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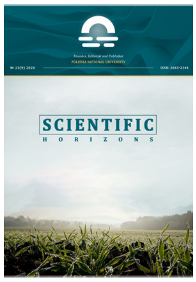

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Analysis of production factors determining agricultural productivity in Cuispes

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Abstract. This study aimed to evaluate the impact of productive factors – Capital, Labour, Knowledge, Technology, Management, and Land – on agricultural productivity in the district of Cuispes. A sample of 50 producers was analysed using a quantitative approach and PLS-SEM models, and further assessed across four productive groups through R statistical software, using ordinary least squares (OLS) and analytic hierarchy process (AHP) models. The results indicate that land fertility plays a fundamental role in the production process. PLS analysis reveals that Management, Technology, and Knowledge exhibit moderate and low positive correlations of 0.680, 0.632, and 0.341, respectively, whereas Capital and Labour show negative correlations of 0.252 and 0.400 with productivity. Group B excels in Land, Capital, and Technology (AHP: 0.44), demonstrating significant productive potential. OLS results confirm that the combination of Technology and Land is critical to agricultural success. Group D performs well in Knowledge and Technology (AHP: 0.25), and OLS identifies it as the second most significant group in terms of Technology use. Groups A and C score lower (AHP: 0.10 and 0.25), with a negative impact according to OLS; these groups require improvements in production methods and management practices to become more competitive in the market. It is concluded that Group B is the most productive sector, followed by Group D, both representing the most profitable activities in the district. Certain production factors should therefore be developed further, and public or private institutions should strengthen agricultural productivity through targeted public policies

Keywords: PLS analysis; analytic hierarchy process; ordinary least squares; capital; management; technology

INTRODUCTION

Agricultural productivity is a fundamental driver of economic development and food security on a global scale. Its enhancement not only ensures a stable food supply but also promotes social welfare, generates employment, and supports equitable income distribution within rural communities. A comprehensive understanding of the factors influencing agricultural productivity is essential for improving production efficiency, advancing long-term sustainability, and guaranteeing fair access to vital resources. This need becomes particularly urgent in light of the escalating global food demand driven by population growth, coupled with pressing environmental challenges such as soil degradation and climate change. As such, research into the determinants of agricultural productivity remains both timely and critical.

Agriculture, as a resource-intensive sector, depends heavily on the strategic management of production inputs – Capital, Labour, Management, Knowledge, and Technology – to sustain productivity. According to Z. Zhou *et al.* (2024), effective coordination of these resources is pivotal for sustained production growth. Notably, J. Chavas and C. Nauges (2020) highlight the transformative role of technological advancement in enhancing agricultural efficiency, particularly in increasing crop yields. Their research further underscores that capital investment, especially in the form of access to financial services, enables farmers to adopt modern machinery and advanced farming techniques. Despite these advancements, many farmers continue to face structural barriers that constrain productivity growth. K. Chacón and D. Gutman (2022) identify limited access to modern agricultural technologies as a significant limiting factor. Similarly, the intensifying effects of climate change, documented by W. Shah *et al.* (2024), pose increasing risks to consistent agricultural output.

As noted by A. Weyori *et al.* (2018), the broader economic contribution of agriculture is contingent upon the efficient utilisation of production factors, where these are deficient, consequences include reduced output, technical inefficiencies, and hindered economic progress. W. Shah *et al.* (2023) support this view, suggesting that without ongoing improvements in key inputs, agriculture becomes vulnerable to stagnation. Land, in particular, remains a critical yet problematic resource. Farmers recognise soil fertility as a major determinant of productivity. However, as L. Nkurunziza *et al.* (2020) argue, challenges such as restricted access to arable land, inadequate education, and weak technological integration persist, undermining both productivity and sustainability in rural areas. In recent years, the competitiveness of the agricultural sector has increasingly been evaluated through the lens of local production capacity and the strategic deployment of endogenous resources. As M. Kobylińska (2021) observes, an emerging trend among farmers is the adoption of organic practices intended to improve yields while preserving ecological integrity. Profitability in this context, as shown by F. Tenchini and C. de Freitas (2024), depends on the optimal use of production factors to enhance logistics, infrastructure, and the management of agricultural knowledge, thereby facilitating market access for high-quality outputs. This transition is supported by H. Xiong *et al.* (2023), who emphasise that agroecological practices, which blend traditional knowledge with scientific advancements, offer a viable pathway for optimising productivity while maintaining environmental stewardship.

Overall, the literature strongly indicates that agricultural productivity is shaped by a dynamic interplay of multiple production factors. By analysing these determinants, both public policymakers and private sector stakeholders can devise more effective strategies to foster efficiency, resilience, and sustainability in agriculture. Therefore, the present study focused on identifying the specific drivers of agricultural productivity in the district of Cuispes, with particular attention to land management, the application of agricultural knowledge, technology adoption, efficient use of capital, farm management practices, and the role of human labour. The insights derived from this investigation are intended to support the development of informed production strategies tailored to the needs of rural agricultural systems.

MATERIALS AND METHODS

Study area. The area of investigation was the district of Cuispes, one of the twelve districts that comprise the Province of Bongará, in the Department of Amazonas, northern Peru. It is bordered by the districts of Florida to the north, Jumbilla to the east, San Carlos and Jazán to the south, and Shipasbamba to the west. The district of Cuispes spans approximately 110.72 square kilometres and features varied terrain, including elevated areas, plains, and altitudes ranging from 1,000 metres above sea level to more than 1,690 metres in its highest regions. The population density is approximately 7.8 inhabitants per square kilometre, and the total population is estimated to exceed 700 residents. The study population consisted of 50 farmers, divided into four productive groups: Group A: crops such as arracacha, yucca, potato, and vituca; Group B: coffee; Group C: gherkin, beans, maize, pineapple; Group D: banana and avocado. The following hypotheses were proposed.

H1: Adequate land management influences productivity in the agricultural sector.

H2: Enhanced application of agricultural knowledge increases productivity in the agricultural sector.

H3: The adoption of technology influences productivity in the agricultural sector.

H4: Efficient use of capital influences productivity in the agricultural sector.

H5: Effective farm management influences productivity in the agricultural sector.

H6: The human labour factor influences productivity in the agricultural sector.

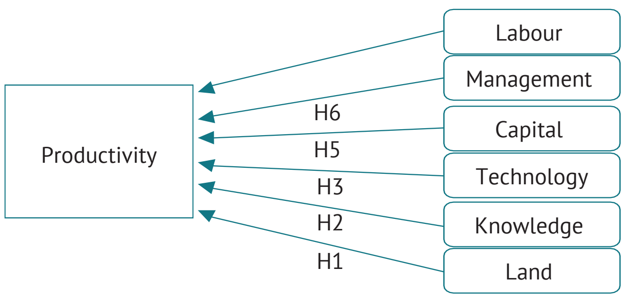

***Figure 1**. Research design*
***Source:** authors' compilation*

Data collection. For data collection, a random sampling method was implemented, targeting the most relevant hamlets in terms of production. The necessary permissions were obtained before the commencement of data collection, with the purpose of the research clearly explained and confidentiality and data security guaranteed. Verbal consent was obtained from the main authorities of the Cuispes district, and farmers engaged in diverse agricultural activities were randomly selected to complete a paper-based questionnaire. Prior to this, concepts related to the productive factors influencing agricultural yields were explained, thereby ensuring the validity of the questionnaire and the reliability of the data collected. The questionnaire comprised two sections: the first gathered sociodemographic information, while the second focused on productive factors and the productivity of agricultural activities. The latter was assessed using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), as proposed by authors such as Y. VegaSampayo *et al.* (2022). The study adhered to the principles outlined in the American Sociological Association's Code of Ethics (1997).

A basic mixed-methods approach was adopted to examine the relationship between productivity factors and farm improvement. This approach was structured to identify, define, and analyse the key factors influencing agricultural productivity. Data collection was conducted via a questionnaire survey administered in March 2024 to a sample of farmers from the district of Cuispes. The analysis employed the PLS-SEM method, hierarchical process analysis (AHP), and the ordinary least squares model to quantitatively examine the impact of productive factors on agricultural outputs.

Data analysis. PLS-SEM was employed to evaluate the productive factors influencing agricultural activity and their impact on productivity enhancement. The data were analysed across four productive groups using R statistical software, incorporating OLS and AHP models to identify the most influential factors in each group and to determine the most significant agricultural activity in the district of Cuispes. The research relied on data obtained through the survey application, and the reliability of the dataset was validated with a Cronbach's alpha coefficient exceeding 0.78 (HerreraGuerra *et al.*, 2023). Data were processed using Smart PLS, R, and Excel software to facilitate a clearer and more detailed analysis.

RESULTS AND DISCUSSION

In the analysis of agricultural productivity in Cuispes, it was identified that land management and land quality are key factors that contribute to improved productive performance, while Technology and Knowledge exert a comparatively lower influence. The PLS-SEM model confirmed the relevance of Management and Technology for productivity but found no significant effect from Labour or Land. AHP and OLS analyses identified coffee as the crop with the greatest productive potential, followed by plantain, thereby suggesting that improvements in Technology and Management are necessary to optimise production.

To estimate potential bias in the structural equation model (PLS-SEM), in this study authors applied tests of internal consistency and construct reliability, such as Cronbach's alpha, composite reliability, and average variance extracted (AVE). These tests are widely accepted in the quantitative research literature. The values initially obtained did not fully support the validity of the SEM model, indicating that certain variables may have been omitted that are necessary to establish the model's viability. The results are presented in Table 1, where Cronbach's alpha, composite reliability and AVE are reported for each construct within the model.

***Table 1**. Reliability and construct validity*

	CA	(rho_a)	(rho_c)	AVE
Capital	0.700	0.724	0.766	0.624
Labour	0.739	0.777	0.851	0.658
Knowledge	0.71	0.757	0.818	0.692
Land	0.866	0.949	0.912	0.775
Management	0.876	0.893	0.905	0.616
Production	0.879	0.885	0.912	0.674
Technology	0.853	0.853	0.895	0.632

***Note:** CA – Cronbach's Alpha; (rho_a) – composite reliability; (rho c) – composite reliability; AVE – average variance extracted*
***Source:** compiled by the authors*

Table 1 shows the internal reliability measures for assessing the coherence of the indicators that constitute each latent variable. These are considered acceptable Cronbach's alpha, composite reliability rho_a values exceeding 0.7. The degree to which indicators of a latent variable share a high proportion of variance is considered satisfactory when the AVE exceeds 0.5. These criteria allow the researcher to determine whether the selected constructs are well-defined and whether the indicators are appropriate. The results from the external model indicate that the constructs – Capital, Knowledge, Land, Management, Production, and Technology – meet the criteria of the measurement model criteria. Thus, the selected latent variables and their associated indicators are deemed reliable and valid for use in a PLS-SEM analysis. Table 2 presents the discriminant validity of the constructs in the measurement model, assessed using the Heterotrait-Monotrait Ratio (HTMT). Values below the critical threshold of 0.85 indicate satisfactory discriminant validity (Hair *et al.,* 2019).

***Table 2**. Heterotrait-Monotrait Ratio analysis*

	Capital	Labour	Knowledge	Management	Production
Capital					
Labour	0.637				
Knowledge	0.248	0.382			
Management	0.415	0.344	0.598		
Production	0.643	0.295	0.480	0.755	
Technology	0.279	0.626	0.804	0.632	0.720

***Note:** this table presents the HTMT values between different constructs in the measurement model, used to assess discriminant validity in PLS-SEM*
***Source:** compiled by the authors*

The construct Capital and Knowledge presents an HTMT value of 0.248, reflecting a significant conceptual distinction between the two. Similarly, Labour and Knowledge yield have an HTMT of 0.382, which also indicates adequate discriminant validity. In addition, Capital and Management show an HTMT of 0.415, while Production and Management report a value of 0.480 – both well below the critical threshold – underlining a clear differentiation between these pairs of constructs. However, the HTMT between Knowledge and Technology is 0.804, suggesting a possible conceptual overlap. Although this value remains below the commonly accepted limit of 0.85, it indicates a potential interrelation or shared dimensions in either conceptualisation or measurement.

The productive factors and their relationship with productivity were evaluated using the PLSSEM algorithm. Some external loadings of the indicators were found to be non-significant for certain constructs and were therefore removed to enhance the model's validity. Figure 2 illustrates the relationships between the latent variables and their observable indicators within the measurement model. The high values of the retained external loadings confirm a strong association between the constructs and the productivity indicators (Hair *et al.,* 2019).

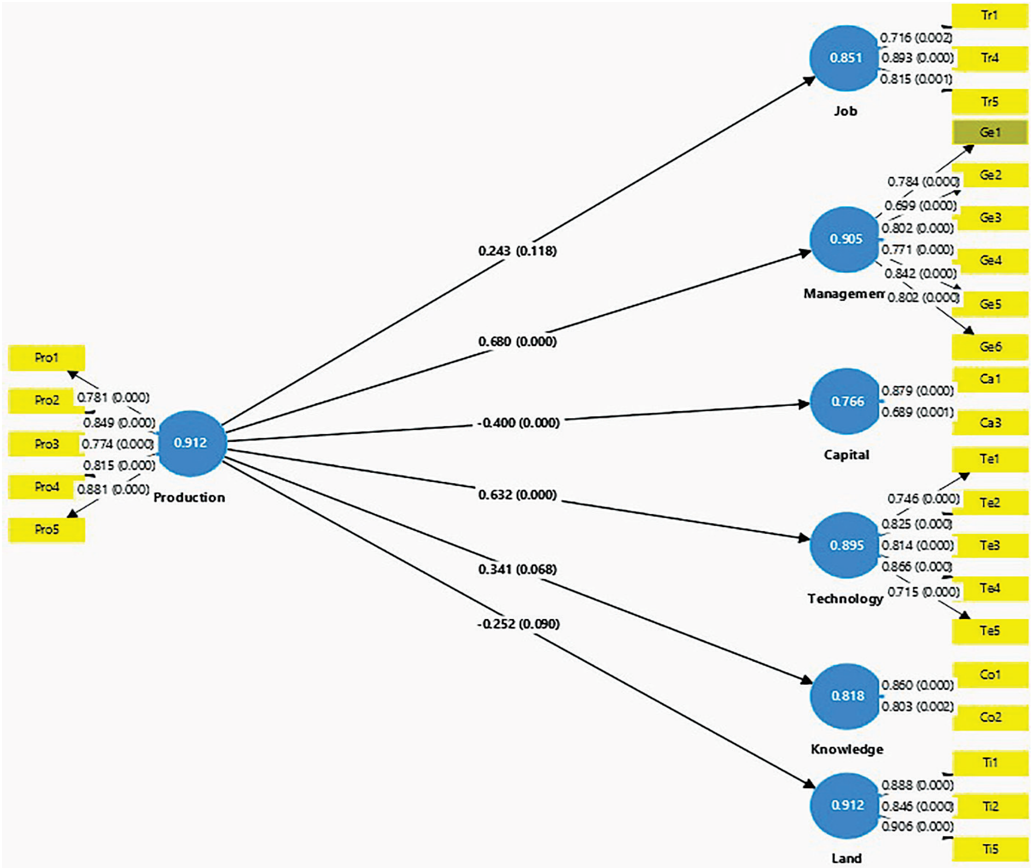

***Figure 2**. Measurement results and structural model – SmartPLS*

***Source:** compiled by the authors*

Evaluation of the structural model using PLS-SEM, based on the data presented in Figure 2, showed that after the removal of some indicators to improve model feasibility, the latent constructs Management and Technology exhibited a statistically significant influence on productivity. The retained indicators for Management (loadings: 0.79, 0.69, 0.80, 0.77, 0.84, 0.80) and Technology (loadings: 0.74, 0.82, 0.81, 0.86, 0.71) all demonstrated external loadings exceeding 0.7, indicating a strong relationship with productivity outcomes. By contrast, the constructs Labour and Land, although supported by indicators with high external loadings (Labour: 0.71, 0.89, 0.81; Land: 0.80, 0.84, 0.90), did not show a statistically significant influence on productivity in this study (Table 3). These findings suggest that while Capital, Management and Technology are key determinants of productivity improvements, Labour, Knowledge and Land may not exert such a strong direct impact. The results underscore the importance of prioritising effective management practices and the adoption of advanced technologies in strategies aimed at enhancing agricultural productivity.

***Table 3**. Results of hypothesis testing*

Hypothesis	t-value	p-value	Decision
Production → Capital	3.696	0.000	Accept
Production → Labour	1.564	0.118	Reject
Production → Knowledge	1.829	0.068	Reject
Production → Land	1.695	0.090	Reject
Production → Management	7.841	0.000	Accept
Production → Technology	4.954	0.000	Accept

***Source:** compiled by the authors*

Table 3 presents an analysis of the structural relationships between the constructs in the PLSSEM model, showing both significant and non-significant results for several hypotheses. Hypotheses indicating positive relationships between Production and Capital ($t = 3.696$, $p = 0.000$), Management ($t = 7.841$, $p = 0.000$), and Technology ($t = 4.954$, $p = 0.000$) were accepted, suggesting that production has a statistically significant and positive influence on these constructs. In contrast, hypotheses linking Production to Labour ($t = 1.564$, $p = 0.118$), Knowledge ($t = 1.829$, $p = 0.068$), and Land ($t = 1.695$, $p = 0.090$) were rejected due to a lack of statistical significance, as their p-values exceed the 0.05 threshold (Table 4). These findings demonstrate that, although production exerts a strong influence on Capital, Management and Technology, it does not have a statistically significant effect on Labour, Knowledge, or Land. This underscores the importance of recognising the variability in the influence of production factors when analysing productivity.

***Table 4**. Analytic hierarchy process and ordinary least squares analysis*

AHP	Analytic hierarchy process						
	Stie	Stra	Scapi	Stec	Scono	Sges	Prioritisation
A	0.25	0.27	0.14	0.07	0.19	0.3	0.21
B	0.55	0.37	0.57	0.57	0.2	0.41	0.44
C	0.08	0.13	0.06	0.12	0.07	0.14	0.1
D	0.13	0.23	0.23	0.25	0.54	0.15	0.25
Weighting	0.18	0.17	0.16	0.15	0.15	0.19	
OLS	Ordinary least squares						Intercept
A	−4.41	−4.41	11.17	−5.69	0	0	−3.1
B	0.28	−0.28	−4.04	2.49	−3.53	−0.4	13.61
C	0.16	0.16	−0.33	0.04	−0.52	1.21	−4.22
D	−0.17	−0.17	−0.86	0.51	0.44	−0.14	8.33

***Source:** compiled by the authors*

Table 4 presents the analytic hierarchy process applied to agricultural production in the district of Cuispes. Group B, corresponding to coffee cultivation, received the highest score of 0.44. This alternative excelled in key productive factors such as Land, Capital, and Technology, suggesting that coffee cultivation is not only viable but also has considerable potential for optimisation. These findings imply that increased investment in Technology and land management could lead to substantial productivity gains. In second place, Group D, which refers to banana production, achieved a score of 0.25. This alternative performed particularly well in the areas of Knowledge and Technology, highlighting the importance of training programmes and technology transfer in improving efficiency and outputs for these crops. However, its relatively modest performance overall signals the need to enhance management and marketing strategies to maximise production outcomes. By contrast, Groups C and A, corresponding to cucumber and plantain, recorded lower scores of 0.10 and 0.25, respectively. Although these crops contribute to the local economy, the findings suggest that their management strategies require reassessment. Identifying areas for improvement and adopting more sustainable and efficient agricultural practices will be essential for enabling these crops to compete more effectively in the market.

From the OLS approach, it can be observed that Group B not only ranks highest in the hierarchical analysis but also explains agricultural activity in the district more effectively. In this model, the interaction between Technology and Land emerges as a critical determinant factor for the success of agricultural production success. This correlation suggests that enhancing access to advanced technologies and implementing efficient land management practices could serve as effective strategies to increase agricultural output. Group D, which represents banana production, is identified as the second most significant agricultural activity and also demonstrates strong performance in the use of technology. In contrast, Groups A and C exhibit a negative influence on agricultural activities, implying that their current methods may be inefficient and require comprehensive revision. The analysis of combining the AHP and OLS models indicates that both approaches offer complementary insights into agricultural productivity in Cuispes. The integration of qualitative and quantitative analyses provides a more comprehensive understanding, underscoring the necessity of implementing strategies to enhance resource management, foster technological innovation, and prioritise capacity-building for farmers to optimise agricultural production in the region. Both models underscore the importance of effective resource management, highlighting Group B as the leading alternative for productivity gains, followed by Group D. This finding implies that while AHP prioritises strategic alternatives, OLS provides contextual explanations for the suboptimal utilisation of certain production factors. Therefore, the combination of both models offers a holistic framework for improving agricultural productivity by addressing both the prioritisation of interventions and the optimisation of specific factors in agricultural activities.

Productive factors such as Land, Labour, Capital, Technology, and Knowledge are fundamental to the development of agricultural activity, as they influence both the efficiency and sustainability of farming systems (Pérez-Fernández *et al.,* 2018). In this context, the organisation of farmers is essential for enhancing responsiveness, transparency, and efficiency, thereby optimising agricultural productivity (Ataei *et al.,* 2024). Furthermore, the diversification of agricultural systems and the integration of value-added activities make it can improve productivity through more efficient use of available resources (Cáceres & Gras, 2020). The results obtained confirm the importance of Capital, Management, and Technology in enhancing agricultural productivity in the Cuispes district. This finding is consistent with the results of X. Zhang *et al.* (2023), who highlighted that the adoption of modern technologies and effective resource management optimises land and water use efficiency. Similarly, M. Dimitrijević (2023) demonstrated that investment in agricultural infrastructure and access to credit are key determinants of increased productivity.

However, in contrast to the findings of S. Liu *et al.* (2023), in the present study, factors such as Land and Knowledge did not show a significant influence ($p > 0.05$). This may be explained by barriers to accessing and efficiently utilising these resources, suggesting that the mere availability of Land or Knowledge is not sufficient to improve productivity unless complemented by appropriate training and technical support. In specific crops, the results indicate that for arracacha, cassava, and potato, Capital and Labour are the most influential factors, which aligns with the findings of A. Díaz Díaz and J. Toscano (2022), emphasised that investment in equipment and the efficient use of the Labour force are essential for agricultural profitability. However, in the case of coffee, it was found that Capital has a negative impact, suggesting inefficiencies in its management, contrasting with the results of M. Di Leginio *et al.* (2024), who reported a positive effect of Capital in highvalueadded crops. In crops such as maize, beans, and cucumber, Technology and Labour were identified as the determining factors, in line with M. Tomas-Simin snd D. Janković (2014), who found that the adoption of technology improves productivity on small farms. However, Capital and Knowledge had negative effects, which may be attributed to deficiencies in their application or ineffective Management. On the other hand, in crops such as banana and avocado, Management and Land emerged as key factors, consistent with J. Salinas Vásquez *et al.* (2023), who highlighted the importance of effective planning and access to quality land for agricultural success. The adoption of modern technologies and efficient management practices are presented as a fundamental strategy for increasing agricultural productivity in similar contexts. Additionally, data-driven decision-making, farmer-to-farmer cooperation, and social innovation can transform production processes and contribute to sustainable agricultural development.

CONCLUSIONS

This research provides significant theoretical contributions through the validation of the PLSSEM model, highlighting the key productive factors that influence agricultural productivity. The results show that Capital, Management, and Technology are determinants of farmers' productive performance, aligning with previous studies and supporting the use of linear regression for different groups of agricultural activities. Specifically, Capital and Labour are critical in Group A; Knowledge, Labour, and Technology in Group B; Labour and Technology in Group C; and Land, Management, and Technology in Group D. These findings underscore that the most relevant productive factors vary by farming activity, suggesting the need for further research to identify the most profitable factors in each case. In terms of practical implications, this study highlights the importance of policies that promote equitable access to resources such as Capital and Technology, alongside training strategies in agricultural management. Such policies would enhance the efficiency, competitiveness, and sustainability of the agricultural sector, particularly benefiting farmers in the Cuispes district. However, factors such as Land, Knowledge, and Labour did not show a significant impact on production, which invites a reconsideration of financial support and the development of strategies tailored to the specific needs of each activity.

In terms of limitations, the study is constrained by the limited availability of prior research on productive factors and their impact on agricultural production, hindering a comprehensive comparison. Moving forward, it is recommended that future research broaden its focus to achieve a deeper understanding of these factors, particularly concerning farmers' awareness of their significance. This would support more technologically advanced and sustainable agricultural development, enhancing both yields and the socioeconomic conditions of rural communities.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Аналіз виробничих факторів, що визначають сільськогосподарську продуктивність у Куїспесі

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Анотація. Метою дослідження була оцінка впливу виробничих факторів (капіталу, праці, знань, управління та землі) на сільськогосподарську продуктивність у районі Куїспес. У вибірку увійшли 50 виробників, аналіз яких здійснювався з використанням кількісного підходу та моделей структурного моделювання на основі часткових найменших квадратів (PLS-SEM).Дані були згруповані у чотири виробничі групи та проаналізовані за допомогою статистичного програмного забезпечення R із використанням методів звичайних найменших квадратів (OLS) і ієрархічного процесного аналізу (AHP). Результати засвідчили, що родючість ґрунту була основоположним фактором у виробничому процесі фермерів. PLS-аналіз показав, що фактори управління, технологій та знань мали помірну і слабку позитивну кореляцію з продуктивністю (0,680; 0,632 і 0,341 відповідно), тоді як капітал і праця виявили негативну кореляцію (-0,252 і -0,400). Група B вирізнялася найвищими показниками за факторами земля, капітал і технології (AHP: 0,44), що вказувало на високий виробничий потенціал; результати OLS підтвердили, що поєднання технологій і землі було ключовим для досягнення аграрного успіху. Група D вирізнялася показниками знань і технологій (AHP: 0,25), а OLS визначив її як другу за значущістю діяльність у контексті застосування технологій. Натомість групи A і C продемонстрували низькі оцінки (AHP: 0,10 та 0,25), а результати OLS вказали на негативний вплив, що вимагало покращення виробничих методів і управлінських підходів для підвищення конкурентоспроможності. У підсумку було встановлено, що група B виявилася найбільш продуктивним сектором, за нею йшла група D – обидві становили найбільш репрезентативні та прибуткові види діяльності в районі Куїспес. Таким чином, окремі виробничі фактори потребували подальшого розвитку, а державні та приватні інституції мали б сприяти підвищенню сільськогосподарської продуктивності через відповідні публічні політики

Ключові слова: аналіз PLS; ієрархічний процесний аналіз; метод звичайних найменших квадратів; капітал; управління; технології