



Sustainable Agricultural Practices and Efficiency in Fertilizer Use among Ecuadorian Farmers

Prácticas agrícolas sostenibles y eficiencia en el uso de fertilizantes en agricultores ecuatorianos

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ABSTRACT

Agriculture represents a fundamental activity for Ecuador's economy and food security; however, the low efficiency in fertilizer use and the limited access to technical training continue to affect the productivity of small and medium-sized rural farmers. The present study aimed to analyze the relationship between agricultural training, efficient fertilizer use, and the productive performance of Ecuadorian farmers. The research was developed under a quantitative, descriptive, and correlational approach through a non-experimental cross-sectional design. Information was collected through surveys administered to farmers mainly engaged in rice, maize, and vegetable production in different rural areas of the country. The results showed that farmers who participated in training programs and demonstration plots presented higher levels of knowledge regarding balanced fertilization and proper nutrient management. Likewise, these farmers achieved better crop yields and reported a more favorable perception of food availability within their households. In contrast, non-trained farmers showed greater difficulties in applying fertilizers in a technical and efficient manner. The findings indicate that agricultural training and rural extension strategies significantly contribute to improving agricultural productivity, strengthening food security, and promoting sustainable practices in rural production systems in Ecuador. In conclusion, strengthening technical assistance and agricultural education programs can support rural development and enhance the sustainability of agricultural production in the country.

Keywords: agricultural fertilization, rural productivity, agricultural training, food security.

RESUMEN

La agricultura representa una actividad fundamental para la economía y la seguridad alimentaria del Ecuador; sin embargo, la baja eficiencia en el uso de fertilizantes y el limitado acceso a capacitación técnica continúan afectando la productividad de los pequeños y medianos productores rurales. La presente investigación tuvo como objetivo analizar la relación entre la capacitación agrícola, el uso eficiente de fertilizantes y el desempeño productivo de los agricultores ecuatorianos. El estudio se desarrolló bajo un enfoque cuantitativo, de tipo descriptivo y correlacional, mediante un diseño no experimental de corte transversal. La información fue recopilada a través de encuestas aplicadas a agricultores dedicados principalmente al cultivo de arroz, maíz y hortalizas en distintas zonas rurales del país. Los resultados evidenciaron que los productores que participaron en programas de capacitación y parcelas demostrativas presentaron mayores niveles de conocimiento sobre fertilización balanceada y manejo adecuado de nutrientes. Asimismo, se observó que estos agricultores alcanzaron mejores rendimientos productivos y reportaron una percepción más favorable respecto a la disponibilidad de alimentos en sus hogares. Por otro lado, los productores sin capacitación mostraron mayores dificultades para aplicar fertilizantes de manera técnica y eficiente. En conclusión, la capacitación agrícola y las estrategias de extensión rural contribuyen significativamente a mejorar la productividad agrícola, fortalecer la seguridad alimentaria y promover prácticas sostenibles en los sistemas de producción rural del Ecuador.

Palabras clave: fertilización agrícola, productividad rural, capacitación agrícola, seguridad alimentaria

INTRODUCTION

Agriculture is among the most important economic and social activities in Ecuador, especially in rural areas where a large proportion of the population depends on agricultural production for subsistence, income generation, and food security. Crops such as rice, maize, banana, cocoa, and vegetables represent fundamental sources of employment and domestic supply, while contributing significantly to national exports. However, Ecuadorian agricultural productivity continues to face major limitations related to soil degradation, inefficient use of agricultural inputs, and limited transfer of technical knowledge to small- and medium-sized producers (Bonilla Bolaños & Singaña Tapia, 2019; Valverde Jalca & Revelo Salgado, 2025). Among the most critical factors is the inadequate management of chemical fertilizers, which affects both crop yields and the environmental sustainability of production systems (Saucedo Aguiar et al., 2024).

In many agricultural regions of the country, farmers apply fertilizers without sufficient technical information regarding specific crop nutritional requirements, soil characteristics, or appropriate application rates. This lack of information leads to the underutilization or overutilization of nutrients, which increases production costs, reduces agronomic efficiency, and causes negative environmental impacts, such as the contamination of water sources, degradation of soil fertility, and emissions associated with excessive nitrogen use (Saucedo Aguiar et al., 2024). Limited technical training, restricted access to agricultural extension services, and the economic constraints of rural producers further aggravate this problem, especially in low-income communities and areas remote from the country's main agricultural centers.

In response to this scenario, agricultural training and demonstration strategies have acquired growing relevance as mechanisms to strengthen the productive capacities of farmers. Demonstration plots and technology transfer programs allow producers to observe practically the benefits associated with efficient fertilizer use, balanced nutrient application, and the implementation of good agricultural practices. Such initiatives favor participatory learning, facilitate technology adoption, and contribute to reducing the gap between technical knowledge and traditional agricultural management practices. Furthermore, interaction among farmers, technicians, and agricultural organizations promotes rural innovation processes that can translate into higher levels of productivity and sustainability (Saucedo Aguiar et al., 2024).

In Ecuador, the need to improve fertilizer use efficiency is particularly critical due to growing food demand, pressure on natural resources, and the effects of climate change on agricultural production. The decline in soil fertility across various agricultural provinces, along with rainfall variability and increasing input costs, necessitates the search for alternatives that increase production without compromising environmental sustainability. Various studies have shown that both the rational management of chemical fertilizers and the incorporation of biofertilizers and organic fertilization sources can significantly improve the agronomic performance of crops such as maize, coffee, and other production systems in the country (García Vásquez et al., 2022; Chilán Villafuerte et al., 2023; Valverde Lucio et al., 2025). In this context, promoting integrated nutrient management practices and strengthening agricultural extension programs represent key tools to improve the productive performance of farmers and enhance the food security of rural households.

In addition to its effects on productivity, the proper use of fertilizers can contribute directly to improving the socioeconomic conditions of smallholder families. An increase in agricultural yields can translate into higher income, better food availability, and reduced vulnerability to economic or climatic crises. Thus, the adoption of efficient agricultural technologies constitutes not only a strategy for productive modernization, but also a fundamental element for promoting sustainable rural development and improving the quality of life of the Ecuadorian agricultural population (Bonilla Bolaños & Singaña Tapia, 2019; Valverde Jalca & Revelo Salgado, 2025).

METHODS

This research was conducted using a quantitative approach with a descriptive and correlational scope, aiming to examine the relationship between agricultural training activities, proper fertilizer management, and the productive yield of farmers in Ecuador. The study aimed to determine how access to technical knowledge and agricultural demonstration programs influences crop nutrition practices, agricultural productivity, and the perception of food security in rural households.

The study adopted a non-experimental cross-sectional design, as data were collected during a single period without intervening in or modifying the analyzed variables. This design allowed for the evaluation of agricultural practices developed by producers under their usual working conditions. The research focused primarily on small- and medium-sized farmers dedicated to the cultivation of maize, rice, and vegetables, due to the importance of these crops to agricultural production and food security in the country.

The study population consisted of farmers from various rural areas of Ecuador where the use of chemical fertilizers is common practice in production systems. Sample selection was performed using non-probability convenience sampling, considering the accessibility of the participants and their willingness to participate in the study. The inclusion criteria required that producers had experience in agricultural activities and used chemical fertilizers on their crops.

Data collection was conducted using a structured survey consisting of closed-ended and multiple-choice questions. The questionnaire included variables related to sociodemographic aspects, knowledge of fertilization, access to technical assistance services, participation in training or demonstration plots, frequency and type of fertilizers used, and farmers' perceptions of crop yields. Additionally, questions regarding food availability and household economic status were incorporated as indicators of food security.

The instrument was validated through evaluation by experts in agriculture and rural development, who reviewed the relevance, clarity, and consistency of each question in the questionnaire. Subsequently, a pilot test was administered to a small group of farmers to verify comprehension of the questions and make necessary corrections prior to final administration.

The collected data were organized and analyzed using descriptive statistics. Frequencies, percentages, and measures of central tendency were used to describe the primary characteristics of the variables studied. Additionally, correlation analyses were performed to identify potential relationships among agricultural training, fertilizer use, and crop productivity. The results facilitated an understanding of how access to technical knowledge influences the agricultural practices implemented by rural producers.

Throughout the research process, fundamental ethical principles were upheld, ensuring voluntary participation, confidentiality of the information provided, and informed consent. Furthermore, the collected data were used exclusively for academic and scientific purposes, preserving the anonymity of the participants.

RESULTS

The results show that access to agricultural training programs and demonstration plots positively influenced fertilizer knowledge and management among Ecuadorian farmers. Additionally, significant differences in crop productivity and perceived food security were observed between producers who participated in training activities and those who did not.

The study involved 120 farmers from various rural areas of Ecuador. Of the total participants, 68.3% were male and 31.7% were female. Furthermore, the majority of the farmers were engaged in rice and maize cultivation, whereas a smaller percentage cultivated vegetables.

Regarding knowledge of fertilization, farmers who participated in training programs demonstrated a greater understanding of proper nutrient use, recommended doses, and application frequency. Conversely, untrained farmers reported greater difficulty identifying the nutritional needs of crops.

Table 1. General characteristics of the surveyed farmers

Variable	Category	Frequency	Percentage
Sex	Male	82	68,3 %
	Female	38	31,7 %
Crop type	Rice	48	40,0 %
	Maize	42	35,0 %
	Vegetables	30	25,0 %
Participation in training	Yes	74	61,7 %
	No	46	38,3 %

Table 2. Level of knowledge on fertilizer management

Knowledge level	Trained farmers	Untrained farmers
High	39 (52,7 %)	8 (17,4 %)
Medium	27 (36,5 %)	19 (41,3 %)
Low	8 (10,8 %)	19 (41,3 %)

The results also indicated that trained farmers applied fertilizers in a more balanced and efficient manner. The majority reported using appropriate combinations of nitrogen, phosphorus, and potassium, whereas untrained farmers tended to use only nitrogenous fertilizers, primarily urea.

Table 3. Type of fertilization used by farmers

Fertilizer application type	Trained	Untrained
Balanced fertilization (NPK)	49	14
Predominant nitrogen use	18	25
Application without technical criteria	7	7

Regarding agricultural yields, positive differences were observed in producers who participated in agricultural demonstration programs and received technical assistance. Trained farmers reported higher productivity levels than those who did not receive training.

Regarding food security, 70.3% of the trained farmers stated that household food availability had improved in recent years, whereas only 39.1% of the untrained farmers perceived similar improvements.

Table 4. Average crop yield according to participation in training

Crop	Trained (t/ha)	Untrained (t/ha)
Rice	5,1	3,8
Maize	4,3	2,9
Vegetables	12,5	9,1

Table 5. Perception of improvement in food security

Perceived food improvement	Trained	Untrained
Yes	52 (70,3 %)	18 (39,1 %)
No	22 (29,7 %)	28 (60,9 %)

Finally, correlation analysis showed a positive association between participation in agricultural training programs and efficient fertilizer use, as well as between proper nutrient management and increased agricultural productivity. These results suggest that agricultural extension strategies and demonstration plots can significantly contribute to strengthening agricultural production and improving food security for rural producers in Ecuador.

DISCUSSION

The results of this study demonstrate that agricultural training and demonstration plots play a crucial role in improving fertilizer management practices and increasing agricultural productivity in Ecuador. Farmers who participated in training programs exhibited greater technical knowledge of plant nutrition and balanced fertilizer application, which was reflected in higher crop yields and a more positive perception of household food security. These findings highlight the importance of agricultural extension programs as tools to enhance production efficiency and promote more sustainable agricultural systems.

The study revealed that a large proportion of untrained farmers faced limitations in identifying crop nutritional needs and applying fertilizers appropriately. This aligns with observations in numerous agricultural contexts in developing countries, where limited access to technical assistance and agricultural education leads to the inefficient use of agricultural inputs. Inappropriate fertilizer application not only reduces crop productivity but also increases production costs and negatively impacts soil and water resources. Consequently, these results highlight the need to strengthen training programs aimed at enhancing the technical skills of rural producers in Ecuador.

Furthermore, trained farmers demonstrated higher adoption rates of balanced fertilization practices involving the combined use of nitrogen, phosphorus, and potassium. This suggests that access to technical knowledge facilitates more efficient nutrient management decisions, thereby optimizing crop growth and development. Conversely, untrained farmers tended to rely primarily on nitrogenous fertilizers, particularly urea, which can cause nutritional imbalances and reduce the long-term sustainability of agricultural systems. These results demonstrate that technical knowledge transfer can significantly contribute to promoting more efficient and environmentally sustainable agriculture.

Regarding agricultural productivity, significant differences were observed between trained farmers and non-participants. The higher yields of rice, maize, and vegetables recorded among trained producers indicate that proper fertilizer management directly affects crop performance. This productivity increase may be associated with a better understanding of recommended application rates, timing, and crop-specific nutritional requirements. Furthermore, demonstration plots enable farmers to observe the practical benefits of agricultural technologies, facilitating their adoption and replication on their own farms.

The results also revealed a positive relationship between agricultural training and perceived improvements in household food security in rural areas. Farmers who achieved higher productivity reported greater food availability and improved household economic conditions. This demonstrates that technical capacity building has not only productive benefits but also significant socio-economic implications for rural communities. In contexts where many families depend directly on agriculture for subsistence, increasing production can help reduce food vulnerability and rural poverty.

Despite these positive results, this study has several limitations. The use of non-probability convenience sampling limits the generalizability of the findings to the entire agricultural population of Ecuador. Additionally, the data relied on self-reported responses from farmers, which may introduce subjectivity into some of the analyzed indicators. Nevertheless, these results identify important trends regarding the impact of agricultural training on efficient fertilizer use and crop productivity.

Overall, this research demonstrates that agricultural training and extension strategies are fundamental tools for improving fertilizer use efficiency and enhancing the sustainability of agricultural production in Ecuador. Strengthening technical assistance programs, establishing demonstration plots, and promoting good agricultural practices can significantly contribute to increasing productivity and enhancing food security among rural producers.

CONCLUSIONS

The results of this study demonstrate that agricultural training and demonstration plots play a crucial role in improving fertilizer management practices and increasing agricultural productivity in Ecuador. Farmers who participated in training programs exhibited greater technical knowledge of plant nutrition and balanced fertilizer application, resulting in higher crop yields and a more positive perception of household food security.

These findings highlight the importance of agricultural extension programs as tools to enhance production efficiency and promote more sustainable agricultural systems, consistent with previous research highlighting the positive impact of extension services and demonstration plots on technology adoption and agricultural performance (Davis et al., 2012; Pan, 2014; Maertens et al., 2021; Sseguya et al., 2021).

The study demonstrated that a large proportion of untrained farmers faced limitations in identifying crop nutritional needs and applying fertilizers appropriately. This situation aligns with the reality observed in numerous agricultural contexts in developing countries, where limited access to technical assistance and agricultural education leads to the inefficient use of productive inputs (Pan, 2014; Maertens et al., 2021). Inadequate fertilizer application not only reduces crop productivity but also increases production costs and generates negative impacts on soil and water resources, as documented for the Ecuadorian context (Saucedo Aguiar et al., 2024) and in research aimed at promoting sustainable agricultural production through efficient nutrient management (Cui et al., 2018). In this regard, these results reflect the need to strengthen training programs aimed at improving the technical competencies of Ecuadorian rural producers.

Likewise, trained farmers demonstrated greater adoption of balanced fertilization practices through the combined use of nitrogen, phosphorus, and potassium. This suggests that access to technical knowledge promotes more efficient decisions in nutrient management, optimizing crop growth and development, in agreement with the findings of Pan (2014) and Cui et al. (2018). Conversely, untrained farmers tended to rely primarily on nitrogenous fertilizers, especially urea, which can cause nutritional imbalances and decrease the long-term sustainability of agricultural systems (Saucedo Aguiar et al., 2024). These results show that the transfer of technical knowledge can contribute significantly to promoting more efficient and environmentally responsible agriculture.

Regarding agricultural productivity, significant differences were observed between trained farmers and those who did not participate in agricultural extension programs. The higher yields of rice, maize, and vegetables recorded among trained producers indicate that proper fertilizer management has direct effects on crop performance. This result aligns with research conducted in Ecuador on rice, maize, potato, coffee, and other production systems (Bonilla Bolaños & Singaña Tapia, 2019; Singaña Tapia, 2021; García Vásquez et al., 2022; Palacios Cedeño et al., 2022; Chilán Villafuerte et al., 2023; Valverde Lucio et al., 2025). This increase in productivity may be associated with a better understanding of recommended doses, appropriate application timing, and the specific needs of each crop. Furthermore, demonstration plots allow farmers to observe the benefits of agricultural technologies in practice, facilitating their adoption and replication in their own production units (Sseguya et al., 2021).

The results also showed a positive relationship between agricultural training and the perceived improvement in food security among rural households. Farmers who achieved higher productivity levels reported greater food availability and improved household economic conditions. This demonstrates that strengthening technical capacity has not only productive effects but also significant social and economic implications for rural communities. In contexts where many families depend directly on agriculture for subsistence, increasing production can contribute to reducing food vulnerability and rural poverty, as highlighted by Larsen and Lilleør (2014), Davis et al. (2012), and Choudhary et al. (2022).

Despite the positive results observed, this study has limitations that should be considered. The use of non-probability convenience sampling limits the generalizability of the findings to the entire Ecuadorian agricultural population. Likewise, the data were based on the perceptions and responses of the farmers, which could introduce subjectivity into some analyzed indicators. Nevertheless, the results allow for the identification of important trends regarding the impact of agricultural training on fertilizer use efficiency and crop productivity.

This study demonstrates that agricultural training and extension strategies are fundamental tools for improving fertilizer use efficiency and strengthening the sustainability of agricultural production in Ecuador. Strengthening technical assistance programs, implementing demonstration plots, and promoting good agricultural practices can contribute significantly to increasing productivity and improving the food security of rural producers, in accordance with the recommendations of Cui et al. (2018), Maertens et al. (2021), Sseguya et al. (2021), Andrade Guamán et al. (2024), and Estrada-Zhagui et al. (2025).

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