yield. In the CP2 *vs.* CP1 plane, three groups of farmers were identified (Figure 5). The first

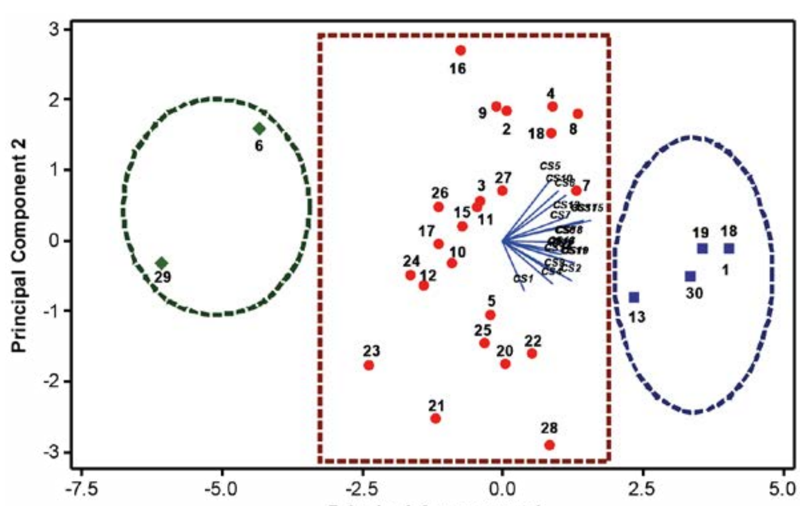

Figure 3. Position of 30 farmers according to their perception considering 19 items of Social Capital on the use of vermicompost in the orthogonal plane defined by the first two Principal Components.

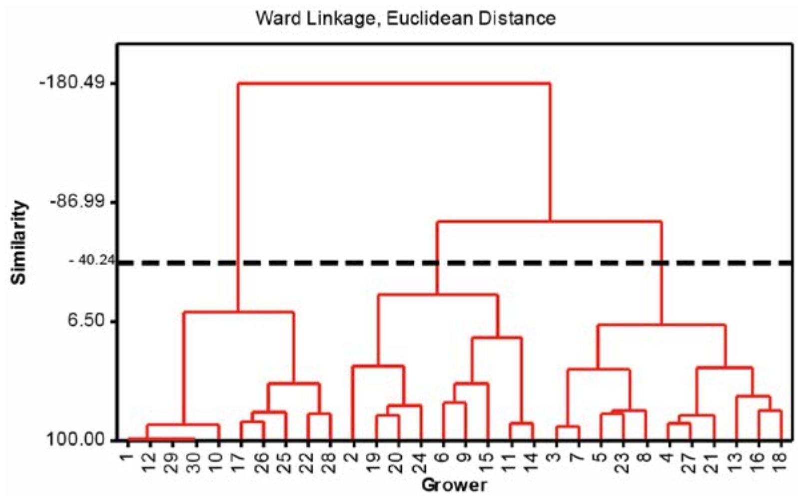

Figure 4. Dendrogram of 30 farmers based on their perception of 23 items regarding Physical Capital on the use of vermicompost as variables.

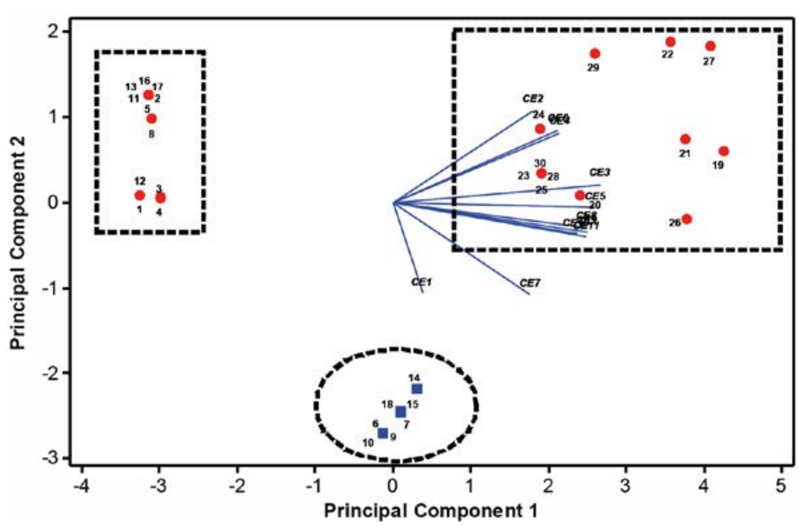

Figure 5. Position of 30 farmers according to their perception, considering 11 items of Economic Capital on the use of vermicompost in the orthogonal plane defined by the first two Principal Components.

group does not perceive cost savings or the need for machinery; the second disagrees with the reduction of chemical fertilizers and hormones but perceives an increase in income; the third perceives reductions in fertilization and plant nutrition costs. The multivariate cluster analysis (CA) confirmed these groups using Ward's method and a Euclidean distance of −139.13.

DISCUSSION

Human Capital

The PCA and the CA identified two groups of farmers based on 14 statements related to Human Capital. The first group, composed of 8 respondents, agrees that vermicompost leachate is a useful foliar fertilizer. This aligns with Kmeťová & Kováčik (2014), who argue that using leachate can increase crop productivity. This effect is attributed to the humic acid in the leachate, which provides nutrients such as calcium, iron, potassium, sulfur, and phosphorus (Adhikary, 2012). The second group, made up of 22 farmers, understands that vermicompost enriches the soil with microorganisms. Edwards *et al.* (1984) observed significant populations of Gram-negative Enterobacteriaceae, protozoa, and fungi in vermicompost substrate. Additionally, they noted that worms, by digesting organic matter, increase the surface area of the material, promoting microbial colonization and the decomposition of organic matter.

Social Capital

When analyzing 19 items on Social Capital, three groups of farmers were identified. The first group, consisting of 5 farmers, agrees that technical advisors and suppliers frequently recommend the use of vermicompost to improve the aggregation of soil mineral particles. According to Ansari & Ramnarain (2020), the application of vermicompost increases microbial activity, enzymes, and humic acid content, which improve soil aggregation, stability, and aeration. The second group, made up of 23 farmers, agrees that vermicompost improves plant nutrition. Several studies (*e.g.*, Atiyeh *et al.*, 2000; Ozores-Hampton & Vavrina, 2002) have shown that a growing medium with 10 to 20% vermicompost enhances plant growth. Finally, the third group (2 farmers) notes that technical advisors and suppliers recommend the use of vermicompost to improve root growth and structure. McClintock (2004) states that vermicompost improves the physical structure, fertility, and microbiological properties of the soil, promoting plant growth both in transplants and field crops.

Physical Capital

Analysis of 15 items on Physical Capital identified three groups of farmers. The first group, consisting of 10 farmers, agrees that the vermicomposting process requires four to six months, although some researchers indicate that vermicomposting can require 40 to 45 days (*e.g.*, Ansari & Ramnarain, 2020). The second group (9 farmers) agrees that vermicompost improves soil fertility. Ansari & Ramnarain (2020) note that its application improves soil properties such as organic matter content, nitrogen, phosphorus, potassium, sulfur, zinc, and boron, which favor crop yields such as cereals. The third group (11 farmers) agrees that vermicompost provides disease resistance. In this regard, vermicompost based on sludge and bovine manure reduces infection by pathogens causing root rot in tomatoes (Szczech & Smolinska, 2001). Other studies (*e.g.*, Asciutto *et al.*, 2006) also indicate that vermicompost controls various species of Phytophthora and Rhizoctonia, through biological disease-suppression mechanisms (Simsek-Ersahin *et al.*, 2009).

Economic Capital

Analysis of the 11 items on economic capital identified three groups of farmers. The first group (11 farmers) disagrees with the idea that the use of vermicompost reduces costs associated with disease control and the application of rooting agents. This perception contradicts the fact that vermicompost contains humic acids (Atiyeh *et al.*, 2002), as well as auxins, gibberellins, and cytokinins (Singh *et al.*, 2008); these compounds are growth regulators that enhance plant growth, and improve productivity in various crops (Atiyeh *et al.*, 2002). The second group, consisting of 7 farmers, disagrees with the idea that vermicompost reduces the amount of chemical fertilizer required; this partially aligns with the findings of Jeyabal & Kuppuswamy (2001), who found that the combination of vermicompost and nitrogen fertilizer increases productivity more than the fertilizer alone. The third group, made up of 12 farmers, agrees that using vermicompost can reduce costs associated with chemical fertilizers. In this regard, Guo *et al.* (2015) demonstrated that although the initial costs of the vermicomposting process are higher than those of traditional composting, the production of worms and the use of cow manure vermicompost increase crop yields, such as maize, resulting in economic benefits.

CONCLUSIONS

When vermicompost is used in production units, one group of farmers (10) perceives improvements in soil fertility and reduced contamination; a second group (9) values soil nutrition and microorganisms; and a third group (11) observes better plant growth and disease resistance. Therefore, it is recommended to foster collaboration among farmers, technicians, and public servants, as this could promote the development of capabilities regarding agroecological practices to enhance the production, commercialization, and use of vermicompost to improve agricultural productivity.

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