INTERDISCIPLINARY SCIENTIFIC ARTICLES

A Collective Volume of English Academic Writing



Compiled and Edited by

Mg. Yury Moisés Rodríguez Chipana

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PRESENTATION

Interdisciplinary Scientific Articles: A Collective Volume of English Academic Writing is a digital academic book that brings together scientific articles developed from different areas of knowledge. This collective volume represents an effort to promote research writing, academic communication, and the dissemination of knowledge through the English language.

The book includes studies related to environmental sciences, engineering, agriculture, economics, public management, health sciences, education, law, technology, and social research. This diversity gives the volume an interdisciplinary character and reflects the importance of connecting different academic fields to analyze real problems from multiple perspectives.

The purpose of this publication is to provide an academic space where authors can present their research, organize their ideas according to scientific structure, and strengthen their ability to communicate knowledge in English. Each article contributes to the development of academic writing, methodological clarity, critical analysis, and responsible scientific dissemination.

As a digital publication, this volume seeks to expand access to academic production and encourage the continuous development of research skills. It also highlights the value of English as a language for international academic exchange and as a means for sharing scientific findings with a wider audience.

The articles presented in this book are the responsibility of their respective authors. Their contributions reflect different research interests, professional experiences, and disciplinary approaches. Together, they demonstrate that interdisciplinary academic production can contribute to the understanding of local, regional, and global challenges.

This collective work is presented as a contribution to academic formation, scientific culture, and the promotion of research-oriented writing in higher education. It is expected that this book will serve as a reference, motivation, and evidence of the authors' commitment to academic improvement and scientific communication.

Mg. Yury Moisés Rodríguez Chipana
Compiler, Editor and Contributing Author
Puno – Peru, 2026

PREFACE

This collective volume, *Interdisciplinary Scientific Articles: A Collective Volume of English Academic Writing*, brings together a diverse set of academic articles developed from different fields of knowledge. The book reflects the effort of authors who have transformed research ideas, professional experiences, academic concerns, and disciplinary problems into written scientific contributions in English.

The main purpose of this book is to promote academic writing in English as a tool for scientific communication, interdisciplinary dialogue, and research dissemination. In a global academic context, the ability to organize ideas, present evidence, discuss findings, and communicate results in English has become an essential competence for postgraduate students, professionals, and researchers.

The articles included in this volume address topics related to engineering, environmental sciences, agriculture, economics, public management, health sciences, education, technology, law, and social studies. This interdisciplinary character gives the book a broad academic value, since it shows how different areas of knowledge can contribute to the understanding of local, regional, and global problems.

As compiler and editor, I have sought to preserve the academic identity of each contribution while organizing the volume under a common editorial structure. Each author is responsible for the content, data, methodology, analysis, conclusions, and references presented in his or her article. The role of this volume is to provide a formal academic space for the dissemination of these works and to encourage the continuous improvement of scientific writing.

This book is also an academic testimony of the importance of strengthening research skills and English academic writing in higher education. It demonstrates that scientific production can be developed progressively when authors are guided toward clarity, structure, evidence-based argumentation, and responsible academic communication.

I express my appreciation to all contributing authors for their effort, commitment, and participation in this collective academic project. Their contributions make this volume possible and reflect the value of interdisciplinary research as a path toward knowledge generation and academic growth.

Mg. Yury Moisés Rodríguez Chipana
Compiler, Editor and Contributing Author
Puno – Peru, 2026

ANNUAL SOIL LOSS ASSESSMENT IN THE ILLPA RIVER BASIN (PERUVIAN ALTIPLANO) USING USLE, REMOTE SENSING, AND GIS

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ABSTRACT

Water erosion drives irreversible soil degradation in high-altitude Andean basins, yet spatially explicit quantitative baselines remain scarce for the circum-Titicaca region. This study determined mean annual soil loss in the Illpa River basin (1,262.27 km², Puno, Peru; mean elevation 4,071 m a.s.l.) by implementing the Universal Soil Loss Equation (USLE). Rainfall erosivity (R) was derived from SENAMHI monthly records (1970–2012) via the Modified Fournier Index; soil erodibility (K) from SoilGrids and FAO textural data; the topographic factor (LS) from the SRTM digital elevation model (30 m); and the cover-management factor (C) from average NDVI of 20 Landsat-8 OLI images (2015–2021, wet and dry seasons) using the Durigon et al. (2014) formula combined with supervised Corine Land Cover classification. Normality was tested with Kolmogorov–Smirnov (n = 384); Wilcoxon signed-rank tests confirmed statistically significant medians for all factors ($p < 0.05$). The R factor averaged 289.02 MJ mm ha^{-1} h^{-1} yr^{-1}; K ranged from 0.19 to 0.23 t ha h ha^{-1} MJ^{-1} mm^{-1}; LS mean was 2.64; and C mean was 0.37. Mean annual actual soil loss was **58.93 t ha^{-1} yr^{-1}**, with 43.84% of the basin exhibiting high-to-critical erosion (>50 t ha^{-1} yr^{-1}), substantially exceeding FAO tolerable thresholds (11.2 t ha^{-1} yr^{-1}). These findings provide a geospatially explicit erosion baseline for prioritizing conservation interventions in Altiplano watersheds draining into Lake Titicaca.

Keywords: soil erosion; USLE; Modified Fournier Index; Landsat-8; NDVI; Altiplano; Lake Titicaca watershed; Kolmogorov–Smirnov; Wilcoxon

INTRODUCTION

Soil erosion by water constitutes one of the most pressing environmental problems affecting agricultural and mountainous landscapes worldwide, threatening food security, land productivity, and the sustainability of natural resources (Montgomery, 2007; Pimentel, 2006). Beyond its direct effect on soil fertility, accelerated erosion disrupts biogeochemical cycles, degrades water quality, and

contributes to sediment accumulation in downstream water bodies (Quinton et al., 2010). Recent global assessments indicate that land use change has intensified soil loss rates during the twenty-first century, with mountainous and semi-arid regions being particularly vulnerable due to steep slopes and fragile vegetation cover (Borrelli et al., 2018).

Water erosion is a complex process governed by the interaction of climatic, topographic, edaphic, and land-cover factors, and its study has evolved from purely descriptive approaches toward predictive, quantitative modeling (Boardman, 2006; Evans, 2010). Meta-analyses conducted across diverse geographic contexts confirm substantial variability in erosion rates depending on relief, precipitation regime, and land management practices, underscoring the need for site-specific estimation rather than generalized assumptions (García-Ruiz et al., 2013, 2015).

Among the available predictive tools, the Universal Soil Loss Equation (USLE), later revised as RUSLE, remains the most widely applied empirical model for estimating average annual soil loss (Renard et al., 1997; Wischmeier & Smith, 1978). Its enduring use is explained by its relatively low data requirements and its capacity to integrate rainfall erosivity, soil erodibility, topography, and cover-management conditions into a single quantitative estimate (Kinnell, 2010). Comparative reviews of erosion models have shown that, despite the emergence of process-based alternatives such as the Water Erosion Prediction Project (Flanagan & Nearing, 1995), USLE/RUSLE continues to offer the best balance between accuracy and applicability, particularly in data-scarce regions (Benavidez et al., 2018; Karydas et al., 2014). Nevertheless, several authors caution that its predictive reliability depends strongly on the quality of input data and on adapting its factors to local environmental conditions, which remains a persistent methodological challenge (Alewell et al., 2019).

The integration of Geographic Information Systems (GIS) and remote sensing has substantially strengthened the operational capacity of USLE, allowing the spatial estimation of its factors over large and heterogeneous territories (Mitasova et al., 1996). Satellite-derived land cover information enables the estimation of the vegetation cover factor (C) with high spatial resolution (Chuvieco, 2016), while global soil databases such as SoilGrids provide standardized inputs for the soil erodibility factor (K) in areas lacking detailed field surveys (Hengl et al., 2017). Similarly, digital elevation models support the calculation of the topographic factor (LS), and satellite-corrected precipitation products improve the estimation of rainfall erosivity (R) in regions with sparse meteorological networks (Panagos et al., 2015). Applications of this GIS-based USLE approach in mountainous watersheds, such as the Dembecha watershed in Ethiopia, have demonstrated its usefulness for identifying critical erosion-prone areas and informing soil conservation planning (Ostovari et al., 2017).

In the Andean context, the accurate estimation of erosion factors faces additional challenges related to the region's complex topography and climatic heterogeneity. Precipitation records from ground stations are often scarce or discontinuous across the Peruvian highlands, which has motivated the correction and validation of satellite precipitation products, such as TRMM data, for hydrological applications in mountainous basins (Condom et al., 2012). Basin-scale analyses of rainfall and runoff further confirm marked spatial variability in the hydrological regime of Peruvian watersheds draining toward the Pacific and Titicaca basins (Lavado et al., 2012). These climatic and hydrological particularities directly affect erosive processes on Andean hillslopes, where steep terrain and seasonal rainfall concentration accelerate soil degradation (Castillo & Amésquita, 2003).

Empirical studies conducted in Peruvian watersheds provide direct precedents for the present research. Investigations applying USLE/RUSLE with GIS support have estimated water erosion in basins such as Huatatas in Ayacucho (Atauje Camasca, 2018), Huarmey (Caycho Torres, 2020), Ichu in Huancavelica (Escobar-Soldevilla, 2019), and Callazas in Tacna (Laqui Calizaya, 2019), consistently identifying critical erosion zones associated with steep slopes and reduced vegetation cover. Comparable methodological approaches have also been applied in other Latin American contexts, such as the Copa reservoir basin in Colombia (Guío Martínez, 2019) and the Acoculco basin in Mexico, where multitemporal land cover analysis was linked to changes in erosion rates over time (Zaragoza Pulido, 2021). Collectively, these studies confirm the applicability and relevance of GIS-based USLE modeling in Andean and Latin American mountain basins, while also revealing that most available evidence remains fragmented across isolated watersheds, with limited coverage of basins in the Puno region.

Despite the recognized vulnerability of high-Andean basins to water erosion and the documented methodological precedents within Peru, no prior study has systematically quantified annual average soil loss in the Illpa River Basin using an integrated USLE, remote sensing, and GIS approach. This gap is particularly relevant given the basin's role in supplying water resources to the city of Puno and surrounding agropastoral areas, where soil degradation may compromise both water quality and land productivity. Therefore, this study aims to determine the annual average water erosion in the Illpa River Basin, Puno, Peru, through the application of the Universal Soil Loss Equation, remote sensing, and Geographic Information Systems, estimating its rainfall erosivity (R), soil erodibility (K), topographic (LS), and vegetation cover (C) factors to identify the spatial distribution of erosion risk across the basin.

METHODOLOGY

This study adopted a quantitative, descriptive, and non-experimental research design aimed at determining the annual average water erosion in the Illpa River Basin, Puno, Peru, through the application of the Universal Soil Loss Equation (USLE), remote sensing, and Geographic Information Systems (GIS). The population consisted of all raster cells representing the Illpa River Basin, covering an area of 1,262.27 km² and comprising 1,402,522 spatial units represented by 30 m × 30 m pixels. A sample of 384 observation points was selected using simple random probabilistic sampling for statistical analysis and hypothesis testing.

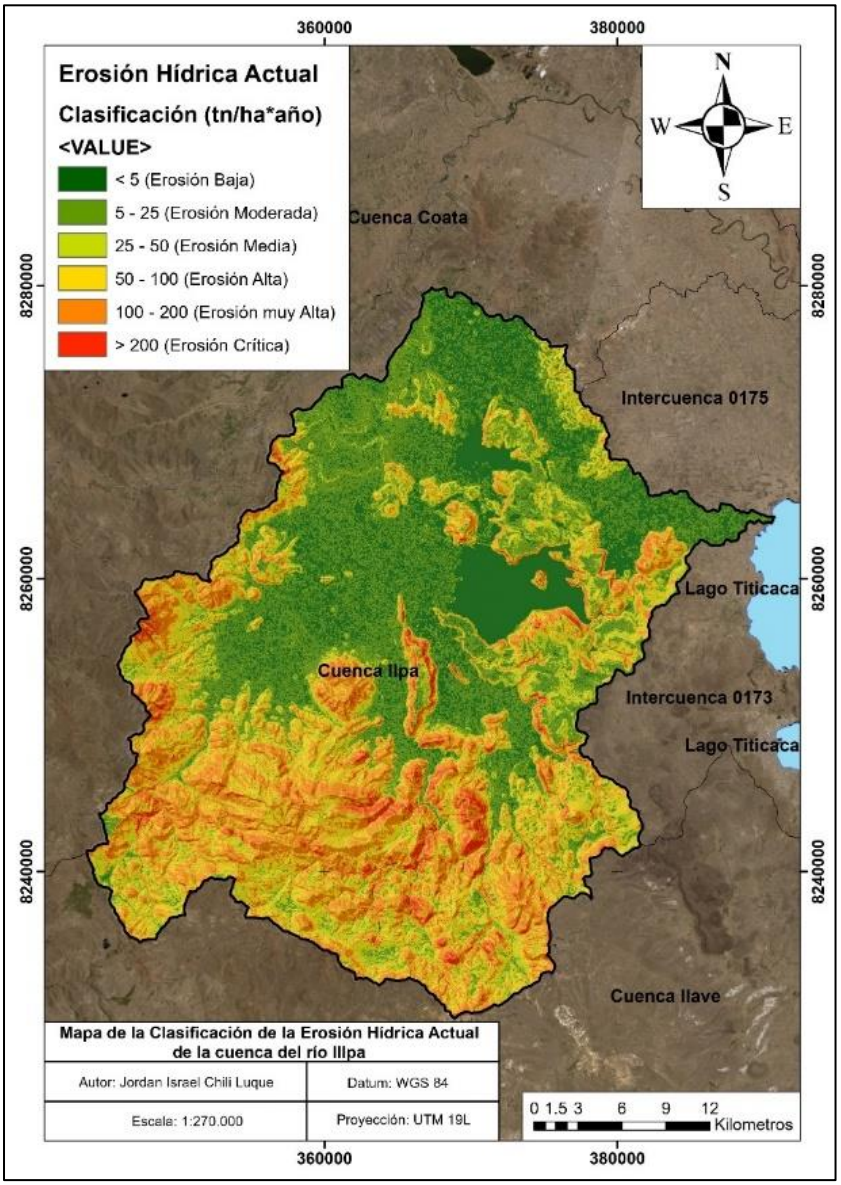
For data collection, first, precipitation records from meteorological stations were collected to estimate the rainfall erosivity factor (R). Second, SRTM digital elevation models were obtained to calculate the topographic factor (LS). Third, soil information from the FAO and SoilGrids databases was collected to determine the soil erodibility factor (K). Finally, Landsat 8 satellite imagery was acquired and processed to estimate the vegetation cover factor (C). All datasets were integrated within a Geographic Information System (GIS) environment and used as inputs for the Universal Soil Loss Equation (USLE) model.

The collected data were organized and processed using QGIS, RStudio, and spreadsheet software. Subsequently, descriptive statistics, including mean, median, mode, standard deviation, skewness, and kurtosis, were calculated for the sampled observations. Box-and-whisker plots, histograms, density plots, bar charts, and pie charts were generated to summarize the data, while geostatistical techniques were applied to characterize the spatial distribution of the USLE factors. The normality of the samples was evaluated using the Kolmogorov–Smirnov test, and the research hypotheses were tested using the Wilcoxon one-sample test. Finally, the estimated soil loss values were classified according to the FAO erosion severity classes to determine the annual average water erosion in the Illpa River Basin.

RESULTS

The estimated annual water erosion in the Illpa River Basin ranged from 0 to 11,536.30 $t \cdot ha^{-1} \cdot year^{-1}$, with a mean soil loss of 58.93 $t \cdot ha^{-1} \cdot year^{-1}$. According to the FAO classification, 17.94% of the basin presented low erosion, 27.33% moderate erosion, 10.89% medium erosion, 20.28% high erosion, 20.93% very high erosion, and 2.63% critical erosion (Figure 1 and Table 1).

Figure 1. *Classification of current water erosion in the Illpa River basin*



Note. The figure shows the classification of current water erosion in the Illpa basin.

Table 1. *Classification of the current degree of water erosion*

Degree of erosion	Soil Loss (tn/ha*year)	Area (km²)	Area (%)
Low erosion	< 5	226.43	17.94
Moderate erosion	5 – 25	344.96	27.33
Medium erosion	25 – 50	137.46	10.89
High erosion	50 – 100	255.96	20.28
Very high erosion	100 – 200	264.2	20.93

Critical erosion	> 200	33.26	2.63
TOTAL		**1,262.27**	**100.00**

Note. The table shows the classification of water erosion in the Illpa basin according to the FAO.

The rainfall erosivity factor (R) ranged from 210.30 to 324.85 MJ·mm·ha^{-1}·h^{-1}·year^{-1}, with a mean value of 289.02 MJ·mm·ha^{-1}·h^{-1}·year^{-1}. The Modified Fournier Index ranged from 86.88 to 114.35, and 99.33% of the watershed was classified within the moderate erosivity class (Table 2).

Table 2. *Surface area distribution according to IMF ranges*

Range	IMF (dimensionless)	IMF value (min - max)	Area (km²)	Area (%)
Low	60 – 90	86.88 – 90	8.46	0.67
Moderate	90 – 120	90 – 114.35	1,253.81	99.33
TOTAL			**1,262.27**	**100**

Note: The table shows the surface area distribution according to the IMF ranges.

The topographic factor (LS) ranged from 0.03 to 524.55, with a mean value of 2.64. Approximately 49.15% of the watershed presented very low LS values, whereas 7.94% corresponded to the very high class (Table 3).

Table 3. *Surface area distribution according to the LS factor ranges*

Range	LS (dimensionless)	LS factor value (Min – Max)	Area (km²)	Area (%)
Very Low	< 1.5	0.03 – 1.5	620.43	49.15
Low	1.5 – 3	1.5 – 3	172.12	13.64
Moderate	3 – 5	3 – 5	220.23	17.45
High	5 – 7	5 – 7	149.22	11.82
Very High	> 7	7 – 524.55	100.27	7.94
TOTAL			**1,262.27**	**100.00**

Note. The figure shows the surface distribution according to the LS factor ranges.

The soil erodibility factor (K) ranged from 0.00 to 0.23 $t \cdot ha \cdot h \cdot ha^{-1} \cdot MJ^{-1} \cdot mm^{-1}$. The dominant K values were 0.19 and 0.23, representing 56.83% and 41.23% of the watershed, respectively. Lake Umayo represented the remaining 1.94% with a K value of zero (Table 4).

Table 4. *Surface area distribution according to the ranges of the K factor*

Range	K (tn*ha*h/ha*MJ*mm)	K factor value	Area (km²)	Area (%)
Low	0.05 – 0.2	0.19	717.41	56.83
Moderate	0.2 – 0.4	0.23	520.41	41.23
Umayo Lake	0	0	24.45	1.94
	TOTAL		**1,262.27**	**100.00**

Note. The table shows the surface area distribution according to the ranges of the K factor.

The vegetation cover factor (C) ranged from 0.00 to 0.50. The estimated C values varied according to the land-cover classes derived from the multi-year NDVI and are summarized in Table 5.

Table 5. *Values of the C factor*

Calculation of the values of the C factor (Dimensionless)				
N°	Classification by the Corine Land Cover methodology for Peru	Mínimum	Máximum	Average
1	Continuous urban fabric	0.38	0.50	0.44
2	Temporary crops	0.16	0.35	0.25
3	Dense grassland (crespillo)	0.35	0.38	0.36
4	Dense grassland (ichu)	0.38	0.40	0.39
5	Dense grassland (chiji)	0.16	0.50	0.33
6	Dense grassland (chilligua)	0.16	0.38	0.27
7	Bare lands (naturally eroded and degraded areas)	0.40	0.50	0.45
8	Permanent natural wetlands, lagoons, lakes	0.00	0.00	0.00

Note. The table shows the values of the C factor (derived from the NDVI).

DISCUSSION

The estimated annual average soil loss of 58.93 $t \cdot ha^{-1} \cdot year^{-1}$ indicates that the Illpa River Basin is affected by a high level of water erosion according to the FAO classification. The results demonstrate that the combined influence of rainfall erosivity, topography, soil erodibility, and vegetation cover controls the spatial distribution of erosion across the watershed.

The estimated soil loss was higher than the average value of 22.40 $t \cdot ha^{-1} \cdot year^{-1}$ reported by Escobar-Valdebenito (2019) for a semi-arid watershed in Chile. Furthermore, the spatial distribution of erosion observed in this study agrees with previous investigations conducted by Portuguez (2015), Solano (2016), Castillo and Rojas (2019), Taco (2021), and Bautista (2023), who also applied the USLE model integrated with Geographic Information Systems and remote sensing under different climatic, topographic, and land-cover conditions. Despite differences in watershed characteristics and environmental settings, these studies consistently identified terrain slope and vegetation cover as the principal factors controlling the spatial variability of water erosion.

These findings support the application of the USLE model integrated with Geographic Information Systems and remote sensing as a reliable approach for estimating water erosion and identifying priority areas for soil conservation. The resulting erosion maps provide a scientific basis for watershed management, land-use planning, and the implementation of sustainable soil conservation strategies. However, the estimated erosion rates depend on the spatial resolution of satellite imagery and digital elevation models, as well as the quality and temporal availability of rainfall and soil databases, which may influence the accuracy of the final erosion estimates.

CONCLUSIONS

The application of the USLE method in the Illpa river basin estimated an average soil loss of 58.93 t/ha·yr, with maximum values reaching 11,536.3 t/ha·yr. The GIS and remote sensing analysis revealed high spatial heterogeneity and critical erosion zones. It is recommended to prioritize reforestation in areas with NDVI < 0.3, implement conservation practices on slopes with LS > 10, and strengthen land use monitoring. The results provide key inputs for territorial management and can be replicated in other high-Andean basins.

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Sciences, and the National University of the Altiplano for their academic support. We also thank SENAMHI for providing access to the climatic database.

CONFLICT OF INTEREST

The author Jordan Israel Chili Luque (JICL) declares that there is no conflict of interest in the development of this research.

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Agroecological Zoning for Agroforestry Systems in the Illpa Experimental Center, Puno, Peru

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ABSTRACT

Agroecological zoning is a key tool for guiding sustainable land use and the implementation of agroforestry systems in high-Andean environments. This study aimed to delineate and classify land suitable for agroforestry systems at the Illpa Experimental Center of the National University of the Altiplano, Puno, Peru. The Analytic Hierarchy Process (AHP) was applied to weight and integrate climatic, edaphic, and topographic criteria. Precipitation and temperature trends for the 1981–2024 period and land-capability classes were also evaluated. The results showed a slight upward trend in annual precipitation (+1.04 mm/year), although it was not statistically significant ($p > 0.05$), and an increase in mean temperature of approximately 0.3 °C per decade, with an annual average of 9.2 °C. Agroecological zoning classified 352.67 ha (87.3%) as moderately suitable (S2) and 51.06 ha (12.7%) as marginally suitable (S3). Agrosilvicultural and silvopastoral systems, supported by live fences, windbreaks, and frost-protection barriers, were proposed for S2 areas, whereas erosion-control and soil-protection practices were recommended for S3 areas. The study concludes that the Illpa Experimental Center is predominantly moderately suitable for agroforestry systems and that the resulting zoning provides a technical basis for differentiated land management, soil conservation, and sustainable territorial planning.

Keywords: agroecological zoning; agroforestry systems; Analytic Hierarchy Process; high Andean environments; land suitability.

INTRODUCTION

Global population growth and the expanding demand for food have intensified pressure on agricultural systems and natural resources. To meet the needs projected for 2050, global agricultural production will need to increase by approximately 60%. However, this challenge coincides with land degradation, declining water resources, biodiversity loss, and the deterioration of ecosystem services associated with unsustainable management practices. Climate change and the increasing occurrence of extreme weather events further threaten food security, agricultural sustainability, and the capacity of rural landscapes to maintain their productive and ecological functions (FAO, 2023).

Within this context, land-use planning requires approaches capable of integrating environmental conditions with production needs. Agroecology combines ecological and social principles for the sustainable design and management of agricultural and food systems (FAO, 2018), whereas agroecological zoning identifies territorial units with similar combinations of climate and soil characteristics and, consequently, comparable biophysical potential for agricultural production (FAO, 1997). This approach is particularly relevant in fragile environments, where productive capacity depends on interactions among climate, soil properties, and terrain. Soil not only provides the physical foundation for production but also sustains multiple ecosystem functions and contributes to food security; therefore, land uses should be matched to land capability and site-specific limitations (Mita & Hervé, 2021).

Agroforestry systems provide an alternative for reconciling production and conservation because they deliberately integrate perennial woody species with agricultural crops and, in some arrangements, livestock within the same land unit (Altieri, 1999; Montagnini et al., 2015). Interactions among these components may diversify production, promote soil conservation, improve water regulation, contribute to carbon sequestration, and support biodiversity protection (Ali et al., 2024; Santoro et al., 2020). Their structural diversity may also strengthen resilience to climatic and economic variability, provided that species, practices, and spatial arrangements are selected according to local environmental conditions (Zhang et al., 2023). Prior assessment of land suitability is therefore essential to avoid interventions that are incompatible with climatic, edaphic, or topographic constraints.

Previous agroecological zoning studies have demonstrated the value of combining climatic, edaphic, physiographic, and spatial information to delineate areas with different suitability levels. In Mexico, Gómez et al. (2022) assessed the potential distribution of oil palm using edaphoclimatic criteria, whereas Carrión et al. (2022) integrated agroclimatic requirements, land use, and georeferenced data to determine the territorial potential of Moringa oleifera. In Ecuador, Aviles et al. (2022) incorporated climate-variability scenarios to estimate future changes in maize suitability. In Peru, Gutierrez (2020) analyzed physiographic, climatic, and edaphic conditions to zone peach cultivation, while Fernandez and Huamani (2022) used geographic information systems to establish adaptation levels for barley, maize, wheat, and potato. Collectively, these studies indicate that geographic information systems and multicriteria evaluation facilitate the integration of thematic layers, the quantification of environmental factors, and the generation of suitability models for territorial decision-making (Acosta et al., 2011; Gómez & Barredo, 2005).

Agriculture remains socially and economically important in Peru, particularly in rural areas. Nevertheless, inadequate natural-resource use and insufficient land-use planning contribute to desertification, deforestation, salinization, agricultural land loss, and ecosystem degradation (Instituto Nacional de Estadística e Informática [INEI], 2017; Ministerio de Desarrollo Agrario y Riego [MIDAGRI], 2015). These challenges are especially relevant in Puno, where the regional economy is closely linked to agriculture, livestock production, and natural-resource use. High-Andean conditions, including frost, hail, drought, intense rainfall, and pronounced soil heterogeneity, increase the vulnerability of production systems and require spatially differentiated management strategies.

The Illpa Experimental Center of the National University of the Altiplano comprises approximately 403 ha allocated to agricultural, livestock, academic, research, and community outreach activities. Previous studies have examined individual components of this territory: Mamani (2004) evaluated the agrological quality of its soils; Flores (2017) analyzed grasslands and carbon capture associated with Festuca dolichophylla; and Goyzueta (2019) developed edaphoclimatic zoning for quinoa in watersheds within the Puno region. However, the available evidence remains fragmented and focuses on individual crops, soil assessments, or isolated environmental components. Consequently, a contextual and practical research gap persists regarding an integrated zoning framework for the Illpa Experimental Center that combines climate variability, land capability, topographic conditions, and management alternatives specifically designed for agroforestry systems.

To address this gap, the present study aimed to delineate and classify agroecological land units suitable for agroforestry systems at the Illpa Experimental Center, Puno, Peru. Specifically, it characterized the influence of climate variability, determined land capability, and designed agroforestry management alternatives according to the identified suitability categories. Climatic, edaphic, and topographic information was integrated through geographic information systems and the Analytic Hierarchy Process (AHP) to generate a spatial and technical basis for assigning land uses compatible with territorial conditions. The study thereby contributes evidence for sustainable land-use planning, soil conservation, production-risk reduction, and the design of agroforestry systems adapted to high-Andean environments.

MATERIALS AND METHODS

Study area

The study was conducted at the Illpa Experimental Center of the National University of the Altiplano, located in the district of Paucarcolla, Puno Province and Region, Peru. The center is situated at kilometer 19 of the Puno–Juliaca highway, at approximately 3,827 m above sea level and at UTM

coordinates 384760.8 E and 8262701.6 N, referenced to WGS 84, Zone 19S. The evaluated area covered 403.50 ha and exhibited climatic, edaphic, and topographic conditions representative of the southern Peruvian Altiplano.

Research design

A quantitative, non-experimental, descriptive-exploratory research design was adopted. The climatic component followed a retrospective longitudinal approach because historical meteorological series from 1981 to 2024 were analyzed. The soil and territorial components followed a cross-sectional spatial approach because soil properties, physiography, terrain, and agroecological suitability were evaluated throughout the Illpa Experimental Center. Climate statistics, laboratory analyses, geographic information systems, and spatial multicriteria evaluation were integrated to delineate land with different levels of suitability for agroforestry systems.

Study units and sampling

The spatial study universe consisted of the entire 403.50-ha area of the Illpa Experimental Center. A physiographic map was produced, and eight territorial units were identified. Sampling points were distributed using a spatially stratified procedure based on physiographic units, followed by random point selection in QGIS 3.40.7. Ten sampling points, separated by a minimum distance of 100 m, were established to represent terrain heterogeneity.

The climatic component included records from 11 meteorological stations located in Santa Rosa, Capachica, Illpa, Lampa, Santa Lucía, Cabanillas, Puno, Uros, Juliaca, Laraqueri, and Lagunillas. The time series covered the 1981–2024 period and included minimum, maximum, and mean temperature, precipitation, solar radiation, relative humidity, wind speed, and evapotranspiration. Missing or complementary records were obtained from WorldClim.

Official crop-yield records for the 1996–2022 period were also obtained from the Regional Directorate for Agricultural Development of Puno. The analyzed crops included alfalfa, forage oats, forage barley, quinoa, cañihua, grain barley, potato, oca, olluco, and mashua.

Materials, instruments, and data sources

Field data were collected using a GPS receiver, soil auger, penetrometer, Munsell soil color chart, measuring tape, soil-profile description forms, and materials for extracting, labeling, and preserving soil samples. Laboratory equipment included an analytical balance, pH meter, conductivity meter, volumetric materials, and chemical reagents required for physical and chemical soil characterization.

Secondary data sources included meteorological records from the National Service of Meteorology and Hydrology of Peru, WorldClim bioclimatic layers, reference evapotranspiration data from CGIAR-CSI, and agricultural production records from the Regional Directorate for Agricultural Development of Puno. Data were initially organized in Microsoft Excel and subsequently processed in R. Cartographic and spatial analyses were conducted using QGIS 3.40.7 and Google Earth Pro.

Data collection and processing procedure

Climate characterization

First, historical records were requested and compiled from the selected meteorological stations. The time series were then organized, cleaned, and verified in spreadsheets before being structured in R. Data were arranged at monthly, annual, interannual, and decadal scales.

Continuous climatic surfaces were generated using ordinary kriging based on the spatial dependence of observations from the meteorological stations. This procedure was used to interpolate climatic variables and produce raster layers covering the Illpa Experimental Center.

The Holdridge life-zone system was applied using the BIO1 annual mean temperature and BIO12 annual precipitation layers obtained from WorldClim at a spatial resolution of 30 arc-seconds. Annual reference evapotranspiration data were obtained from CGIAR-CSI. The layers were processed using QGIS 3.40.7 and Google Earth Pro.

Soil characterization and land-capability classification

Second, the ten sampling locations were verified and georeferenced in the field. A soil pit was opened at each point until the C horizon was reached. UTM coordinates, altitude, landscape, terrain, and vegetation cover were recorded before excavation. Soil horizons were then described, and an approximately 1-kg sample was collected from each identified horizon, labeled, and prepared for transportation.

The samples were analyzed at the Soil Laboratory of the National Institute for Agricultural Innovation in Salcedo, Puno. Field and laboratory data were integrated to determine the land-capability group, class, and subclass following Peruvian Supreme Decree No. 005-2022-MIDAGRI. The classification considered life zone, slope, microrelief, effective soil depth, texture, drainage, soil reaction, and other edaphic, topographic, and climatic limitations.

Multicriteria evaluation and agroecological zoning

Third, the variables were organized into three main criteria. The climatic criterion included annual mean temperature, annual precipitation, relative humidity, solar radiation, and wind speed. The soil criterion included pH, organic matter, texture, and major land-use capability. The topographic criterion comprised slope and altitude.

Each variable was transformed into a common suitability scale, in which higher values represented more favorable conditions for agroforestry systems. Relative weights were derived using the Analytic Hierarchy Process through pairwise comparisons based on Saaty's 1–9 preference scale (Saaty, 1987).

The Agroecological Suitability Index was calculated using weighted linear combination:

$$IAA = \sum_{i=1}^{n} (w_i \times x_i)$$

where xi represented the normalized value of each criterion, wi was the weight derived through AHP, and n represented the total number of variables. Raster layers were overlaid in a GIS environment to produce a continuous suitability surface.

The final index was expressed on a 0–1 scale and classified using the Jenks natural-breaks method. The resulting classes were interpreted according to FAO land-suitability categories: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1), and permanently not suitable (N2).

Agroforestry management alternatives were subsequently formulated by comparing the characteristics of each suitability class with the agroecological requirements of forest, crop, and forage species. Temperature, precipitation, altitude, slope, soil texture, effective depth, pH, organic matter, and the productive or conservation function of each species were considered.

Data analysis

Climate series were analyzed using descriptive statistics, including the mean, median, minimum and maximum values, standard deviation, and coefficient of variation. Interannual variability was assessed through anomalies from the long-term mean, whereas decadal variability was evaluated by grouping records into ten-year periods.

Long-term trends were examined using the non-parametric Mann–Kendall test at a significance level of 0.05. Trend magnitude was estimated using Sen's slope estimator, and abrupt changes in the time series were identified using Pettitt's test (Mann, 1945; Kendall, 1975; Sen, 1968; Pettitt, 1979). Statistical analyses were performed in R, whereas interpolation, normalization, weighting, and spatial overlay procedures were conducted in QGIS 3.40.7.

RESULTS

Climatic trends at the Illpa Experimental Center

The climatic trend analysis showed differentiated changes among the variables evaluated during the 1981–2024 period. Significant upward trends were detected for mean, maximum, and minimum temperatures and for wind speed. In contrast, precipitation, solar radiation, relative humidity, and reference evapotranspiration did not show statistically significant long-term trends.

Table 1

Climate trends at the Illpa Experimental Center (CE) from 1981 to 2024

Variables	Mean	Sen's Slope	Z (Sen)	p-value (Sen)	Tau (MK)	p-value (MK)	p-value (Pettitt)	Change Year (Pettitt)
Precipitation (mm)	653	+1.0391	0.50	0.6202	0.053	0.6202	0.5086	2011
Mean Temperature (°C)	9.34	+0.0225	3.79	0.0001*	0.397	0.0001*	0.0008*	2003
Maximum Temperature (°C)	18.99	+0.0255	2.74	0.0061*	0.288	0.0061*	0.0404*	2004
Minimum Temperature (°C)	-3.02	+0.0142	2.58	0.0099*	0.271	0.0099*	0.0575	2001
Wind Speed (m/s)	2.32	+0.0025	2.05	0.0400*	0.215	0.0410*	0.0879	2003

Relative Humidity (%)	17.29	+0.0059	0.49	0.6246	0.055	0.6246	0.2847	2017
Relative Humidity (%)	62.28	-0.0054	-0.09	0.9275	-0.011	0.9275	0.4425	1988
ETo (mm)	2.67	+0.0019	0.48	0.6329	0.054	0.6329	0.6093	2003

Note: (*) indicate statistical significance ($p<0.05$) based on the Sen, Mann-Kendall, and Pettitt tests; (+) increasing Sen's slope, (-) decreasing Sen's slope.

Mean temperature increased at a rate of 0.0225 °C year^{-1}, corresponding to an accumulated increase of approximately 0.99 °C over the 44-year study period. The Pettitt test identified a significant change in mean temperature in 2003. Maximum temperature showed the largest thermal increase, at 0.0255 °C year^{-1}, with a significant change point in 2004. Minimum temperature also increased significantly according to the Sen and Mann–Kendall tests; however, its Pettitt change point did not reach statistical significance because its *p*-value was 0.0575.

Wind speed increased by 0.0025 m s^{-1} year^{-1} and was significant according to the Sen and Mann–Kendall tests. Nevertheless, the change identified for 2003 was not significant according to the Pettitt test. Annual precipitation increased by 1.0391 mm year^{-1}, but this trend was not significant. Solar radiation, relative humidity, and reference evapotranspiration also remained statistically stable during the study period.

Land-capability classification

The land-capability assessment identified two major land-use groups within the Illpa Experimental Center: land suitable for forestry and protection land. Forest land represented 80.91% of the evaluated territory and was divided into the F2ws and F3e subclasses.

Table 2

Major land-use capability classes at the Illpa Experimental Center

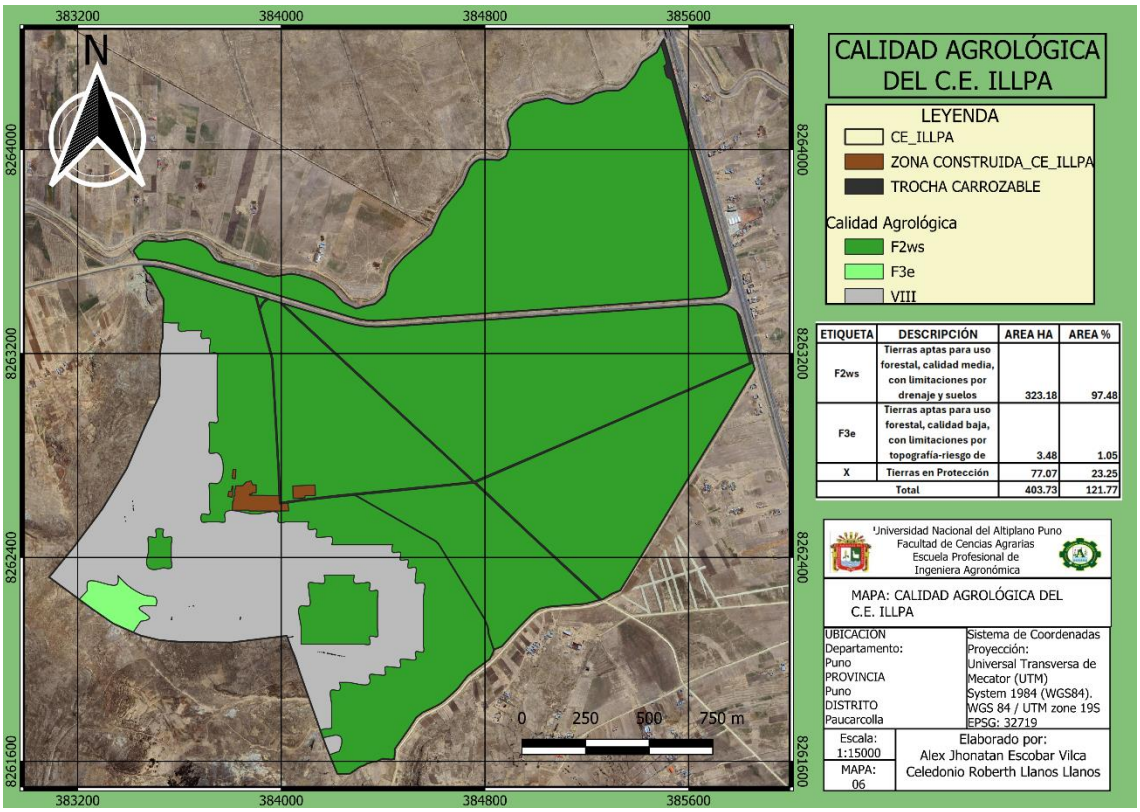
Major land-use group	CLASS	SUB-CLASS CUM	Description	Area (ha)	Area (%)
F	F2	F2ws	Land suitable for forestry, with medium agrological quality and limitations related to drainage and soil conditions	323.181	80.05
	F3	F3e	Land suitable for forestry, with low agrological quality and limitations related to topography and erosion risk	3.477	0.86
X			Protection land with limitations related to relief, erosion, and locally shallow soil depth	77.071	19.09
Total				403.729	100

The F2ws subclass was the dominant land-capability unit, covering 323.181 ha. This subclass was concentrated mainly on relatively level areas and was characterized by medium agrological quality, imperfect drainage, fine-to-medium soil textures, and generally low natural fertility. The F3e subclass covered only 3.477 ha and corresponded to localized areas with lower agrological quality and greater topographic and erosion limitations.

Protection land covered 77.071 ha. These units were associated with steeper terrain, severe-to-extreme erosion and, in some locations, shallow effective soil depth and rocky fragments. Spatially, protection land was concentrated mainly in the southwestern and south-central portions of the study área.

Figure 1

Spatial distribution of major land-use capability classes at the Illpa Experimental Center



ETIQUETA	DESCRIPCIÓN	AREA HA	AREA %
F2ws	Tierras aptas para uso forestal, calidad media, con limitaciones por drenaje y suelos	323.18	97.48
F3e	Tierras aptas para uso forestal, calidad baja, con limitaciones por topografía-riesgo de	3.48	1.05
X	Tierras en Protección	77.07	23.25
	Total	403.73	121.77

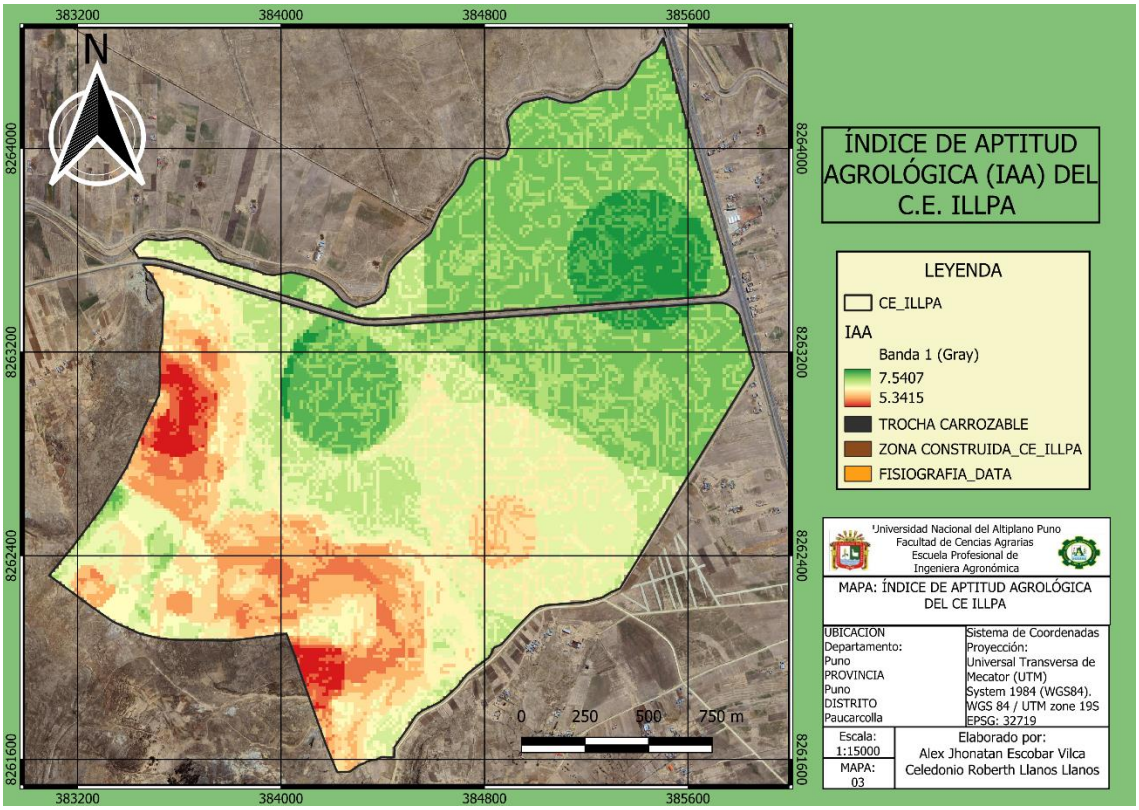
Figure 1 shows the spatial predominance of the F2ws subclass across the central, northern, and eastern sectors of the experimental center. The protection category was concentrated primarily in the southwestern sector, whereas the F3e subclass appeared in a small and spatially restricted area. The map therefore shows that the agrological limitations were not uniformly distributed but were concentrated in specific sectors of the territory.

Agroecological Suitability Index

The integration of climatic, edaphic, and topographic criteria generated a continuous Agroecological Suitability Index. The index ranged from 5.3415 to 7.5407 across the study area.

Figure 2

Spatial distribution of the Agroecological Suitability Index at the Illpa Experimental Center



Note: Elaboration based on the integration of climatic, edaphic, and topographic criteria.

The highest suitability values, reaching approximately 7.54, were located mainly in the northeastern sector and in some central portions of the study area. Lower index values, close to 5.34, were concentrated in the western, southwestern, and southern sectors. Intermediate values occupied most of the central territory.

The spatial pattern differentiated sectors with comparatively more favorable combinations of climatic, soil, and terrain conditions from sectors presenting greater restrictions. The continuous index was subsequently reclassified into the agroecological suitability categories presented in Table 3.

Agroecological zoning for agroforestry systems

The reclassification of the Agroecological Suitability Index identified two suitability classes: moderately suitable and marginally suitable. No highly suitable, currently unsuitable, or permanently unsuitable classes were identified within the evaluated area.

Table 3

Agroecological suitability classification for agroforestry systems at the Illpa Experimental Center

FAO Class	AAI Category	Interpretation	Area (ha)	Area (%)
S2-Moderately suitable	High	Suitable with few limitations; sustainable management required.	352.667	87.3
S3-Marginally suitable	Medium	Suitable under restrictive conditions or with conservationist management.	51.057	12.7
Total			**403.72**	**100**

The S2 category occupied 352.667 ha and represented 87.3% of the study area. It was therefore the predominant agroecological suitability category. The S3 category covered 51.057 ha, equivalent to 12.7% of the evaluated territory.

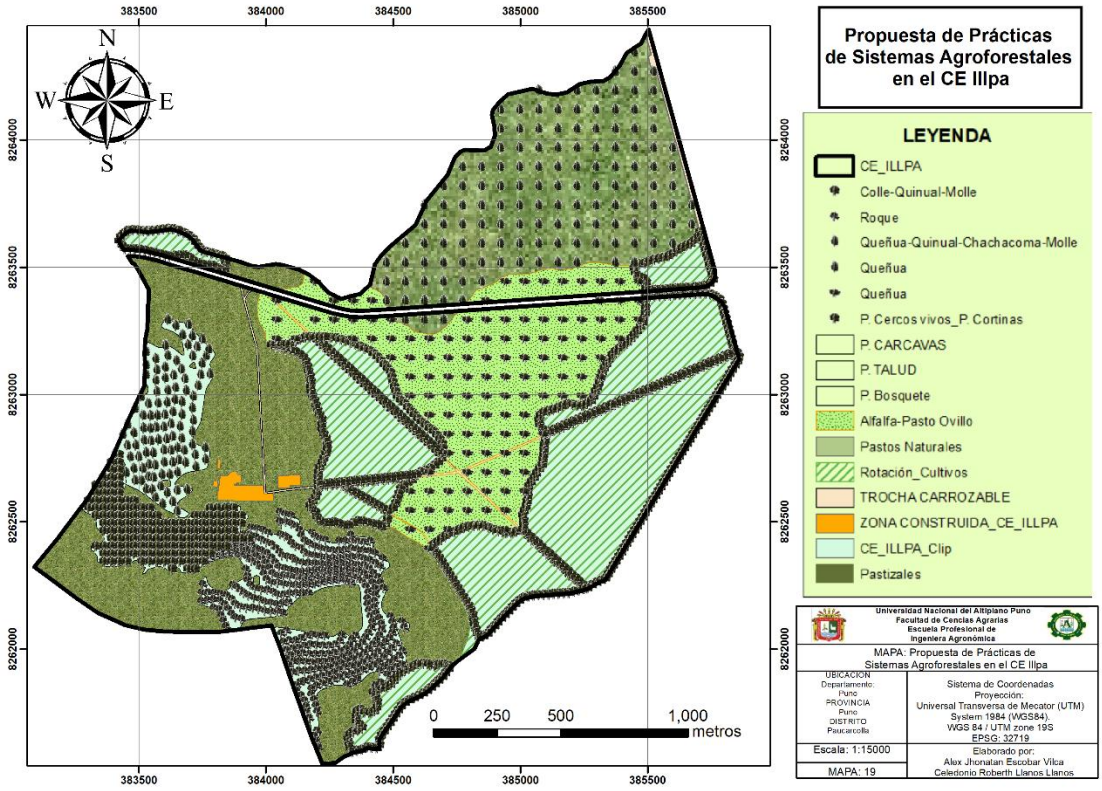
The S2 areas were distributed mainly across the central and northeastern sectors, coinciding with the areas showing higher values in the continuous suitability index. The S3 areas were located primarily toward the southwest and in other restricted sectors identified by the lower index values.

Spatial proposal for agroforestry management

The final spatial proposal differentiated management practices according to the suitability classes identified in the agroecological zoning. Areas classified as S2 were assigned primarily to agrosilvicultural management, whereas S3 areas were assigned to silvopastoral and protection-oriented management.

Figure 3

Spatial proposal of agroforestry practices at the Illpa Experimental Center



Note. The map was generated based on the criteria defined during the research process, considering the agroecological requirements of the forest, agricultural, and forage species, as well as the agroecological zoning for agroforestry systems developed in the present study.

In the S2 areas, the mapped proposal included crop rotation, live fences, windbreaks, vegetation barriers against frost, cultivated pastures, and combinations of agricultural and forest components. The proposed crop rotation included potato, quinoa, and barley, while the cultivated pasture component included alfalfa and orchard grass. The woody component included combinations of colle, quinual, queñua, chachacoma, and molle.

The wind-protection component was represented by rows and perimeter barriers, including quinual as one of the species assigned to windbreak functions. The frost-protection component included colle, japur, quinual, and chachacoma. Silvopastoral arrangements combined queñua with permanent pastures such as alfalfa, clover, ryegrass, and orchard grass.

In the S3 areas, the map assigned practices related to gully stabilization, slope protection, establishment of woodlots, natural pastures, and permanent vegetation cover. The gully-management

component included queñua, quinual, chachacoma, molle, and mutuy. Roque was assigned to slope-protection practices, while the headwater woodlot component included colle, quinual, molle, mutuy, and japur.

Overall, the spatial proposal assigned productive agrosilvicultural arrangements to the predominantly S2 territory and conservation-oriented silvopastoral arrangements to the more restricted S3 areas. The mapped design integrated agricultural crops, cultivated and natural pastures, woody species, and soil-protection practices within the evaluated territory.

DISCUSSION

The findings indicate that the agroecological suitability of the Illpa Experimental Center was determined by the combined influence of climate, soil, and topography. Mean, maximum, and minimum temperatures increased significantly during 1981–2024, whereas precipitation showed no significant long-term trend. Therefore, water availability was characterized more by interannual variability than by a sustained increase or decrease. This climatic pattern suggests that agroforestry planning should consider both increasing thermal conditions and the continued risk of drought, frost, and irregular rainfall.

The land-capability assessment showed that 80.05% of the area belonged to the F2ws subclass, characterized by moderate agrological quality and limitations related to soil and drainage, while 19.09% was classified as protection land. These findings indicate that intensive soil disturbance would be unsuitable across much of the study area. Instead, permanent vegetation cover and agroforestry arrangements represent more appropriate alternatives for maintaining productive use while reducing erosion and soil degradation.

These results differ from those reported by Mamani (2004), who classified much of the same area as suitable for clean cultivation and pastures. This difference may be related primarily to the more restrictive criteria established by the current Peruvian land-capability regulation, particularly regarding drainage, soil depth, and erosion. The climatic trends were consistent with Seiler et al. (2013), Vuille et al. (2015), and Salas (2014), who also reported increasing temperatures in Andean and Altiplano environments. Similarly, the agroecological zoning supports the findings of Gómez et al. (2022), who demonstrated that GIS and the Analytic Hierarchy Process can integrate multiple environmental criteria and identify land-suitability patterns that are not evident from conventional soil classification alone.

The final zoning classified 87.3% of the territory as moderately suitable (S2) and 12.7% as marginally suitable (S3) for agroforestry systems. This result shows that the experimental center has substantial agroforestry potential, although no area was free from limitations. Productive agrosilvicultural and silvopastoral practices may be implemented in S2 areas, together with live fences, windbreaks, and frost-protection barriers. In S3 areas, management should prioritize permanent vegetation, gully stabilization, slope protection, and erosion control. Native species such as Polylepis incana and Buddleja coriacea are particularly relevant because of their adaptation to high-Andean conditions (Reynel & León, 1990).

The main limitations were the single-site scope, the uncertainty associated with spatial interpolation, and the absence of field validation of the proposed agroforestry practices. Future research should establish pilot plots to evaluate plant survival, crop yield, soil-moisture conservation, wind reduction, and erosion control under the identified S2 and S3 conditions.

CONCLUSION

This study aimed to delineate and classify land suitable for agroforestry systems at the Illpa Experimental Center by integrating climatic, edaphic, and topographic criteria. The findings demonstrate that the study area is predominantly moderately suitable for agroforestry, whereas smaller sectors present marginal suitability due to drainage, soil-depth, erosion, and terrain constraints. Significant temperature increases and persistent rainfall variability further emphasize the need for climate-responsive land management. By combining the Analytic Hierarchy Process, geographic information systems, and land-capability assessment, this research provides an integrated spatial framework for distinguishing areas suitable for productive agrosilvicultural and silvopastoral arrangements from those requiring conservation-oriented practices. The resulting zoning offers a technical basis for implementing live fences, windbreaks, frost-protection barriers, permanent vegetation cover, and erosion-control measures. Overall, this study advances site-specific agroecological planning in high-Andean environments and supports sustainable land management, soil conservation, and the future field implementation of agroforestry systems at the Illpa Experimental Center.

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TEMPORAL ASSESSMENT OF THE ANNUAL MASS BALANCE OF THE QUELCCAYA ICE CAP (1994–2024)

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Abstract

This study assessed the temporal behavior of the annual mass balance of the Quelccaya ice cap, located in the Vilcanota mountain range (southern Peru), during the period 1994–2024. The objective was to determine changes in glacier area and volume, as well as their relationship with the main climatic variables. To this end, Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI/TIRS satellite images were processed on the Google Earth Engine platform, delineating glacier cover using the Normalized Difference Snow Index (NDSI) and estimating volume through three area–volume scaling relationships. Temporal trends were assessed using the Mann–Kendall test and linear regression (n = 31), and the relationship with climatic variables from the PISCO dataset (SENAMHI) was determined using Pearson's correlation coefficient (n = 23; period 1994–2016). The results showed a reduction in glacier area from 46,683,300 m² in 1994 to 33,916,400 m² in 2024 (a loss of 27.35%; $R^2 = 0.793$) and a decrease in glacier volume of more than 31% according to the three methodologies applied. All trends were statistically significant ($p < 0.05$), and maximum air temperature showed the strongest association with glacier area loss ($r = -0.649$; $p = 0.001$). These results confirm a persistent, long-term glacier retreat driven primarily by rising temperatures, and highlight the need to strengthen continuous satellite monitoring of Quelccaya for the sustainable management of water resources and adaptation to climate change in the tropical Andes.

Keywords: Quelccaya Glacier, Mass balance, Climate change, Remote sensing, Landsat, NDSI, Google Earth Engine, Glacier retreat, Water resources.

1. Introduction

Tropical glaciers are essential components of high-mountain hydrological systems, as they store and regulate freshwater resources. In addition to their hydrological relevance, glaciers are widely recognized as sensitive indicators of climate variability and change, since they respond directly to

fluctuations in temperature and precipitation (Rabatel et al., 2013). In recent decades, numerous studies have documented substantial glacier retreat in the tropical Andes, evidencing the impacts of changing climatic conditions on high-mountain environments (Hanshaw & Bookhagen, 2014; Turpo Cayo et al., 2022). Consequently, glacier monitoring has become increasingly relevant for understanding the consequences of climate change and assessing potential impacts on water availability and ecosystem sustainability.

The Quelccaya ice cap, located in the Vilcanota mountain range in southern Peru, is the most extensive tropical ice mass in the world and represents a valuable natural laboratory for glaciological research. Previous research has examined changes in glacier extent and dynamics through field observations and remote sensing techniques (Hanshaw & Bookhagen, 2014). Likewise, advances in satellite imagery and geospatial technologies have improved the ability to monitor glacier evolution over extended periods. However, despite the growing availability of satellite and climatic data, research on the long-term temporal behavior of the Quelccaya ice cap's mass balance, and its relationship with climate variability, remains limited.

To address this knowledge gap, the present study assesses the temporal behavior of the annual mass balance of the Quelccaya ice cap during the period 1994–2024, using satellite imagery and climatic data. The study analyzes temporal trends in glacier mass balance and examines their association with climatic conditions throughout the evaluated period. By providing updated evidence on the recent evolution of the Quelccaya ice cap, this research contributes to a better understanding of glacier response to climate variability and lays the groundwork for future studies on glacier monitoring, water resources, and climate change in the tropical Andes.

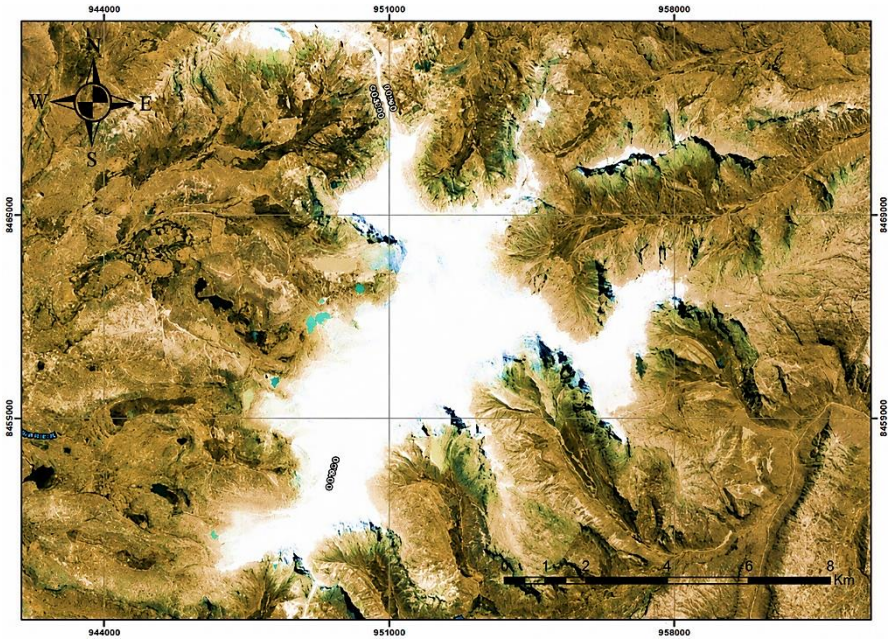
2. Materials and Methods

2.1 Study Area

The study was conducted at the Quelccaya ice cap, located in the Vilcanota mountain range in southeastern Peru, between the regions of Cusco and Puno. Quelccaya is the most extensive tropical ice mass in the world and constitutes a strategic water resource for the surrounding high-Andean watersheds. The analysis covered the period between 1994 and 2024, with the purpose of assessing changes in glacier extent, mass balance, and their relationship with climatic variables.

Figure 1

Geographic location of the Quelccaya ice cap



Note. Own elaboration.

2.2 Data Sources

Multispectral images from the Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI/TIRS satellites were used, obtained from the United States Geological Survey (USGS) for the period 1994–2024. Likewise, climatic data on maximum temperature, minimum temperature, and precipitation from the PISCO dataset, developed by Peru's National Meteorology and Hydrology Service (SENAMHI), were used to assess the influence of climatic conditions on glacier dynamics.

Table 1

Datasets used in the study

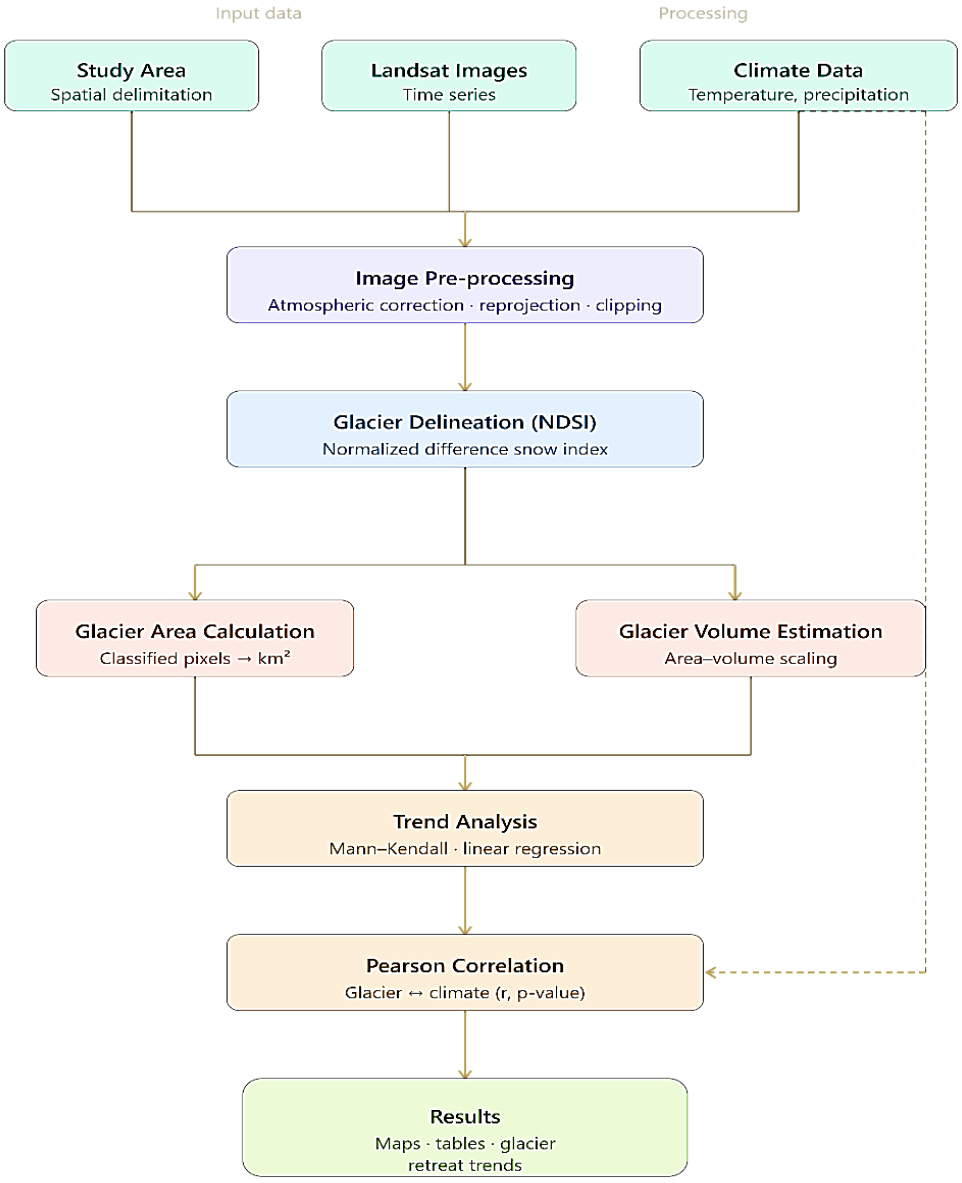
Source	Dataset	Spatial resolution	Purpose
USGS	Landsat 5 TM	30 m	Glacier delineation
USGS	Landsat 7 ETM+	30 m	Glacier delineation
USGS	Landsat 8 OLI/TIRS	30 m	Glacier delineation
SENAMHI	PISCO	0.1°	Climatic variables

Note. USGS = United States Geological Survey; SENAMHI = Peru's National Meteorology and Hydrology Service.

2.3 Image Processing

Satellite images were processed on the Google Earth Engine platform using correction and preprocessing procedures. Glacier extent was delineated using the Normalized Difference Snow Index (NDSI), which allowed the glacier area to be estimated for each study year. Subsequently, glacier volume was estimated using the area–volume scaling relationships proposed by Chen and Ohmura (1990), Bahr et al. (1997), and the Lanzhou Institute of Glaciology and Geocryology [LIGG] (1988).

Figure 2 Methodological workflow for glacier delineation and volume estimation



Note. Own elaboration.

2.4 Statistical Analysis

Temporal trends in glacier area and volume were assessed using the non-parametric Mann–Kendall test and simple linear regression. Subsequently, the normality of the climatic variables was assessed using the Shapiro–Wilk test. Finally, the relationship between glacier area loss and climatic variables was determined using Pearson's correlation coefficient, considering a significance level of 0.05. Statistical analyses were performed using RStudio and IBM SPSS Statistics software.

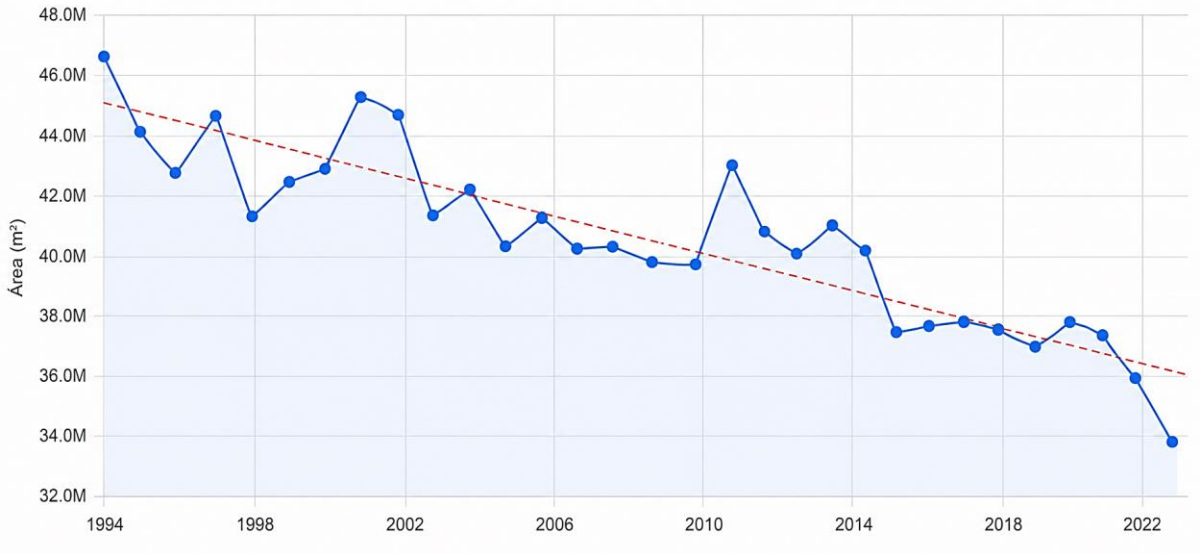
3. Results

3.1 NDSI-based glacier cover (1994–2024)

The total area of the Quelccaya glacier decreased from 46,683,300 m² in 1994 to 33,916,400 m² in 2024, representing a cumulative loss of 12,766,900 m² (27.35%). The linear trend line fitted to the time series explained a considerable proportion of the observed variability ($R^2 = 0.793$).

Figure 3

Temporal evolution of the total area of the Quelccaya glacier (1994–2024)



Note. The dashed line represents the fitted linear trend ($R^2 = 0.793$).

3.2 Glacier mass balance: area–volume method

Glacier volume was estimated using three area–volume scaling parameterizations: Chen and Ohmura (1990), Bahr et al. (1997), and LIGG (1988). All three methods showed parallel behavior and synchronous decreasing trends throughout the study period.

Table 2

Total glacier volume (m^3) estimated using the three area–volume methods

Year	Chen and Ohmura (1990)	Bahr et al. (1997)	LIGG (1988)
1994	2 395 277 266	2 804 591 048	3 905 216 469
1998	2 058 928 504	2 407 690 773	3 373 976 868
2001	2 327 991 776	2 725 753 105	3 795 758 613
2005	1 992 785 187	2 329 910 942	3 268 077 703
2011	2 173 841 219	2 543 276 795	3 555 537 243
2016	1 829 116 639	2 137 212 194	3 007 301 849
2020	1 797 321 140	2 099 767 038	2 956 670 470
2024	1 608 289 732	1 877 094 733	2 656 121 892
Total loss	−787 037 534 (−32.86%)	−927 496 315 (−33.07%)	−1 249 094 577 (−31.99%)

Note. The methods differ by up to 49.75% from one another, but all agree on a reduction in glacier volume of more than 31% relative to 1994.

3.3 Trend analysis (Mann–Kendall test and linear regression)

The non-parametric Mann–Kendall test and linear regression were applied to the glacier area and volume time series for the period 1994–2024 (n = 31). All variables showed statistically significant decreasing trends ($p < 0.05$).

Table 3

Mann–Kendall test results for glacier area and volume (n = 31)

Variable	Trend	p-value (Mann–Kendall)	Slope (unit $year^{-1}$)

Total glacier area	Decreasing	1.4×10^{-8}	−283 854 m²
Volume — Chen and Ohmura (1990)	Decreasing	8.0×10^{-9}	−17 496 820 m³
Volume — Bahr et al. (1997)	Decreasing	8.0×10^{-9}	−20 614 550 m³
Volume — LIGG (1988)	Decreasing	9.0×10^{-9}	−27 755 680 m³

Note. All p-values were below 0.05, allowing rejection of the null hypothesis of no monotonic trend. The reported slope represents the median annual loss.

Table 4

Linear regression analysis for glacier area and volume, 1994–2024 (n = 31)

Variable	Slope (unit year^{-1})	p-value	R^2
Total glacier area	−290 620 m²	1.9×10^{-11}	0.793
Volume — Chen and Ohmura (1990)	−18 030 550 m³	2.0×10^{-11}	0.792
Volume — Bahr et al. (1997)	−21 251 790 m³	2.1×10^{-11}	0.792
Volume — LIGG (1988)	−28 603 750 m³	1.9×10^{-11}	0.793

Note. $R^2 \approx 0.793$ indicates that the linear model explains approximately 79.3% of the temporal variability in glacier area and volume.

3.4 Relationship between climatic variables and glacier retreat

A Pearson correlation analysis was performed between the annual rate of change in glacier area and precipitation, minimum temperature, and maximum temperature, obtained from SENAMHI's PISCO dataset, for the period 1994–2016 (n = 23), as determined by the availability of the climatic series used. Data normality was confirmed using the Shapiro–Wilk test ($p > 0.05$ for all variables).

Table 5

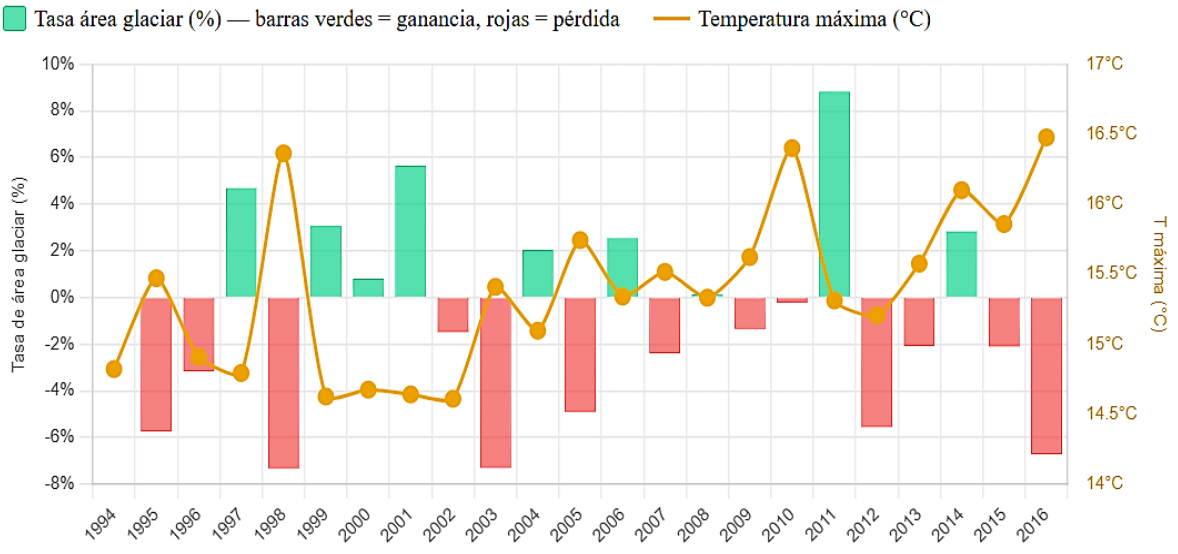
Pearson correlation between the rate of change in glacier area and climatic variables, 1994–2016 (n = 23)

Climatic variable	Pearson's r	p-value	n	Interpretation
Precipitation	+0.650**	0.001	23	Moderate positive correlation
Minimum temperature	−0.140	0.523	23	Weak negative correlation (not significant)
Maximum temperature	−0.649**	0.001	23	Moderate negative correlation

Note. ** $p < 0.01$ (two-tailed). Shapiro–Wilk normality was confirmed for all variables ($p > 0.14$). Maximum temperature was the climatic variable most strongly associated with glacier retreat.

Figure 4

Annual variation in mean maximum temperature and the rate of change in glacier area (1994–2016)



Note. Years with maximum temperatures ≥16 °C (1998 and 2016) coincided with the largest glacier area losses. Own elaboration.

Years with elevated maximum temperatures (≥16 °C) coincided with the largest glacier area losses (1998: −7.31%; 2016: −6.70%). In contrast, years of glacier recovery (2001 and 2011) corresponded to the lowest maximum temperatures recorded during the study period.

4. Discussion

The results showed a continuous reduction in the area and estimated volume of the Quelccaya ice cap between 1994 and 2024, confirming persistent glacier retreat over the last three decades. The

significant negative trends identified through the Mann–Kendall test and linear regression indicate that glacier mass loss constitutes a long-term process rather than an isolated temporal fluctuation. Likewise, the positive relationship between glacier area loss and maximum air temperature suggests that rising temperatures have been one of the main drivers of glacier retreat during the study period. These findings are consistent with Rabatel et al. (2013), who report that tropical glaciers are highly sensitive to changes in air temperature, since even slight warming can substantially alter their mass balance. Similarly, Luque Gonzales (2024) documented a continuous reduction of the Quelccaya ice cap between 2010 and 2022 using Landsat imagery, supporting the long-term retreat observed in the present study.

The observed glacier recession is also consistent with the findings of Hanshaw and Bookhagen (2014), who identified significant glacier loss in the Vilcanota mountain range through multitemporal analysis of satellite imagery. Similarly, Turpo Cayo et al. (2022) reported persistent negative glacier trends in the tropical Andes using Landsat time series processed in Google Earth Engine. Minor differences between studies may be explained by variations in the study period, satellite image availability, spatial resolution, glacier delineation methods, and glacier volume estimation techniques. As noted by Frey et al. (2014), empirical area–volume relationships introduce methodological uncertainties that must be considered when comparing glacier volume estimates across studies.

The continuous reduction of the Quelccaya ice cap has important implications for water availability and ecosystem sustainability in the tropical Andes. Although Landsat imagery and empirical area–volume models constituted an effective approach for long-term glacier monitoring, uncertainties associated with image resolution and model assumptions remain. Future research should integrate higher-resolution satellite imagery, digital elevation models, and field observations, in order to improve glacier volume estimates and strengthen assessments of climate change in tropical glacial environments.

5. Conclusions

This study shows that the Quelccaya ice cap experienced a sustained reduction in its area and volume between 1994 and 2024, with an area loss of 27.35% and a volume decrease of more than 31% according to the three area–volume scaling methodologies used. The Mann–Kendall and linear regression statistical tests confirmed that these decreasing trends are statistically significant and consistent throughout the entire time series analyzed, supporting the interpretation of glacier retreat

as a long-term structural process, linked to regional climatic conditions, rather than an isolated interannual fluctuation resulting from the system's natural variability.

Regarding the associated climatic factors, maximum air temperature was identified as the variable most closely related to glacier area loss, showing a statistically robust association throughout the study period. Precipitation, in turn, showed a moderate positive relationship, suggesting a secondary role in the retreat dynamics, while minimum temperature showed no statistically significant association. Taken together, these results suggest that atmospheric warming, rather than precipitation variability, has been the main climatic driver of Quelccaya's retreat during the evaluated period, consistent with findings reported for other tropical Andean glaciers.

The findings of this research reinforce the need to strengthen continuous satellite monitoring of Quelccaya and other tropical Andean glaciers, as well as to incorporate higher spatial resolution data and field observations that can reduce the methodological uncertainties associated with empirical area–volume relationships. Given Quelccaya's relevance as a strategic source of freshwater for the high-Andean watersheds of southern Peru, it is recommended that future water management and climate change adaptation policies explicitly consider the retreat trends documented in this study, prioritizing long-term monitoring strategies.

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GEOELECTRIC STUDY TO ESTABLISH THE EXISTENCE OF GROUNDWATER AT A POINT IN THE CHAÑOCAHUA JOVEN COMMUNITY, LAMPA DISTRICT, PUNO DEPARTMENT

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ABSTRACT

To evaluate the presence of groundwater and delineate potential aquifers through geophysical prospecting at a strategic point in the Chañocahua Joven community, Lampa district and province, Puno department, in order to determine the technical feasibility for drilling water exploitation wells. The geoelectric method was applied through the execution of five (5) Vertical Electrical Soundings (VES) with a Schlumberger array. The one-dimensional (1-D) inverse processing and interpretation of apparent resistivity curves was carried out using IPI2WIN software, integrating the correlation of geomorphological data, satellite imagery, and regional geological mapping. The geoelectric modeling described a lithostratigraphic sequence corresponding to Quaternary alluvial deposits, with resistivity values ranging between 0.2 Ω-m and 19299.2 Ω-m. Horizons of saturated fine-grained sands (47 to 101 Ω-m), moderately saturated sand with gravels (65.3 to 110 Ω-m), and deep layers of saturated clays with a brackish trend (17.5 to 38.7 Ω-m) were identified. The average water table level for the area and study date was estimated at a depth of 1.47 meters. It was determined that the subsoil has a predominantly silty-sandy composition of moderate to low permeability, with limited exploitation flow rates anticipated. The technical feasibility for the utilization of the resource was determined through an initial exploratory drilling with a recommended minimum depth of 15 meters at the VES-1 location.

Keywords: Aquifer, Groundwater, Lithostratigraphy, Electrical Resistivity, Vertical Electrical Sounding.

1. INTRODUCTION

Access to water resources in the high Andean regions of Peru constitutes one of the most critical socioeconomic and environmental challenges of recent decades, especially in light of the effects of climate change and variability in precipitation regimes. In the department of Puno, rural communities rely heavily on surface water sources; however, these exhibit high seasonal vulnerability. A clear example is observed at the

Lampa weather station, where rainfall is strictly concentrated between November and March, giving way to a prolonged dry season of four months (June to September) where rainfall is practically zero, recording minimum averages of up to 1.7 mm in July. This marked seasonality generates a severe water deficit that restricts the development of agricultural and livestock activities, as well as the supply for basic population needs.

Faced with scarcity and surface water stress, planned exploration and exploitation of groundwater emerges as a strategic and sustainable alternative to guarantee water security in rural areas. Subsurface aquifers act as natural reservoirs capable of buffering extreme climate fluctuations. Nevertheless, the precise location of these structures requires a detailed characterization of the local geology and hydrogeology of subsurface formations, minimizing the economic risk associated with unsuccessful drillings.

Traditionally, geophysical prospecting has consolidated itself as a fast, economical, and highly efficient tool for determining subsoil conditions. Among the various available techniques, the geoelectric method, specifically through the execution of Vertical Electrical Soundings (VES), stands out for its high precision and depth resolution, allowing the mapping of resistivity variations associated with the presence of saturated horizons. By injecting electric current and measuring the apparent potential difference through symmetrical tetrapolar arrays, it is possible to model lithostratigraphic sequences, discriminating permeable layers (such as sands and gravels) from impermeable levels or clayey aquitards.

Under this context, the present research addresses an integrated study at a strategic point in the Chañocahua Joven Rural Community, located on the inter-district boundary of Lampa and Juliaca, within the department of Puno. The main objective of this work is to evaluate the hydrogeological potential of the subsoil and establish the actual existence of usable aquifers or water tables through the design of a geoelectric prospecting campaign that includes the execution and interpretation of five (5) Vertical Electrical Soundings using the Schlumberger configuration. Through this collaborative research effort, the goal is to provide a solid scientific foundation to successfully guide future well drilling, directly contributing to the design of efficient multi-purpose supply solutions for the community and enriching knowledge of aquifer systems in the southern macro-region of the country.

2. RESEARCH DESIGN

2.1 Geophysical Prospecting

An economical and fast procedure for determining the hydrogeological and geological conditions of the subsoil is geophysical prospecting.

Vertical electrical soundings are, today, one of the most precise geophysical methods for determining the hydrogeological and geological conditions of the subsoil. Furthermore, they are increasingly modernized with technological resources, thereby replacing other prospecting methods. This activity must be carried out by specialized personnel (hydrogeologists), who have the equipment and software required for the interpretation of results.

2.2 Methodology

The geoelectric method consists of injecting an electric current into the ground and subsequently analyzing the resistive response of the various materials present in the subsoil as said current travels. For the above, an array developed by Schlumberger, bearing its name, is used, in which by means of 4 symmetrically distributed electrodes—two located at the ends through which current is injected and two in the center of the former through which the voltage drop occurring as it passes through rocks due to their resistivity is measured (Figure 2-1).

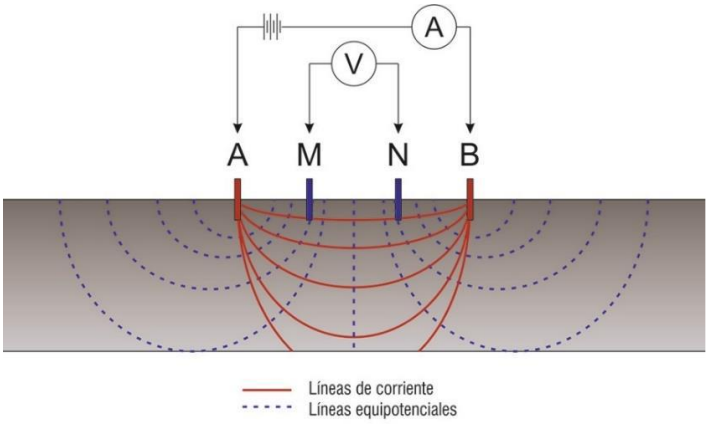


Figure 2-1 Electrode distribution

With the field data collected for Voltage and Current associated with a symmetrical electrode distribution imposed by the method, Apparent Resistivity curves in Ohm-m versus depth are obtained. The above, combined with geological, geomorphological, and other information from the area, professional

expertise, and appropriate software, allows for the interpretation of these curves to obtain Geoelectric models showing depth distribution of thickness and resistivity of detected layers at each point.

With the voltage and current data collected in the field related to a distribution of resistivity and thickness of the layers detected at each location, the technique allows obtaining resistivity curves. Appears in ohm - m, against depth. The above, along with geological, geomorphological data, among others, of the area, the experience of the professional, and appropriate software, analyzes the mentioned curves and creates geoelectronic models of depth distribution.

The development of this method has identified the responses of different rock types, which have been tabulated and adapted to each specific investigation (Figure 2-2).

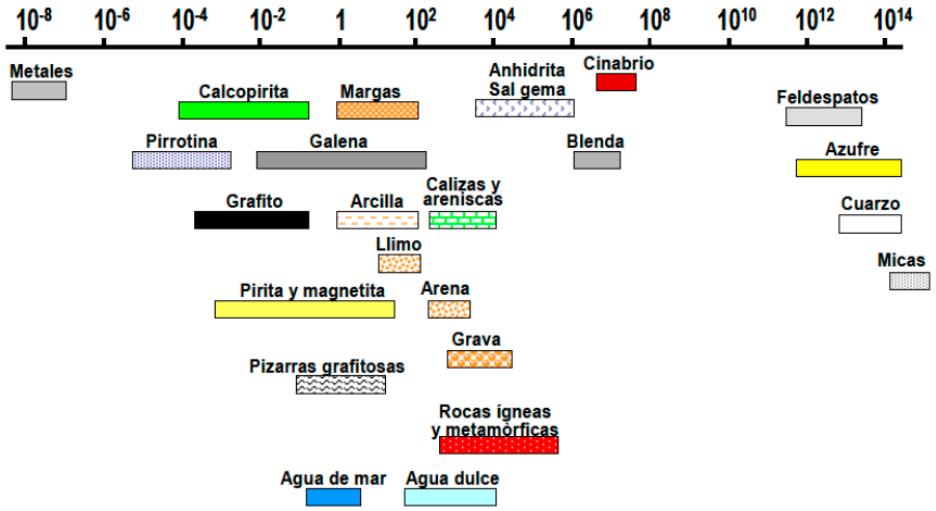


Figure 2-2 Classification of resistivity in different rock types

The interpretation of a Vertical Electrical Sounding curve is based on discovering a detailed subsoil model composed of materials with dissimilar resistivities and thicknesses and/or depths, so that the curve calculated for that model matches the field curve. This model is just one among numerous models that generate sounding graphs. Equivalence is the term used to refer to these models. The interpreter's analysis skills, together with the constraints established by the geology of the area—based on normal resistivities for specific types of rocks—are of great help in discarding numerous mathematically equivalent models that have little in common with the true nature of the geological units found in the subsoil (for example: sandstones for

dry clays, impermeable basement, impermeable rocks as aquifers, unreal thicknesses, very high or low resistivities, and others).

This study makes use of several interpretation programs (IPI2WIN), which find a geologically reasonable subsoil model. Subsequently, what each program returns is analyzed and similar models are averaged in order to adapt the final model to the geological information of the sounding site, which is interpreted by an experienced geologist. This allows for a reliable estimation regarding whether or not underground resources exist that can be exploited.

2.3 Data Processing and Interpretation

If necessary, the field curve is smoothed by eliminating discontinuous points and digitizing it through 6 equally spaced points in a logarithmic decade, starting from the highest AB/2 value.

The reason for digitizing the curve at 5 equally spaced points per decade is to increase the calculation speed of several theoretical sounding curves during the iterative adjustment process (Zohdy 1973). Interpretation programs generate detailed models from field or digitized curves, which are subsequently examined, modified, and selected to perform the interpretation with the model that best fits the conditions present in the subsoil. To achieve a detailed model and an adequate estimation, as well as to detect areas with groundwater resources, knowledge of subsoil geology is essential.

2.3.1 Field Data

Field curves, AB/2, resistivity results, and their meanings are produced using a computer program called IPI2WIN. This software aims to interpret induced polarization and resistivity curves in one dimension.



Figure 2-3 SUBREME DC 600 high-precision resistivity equipment

The quality of the field curves was analyzed during office work. After making some corrections (digitization, smoothing), interpretation of data collected in the field proceeded using software specialized in geophysical data processing. These programs generate a detailed model of thicknesses and resistivities equivalent to a section of rock layers or levels actually present below the surface where the sounding was performed.

This task is in addition to a thorough examination of the morphology and geology of the area; this analysis is complemented by INGEMMET geological maps, Google Earth satellite imagery, and covers the analysis of recharge areas, topographies of surrounding relief around the chosen area, and surface drainage.

In the following chapter, titled "Analysis of Results", the analyzed lithology and its link to existing subsoil geology in the studied area are presented. In this same chapter, observations are made pointing out the most interesting areas and the suggested depth for the exploratory well. This is intended to exploit aquifer levels located within the detailed model obtained through interpretation software and related to data on geological conditions present in the region where geoelectric subsoil studies were carried out.

2.4 Advantages and Limitations of the Method

The advantages presented by this method are as follows:

The data capture process is fully automated, allowing a large number of measurements to be made so that 2-D sections of exceptional depth resolution are obtained.

Thanks to this two-dimensional view, the Vertical Electrical Sounding (VES) method will allow us to:

- Detect areas susceptible to presenting seepage focal points, as well as geometrically characterize the issue (estimate flow depth).
- Efficaciously address problems in terrains with high structural complexity.
- Locate with high efficiency other types of procedures (soundings or piezometers), given that it marks the location and depth at which the anomaly is located.

Advantages:

- Data processing can be carried out directly in the field with the help of a laptop in a very short time. This near real-time mode of action gives the method great versatility when resolving possible issues arising during the field process or deciding to execute new profiles that were not initially projected.
- The maximum study depth can be controlled.
- It is a non-destructive method.

Limitations:

- Unlike other methods, Vertical Electrical Sounding requires fairly expensive equipment and a time-consuming field procedure.
- As occurs with all electrical resistivity methods, the presence of highly resistive material at the surface prevents proper functioning of the method, necessitating the use of other techniques.

3. RESULTS

The results obtained from geophysical prospecting using the Vertical Electrical Sounding (VES) method made it possible to define the geometric configuration and resistive characteristics of the subsoil in the study area. The investigation included the execution of five (5) sounding stations using a symmetrical Schlumberger array with maximum current line openings (AB/2) reaching significant investigation depths for regional hydrogeological flow. One-dimensional (1-D) processing and inversion of apparent resistivity curves were

performed using specialized software IPI2WIN, achieving a fit with a minimal margin of error relative to data measured directly in the field.

3.1 Location and Georeferencing of Control Points

To ensure spatial control and reproducibility of the research, the centers of the five vertical electrical soundings were georeferenced with high precision. Table 3-1 details coordinates in the projection system corresponding to the study area.

Table 3-1 Location of VES performed in the Chañocahua Central community

ID	EAST	NORTH
VES-1	362230.25	8296041.49
VES-2	362224.96	8296011.11
VES-3	362240.98	8296063.32
VES-4	362198.85	8296048.59
VES-5	362261.64	8296029.21

3.2 Lithological Correlation

A logarithmic resistivity scale will be used for the area, generating a geometric sequence or progression with a ratio of 1.7 and starting the series at 1.0 Ω-m; within the interpreted values, the minimum resistivity value was 0.2 Ω-m, with a maximum of 19299.2 Ω-m.

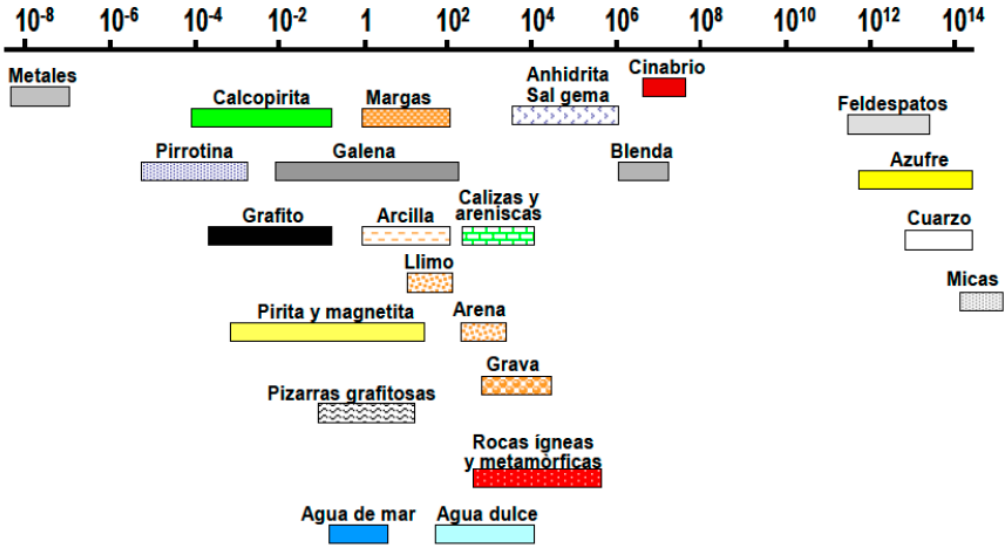


Figure 2-4 Classification of resistivity in different rock types

3.3 Geoelectric Model and Hydrogeological Correlation

Below are the five geoelectric models and hydrogeological correlation for each VES:

3.3.1 VES-1

GEOELECTRIC SECTION VES-1

LAYER	LITHOSTRATIGRAPHIC INTERPRETATION	RESISTIVITY (OHM-M)	DEPTH (M)		THICKNESS (M)
1	Dry surface material in dry sand matrix.	82.4	0.00	1.62	1.62
2	Sand and fine materials clay and silts with water saturation.	47	1.62	8.13	6.51
3	Sands with some moderately water-saturated gravels.	80.8	8.13	15.2	7.07
4	Saturated clays with brackish water.	17.5	15.2	32.9	17.70
5	Geoelectric horizon.	29	?	?	?

LEGEND:

DRY MATERIAL

SAND AND FINES

SAND

CLAY

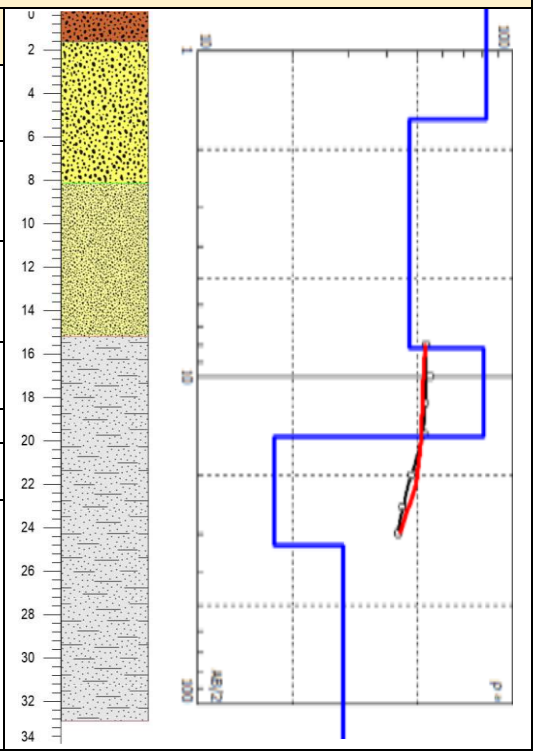


Figure 3-1 Geoelectric model and hydrogeological correlation VES-1

3.3.2 VES-2

GEOELECTRIC SECTION VES-2

LAYER	LITHOSTRATIGRAPHIC INTERPRETATION	RESISTIVITY (OHM-M)	DEPTH (M)		THICKNESS (M)
1	Dry surface material in dry silty sand matrix.	54.1	0.00	1.57	1.57
2	Sand with clay and silts with water saturation.	101	1.57	3.65	2.08
3	Fine material combination of clay and silts moderately water-saturated.	14.3	3.65	8.23	4.58
4	Sand with clay and silts with water saturation.	89	8.23	23.2	14.97
5	Geoelectric horizon.	11.2	?	?	?

LEGEND:

DRY MATERIAL

SAND AND FINES

SAND

CLAY

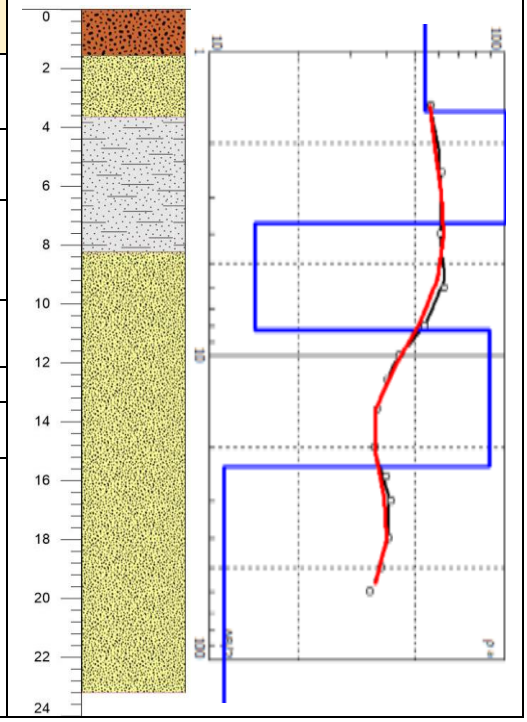


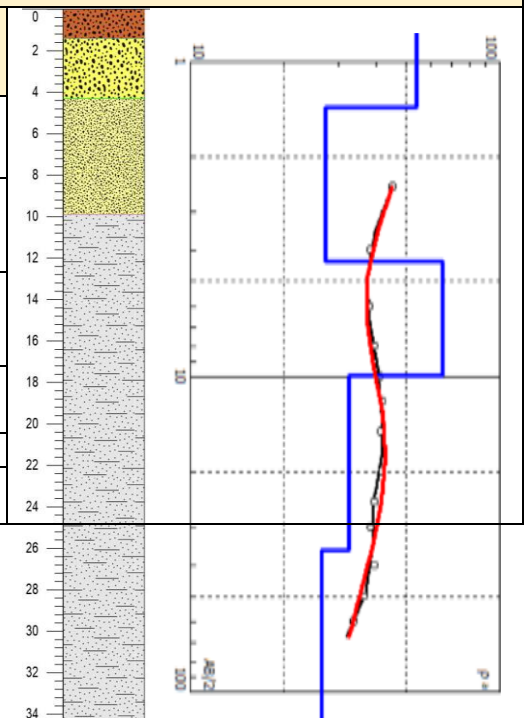
Figure 3-2 Geoelectric model and hydrogeological correlation VES-2

3.3.3 VES-3

GEOELECTRIC SECTION VES-3

LAYER	LITHOSTRATIGRAPHIC INTERPRETATION	RESISTIVITY (OHM-M)	DEPTH (M)		THICKNESS (M)
1	Dry surface material in dry silty sand matrix.	53.8	0.00	1.4	1.40
2	Sand and fine materials clay and silts with water saturation.	27.4	1.4	4.31	2.91
3	Sand with some moderately water-saturated gravels.	65.3	4.31	9.9	5.59
4	Saturated clays with brackish water.	32.6	9.9	35.5	25.60
5	Geoelectric horizon.	26.6	?	?	?

LEGEND:



DRY MATERIAL **SAND AND FINES** **SAND** **CLAY**	

Figure 3-3 Geoelectric model and hydrogeological correlation VES-3

3.3.4 VES-4

GEOELECTRIC SECTION VES-4

LAYER	LITHOSTRATIGRAPHIC INTERPRETATION	RESISTIVITY (OHM-M)	DEPTH (M)		THICKNESS (M)
1	Dry surface material in dry silty sand matrix.	67.3	0.00	1.52	1.52
2	Saturated clays with brackish water.	35.9	1.52	6.22	4.70
3	Sands with some moderately water-saturated gravels.	67.9	6.22	18	11.78
4	Saturated clays with brackish water.	38.7	18	29.8	11.80
5	Geoelectric horizon.	21.7	?	?	?

LEGEND:

DRY MATERIAL **SAND AND FINES** **SAND** **CLAY**	

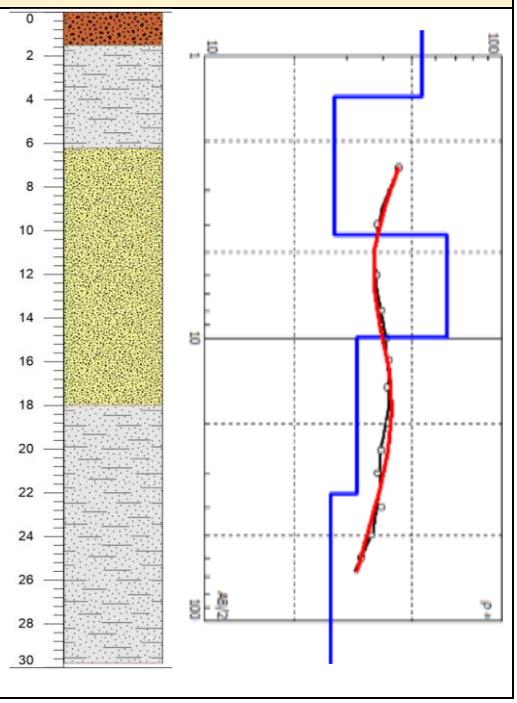


Figure 3-4 Geoelectric model and hydrogeological correlation VES-4

3.3.5 VES-5

GEOELECTRIC SECTION VES-5

LAYER	LITHOSTRATIGRAPHIC INTERPRETATION	RESISTIVITY (OHM-M)	DEPTH (M)		THICKNESS (M)
1	Dry surface material in dry silty sand matrix.	134	0.00	1.25	1.25
2	Sand and fine materials clay and silts with water saturation.	509	1.25	2.51	1.26
3	Saturated clays with brackish water.	30.1	2.51	8.48	5.97
4	Sands with some moderately water-saturated gravels.	110	8.48	25.8	17.32
5	Geoelectric horizon.	0.93	?	?	?

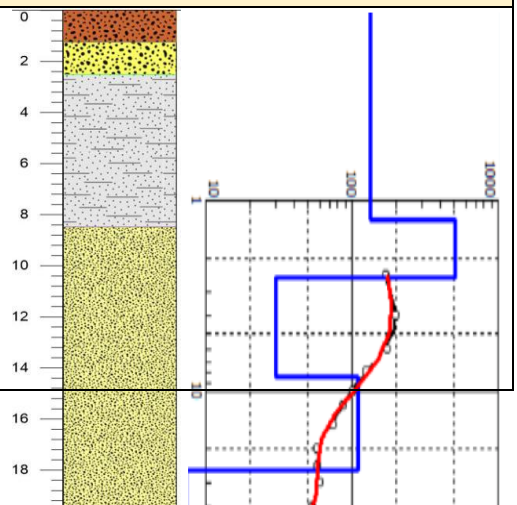




Figure 3-5 Geoelectric model and hydrogeological correlation VES-5

4. DISCUSSION

4.1 Interpretation of Results

- The results from the integrated analysis of the five geoelectric models determine that the water table in the study area is located at an average depth of 1.47 m for the monitoring date (December 23, 2023). From a lithological and hydrogeological perspective, aquifer horizons are predominantly composed of silty sands, fine sands, and gravel lenses interbedded with thick clay layers.
- This composition confers to the terrain a water production and transmissivity capacity classified as moderate to low, with exploitation flows of the same nature being estimated. To optimize the abstraction of subsurface water resources, the design and drilling of a pilot exploratory well with a minimum depth of 15 meters is prescribed, suggesting the location of station VES-1 or VES-5 due to the better spatial continuity of its permeable sandy layers.

5. CONCLUSIONS

- According to the analyzed characteristics resulting from the interpretation of the Vertical Electrical Soundings, the water table in the study area is on average at 1.47 m in the study area and for the studied date of December 23, 2023. It can be concluded that for the exploitation of possible existing groundwater streams, an exploratory or test drilling of 15 meters depth at minimum should be performed at the VES-1 sounding locations.
- From the distribution of resistivities found in the study area, it has been possible to infer a stratigraphic sequence that, composed in a higher percentage by silty sands, which from a

hydrogeological perspective have a moderate groundwater production capacity; therefore, moderate to low production flows are expected.

- It is not possible to calculate the flow rate of a well by means of a geoelectric study, nor by any other study, because these are indirect measurements performed on the ground to learn its characteristics, both lithological and water-related. The only way to know the flow rate is by performing a pumping test when the well is completed.

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Efecto de los riegos por goteo y microaspersión en el rendimiento de ajo chino (*allium sativum*) en la comunidad de challapujo, ilave-el collao-puno

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ABSTRACT

The limited availability of water resources in high Andean regions is one of the main constraints to the sustainability of agricultural production, making it necessary to implement irrigation technologies that improve water-use efficiency. In this context, the present study aimed to evaluate the effect of drip and micro-sprinkler irrigation on the yield of Chinese garlic (*Allium sativum* L.) in the community of Challapujo, Ilave district, El Collao province, Puno region, during the 2021–2022 growing season. The study was conducted using six crop beds under both irrigation systems, where meteorological variables, soil moisture, irrigation depth, water balance, and agronomic characteristics of the crop were monitored. The results showed that drip irrigation consumed 648.00 mm of water, representing a 16% reduction compared with micro-sprinkler irrigation, which used 771.06 mm. Likewise, the net irrigation depths were 223.87 mm and 346.76 mm, respectively, considering a total rainfall of 424.30 mm during the crop cycle. Yields reached 14.70 t/ha under drip irrigation and 14.83 t/ha under micro-sprinkler irrigation, with no significant differences between treatments. It is concluded that drip irrigation improves water-use efficiency without affecting crop productivity, constituting a sustainable alternative for agricultural production in high Andean regions.

Keywords: Chinese garlic, drip irrigation, micro-sprinkler irrigation, water-use efficiency, agricultural yield.

1. Introduction

In the highland region of Puno, Chinese garlic cultivation has become an important productive alternative to traditional crops such as potato, quinoa, and barley due to the yields and income obtained by farmers since 2020 in the district of Acora (3,867 m above sea level). During an experimental production phase promoted by the District Municipality of Acora, commercial yields of up to 13.83 t ha^{-1} were achieved, promoting the adoption of this crop by local (Cortez, 2022). Additionally, Chinese garlic has shown good adaptation to Altiplano conditions using planting material from Chiguata, Arequipa (Fernández, 2021).

However, garlic production in the region is mainly conducted under rainfed conditions with intermediate technology levels. Although a cumulative rainfall of 595.25 mm was recorded during the 2020–2021 growing season (Senamhi, 2020), rainfall deficits at the beginning of the crop cycle can restrict germination and vegetative development (Andina, 2022). Consequently, farmers use irrigation systems such as drip and flood irrigation to complement crop water requirements (Fernández, 2021). Nevertheless, technical information regarding irrigation management, water requirements, and its effects on garlic yield under high-altitude conditions remains limited.

Garlic (*Allium sativum* L.) productivity is strongly influenced by water availability and agronomic management practices. Recent studies have demonstrated that irrigation strategies significantly affect garlic yield and yield components, emphasizing the importance of adequate water management throughout the crop cycle (Ayele et al., 2025a). Similarly, (Hassan, 2015) reported that proper crop management improves garlic growth and bulb quality.

Efficient irrigation management is essential in areas with irregular rainfall and limited water availability. Drip irrigation improves water application efficiency by supplying moisture directly to the root zone and reducing water losses (Salazar et al., 2014). Previous studies have shown that drip fertigation improves garlic growth, nutrient availability, and productivity (Gupta and Mishra, 2020). Likewise, Badawy et al., 2019 demonstrated that irrigation levels influence garlic productivity and quality, while Torres (2018) highlighted the importance of determining crop water requirements for adequate irrigation scheduling.

Micro-irrigation systems, including micro-sprinklers, have also shown potential for improving crop performance by enhancing water distribution and resource efficiency.Fei et al., (2018) reported that water and fertilizer integration through fertigation improves garlic productivity. In addition, Calle (2023) evaluated drip and micro-sprinkler irrigation in Chinese garlic under conditions of Challapujo, Ilave–El Collao–Puno, providing a local reference for irrigation management in the Altiplano.

Therefore, this study aims to evaluate the effect of drip and micro-sprinkler irrigation on the yield of Chinese garlic (*Allium sativum* L.) in the community of Challapujo, Ilave district, El Collao province, Puno region, during the 2021–2022 growing season.

2. General Objective

Evaluate the effect of drip and micro-sprinkler irrigation on the yield of Chinese garlic (*Allium sativum* L.) in the community of Challapujo, Ilave district, El Collao province, Puno region, during the 2021–2022 growing season.

3. Methodology

3.1 Study design

The study adopted a quantitative, applied, and quasi-experimental approach, aimed at comparing the effect of drip and micro-sprinkler irrigation systems on the yield of Chinese garlic (Allium sativum L.). It was conducted in the community of Challapujo (Ilave, Puno) during the 2021–2022 growing season, under high-Andean conditions characterized by low precipitation and high thermal variability. The experiment was carried out in open-field conditions under homogeneous management, considering the natural variability of the soil–plant–atmosphere system for comparative treatment analysis.

3.2 Study area, population, and sample

The study was conducted on an experimental plot of 605.2 m², divided into six production beds, with a total of 11,880 Chinese garlic plants (*Allium sativum* L.), grown under loam to silt-loam soil conditions, as shown in Figure 1.



Figure 1. *Geographical Location of the Experimental Area and Experimental Design of the Irrigation Systems in the Challapujo Community*

Two treatments were evaluated:

- **T-1 (drip irrigation):** three cultivation beds with 5,940 plants, implemented using 12 drip lines (4 per bed), designed for localized application in the root zone.
- **T-2 (micro-sprinkler irrigation):** three cultivation beds with 5,940 plants, with 45 micro-sprinklers (15 per bed), generating a wider surface wetting pattern.

Each treatment constituted an independent experimental unit, with homogeneous agronomic management, soil preparation, and hydraulic conditions. Sampling was non-probabilistic and based on convenience due to the availability of the experimental area and the existing irrigation infrastructure.

3.3 Crop management and irrigation system

Sowing was carried out on November 4, 2021, using certified seed from Chiguata, Arequipa. Agronomic management was uniform for both treatments and included land preparation (plowing, harrowing, and bed formation), incorporation of fermented sheep manure, and manual weed control.

Irrigation scheduling was based on a daily dynamic water balance, integrating crop evapotranspiration (ETc), estimated from reference evapotranspiration (ET0) using the Penman–Monteith method and adjusted with the crop coefficient (Kc) according to phenological stage.

Effective rainfall recorded in situ, soil volumetric moisture content, and effective root depth were also incorporated. Root depth varied from 0.03–0.06 m in early stages to 0.50–0.51 m during full development. This approach allowed irrigation water to be supplied according to the actual crop water demand.

The irrigation system flow rate was 92.46 L/min, determined through volumetric flow measurements of the main pipeline with repeated readings. Precipitation was incorporated daily into the water balance to avoid overestimation of irrigation requirements.

3.4 Instruments and equipment

Field, laboratory, and environmental measurement instruments with metrological traceability were used:

- **Pyranometer (YK-35UV, Taiwan):** used to measure global solar radiation (W/m²), supporting the estimation of evapotranspiration using the Penman–Monteith method.
- **Rain gauge (J. Prolab, Brazil):** with a 130 mm capacity and ±0.5 mm accuracy, used for daily in situ precipitation recording.
- **TDR sensors (China) AMT-300 and XLUX MSO3:** used for continuous monitoring of soil moisture, pH, temperature, and light intensity, allowing tracking of soil behavior throughout the crop cycle.
- **Vernier caliper and measuring tape:** used for precise measurement of crop morphological variables (plant height, leaf length, pseudostem diameter, and bulb diameter).
- **Electronic balance and spring scale:** used to quantify fresh biomass and crop commercial yield.
- **Irrigation dose measurement tools:** in T-1, three 2.5 L graduated containers were used, while in T-2 a 25 L graduated bucket with millimetric scale was employed, allowing daily measurement of applied water volume and its conversion into irrigation depth (mm).

Soil and water samples were analyzed at the INIA–Illpa laboratory (Puno) under INACAL certification, ensuring analytical quality standards. Measurement equipment was calibrated with traceability to the Metrology Laboratory of Lima, ensuring the reliability of experimental data.

3.5 Data collection

The agronomic variables evaluated included plant height, leaf length, number of leaves, pseudostem diameter, bulb diameter, and commercial yield.

Measurements were carried out periodically on randomly selected plants within each experimental unit, following standardized measurement protocols. The crop cycle lasted from November 4, 2021 to May 13, 2022, when harvesting, bulb classification, and final yield determination per treatment were performed.

3.6 Statistical analysis

Data were processed using IBM SPSS Statistics v22, complemented with Microsoft Excel for data organization and visualization.

Normality assumptions were verified using the Shapiro–Wilk test, and homogeneity of variances was assessed using Levene's test. Differences between treatments were analyzed using Student's t-test for independent samples ($p < 0.05$).

Additionally, descriptive statistics (mean, standard deviation, minimum, and maximum values) were calculated, along with the percentage of water savings between irrigation systems based on total irrigation depths applied during the crop cycle.

4. Result

*4.1. **Cumulative Precipitation and Total Water Supply During the Garlic Crop Growing Cycle***

During the 2021–2022 growing season, cumulative precipitation throughout the garlic crop phenological cycle reached 424.30 mm, with an irregular distribution that caused water deficits during the initial and final growth stages. Total water supply, including both rainfall and irrigation, amounted to 647.67 mm in treatment T-1 and 771.06 mm in T-2, indicating a higher water requirement in T-2 (Figure 2).

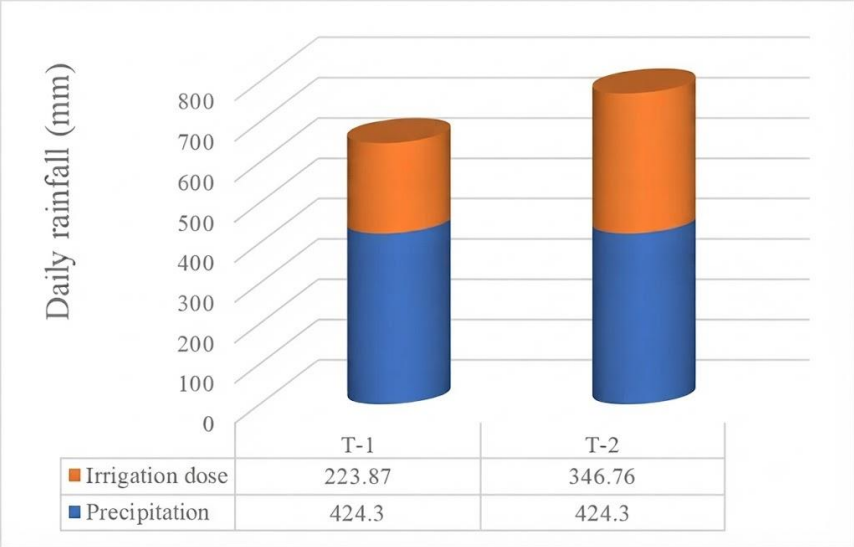


Figure 2. *Total water input (rainfall and irrigation) in treatments T-1 and T-2***.**

4.2 Water Requirements and Water Balance During the Phenological Stages of Garlic Crop Under Two Irrigation Systems.

The micro-sprinkler irrigation system (T-2) required a longer operating time (1280.75 min) and a higher applied water depth (346.76 mm) compared to the drip irrigation system (T-1), which used 1099.98 min and 223.87 mm. The highest water demands were recorded during the vegetative growth, pre-bulb formation, and bulb formation stages. Throughout the crop cycle, soil moisture was maintained above 70% of field capacity in both irrigation treatments, ensuring adequate water availability for crop growth and development during all phenological stages. Overall, both irrigation systems maintained a similar water balance; however, the drip irrigation system achieved

equivalent conditions using a lower amount of water, demonstrating greater efficiency in water use, as shown in Table 1.

Table 1.
Irrigation distribution and water balance during the phenological stages of garlic cultivation

Phenological stages	irrigation days	cumulative irrigation duration (min)	applied water depth (mm)	and average water balance (mm)	
		Drip irrigation (T-1)	Micro-sprinkler irrigation (T-2)	(T-1)	(T2)
Planting	6	140.96	154.05	27.67	44.82
Emergency	9	101.73	106.08	20.01	29.94
Initial leaf development	14	125.46	130.88	25.11	39.49
Vegetative growth I	22	205.7	235.73	42.18	64.44
Vegetative growth II	12	132.33	172.29	32.37	49.61
Pre-bulbing	9	192.16	239.42	37.08	57.55
Bulbing stage	12	201.64	242.31	39.44	60.91
Bulb filling	–	–	–	–	
Total / Average	**84**	**1099.98**	**1280.75**	**223.87**	**346.76**

Source: Own elaboration

4.2 ***Evaluation of the agronomic performance and yield of Chinese garlic under drip and micro-sprinkler irrigation systems***

The results of the Shapiro–Wilk test showed significance values higher than 0.05 for all evaluated variables, indicating that the data followed a normal distribution. Subsequently, Student's t-test revealed p-values greater than 0.05 for all analyzed variables, indicating that there were no statistically significant differences between drip and micro-sprinkler irrigation systems in vegetative growth and yield of Chinese garlic, as shown in Table 2.

Table 2.

Sources of variation	Treatments	Shapiro-Wilk		
		Statistic	df	Sig. 0.05
Plant height	T-1	0.893	3	0.363
	T-2	0.923	3	0.463
False stem diameter	T-1	0.987	3	0.780
	T-2	0.908	3	0.411
Leaf length	T-1	1.000	3	1.000
	T-2	0.855	3	0.253
Number of leaves	T-1	1.000	3	1.000
	T-2	0.750	3	0.980
	T-1	0.811	3	0.141

Normality tests	Bulb diameter	T-2	0.873	3	0.303

(Shapiro–Wilk) for agronomic parameters under T-1 and T-2
Source: Own elaboration

Regarding yield, the Shapiro–Wilk test showed significance values of 0.426 and 0.915 for treatments T-1 and T-2, respectively, indicating that the yield data followed a normal distribution ($p > 0.05$). Likewise, Levene's test indicated homogeneity of variances between treatments ($p = 0.742$). Under these conditions, Student's t-test was applied, obtaining a bilateral significance value of 0.970 ($p > 0.05$), which demonstrates that there were no statistically significant differences in garlic yield between the drip irrigation system and the micro-sprinkler irrigation system. Yields reached 14.70 t ha^{-1} under drip irrigation (T-1) and 14.83 t ha^{-1} under micro-sprinkler irrigation (T-2), showing very similar productive performance between the two irrigation methods. Therefore, both treatments exhibited comparable productivity during the 2021–2022 agricultural season, as shown in Table 3.

Table 3.
Student's t-test for yield of Chinese garlic (Allium sativum) in t ha^{-1} under T-1 and T-2

Variable	Treatment	Shapiro-Wilk (p-valor)	Levene's test (p-value)	t	df	Student's t-test (p-value)
Yield (t ha^{-1})	T-1	0.426	0.742	-0.04	6	0.97
	T-2	0.915				

Source: Own elaboration

5. DISCUSSION

The results showed that micro-sprinkler irrigation (T-2) required a greater water supply (771.06 mm), longer irrigation duration (1280.75 min), and higher applied water depth (346.76 mm) than drip irrigation (T-1), which required 647.67 mm, 1099.98 min, and 223.87 mm, respectively. During the crop cycle, cumulative precipitation reached 424.30 mm, and soil moisture remained above 70% of the total available water. Despite differences in water use, both irrigation systems achieved similar yields, with 14.70 t ha^{-1} for T-1 and 14.83 t ha^{-1} for T-2. These results indicate that drip irrigation achieved comparable productivity while using less water, demonstrating greater water-use efficiency.

These findings are consistent with those reported by **Fabeiro et al., Barrios et al., and Ayele et al.**, who highlighted that adequate irrigation management and maintaining favorable soil moisture conditions during critical growth stages are essential for optimizing garlic bulb development and yield. Similarly, the importance of maintaining continuous water availability in garlic production agrees with

Badawy et al., who reported that irrigation levels significantly influence garlic productivity and quality under different environmental conditions.

The differences observed compared with the results reported by **Soranj et al.,** may be attributed to variations in climatic conditions, soil characteristics, crop variety, irrigation management, and water application rates. In the present study, the combination of irrigation and seasonal precipitation maintained favorable soil moisture conditions throughout crop development, which may have contributed to the similar yields obtained under both irrigation systems. These results are also supported by **Léllis et al.,** who indicated that irrigation strategies adapted to crop water requirements can maintain garlic yield while improving water-use efficiency.

The practical implications of these findings suggest that drip irrigation is the most suitable irrigation system for Chinese garlic production under the conditions of this study. Although micro-sprinkler irrigation achieved a slightly higher yield, the difference was minimal (0.13 t ha^{-1}), while drip irrigation required less water and shorter irrigation times. Therefore, drip irrigation can improve water-use efficiency and contribute to sustainable garlic production, particularly in regions where water resources are limited. Similar conclusions were reported by **Akbar et al.,** Sivasakth et al., Mendoza et al., and **Ayele et al.,** who demonstrated that drip irrigation systems improve water productivity and maintain crop yield under conditions of limited water availability.

Limitations of this study include its evaluation during a single growing season, under specific environmental and soil conditions, and using only one garlic cultivar. Furthermore, the experiment was conducted at a single location, which may limit the extrapolation of the results to other production areas. Future studies should evaluate different climatic conditions, soil types, irrigation strategies, and garlic cultivars to validate these findings under a broader range of production environments.

6. Conclusions

This study evaluated the effect of drip and micro-sprinkler irrigation systems on the agronomic development and yield of Chinese garlic (*Allium sativum* L.) under high-Andean conditions in the community of Challapujo, Ilave, Puno. The results provide evidence that both irrigation systems are capable of maintaining suitable conditions for crop growth and production throughout the entire growing cycle, even under irregular rainfall conditions during the agricultural season.

Specifically, the results show, first, that the drip irrigation system required a lower amount of applied water during the crop cycle, with a cumulative irrigation depth of 223.87 mm, a total water supply of

647.67 mm, and a total operating time of 1099.98 minutes, achieving an average yield of 14.70 t ha^{-1}. Second, the micro-sprinkler irrigation system required a greater amount of water, with an irrigation depth of 346.76 mm, a total water supply of 771.06 mm, and a cumulative operating time of 1280.75 minutes, obtaining an average yield of 14.83 t ha^{-1}. Third, a cumulative rainfall of 424.30 mm was recorded during the crop cycle, which, together with irrigation management, maintained adequate soil moisture levels and favorable conditions for plant development throughout the different phenological stages. Finally, statistical analysis showed that there were no significant differences between irrigation systems in the agronomic variables evaluated or in Chinese garlic yield, indicating similar productive performance between both treatments.

These findings provide a scientific basis to demonstrate that the drip irrigation system can maintain productivity levels similar to those achieved with micro-sprinkler irrigation while using a lower amount of water. In practical terms, drip irrigation reduced the applied irrigation depth by approximately 35.4% and decreased the operating time of the irrigation system compared with micro-sprinkler irrigation, without significantly affecting crop yield. Therefore, its implementation represents an efficient alternative for optimizing water use, improving irrigation efficiency, and contributing to the sustainability of garlic production under the agroclimatic conditions of the Peruvian Altiplano.

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IMPACT OF PRODUCTION COSTS ON THE PROFITABILITY OF TROUT PRODUCTION BY TROUT FARMING COMPANIES IN THE POMATA DISTRICT ON 2025

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ABSTRACT

Trout farming companies in the district of Pomata, Puno, face difficulties in identifying their production costs and analyzing the profitability of their main economic activity. In addition, there is limited research addressing this topic. The main objective of this study was to determine the influence of production costs on the profitability of trout production in companies located in the district of Pomata.

This research was applied in nature, cross-sectional, and causal in scope, and employed a non-experimental research design because the variables were not manipulated during the study, data were collected over a single period, and the research sought to determine the cause-and-effect relationship between the variables. The population consisted of 26 trout farming companies in the district, while the sample comprised three companies selected through non-probability sampling based on inclusion and exclusion criteria.

Data were collected using semi-structured interviews, a documentary record sheet, and an observation guide. Data processing was carried out using Microsoft Excel, while hypothesis testing and the linear regression model were performed using SPSS statistical software.

The results revealed an average operating profit margin of 34.66% and an average profitability margin of 36.29%. Furthermore, production costs were found to have a direct influence on profitability, explaining 95.90% of its variation, indicating a very high level of influence.

Keywords: Production cost, Profitability, Trout farming, Profit.

INTRODUCTION

In recent years, aquaculture has become one of the fastest-growing productive activities in the global food sector due to its contribution to food security, employment generation, and the economic development of rural communities and companies engaged in this activity. According to the Food and Agriculture Organization of the United Nations (2024), aquaculture production represents a fundamental source of animal protein for an increasingly expanding global population, progressively surpassing capture fisheries as the main source of aquatic products. Within this sector, rainbow trout production (Oncorhynchus mykiss) stands out due to its commercial importance in the global market, its ability to adapt to different farming systems, and its high demand in national and international markets. (Food and Agriculture Organization of the United Nations - FAO, 2022)

Global trout production is mainly developed in countries with adequate water resources and favorable environmental conditions for intensive, semi-intensive, and low-intensity farming systems. In this context, the productive efficiency and economic profitability of aquaculture companies depend on several operational and administrative factors, including fingerling feeding, health management, production infrastructure, labor, and financial management capacity (Baltazar Guerrero, 2014). These elements represent a significant portion of production operating costs and determine the ability of companies to generate sustainable economic benefits, thereby contributing to local economies regardless of where fish farming enterprises operate.

In Latin America, aquaculture has experienced progressive expansion; however, it faces limitations related to technological availability, access to financing, business training, and efficient management of productive resources. According to Hermoza (Hermoza Negreiros, 2025), director of Mypes Unidas, 9 out of 10 micro and small enterprises cease operations during their first years of activity. Likewise, Escobar (2021) states that many small and medium-sized aquaculture companies face difficulties in determining their actual production costs due to the limited use of specialized accounting systems. This situation affects business planning and reduces producers' competitiveness, as they lack sufficient tools to meet the increasingly demanding quality standards of current markets. Similarly, Engle (2010) indicates that profitability in productive activities, particularly aquaculture, depends on the ability to control production costs and optimize resource utilization in order to achieve maximum production capacity.

In Peru, Dolores Salinas and Miret Pastor (2025) state that aquaculture represents a potential economic activity due to the availability of continental and marine water resources, not only along the coastal area but also in the highlands, where sufficient water resources such as lakes are available. The author

also highlights that among cultivated species, rainbow trout is one of the main aquaculture products, with production concentrated mainly in high Andean regions such as Puno. According to the Peruvian Ministry of Production (2024), trout production represents a significant proportion of national aquaculture production, with the Puno region being the country's leading producer due to its favorable natural conditions for this activity, with an estimated production of approximately 38,726 tons of trout in 2024.

The economic importance of trout production in the Puno region has enabled the development of numerous family-based and business-oriented production units. However, many of these producers face limitations related to administrative and financial management. In this regard, Jara (2019), Gilces-Zambrano and Mendoza-Vera (2025), Mamani and Cahuapaza (2021) and Cruz and Ladines (2024) analyzed the cost structure and profitability of trout production in Lake Titicaca. Their findings showed that trout feed constitutes the main component of total production costs, accounting for approximately 70% or more of total costs, representing a significant proportion of production expenses. Furthermore, they demonstrated that adequate management of productive resources contributes to improving profitability levels among producers and companies engaged in this activity.

The proper determination of production costs is a fundamental aspect of business management because it allows companies to identify the unit production cost, establish competitive market prices, and evaluate the economic efficiency of their operations. In accordance with Gonzales (2025), cost accounting provides relevant information for planning, control, and administrative decision-making, allowing the identification of factors that generate higher economic expenditures within the production process. In agricultural and aquaculture companies, this information becomes increasingly important due to the variability of costs associated with inputs, feed, energy, labor, and facility maintenance.

In the aquaculture sector, feed costs generally represent the most significant component of total production costs. According to Tacon and Metian (2008), feed may represent between 50% and more than 70% of production costs in intensive aquaculture systems due to the high price of balanced feeds and their direct influence on fish growth rates and feed conversion ratios. According to Yépez et al. (2023) , in artisanal trout production systems, expenditures on feed represent approximately 75% or more of total production costs. Therefore, poor management of this resource can considerably reduce business profit margins. Likewise, the second-largest cost incurred by producers is labor, which is essential for the care, management, and preservation of the production process.

Besides feed, other factors such as labor, infrastructure, health management, and mortality directly influence the profitability of trout production companies. According to Engle (2010) production cost

control in aquaculture companies must consider both direct and indirect costs because both determine the financial efficiency of the enterprise. The absence of adequate records makes it difficult to identify the actual expenditures on feed, labor, and other production inputs, which may lead to incorrect business decisions.

From a financial perspective, business profitability depends on the relationship between the income obtained and the costs required to generate such income. According to Amat (2008), profitability indicators allow companies to evaluate their ability to generate benefits through the efficient use of assets and economic resources. In productive activities such as aquaculture, reducing unnecessary costs and optimizing production processes represent strategies to improve financial performance.

Several studies have demonstrated that companies implementing adequate cost-control systems achieve higher levels of efficiency and competitiveness in productive activities such as livestock, agriculture, and aquaculture. Tobar et al. (2023) reported that information generated by cost systems enables organizations to identify improvement opportunities through decision-making, control budget deviations, and establish strategies aimed at business growth. Therefore, cost management should not be considered merely as an accounting process designed to comply with tax authority requirements, but rather as a strategic tool for organizational sustainability.

At the national level, Cacho Revilla et al. (2025) evaluated production costs and profitability in trout farming enterprises using floating cages in the Puno region. The study identified that the lack of adequate cost determination systems limits producers' ability to understand their actual profits, which may result in inappropriate decision-making. The research highlighted the need to strengthen administrative and accounting tools in trout farming companies to achieve better levels of business profitability.

Likewise, studies conducted in different productive contexts indicate that the economic efficiency of companies largely depends on the optimization of available resources. According to Guerrero, Vega and Romero (2025), cost reduction through improved cost allocation and control represents a determining factor for increasing profitability and competitiveness in aquaculture companies. Similarly, Benegas (2011), emphasizes that economic analysis allows the identification of the main factors affecting profitability and the establishment of more efficient management strategies suitable for companies.

In the district of Pomata, located in the province of Chucuito, Puno region, there are companies dedicated to trout farming that contribute to local economic development. However, these productive units face difficulties related to the accurate identification of their production costs, mainly due to the

absence of formal recording and financial control systems. In other words, companies do not adequately monitor the costs involved in the production process. This situation creates uncertainty regarding the actual production cost, affects pricing decisions, limits the evaluation of business profitability, and consequently hinders effective managerial decision-making.

The problem described above reveals a research gap because, although studies related to trout production in Puno exist, limited research has analyzed the influence of production costs on profitability in trout farming companies located in the district of Pomata. Therefore, it is necessary to generate evidence that allows understanding how cost structures and production processes influence the economic performance of companies and provide useful information to improve business management through better decision-making.

In this context, the present study aims to determine the influence of production costs on the profitability of trout production in fish farming companies located in the district of Pomata during the 2025 period.

METHODS

a) Research Design

This study adopted a quantitative approach with a non-experimental, cross-sectional, and causal research design. Its purpose was to determine the relationship between production costs and the profitability of trout production.

b) Population and Sample

The population consisted of 26 aquaculture companies located in the district of Pomata in Puno. The sample comprised three companies, selected through non-probability purposive sampling based on three inclusion criteria: (1) companies formally registered with the tax administration, (2) companies engaged exclusively in a single business activity, and (3) companies with more than ten years of market experience.

c) Instruments

Data were collected using an observation guide, a documentary record form, and a semi-structured interview. The observation guide was used to identify the trout production process, resource management practices, and activities related to trout farming, allowing the documentation and analysis of processes associated with production costs. The documentary record form was used to obtain

information from cost reports, expense records, accounting books, and financial statements. The semi-structured interview provided complementary information regarding cost management practices, expenditures, and factors influencing profitability.

d) Procedure

First, authorization was obtained from the aquaculture companies in the district of Pomata to access the financial and production information required for the study. The company representatives were informed about the objectives of the research, and the confidentiality of the information provided was guaranteed.

Subsequently, the observation guide was applied to identify and verify the activities involved in the trout production process, as well as the resources used during the stocking, rearing, grow-out, and harvesting stages.

Next, documentary data were collected from financial statements, cost sheets, accounting records, and other documents related to production costs and company profitability. The information obtained was organized and classified to calculate production costs, prepare the income statement, and determine financial profitability.

Then, semi-structured interviews were conducted with production workers to complement the documentary information and identify the practices employed in the determination and management of production costs.

e) Data analysis

Data were analyzed and entered into a database in Microsoft Excel and subsequently analyzed using SPSS version 26. Descriptive statistics were used to summarize the data. The Shapiro–Wilk normality test was performed to assess the distribution of the variables, and based on its results, Pearson's correlation coefficient was applied to test the research hypothesis. Statistical significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Results

The results indicated that the average production cost was S/ 901,595.29, and the operating profitability margin was 34.66%. Furthermore, the statistical analysis conducted for hypothesis testing revealed that the adjusted R-squared value was 0.959, indicating that the production cost variable

explains 95.90% of the variability in the profitability variable, demonstrating that the model is highly efficient.

TABLE 1

Production Cost

DIRECT COST	TITIKAKA	TROUTEX	AMERICAN	AVERAGE COST	%
Direct Material	806,986.55	559,655.43	656,293.52	674,311.83	74.79%
Direct Labor	21,899.67	88,562.45	103,378.28	137,946.80	15.30%
Indirect Production Cost	124,481.81	46,652.95	96,875.21	89,336.66	9.91%
Production Cost	**1,153,368.03**	**694,870.83**	**856,547.01**	**901,595.29**	**100.00%**

Source: Own elaboration

The results indicate that the average cost of direct materials, including fingerlings and balanced feed, was S/ 674,311.83, accounting for 74.79% of the total production cost. The average cost of direct labor, which includes personnel responsible for trout rearing, feeding, monitoring, and harvesting, was S/ 137,946.80, representing 15.30% of the total production cost. In addition, indirect production costs averaged S/ 89,336.66, corresponding to 9.91% of the total production cost.

TABLE 2

Income Statement

INCOME STATEMENT	TITIKAKA	TROUTEX	AMERICAN	AVERAGE
Sales	1,838,950.00	1,014,785.00	1,350,127.00	1,401,287.33
Production cost	1,153,368.03	694,870.83	856,547.01	901,595.29
Gross Profit	685,581.97	319,914.17	493,579.99	499,692.04
Bills	9,584.00	4,500.00	5,780.00	6,621.33
Operating Profit	675,997.97	315,414.17	487,799.99	493,070.71

Operating Profit Margin	36.76%	31.08%	36.13%	34.66%

Source: Own elaboration

In the income statement, the table indicate the data to determine the operating profit margin for the period for each company. Regarding the average operating profit amounts to S/ 493,070.71 and the average operating profit margin is 34.66%.

TABLE 3

Financial Profitability

FINANCIAL PROFITABILITY	TITIKAKA	TROUTEX	AMERICAN	AVERAGE
Net Profit	458,389.72	203,018.53	348,591.78	336,666.68
Investment (equity)	1,162,952.03	699,370.83	862,327.01	908,216.62
RETURN ON EQUITY	**39.42%**	**29.03%**	**40.42%**	**36.29%**

Source: Own elaboration

Table 3 presents the financial profitability of the companies analyzed. On average, net profit amounted to S/ 336,666.68 and the average of investment equity was S/ 908,216.62. The average return on equity was 36.29%. Among the companies evaluated, American Trout Faro showed the highest return on equity at 40.42%, followed by Titikaka Trout Peru with 39.42% and Troutex of Peru with 29.03%.

TABLE 4

Test of Normality

	Shapiro-Wilk		
	Statistic	gl	Sig
Direct Materials	.984	3	.760
Direct Labor	.832	3	.194
Indirect Production Costs	.973	3	.683
Production Cost	**.972**	**3**	**.678**
Bills	.924	3	.467
Operating Profit	**.999**	**3**	**.952**
Income	.989	3	.795

Total Production Cost	**.971**	**3**	**.676**
Profit Margin	.871	3	.298

Source: IBM SPSS

The Shapiro-Wilk normality test was performed because the study involved a sample size of less than 50; the results yielded a significance level (p-value) greater than 0.05 in all cases; therefore, the use of the Pearson correlation statistic is required.

TABLE 5

Hypothesis Testing

Model summary				
Model	R	R-squared	Adjusted R-squared	Standard error of the estimate
1	.990[a]	.980	.959	36411.75586

a. Predictors: (Constant), Production Cost

Source: IBM SPSS

The table presents the results of the Pearson correlation coefficient and the simple linear regression model used to analyze the relationship between the study variables. The results show a Pearson correlation coefficient (R) of 0.990, indicating a very strong positive relationship between production cost and profitability. Furthermore, the regression analysis reveals an adjusted R^2 of 0.959, meaning that 95.90% of the variation in profitability is explained by production cost, indicating a high level of fit and efficiency for the statistical model.

Discussion

The findings of this study suggest that production costs have a significant influence on the profitability of trout production in aquaculture companies located in the district of Pomata. This influence is particularly evident when companies effectively manage and control the elements of production costs, leading to greater operational efficiency and higher profitability.

These findings are consistent with previous studies by Hofmann, Cruz and Ladines, Jara, Puma, and Venegas, which indicate that efficient management and control of production cost elements improve the efficiency of trout production, thereby positively affecting the profitability and productivity of each company. These studies highlight the importance of cost control, financial planning, and the efficient use of resources as key factors in improving business profitability. The results have important

implications for business management, as they demonstrate that implementing a costing system and cost control mechanisms facilitates decision-making and promotes business growth.

However, this study has some limitations related to the small sample size and the limited availability of accounting information from some companies. Therefore, future research should include a larger number of companies and different production contexts to expand the evidence on this topic.

CONCLUSIONS

By analyzing the composition of production costs, it became evident that their proper allocation, distribution, and control directly influence the profitability of trout farming companies in the district of Pomata. It was also observed that a substantial proportion of production costs consists of expenditures on balanced feed and trout fingerlings, followed by labor costs and other operating expenses, highlighting the importance of each cost component for effective cost control. These findings demonstrate that profitability depends not only on sales volume but also on the efficient allocation, control, and management of productive resources throughout the entire production process.

Finally, the study concludes that the implementation of effective production cost management systems is essential to improve the profitability and long-term sustainability of trout farming companies. The evidence obtained confirms that the systematic identification of costs, accurate financial record-keeping, and continuous monitoring of production expenditures provide reliable information for managerial decision-making, resource optimization, and strategic planning. Consequently, strengthening accounting practices and production cost management should be considered a priority for trout farming companies seeking to enhance their competitiveness, maximize economic returns, and ensure sustainable growth in the aquaculture sector.

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PROSPECTIVE ENERGY GENERATION IN PHOTOVOLTAIC SYSTEMS, BASED ON THE COMPARISON AND EVALUATION OF DIFFERENT CONFIGURATIONS BASED ON ARTIFICIAL NEURAL NETWORKS (ANN)

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ABSTRACT

To ensure the long-term sustainability and stable integration of solar energy into power grids, photovoltaic systems heavily rely on accurate probabilistic forecasting of climatological variables that directly affect electrical power production. Among these variables, solar irradiation is the most critical parameter for managing energy generation and optimizing grid balance. This study aims to evaluate and compare the predictive performance of different Artificial Neural Network (ANN) configurations to forecast daily solar irradiation. Utilizing a 20-year meteorological dataset (2000–2020) validated by high-precision PLC data collection, correlation analysis identified ambient temperature and the insulation clearness index as the most significant inputs. Consequently, Gated Recurrent Unit (GRU) networks and three variants of Multi-Layer Perceptron (MLP) architectures—univariable, multivariable, and time-series with embeddings—were trained using 80% of the dataset and validated with the remaining 20%. The results showed that while the recurrent GRU network yielded the lowest error metrics (loss = 0.0935); (Val_loss = 0.0923), the multivariable MLP model demonstrated superior practical accuracy for daily forecasting. The multivariable MLP achieved a daily average prediction of 5.92 kW-hr/day against a real measured value of 5.88 kW-hr/day, representing an exceptional error margin of only 0.04 kW-hr/day. The findings suggest that multivariable MLP networks provide an optimal balance for solar energy management because they deliver highly reliable daily irradiation predictions while requiring substantially less training time than complex recurrent architectures.

Keywords: Energy prediction, photovoltaic generator, artificial neural networks, modelling, irradiation.

INTRODUCTION

In recent years, solar energy has emerged as the most significant contributor to global renewable energy generation, utilizing photovoltaic cells to directly convert incident solar radiation into electrical energy. As the integration of both autonomous and grid-connected large-scale photovoltaic systems accelerates, ensuring their long-term technical and economic sustainability has become a critical priority for modern electrical grids[1]. Because solar resource availability is inherently intermittent due to atmospheric conditions, probabilistic meteorological forecasting has become essential for system operators to anticipate generation capacity, balance demand, and maintain grid stability[5]. Among the variables influencing power production, solar irradiation is widely recognized as the primary factor dictating electrical output. Consequently, recent research has focused heavily on data-driven approaches, utilizing artificial neural networks (ANN) and machine learning frameworks to model meteorological parameters and predict solar availability[12,20,22]

However, despite the proliferation of predictive frameworks in the current literature, comprehensive evaluations comparing distinct network topologies under identical climatological datasets remain limited[4]. While several studies look at independent parameters, fewer works systematically evaluate the explicit trade-offs between standard feedforward structures—such as single-variable and multivariable Multi-Layer Perceptrons (MLP)—and specialized time-series architectures like Gated Recurrent Units (GRU). Furthermore, there is insufficient evidence assessing how the correlation of auxiliary local variables (such as ambient temperature and insolation clearness indices) impacts the operational balance between strict computational training ease and minimized predictive error bounds[2].

To address this gap, the present study evaluates and compares different configurations of artificial neural networks to optimize solar irradiation forecasting for photovoltaic management[3]. Specifically, this paper models and tests single-variable MLP, multivariable MLP, MLP with categorical embeddings, and recurrent GRU networks using a combination of long-term NASA historical databases and high-precision, real-time data collected via programmable logic controllers (PLCs) in the Peruvian Altiplano[4]. The primary objective is to determine which architectural configuration provides the highest predictive accuracy across different horizons[5]. The contribution of this research is twofold: first, it provides empirical evidence establishing that GRU recurrent networks yield the lowest generalized error metrics (MAE and loss below 0.1); second, it demonstrates that multivariable MLP models offer a highly practical, acceptable, and computationally efficient alternative for daily operational forecasting.

METHODOLOGY

This study adopted a quantitative, comparative, and predictive research design to evaluate prospective energy generation in photovoltaic systems through different artificial neural network configurations. The investigation focused on analyzing the mathematical correlation between climatological variables and solar irradiation to optimize forecasting models. The historical environmental data analysis encompassed a 21-year period spanning from 2000 to 2020. The structural framework was established to systematically contrast multi-layer perceptron networks against gated recurrent unit architectures under regional environmental conditions.

The population consisted of historical climatological and solar irradiance records generated between 2000 and 2020 in the Altiplano region. A sample of 46800 data points per day was selected using an automated logging system and preprocessed to eliminate measurement anomalies through data interpolation. For the network training phase, 80% of the validated dataset was selected using a stratified random division method. The remaining 20% of the dataset was strictly reserved for the subsequent validation and model testing procedures.

Data were collected using two 120W monocrystalline photovoltaic modules oriented at an inclination angle of 15° and connected to analog-to-current converters. The automated monitoring instrument was designed to measure real-time solar irradiance data at intervals of 1 second through a high-precision programmable logic controller. Complementary meteorological data were obtained using a automated weather station and the NASA Power Data Access Viewer platform. Calibration of the measurement array was performed using a portable MAC-SOLAR SLM018c-2 polarimeter combined with linear regression analysis.

RESULTS

This section presents the empirical findings obtained from the evaluation of different artificial neural network configurations for solar irradiation prediction. A correlation coefficient of 0.29 was observed between solar irradiation and ambient temperature. Additionally, a correlation of 0.66 was found regarding the insolation clearness index.

The performance metrics for all evaluated models are summarized in Table I. The Gated Recurrent Unit (GRU) network achieved the lowest training loss of 0.0935 and a validation loss of 0.0923. Regarding the Multilayer Perceptron (MLP) configurations, the multivariable model yielded a training loss of 0.1625 and a validation loss of 0.1703. Over a 365-day testing horizon, this multivariable MLP model demonstrated a daily average prediction of 5.92 kW-h/m²/day. This outcome represented an

absolute descriptive error of 0.04 kW-h/m²/day compared against the real measured baseline mean of 5.88 kW-h/m²/day. Overall, the findings reveal that architectural configurations directly influenced prediction precision metrics, Table N° 1.

Table I
Final Metric Values of the Utilized Neural Networks

Model	loss	val loss
Single-variable neural network	0.1583	0.1752
Multivariable neural network	0.1625	0.1703
Neural network embeddings	0.1878	0.1898
Neural network GRU	0.0935	0.0923

DISCUSSION

The implementation of diverse artificial neural network (ANN) architectures successfully predicted solar irradiance, a critical parameter directly linked to photovoltaic energy production. The identified correlations between solar irradiance, ambient temperature, and the insolations clearness index align with established solar engineering methodologies[7]. The predictive certainty and validation metrics match benchmarks set by prior studies, such as the multilayer perceptron models developed by Muhammad Ehsan et al. [22] and the real-time meteorological forecasting frameworks by Alomari et al. [23]

The generation of continuous, high-precision irradiance data serves as a high-utility asset for energy management strategies[9]. Integrating these models into grid-connected photovoltaic systems enables operators to optimize solar energy exploitation, anticipate output fluctuations, and effectively balance grid supply and demand.

Although the recurrent Gated Recurrent Unit (GRU) network minimized loss functions below 0.1 during validation, its performance was bound to processed historical data[11]. Future research must evaluate the deployment of these neural networks under changing real-world conditions, incorporating sky-image pattern recognition to account for dynamic cloud coverage and transient environmental factors.

CONCLUSION

This study aimed to compare and evaluate different configurations of artificial neural networks (ANNs)—specifically Multi-Layer Perceptron (MLP) and Gated Recurrent Unit (GRU) architectures—to optimize day-ahead solar irradiation forecasting for photovoltaic systems.

The findings provide robust evidence that while the recurrent GRU model achieves lower validation loss metrics (below 0.1), the multivariable MLP network produces the most accurate daily forecasting results. Over a 365-day testing period, the multivariable MLP achieved an average prediction of 5.92 kW-hr/day compared to the actual historical average of 5.88 kW-hr/day, yielding a minimal error of only 0.04 kW-hr/day. Furthermore, data correlation analysis confirmed that ambient temperature and the insolation clearness index are highly correlated variables that significantly improve prediction accuracy when integrated into the neural network inputs. Finally, if computational efficiency is prioritized, the MLP structure requires substantially less training time than the GRU alternative.

This research advances current knowledge by providing a systematic, comparative performance evaluation of time-series machine learning models utilizing real operational and climatological datasets. Practically, the study offers meaningful implications for grid operators and photovoltaic system managers, delivering a highly precise tool to anticipate energy fluctuations, balance load demand, and minimize overall production costs. Ultimately, these results demonstrate that optimized, data-driven forecasting models constitute an indispensable asset for accelerating sustainable engineering innovations and ensuring the long-term stability of renewable energy infrastructures.

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Evaluation of Highway Sight Distance on the Puno–Juliaca Highway (KM 5+200–KM 5+700), Patallani, 2024

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1. ABSTRACT

This study evaluates sight distance conditions on the Puno–Juliaca Highway along the section between KM 5+200 and KM 5+700 in the Patallani sector, Paucarcolla district, Puno. The analysis examines whether the available stopping, passing, and overtaking sight distances meet the requirements of the DG-2018 Highway Geometric Design Manual, taking into account roadway geometry, operating speeds, and traffic conditions. Data were obtained from traffic counts recorded at 15-minute intervals, field measurements of vehicle speeds, UAV-based topographic surveys, and digital cartographic information processed in AutoCAD Civil 3D, Google Earth, Excel, and Jamovi. A quantitative approach was used to integrate the geometric analysis of the road with the assessment of operating speeds and the statistical evaluation of visibility conditions. The average daily traffic volume was approximately 4,900 vehicles, of which 82.3% were light vehicles and 17.7% were heavy vehicles. The average operating speed was 87.4 km/h, while maximum speeds approached 105 km/h during peak periods. The visibility assessment showed that 71% of the study section met the minimum stopping sight distance requirement and 61% met the applicable passing sight distance standard. These results indicate that the interaction between roadway geometry and actual operating speeds may create visibility restrictions and increase crash risk. Road-safety measures and targeted geometric improvements are therefore recommended to provide safer and more consistent operating conditions along this section of the highway.

Keywords: Visibility, evaluation, speed, distance, accidents.

2. INTRODUCTION

This study adopted a quantitative, non-experimental, and applied research design aimed at evaluating the sight distance of the Puno–Juliaca Highway in accordance with the Geometric Design Standards for Highways (DG 2018).

The population consisted of the entire Puno–Juliaca Highway, while the sample corresponded to the section between KM 5+200 and KM 5+700, located in Patallani. This section presents geometric and topographic conditions that may influence the effective visibility available to drivers. The configuration of the terrain, the horizontal and vertical alignment of the roadway, and the presence of physical elements in the surrounding environment can restrict visibility and potentially compromise the safety conditions established by current technical standards.

Data were collected during fieldwork through topographic surveying, traffic counts, and vehicle speed measurements. The information obtained was used to evaluate the stopping, passing, and overtaking sight distances of the study section. The geometric characteristics of the roadway and its topography were also considered in order to represent the actual conditions of the highway and identify possible limitations in driver visibility. The study incorporated field information and digital processing as part of the evaluation of the geometric and operational characteristics of the road.

Sight distance is an important element of geometric road design because it determines the driver's ability to perceive obstacles in time, make appropriate decisions, and perform safe maneuvers while driving. Its evaluation makes it possible to identify deficiencies in road infrastructure that may increase the risk of traffic accidents. In this sense, sight distance is closely related to design speed and the physical conditions of the roadway environment, making it an important indicator for evaluating highway service and safety conditions. The use of geospatial tools and digital elevation models also facilitates the analysis of visibility and the identification of critical areas where road-user safety may be affected.

The relationship between sight distance and vehicle speed is particularly relevant because the actual speed at which drivers travel may differ from the speed considered in the geometric design of the roadway. The research identified a difference between the operating speed recorded under field conditions and the design speed established according to DG 2018. This situation is

important because drivers may exceed the speed for which the roadway was designed, increasing the risk associated with braking and overtaking maneuvers. Therefore, evaluating actual operating conditions is necessary to determine whether the available visibility provides adequate safety for road users.

Previous research has addressed sight distance as an important factor in the analysis of road safety. Angulo (2018) evaluated stopping sight distance on Avenida Boyaca´ in Colombia by considering operating-speed data, roadway geometric characteristics, and topographic information. The study used a Doppler radar to record operating speeds and developed a three-dimensional model to compare theoretical and experimental sight-distance conditions. Among its main findings, the research indicated that the analyzed roadway complied with parameters such as superelevation, curve radius, and design speed; however, the operating speeds recorded in the field were associated with an increase in the frequency and severity of accidents. The study recommended measures such as speed reduction and the implementation of acceleration and deceleration lanes in appropriate areas (Angulo, 2018).

Likewise, Asly (2019) analyzed and verified road safety with a particular focus on speed on the Condina–Pereira bypass in Risaralda, Colombia. This research is included among the international studies considered in the present work and contributes to understanding the importance of analyzing actual vehicle speeds when evaluating road safety conditions. The consideration of operating speed is relevant because driver behavior under real traffic conditions may differ from the parameters initially established in the geometric design of a highway (Asly, 2019).

Other studies have focused on the use of technological tools for evaluating roadway geometry. Arimuya and Beatriz (2022) studied the feasibility of geometric road design using a digital terrain model generated with InfraWorks and total-station information in San Ignacio, Cajamarca. Their work forms part of the research background supporting the use of digital terrain information in the geometric analysis of road infrastructure. These tools make it possible to represent terrain conditions and support the evaluation of geometric characteristics that may influence roadway performance (Arimuya & Beatriz, 2022).

At the national level, Cubas (2020) studied the effects of geometric design on road safety using the DG 2013 standard on the Cajamarca–Bambamarca highway, specifically between KM

1+000 and KM 5+000. This research is relevant to the present study because it relates geometric road design to safety conditions and evaluates the influence of roadway characteristics on the safe operation of vehicles. Its inclusion as a national reference provides a basis for analyzing the importance of verifying whether existing highway geometry meets the technical requirements associated with road safety (Cubas, 2020).

Similarly, Castro and Armando (2022) addressed the standardization of geometric road design through an analysis of standards from other South American countries, with the purpose of contributing to the updating of the Geometric Design Standards for Highways DG 2018. Their research highlights the relevance of reviewing and comparing geometric design criteria used in road infrastructure. This is closely related to the present study, which evaluates sight distance based on the technical criteria established by DG 2018 and considers the actual geometric and operational conditions of the Puno–Juliaca Highway (Castro & Armando, 2022).

Taken together, the studies reviewed in the research show that the evaluation of sight distance cannot be separated from roadway geometry, topographic conditions, and actual vehicle operation. Previous investigations have used operating-speed measurements, topographic surveys, digital terrain models, and geometric design standards to evaluate road safety from different perspectives (Angulo, 2018; Arimuya & Beatriz, 2022; Asly, 2019; Cubas, 2020; Castro & Armando, 2022). These contributions provide the technical basis for evaluating the conditions present on the Puno–Juliaca Highway using field information and the criteria established in current road-design standards.

In the specific case of the Puno–Juliaca Highway, the need for this evaluation is related to the road-safety conditions observed along the corridor. The research identifies an increase in the frequency of traffic accidents on the Juliaca–Puno Highway, which has generated human, economic, and social losses. Within this context, evaluating stopping, passing, and overtaking sight distances becomes important because drivers may operate at speeds that differ from those considered in the geometric design, potentially increasing the risk associated with braking and overtaking maneuvers.

The study is therefore justified by the need to verify compliance with the geometric design criteria established in current road regulations, particularly in relation to design speed and the operating speed observed under actual field conditions. A possible difference between these

variables may directly affect road safety. From a practical perspective, the information generated by the research can support decisions aimed at improving road infrastructure and implementing corrective measures to reduce the probability of traffic accidents. The study also has economic and social relevance because reducing accidents can help decrease costs associated with material damage and vehicle insurance while, most importantly, contributing to the preservation of human lives.

From an academic perspective, the research contributes updated information on the evaluation of sight distance on roads with high traffic levels and can serve as a reference for future studies in the fields of highway engineering and transportation safety. By evaluating the actual conditions of a specific section of the Puno–Juliaca Highway, the study seeks to provide technical evidence that can contribute to a better understanding of the relationship between roadway geometry, operating conditions, and driver visibility.

Therefore, the general objective of this study was to evaluate the sight distance of the Puno–Juliaca Highway between KM 5+200 and KM 5+700. Specifically, the research sought to determine the passing sight distance, overtaking sight distance, and stopping sight distance of the evaluated highway section. These objectives were established to assess the visibility conditions of the roadway and provide technical information related to the safe operation of vehicles in the study area.

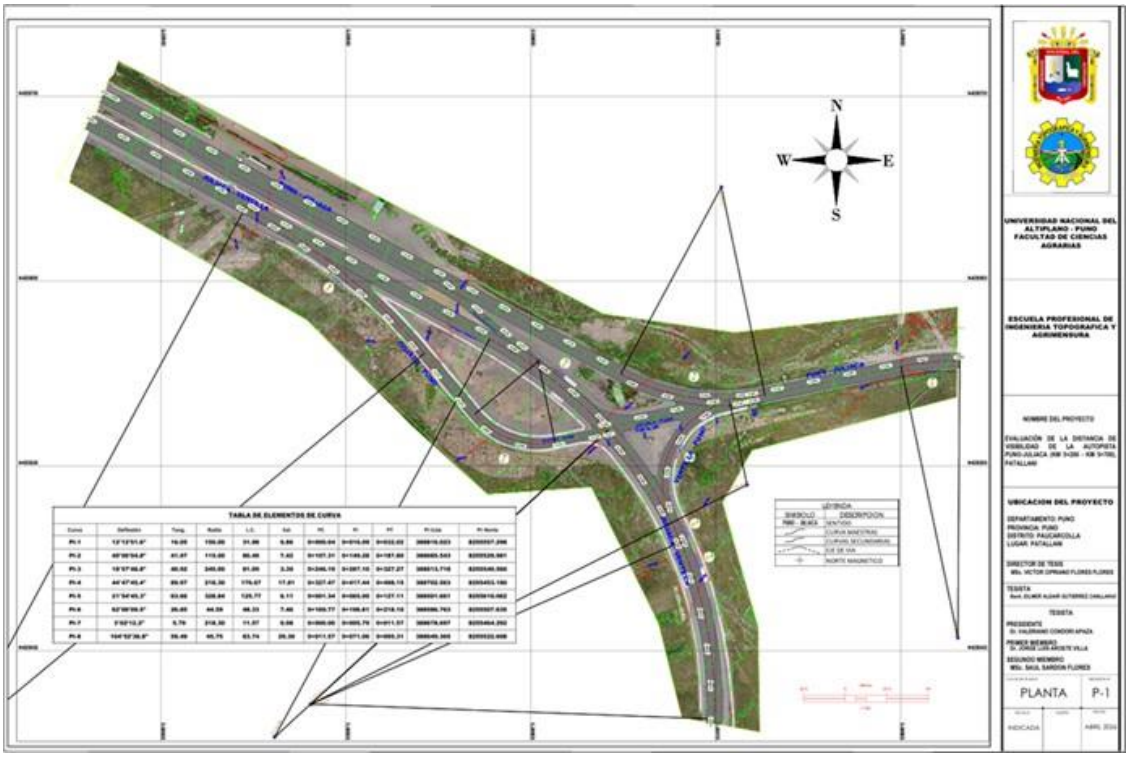
3. METHODOLOGY

3.1. STUDY AREA

The study was conducted on the Puno–Juliaca Highway, specifically along the section between KM 5+200 and KM 5+700, located in the Patallani sector, Puno Region, southern Peru. This highway is one of the main transportation corridors in the Peruvian Altiplano, connecting the cities of Puno and Juliaca. The study area is located at an altitude of approximately 3,850 m above sea level and is characterized by high traffic volumes and geometric features that influence road safety. The research focused on evaluating stopping, passing, and overtaking sight distances under actual operating conditions in accordance with the Geometric Design Standards for Highways (DG 2018).

Figure 1

Geographic location of the study area and plan view of the study section of the Puno–Juliaca Highway (KM 5+200–KM 5+700), Patallani.



Note. The figure shows the plan view of the evaluated highway section and its immediate surroundings. It provides a spatial reference for the geometric and topographic conditions considered in the sight distance assessment.

3.2. DATA SOURCES

Topographic and traffic data were collected through field surveys conducted on the study section. The datasets included drone photogrammetry, GNSS observations, traffic counts, and vehicle operating speed measurements. Additional technical information was obtained from the Geometric Design Standards for Highways (DG 2018) to evaluate the available sight distances.

Table 1

Datasets Used in the Study

Source	Dataset	Purpose
Field survey	Drone imagery	Topographic survey
Field survey	GNSS observations	Geodetic control
Field survey	Vehicle speed measurements	Operating speed analysis
Field survey	Traffic counts	Traffic demand analysis
MTC (DG 2018)	Highway geometric standards	Sight distance evaluation

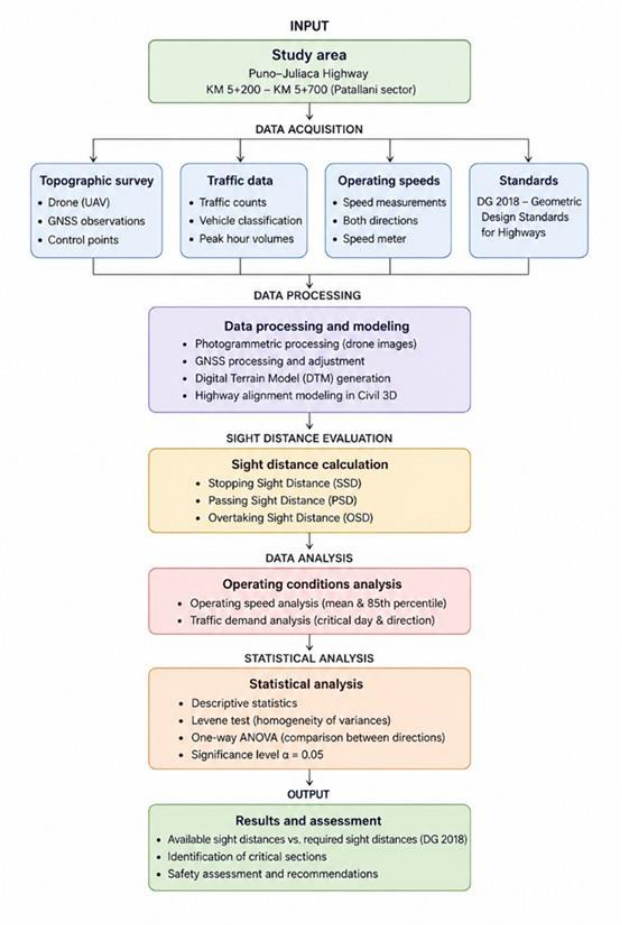
Note. The study combined field observations with the geometric criteria established in DG 2018. Each dataset supported a specific stage of the analysis, from terrain reconstruction and traffic characterization to the final evaluation of sight distance.

3.3. DATA PROCESSING

The collected data were processed using Civil 3D, Microsoft Excel, and Jamovi. Drone imagery and GNSS observations were used to generate the digital terrain model and reconstruct the highway alignment. Traffic counts and operating speed measurements were analyzed to determine representative operating conditions. Stopping, passing, and overtaking sight distances were then evaluated according to the requirements established in the Geometric Design Standards for Highways (DG 2018).

Figure 2

Methodological workflow for sight distance evaluation.



Note. The workflow summarizes the sequence followed in the study, beginning with field data collection and continuing through terrain modeling, sight distance calculations, operating-condition analysis, and statistical evaluation. The final stage integrates these results to identify critical sections and support road-safety recommendations.

3.4. STATISTICAL ANALYSIS

Operating speed and traffic count data were analyzed using descriptive statistical techniques. Differences between traffic corridors were evaluated using the Levene test and one-way ANOVA, considering a significance level of 0.05. Statistical analyses were performed using Jamovi and Microsoft Excel to assess operating speed characteristics and support the evaluation of highway sight distance.

4. RESULTS

The results showed significant differences in operating speeds between the two traffic corridors. Mean speed was 83.6 km/h from Ventilla to Juliaca and 68.2 km/h from Puno to Juliaca, producing estimated stopping sight distances of 153.65 m and 103.75 m, respectively. Friday recorded the highest traffic demand in both directions. The GNSS survey also identified geometric variations that influence the sight distance available for stopping, passing, and overtaking maneuvers.

Table 2

Global Operating Speeds by Corridor

Corridor	Mean Speed (km/h)	Minimum Speed (km/h)	Maximum Speed (km/h)	Standard Deviation (km/h)
Ventilla–Juliaca	83.6	60	120	14.8
Puno–Juliaca	68.2	38	115	17.6

Note. The Ventilla–Juliaca corridor recorded the highest mean operating speed (83.6 km/h), whereas the Puno–Juliaca corridor presented a lower mean speed (68.2 km/h). These differences indicate distinct traffic operating conditions between the two corridors and suggest that roadway geometry, traffic composition, and flow characteristics influence vehicle operating speeds.

Table 3

Design Speed and Stopping Sight Distance

Corridor	Design Speed (km/h)	85th Percentile Speed (km/h)	Stopping Sight Distance (m)
Ventilla–Juliaca	90	100	153.65
Puno–Juliaca	70	90	103.75

Note. The design speeds were established using the 85th percentile operating speed, which represents the prevailing traffic conditions. Consequently, the Ventilla–Juliaca corridor required a longer stopping sight distance (153.65 m) than the Puno–Juliaca corridor (103.75 m). These values provide the minimum safe distance required for drivers to perceive hazards and stop safely according to the DG 2018 standards.

Table 4

Critical Traflc Demand

Traffic Direction	Critical Day	Total Vehicles
Ventilla–Juliaca	Friday	1,942
Puno–Juliaca	Friday	6,184

Note. Traffic count analysis identified Friday as the day with the highest traffic demand. The Puno–Juliaca direction registered more than three times the traffic volume of the Ventilla–Juliaca direction, indicating greater traffic density and a higher potential for interactions between vehicles that may affect overtaking and sight distance conditions.

Table 5

Statistical Analysis of Operating Speeds

Statistical Test	Statistic	p-value	Interpretation
Levene test	4.82	0.031	Unequal variances
One-way ANOVA	18.76	< 0.001	Significant difference

Note. The Levene test indicated unequal variances between the two traffic corridors ($p = 0.031$), while the one-way ANOVA revealed statistically significant differences in operating speeds ($p < 0.001$). These findings confirm that traffic performance is not homogeneous between the evaluated corridors and that each direction exhibits distinct operational characteristics.

Table 6

GNSS Processing Results

Parameter	Result
GNSS Solution	Fixed (100%)
Horizontal Accuracy	±0.0035 m
Vertical Accuracy	±0.0058 m
Maximum Baseline Distance	272.26 m
Maximum Elevation Variation	±12.11 m

Note. GNSS processing achieved a 100% fixed solution with millimeter-level horizontal and vertical accuracy, demonstrating the reliability of the geodetic control network. The geometric variations identified through the topographic survey provided a precise representation of the roadway, supporting the evaluation of stopping, passing, and overtaking sight distances under actual field conditions.

5. DISCUSSION

The differences in operating speed between the Ventilla–Juliaca and Puno–Juliaca corridors led to distinct stopping sight distance requirements. The heavier demand observed in the Puno–Juliaca direction also suggests that traffic volume must be considered when interpreting whether drivers have enough space and time to complete maneuvers safely. At the same time, the accuracy obtained from the GNSS survey and drone photogrammetry supports the reliability of the geometric model used in the assessment. Together, these results show the value of examining roadway geometry and real traffic behavior as part of the same safety analysis.

These findings are consistent with Cubas (2020), who linked inadequate road geometry with reduced sight distance and greater safety risk. They also support the position of Castro and Armando (2022), who argued that geometric assessments are more reliable when they reflect actual operating conditions. This interpretation agrees with DG 2018, which treats speed as a central parameter in the determination of stopping, passing, and overtaking sight distances. The comparison with previous work therefore reinforces the need to evaluate existing roads using field speeds rather than relying only on nominal design values.

Combining drone photogrammetry, GNSS surveying, Civil 3D modeling, traffic counts, and statistical analysis made it possible to identify sections where geometric improvements may be needed. The resulting information can support practical decisions on road safety and geometric design. Nevertheless, the analysis covered only the section between KM 5+200 and KM 5+700 and reflects the traffic conditions observed during the field campaign. Further research should include longer highway sections, repeated measurements, and a wider range of traffic conditions to determine whether the same patterns occur elsewhere along the corridor.

6. CONCLUSIONS

The sight distance evaluation for the section between KM 5+200 and KM 5+700 was based on a high-precision geodetic model. GNSS processing achieved a 100% fixed solution, with average horizontal and vertical accuracies of ±0.0035 m and ±0.0058 m, respectively. This

precision provided a reliable geometric basis for analyzing visibility along the study section.

The horizontal geometry varied considerably, with baseline distances ranging from 56.75 m to 272.26 m. This variation suggests that passing sight distance may be restricted in some locations, especially on tighter curves where changes in alignment interrupt the driver's continuous field of view.

The FC07–FC08 and FC08–FC09 sections require particular attention because their curvature and alignment changes may limit the visibility needed for safe overtaking. These locations should be examined carefully to determine whether drivers have sufficient distance to begin and complete an overtaking maneuver without increasing their exposure to risk.

Altimetric variations of up to ±12.11 m were also identified. These changes in the longitudinal profile are especially relevant to stopping sight distance on pronounced grades, where both the visible roadway length and the distance required to stop must be considered. Overall, the study confirms that the geometry and topography of this highway section directly influence driver visibility. The results provide a technical basis for identifying locations where targeted road-safety improvements should be considered.

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PRIOR POSSESSION AND EVIDENCE IN AGGRAVATED USURPATION: ANALYSIS OF CASE FILE 04060-2019-PUNO

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ABSTRACT

This article examines the evidentiary treatment of prior possession in criminal proceedings for aggravated usurpation—understood in Peruvian law as the unlawful dispossession of real property—conducted in Puno, Peru, between 2019 and 2023. The objective was to determine whether the evidence concerning prior possession, identification of the property, dispossession, and attribution of co-perpetration supported the first-instance conviction or justified the acquittal on appeal. A qualitative, doctrinal legal approach was used, applying a single-case study design and documentary analysis of the procedural record described in Case File No. 04060-2019-7-2101-JR-PE-02, Peruvian criminal and criminal procedural legislation, and relevant case law. The findings reveal inconsistencies in the property's stated areas and names, insufficient corroboration of prior possessory acts, the absence of a robust evidentiary reconstruction of dispossession, and a generic attribution of each defendant's contribution. The victims' failure to become civil parties limited their additional procedural powers, but it could not remedy the prosecution's evidentiary deficiencies. The appellate acquittal was therefore more consistent with the presumption of innocence and the *in dubio pro reo* principle. As a contribution, the article proposes a minimum evidentiary matrix to guide the investigation of aggravated usurpation cases.

Key words: aggravated usurpation, co-perpetration, criminal evidence, dispossession, prior possession

INTRODUCTION

Aggravated usurpation is an offence against property regulated by Articles 202 and 204 of the Peruvian Criminal Code. Its distinctive feature is that criminal protection is not immediately directed at determining ownership of real estate; rather, it protects the factual exercise of possession against alteration of boundaries, dispossession, or disturbance carried out through legally defined means. This distinction is decisive: deeds and ownership disputes may explain the conflict, but they do not replace proof that the complainant possessed the property before the alleged event and was deprived of it under the conditions required by the offence (Congress of the Republic of Peru 1991; Abanto Vásquez 2013; Salinas Siccha 2015; Villavicencio Terreros 2014; Prado Saldarriaga 2017; Lascuraín Sánchez 2019).

Under Article 896 of the Peruvian Civil Code, possession is the factual exercise of one or more powers inherent in ownership. In criminal proceedings, this definition requires the identification of verifiable possessory acts, their temporal continuity, and their correspondence with the physical area allegedly usurped. A deed of transfer may constitute relevant circumstantial evidence, but it does not by itself establish material possession unless it is supported by evidence of occupation, use, custody, buildings, fences, payments, inspections, or other outward acts of control. Peruvian case law has reiterated that prior peaceful possession forms part of the factual premise that must be proven to sustain a conviction for dispossession (Congress of the Republic of Peru 1984; Cassation 1252-2021/Huaura; Constitutional Court of Peru 2024).

The evaluation of such evidence must respect the presumption of innocence. A criminal conviction cannot rest on the mere plausibility of the prosecution's account; it requires an evidentiary inference capable of overcoming reasonable alternative explanations. Relevant

doubt is not a judge's subjective hesitation. It arises when the evidence does not sufficiently justify all elements of the offence and the defendant's participation. Contemporary scholarship emphasises the need for explicit inferential links, rational standards of proof, and reasons capable of intersubjective control (Ferguson 2016; Sahuanay Calsín 2016; Picinali 2020; Roberts 2020; Allen 2021; Ferrer Beltrán 2021; Vera Sánchez 2021; Accatino 2023; Díaz 2024; Zaragoza-Rímac *et al.* 2025). This standard is particularly important in possession-related disputes, where conflicting deeds, overlapping occupations, poor boundaries, and testimony from persons connected to the parties frequently coexist.

Case File No. 04060-2019-7-2101-JR-PE-02 arose from events of 18 March 2019 concerning land described in different procedural documents as "Cuartel Pata," "Ccarccahuata Pata Estancia," or equivalent expressions, in Puno, Peru. The prosecution alleged that a large group entered the land through violence and that three defendants acted as co-perpetrators. The single-judge criminal court convicted them on 12 September 2022. The Criminal Appeals Chamber reversed that judgment and acquitted them on 23 March 2023, mainly because prior possession had not been established, the property had not been adequately identified, dispossession had not been sufficiently proven, and individual participation had not been clearly attributed (Case File No. 04060-2019-7-2101-JR-PE-02, 2019-2023).

The case reveals a recurring problem: a property or possession dispute may be transferred to criminal proceedings without first developing an evidentiary theory that distinguishes title from factual possession, defines the material object, and explains each defendant's specific contribution. It also permits analysis of procedural mechanisms such as civil-party status and preventive eviction with provisional restoration of possession. These mechanisms can strengthen victim protection, but they do not replace proof of the elements of the charge (Congress of the Republic of Peru 2004; Velásquez Oyola 2019).

The general objective was to determine whether the evidentiary treatment of prior possession, identification of the property, dispossession, and co-perpetration justified the first-instance conviction or the appellate acquittal. The specific objectives were to identify deficiencies in proving possession and the material object; evaluate the sufficiency of the allegation of co-perpetration; examine the consequences of the victims' procedural decisions; and formulate a minimum evidentiary matrix for future investigations.

METHODS

The study adopted a qualitative approach, an analytical scope, and a doctrinal legal single-case design. The unit of analysis was the criminal proceeding recorded as Case File No. 04060-2019-7-2101-JR-PE-02, litigated in the Judicial District of Puno between 2019 and 2023. The analysis was based on the procedural decisions, actions, and arguments described in the case file and systematised in the professional legal report that preceded this article (Case File No. 04060-2019-7-2101-JR-PE-02, 2019-2023; Rodríguez Sardón 2023).

Documentary analysis and legal hermeneutics were applied. The corpus included the complaint and reconstruction of facts; decisions issued during preliminary investigation, intermediate proceedings, trial, and appeal; the Criminal Code, Code of Criminal Procedure, and Civil Code; national precedents on prior possession, possessory remedies, civil-party status, the requirement of a specific accusation, and evidentiary assessment; and specialised literature on offence theory, evidence, and procedural guarantees (Flores Sagástegui 2016; San Martín Castro 2020).

The analysis was organised into five categories: (a) prior possession; (b) identification of the property; (c) dispossession and means of commission; (d) specific accusation and co-perpetration; and (e) the victim's procedural participation. A structured documentary analysis matrix served as the instrument. For each category, it recorded the prosecution proposition, the evidence described in the case, the assessment made by both judicial instances, and the applicable legal requirement. No statistical tests or software were used because the purpose was not to generalise frequencies but to assess the legal and rational correctness of the evidentiary inference in a single case.

Normative, case-law, and doctrinal triangulation was used as a rigor criterion. Established facts in the decisions, judicial inferences, and the author's critical assessments were distinguished. The principal limitation derives from the case-study design: the findings cannot estimate the national incidence of similar errors. They can, however, identify argumentative risks and propose replicable analytical criteria.

RESULTS AND DISCUSSION

Proof of prior possession

The prosecution linked the complainants' possession to a 2012 public deed of transfer, testimony concerning occupation, and the alleged existence of rooms built on the land. However, the documentary material described in the case did not establish precisely who exercised material possession, from what date, over which exact area, and through what outward acts. The deed involved several persons and referred to an area that did not consistently coincide with the measurements used in other procedural documents. It therefore did not answer the central question: who held factual possession immediately before the alleged dispossession.

This deficiency was substantive rather than formal. If prior possession is the premise that enables a third party's entry to be characterised as dispossession, its lack of corroboration prevents the objective elements of the offence from being established. Testimony may prove possessory acts, but its probative value increases when connected to georeferenced inspections, dated images, community records, productive activity, property-related payments, fences or buildings, and expert evidence placing those acts within the disputed area. Requiring corroboration does not turn the criminal case into an ownership action; it prevents a title from being treated as an automatic substitute for possession (Ledesma Narváez 2011; Cassation 1688-2018/Huánuco).

The Appeals Chamber identified this insufficiency and found no certainty concerning the complainants' possession. That conclusion is compatible with the presumption of innocence: when the prosecution fails to establish the possessory premise, the dispute may retain civil relevance, but it does not by itself justify criminal punishment.

Table 1. Evidentiary matrix for the analysed case

Dimension	Evidence described in the case	Assessment and minimum requirement
Prior possession	Deed of transfer, testimony, and references to built rooms.	Insufficient without corroborated possessory acts, temporal continuity, and precise location.

Dimension	Evidence described in the case	Assessment and minimum requirement
Identification	Different names and areas: 34,500.00 m²; 25,463.00 m²; 8,259.99 m².	Requires a plan, coordinates, topographic evidence, and correspondence with each item of evidence.
Dispossession and violence	Complaint, testimony, group entry, destruction, and later fencing.	The before-and-after condition must be reconstructed and linked to the area and defendants.
Co-perpetration	Collective attribution to three defendants in a larger group.	Requires a common plan, divided functions, an essential contribution, and individualised evidence.
Victim participation	No civil-party application or effective request for provisional restoration.	Limits powers; does not replace the prosecution's burden of proof.

Identification of the property and proof of dispossession

The case used different names for the land and referred to areas of approximately 34,500.00 m², 25,463.00 m², and 8,259.99 m², depending on the document or procedural act. These discrepancies prevented the court from determining whether all evidence concerned the same space, whether the alleged dispossession was total or partial, and whether the destroyed structures were located within the area attributed to the complainants. Identification of the property is not a mere registry detail; it defines the material object of the offence and permits verification of the relationship between alleged possession, the reported entry, and subsequent occupation.

A technically adequate investigation should have combined a georeferenced inspection, perimeter plan, coordinates, cadastral comparison, and topographic expert report. It should also have reconstructed the condition of the land before and after 18 March 2019. Without that connection, the later presence of persons, machinery, or fences does not necessarily prove that the defendants dispossessed the prior possessors of the specific area. The absence of a chain of corroboration weakened both proof of dispossession and the attribution of violence.

The first-instance judgment treated several items of circumstantial evidence cumulatively but did not sufficiently explain how they excluded alternative hypotheses, including a pre-existing possession dispute or the occupation of different areas. The appellate judgment gave weight to the spatial inconsistencies and concluded that the object of dispossession had not been established with the degree of certainty required for conviction. This second assessment is more consistent with a rational conception of proof, which requires the link between data, inference, and conclusion to be made explicit and the evidentiary chain to remain traceable (Sahuanay Calsín 2016; Simón Castellano 2021; Vera Sánchez 2021; Accatino 2023; Aguilar Cabrera 2024; Valdez Marrou 2025).

Specific accusation and co-perpetration

The prosecution attributed co-perpetration to three individuals within a collective intervention. However, the existence of several participants does not by itself prove that each defendant executed the core conduct or made an essential contribution pursuant to a common plan. The accusation needed to specify who coordinated the entry, who used violence or threats, who

ordered the destruction of structures, who assumed control of the property, and what evidence connected each defendant to those actions.

The requirement of a specific accusation serves both a guarantee function and an evidentiary function: it defines the conduct that must be contested and prevents individual responsibility from dissolving into a group description. In the case examined, the factual propositions concerning division of roles, functional control, unity of decision, and essential contribution were not sufficiently differentiated. This affected the defence and prevented an individual inference of guilt from being constructed (Binder 1993; Márquez Cárdenas 2007; Recurso de Nulidad 956-2011/Ucayali; Casación 247-2018/Áncash; Quintero Olivares 2018; San Martín Castro 2020).

The aggravating circumstance of participation by two or more persons does not cure this defect. The basic offence and each defendant's participation must first be established; only then can the aggravating circumstance be assessed. Treating mere presence or association with other occupants as co-perpetration would amount to objective liability, which is incompatible with an act-based system of criminal responsibility.

Procedural decisions of the complainants

The complainants did not timely seek recognition as civil parties. This omission limited the additional powers available to participate in evidentiary activity and directly pursue compensation. It is not technically accurate, however, to state that the omission automatically violated their right of defence. Victims retain basic procedural rights, while the Public Prosecutor continues to conduct the criminal action. The more precise consequence is that the injured parties had less procedural influence, particularly regarding the proposal of investigative measures, contestation of compensation, and broader participation under Articles 101 and 104 of the Code of Criminal Procedure (Congress of the Republic of Peru 2004; Supreme Court Plenary Agreement 04-2019/CIJ-116; Cassation 482-2022/Puno; Huerta Molina 2024).

Preventive eviction and provisional restoration of possession could also have been requested during preliminary proceedings or the preparatory investigation. The relevant provision is Article 311 of the Code of Criminal Procedure, not Article 310, which governs orders restricting the disposal of property. The measure required reasonable grounds concerning the offence and sufficient proof of the injured party's right. Its availability therefore depended on resolving the very problems of possession and identification found in the case. The measure could have provided provisional protection, but it could not anticipate a conclusion that the evidence did not yet support (Congress of the Republic of Peru 2004; Velásquez Oyola 2019).

The defence could have requested judicial control of the investigation period if the prosecution sought an extension after the statutory period had expired. This matter concerns procedural regularity and reasonable duration, but it does not determine whether the offence occurred. Procedural defects affecting guarantees should be distinguished from substantive and evidentiary deficiencies that preclude conviction.

Table 2. Consequences of the main procedural decisions

Procedural act	Legal function	Effect in the case
Civil-party status	Expands powers to participate and pursue the civil claim.	Its omission reduced the complainants' participation; it neither invalidated proceedings nor proved the offence.
Preventive eviction and provisional restoration	Provisional protection where reasonable grounds and a sufficiently proven right exist.	It depended on proving possession and defining the land; Article 311 was the relevant provision.
Judicial control of time limits	Prevents unjustified extension of the investigation.	It could challenge an untimely extension but could not resolve the elements or sufficiency of proof.
Possessory recovery action	Civil protection of factual possession against dispossession.	A relevant alternative where the conflict does not satisfy the threshold for criminal intervention.

Comparative assessment of the judicial decisions

The first-instance judgment began with a plausible prosecution hypothesis but did not sufficiently justify the transition from the available indications to findings of prior possession, dispossession, and individual participation. The appellate judgment recognised that the doubts concerned structural elements of the offence rather than secondary details. The acquittal did not demand impossible absolute certainty; it reflected the absence of evidence sufficient to meet the conviction threshold.

The *in dubio pro reo* principle applies when, after rational evaluation of the evidence, relevant doubt remains concerning responsibility. It is consistent with the presumption of innocence and the allocation of the burden of proof: the prosecution must prove the offence and the defendant's participation, while the defendant is not required to establish a complete alternative account in order to be acquitted (Organization of American States 1969; Ferguson 2016; Picinali 2020; Roberts 2020; Allen 2021; Ferrer Beltrán 2021; Pineda 2021; Díaz 2024; Zaragoza-Rímac *et al.* 2025; Zuluaga Taborda 2025).

The criminal acquittal does not finally determine ownership claims or exclude civil remedies. Where the core controversy concerns factual possession and dispossession, a possessory recovery action may be appropriate if its statutory requirements are met (Ledesma Narváez 2011; Cassation 1688-2018/Huánuco). The subsidiary character of criminal law requires courts to avoid using criminal proceedings as a substitute for unresolved civil or cadastral delimitation (Prado Saldarriaga 2017; Lascuraín Sánchez 2019).

Proposed minimum evidentiary matrix

Based on the identified deficiencies, prosecutors and parties should organise an initial matrix connecting each legal element to a factual proposition, a source of evidence, and a corroboration criterion. The matrix does not replace judicial assessment; it prevents

fragmented investigations and permits early detection of gaps that may be impossible to remedy at trial.

The proposal contains six minimum dimensions: prior possession; spatial identification; the act of dispossession or disturbance; the means of commission; individual participation and possible co-perpetration; and continuity between the prior condition and subsequent occupation. Each dimension should be supported by convergent evidence, preferably from different types of sources. This method improves the traceability of the accusation and reduces the risk of confusing ownership, possession, and criminal responsibility.

CONCLUSIONS

1. The first-instance conviction was not sufficiently supported because the prosecution did not establish material possession immediately before the event through convergent evidence. The deed of transfer was relevant circumstantial evidence, but it did not replace proof of specific and continuous possessory acts.

2. Differences in the property's name and area prevented certain identification of the material object and determination of whether the alleged dispossession was total or partial. This deficiency also affected the assessment of testimony, structures, fences, and subsequent occupation.

3. Co-perpetration was alleged generically. The common plan, division of functions, and essential contribution of each defendant were not sufficiently specified. Participation by several persons as an aggravating circumstance cannot create a presumption of individual responsibility.

4. Failure to become civil parties limited the complainants' procedural powers, but it did not automatically produce a denial of defence and could not repair the prosecution's evidentiary deficiencies. Preventive eviction and provisional restoration were available under Article 311 of the Code of Criminal Procedure only if reasonable grounds for the offence and the claimed right were established.

5. The appellate acquittal was more consistent with the presumption of innocence and the in dubio pro reo principle because the doubts concerned essential elements of the offence and the defendants' participation.

6. The proposed minimum matrix is the study's main practical contribution. It requires each element of aggravated usurpation to be connected to verifiable and corroborated evidence, promoting more precise investigations and better-reasoned judicial decisions.

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CONFLICT OF INTEREST

Ronaldo Aldair Rodríguez Sardón (RARS) declares no conflict of interest related to the research, preparation, or publication of this article.

AUTHOR CONTRIBUTION

Ronaldo Aldair Rodríguez Sardón (RARS) performed the conceptualisation, documentary review, legal analysis, drafting, preparation of the English version, and final review of the manuscript.

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Job Stress and Individual Work Performance in the Regional Directorate of Foreign Trade and Tourism of Puno during the COVID-19 Pandemic, 2021

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ABSTRACT

This study aimed to determine the relationship between job stress and individual work performance among the administrative personnel of the Regional Directorate of Foreign Trade and Tourism of Puno (DIRCETUR Puno) during the COVID-19 pandemic in 2021. A quantitative, cross-sectional, descriptive-correlational, and non-experimental design was adopted. Data were collected through standardized questionnaires administered to administrative employees, and the results were analyzed using Spearman's rank correlation coefficient.

The findings revealed a statistically significant negative relationship between job stress and individual work performance (ρ = -0.761), indicating that higher levels of occupational stress were associated with lower work performance. Likewise, workload showed a significant negative relationship with individual work performance (ρ = -0.781), while job stress was negatively associated with contextual performance (ρ = -0.751). Additionally, 80% of the employees reported experiencing high levels of job stress during the study period.

The study concludes that occupational stress significantly reduced the individual work performance of DIRCETUR Puno employees during the COVID-19 pandemic. These findings highlight the importance of implementing organizational strategies aimed at reducing occupational stress and promoting employee well-being to improve institutional performance.

***Keywords*:** job stress, workload, individual work performance, contextual performance, COVID-19.

INTRODUCTION

The COVID-19 pandemic significantly affected public institutions worldwide by disrupting organizational processes, increasing workload, and altering working

conditions. In Peru, public employees faced major challenges associated with remote work, technological adaptation, and increased occupational demands, all of which contributed to higher levels of job stress and reduced work performance.

Within the tourism sector, the suspension of tourism activities and the implementation of health restrictions considerably affected institutional operations, particularly in regional public organizations responsible for tourism management. In the Puno region, the Regional Directorate of Foreign Trade and Tourism (DIRCETUR Puno) experienced operational limitations due to workforce shortages, changes in work modalities, and increased administrative responsibilities during the COVID-19 pandemic.

Although previous studies have examined the relationship between occupational stress and work performance in different organizational settings, limited evidence is available regarding public institutions in the tourism sector during the COVID-19 pandemic. This research addresses that gap by analyzing the relationship between job stress and individual work performance among the administrative personnel of DIRCETUR Puno.

MATERIALS AND METHODS

Population

The study population consisted of public employees working at the Regional Directorate of Foreign Trade and Tourism of Puno (DIRCETUR Puno). According to the Position Classification System established by the Ministry of Economy and Finance (MEF), the institution comprised thirty-three (33) authorized positions distributed across five organizational units and the Regional Directorate.

However, as of December 2021, only nineteen (19) positions were effectively occupied. These employees were distributed among the Regional Directorate, the Administrative Technical Office, the Directorate of Tourism, the Directorate of Foreign Trade, the Directorate of Handicrafts, and the Juliaca Zonal Directorate.

Table 1

Current Staff of DIRCETUR Puno

AREA	POSITIONS	QUANTITY TOTAL
Regional Directorate	01 Regional Director 01 Secretary 01 Driver	03
Technical and	01 Administrator	

Administrative Office	01 Procurement 01 Treasury 01 Planning 01 Security	05
Tourism Directorate	01 Director 02 Technicians	03
Foreign Trade Directorate	01 Director 01 Professional	02
Handicrafts Directorate	01 Director 02 Technicians	03
Juliaca Zonal Directorate	01 Director 01 Foreign Trade 01 Security	03
TOTAL		19

Source: MOF DIRCETUR PUNO (2006) - Prepared by the author

Sample

A non-probability convenience sampling technique was employed (Cohen & Gómez, 2019; Hernández-Sampieri & Mendoza, 2018). The final sample consisted of ten (10) public employees who were actively working at DIRCETUR Puno during the COVID-19 health emergency, either through face-to-face or remote work modalities.

Given the cross-sectional nature of the research, one employee was selected from each organizational unit. In contrast, all personnel assigned to the Administrative Technical Office were included because this office concentrates the institution's administrative procedures and assumes the highest operational workload within DIRCETUR Puno.

Table 2

List of Sample Employees

AREA	POSITIONS	PARTICIPANTS	QUANTITY TOTAL
Regional Directorate	01 Driver	Participant 1	01
Technical and Administrative Office	01 Administrator 01 Procurement 01 Treasury 01 Planning	Participant 2 Participant 3 Participant 4 Participant 5	05

	01 Security	Participant 6	
Tourism Directorate	01 Technicians	Participant 7	01
Foreign Trade Directorate	01 Director	Participant 8	01
Handicrafts Directorate	01 Technicians	Participant 9	01
Juliaca Zonal Directorate	01 Director	Participant 10	01
TOTAL			10

Source: CAP DIRCETUR PUNO (2006)- Prepared by the author

Research Methodology

The study adopted a quantitative approach, applying the deductive scientific method, whereby the research progressed logically from general theoretical principles toward the analysis of specific empirical evidence to answer the research questions (Hernández-Sampieri, Fernández, & Baptista, 2014; López & Fachelli, 2015).

Furthermore, the study employed a non-experimental cross-sectional design, since the variables were observed in their natural context without experimental intervention, and data were collected at a single point in time.

Data Collection Techniques

Data were collected using the survey technique, applying structured questionnaires based on a five-point Likert scale. Data were collected using structured questionnaires based on a five-point Likert scale.

Two standardized instruments were employed:

Job Stress

Occupational stress was assessed using the New Job Stress Scale, developed by Leite et al. (2019). This instrument evaluates several dimensions of occupational stress, including:

- Workload (excessive work demands)
- Role expectations
- Role conflict
- Work-life balance

- Coworker support

These dimensions provide a comprehensive assessment of employees' perceptions of occupational stress within their work environment.

Individual Work Performance

Individual work performance was measured using the Individual Work Performance Scale developed by Koopmans et al. (2013). This instrument evaluates three major dimensions:

- Task Performance, referring to the effectiveness with which employees perform their assigned duties.
- Contextual Performance, which includes voluntary behaviors that contribute positively to organizational functioning.
- Counterproductive Work Behaviors, encompassing actions that may negatively affect organizational performance or interpersonal relationships.

Reliability of the Instruments

The reliability of both research instruments was evaluated using Cronbach's Alpha coefficient (α).

The obtained reliability coefficients indicated high internal consistency, confirming that both instruments were appropriate for measuring the study variables and ensuring the reliability of the collected data.

Statistical Analysis

Descriptive statistics were first calculated to summarize the characteristics of the study variables.

Subsequently, inferential statistical analyses were conducted using Spearman's Rank Correlation Coefficient (ρ) to determine the strength and direction of the relationship between job stress and individual work performance. Spearman's correlation was selected because both variables were measured using ordinal scales derived from Likert-type questionnaires.

Hypothesis testing was performed using a 5% significance level ($\alpha = 0.05$). Correlation coefficients and corresponding p-values were interpreted to determine the statistical significance of the relationships among the study variables.

All statistical analyses were performed using IBM SPSS Statistics Version 25 (Academic Edition).

Ethical considerations

Participation in the study was voluntary, and informed consent was obtained from all participants. The confidentiality and anonymity of the respondents were guaranteed throughout the research process, and the study complied with ethical principles for research involving human participants.

RESULTS

RELATIONSHIP BETWEEN WORKLOAD AND INDIVIDUAL WORK PERFORMANCE AMONG THE ADMINISTRATIVE STAFF OF DIRCETUR PUNO DURING THE COVID-19 PANDEMIC

Table 3

Rho de Spearman		Workload	Individual Job Performance
Workload	Correlation coefficient	1.000	-.781*
	Sig. (bilateral)		.013
	N	10	10
Individual Job Performance	Correlation coefficient	-.781*	1.000
	Sig. (bilateral)	.013	
	N	10	10

* Correlation is significant at the 0.05 level (bilateral).

Source: Author's own elaboration.

Table 3 presents the analysis of the relationship between workload and individual work performance among the administrative personnel of DIRCETUR Puno during the COVID-19 pandemic.

The findings reveal a statistically significant negative relationship between workload and individual work performance, with a Spearman's rank correlation coefficient of $\rho = -0.781$ and a p-value of 0.013. These results indicate that as employees' workload increases, their individual work performance tends to decrease.

Consequently, excessive workload reduces employees' effectiveness in performing their assigned duties and increases their exposure to psychosocial risks within the workplace.

Since the obtained p-value (0.013) is lower than the significance level (0.05), the null hypothesis is rejected, and the alternative hypothesis is accepted.

Therefore, the study confirms a statistically significant relationship between workload and individual work performance.

ANALYSIS OF THE RELATIONSHIP BETWEEN WORK STRESS AND PERFORMANCE IN THE CONTEXT OF THE ADMINISTRATIVE STAFF OF DIRCETUR PUNO IN TIMES OF COVID-19.

Table 4

Correlation Between Work Stress and Performance in Context

Rho de Spearman		Work-Related Stress	Performance in Context
Work-Related Stress	Correlation coefficient	1.000	-.751*
	Sig. (bilateral)		.018
	N	10	10
Performance in Context	Correlation coefficient	-.751*	1.000
	Sig. (bilateral)	.018	
	N	10	10

* Correlation is significant at the 0.05 level (bilateral).

Source: Author's own elaboration.

Table 4 summarizes the relationship between job stress and contextual performance among the administrative personnel of DIRCETUR Puno during the COVID-19 pandemic.

The results demonstrate a significant negative association between the two variables ($\rho = -0.751$, $p = 0.018$).

This finding indicates that increasing levels of occupational stress are associated with lower contextual performance among employees.

Specifically, elevated job stress negatively affects work planning, organizational participation, teamwork, and the willingness to perform activities beyond formal job responsibilities. Moreover, employees experiencing high stress levels are more likely to exhibit counterproductive work behaviors, reduced problem-solving capacity, and lower levels of workplace assertiveness.

Because the obtained p-value (0.018) is lower than 0.05, the alternative hypothesis is accepted, confirming a statistically significant negative relationship between job stress and contextual performance.

DETERMINATION OF JOB STRESS LEVELS AMONG THE ADMINISTRATIVE PERSONNEL OF DIRCETUR PUNO DURING THE COVID-19 PANDEMIC

Table 5

Perceptions of Work-Related Stress Levels at DIRCETUR Puno During the COVID-19 Pandemic

		f	%
Work-Related Stress	Low stress	1	10.00
	Moderate stress	1	10.00
	High stress	8	80.00
	Total	10	100 %

Source: Compiled by the author.

Table 5 presents employees' perceptions regarding their level of occupational stress during the COVID-19 pandemic.

The results indicate that:

- 80% of employees experienced high levels of job stress.
- 10% reported moderate job stress.
- 10% reported low job stress.

These findings demonstrate that occupational stress constituted a significant problem within DIRCETUR Puno during the study period, as the vast majority of employees reported experiencing high stress levels.

Based on the descriptive results presented in Table 5, the null hypothesis is rejected, confirming that occupational stress represented a significant condition affecting the administrative personnel of DIRCETUR Puno during the COVID-19 health emergency.

RELATIONSHIP BETWEEN JOB STRESS AND INDIVIDUAL WORK PERFORMANCE

Table 6

Correlation Between Work-Related Stress and Individual Job Performance at DIRCETUR Puno

Rho de Spearman		Work-Related Stress	Individual Job Performance
Work-Related Stress	Correlation coefficient	1	-.761*
	Sig. (bilateral)		0.038
	N	10	10
Individual Job Performance	Correlation coefficient	-.761*	1
	Sig. (bilateral)	0.038	
	N	10	10

*. The correlation is significant at the 0.05 level (two-tailed).

Source: Compiled by the author.

Table 6 presents the correlation analysis between job stress and individual work performance among the administrative personnel of DIRCETUR Puno during the COVID-19 pandemic.

A statistically significant negative correlation was found ($\rho = -0.761$; $p < 0.05$).

Accordingly, the results demonstrate that employees who experience higher levels of occupational stress tend to exhibit lower levels of individual work performance.

This negative relationship suggests that occupational stress substantially reduces employees' ability to perform their assigned responsibilities efficiently and effectively, thereby negatively affecting overall organizational performance.

DISCUSSION

This study confirms that job stress is negatively associated with individual work performance among the administrative personnel of DIRCETUR Puno during the COVID-19 pandemic. These findings are consistent with previous studies reporting that increased occupational stress reduces employees' effectiveness, productivity, and overall organizational performance (Ching, 2019; Egoavil & Mamani, 2013; Isla, 2016). Likewise, Pachari et al. (2020) emphasized that occupational stress during the COVID-

19 health emergency negatively affected employees' performance and organizational efficiency.

The inverse relationship identified between workload and individual work performance also agrees with previous evidence. Fernández (2010) and Usma (2020) reported that increased workload and the organizational changes imposed during the pandemic intensified occupational stress and negatively influenced employees' physical and psychological well-being, ultimately reducing work performance. These findings reinforce the importance of implementing organizational strategies that balance workload and minimize psychosocial risks in the workplace.

Similarly, the negative association between job stress and contextual performance supports the conclusions of Durán (2010) and Huacho and Núñez (2019), who found that occupational stress adversely affects employees' participation, collaboration, and organizational commitment. Reduced contextual performance may limit teamwork, problem-solving capacity, and employees' willingness to contribute beyond their formal job responsibilities.

The high prevalence of occupational stress observed among the participants is also consistent with previous research conducted in public organizations. Ticona (2017) and Achahuanco and Fuentes (2019) reported that technological changes, organizational demands, and adaptation to new working conditions increase occupational stress and negatively affect employees' performance. In the present study, these circumstances were intensified by the COVID-19 pandemic, which required rapid adaptation to remote work and digital technologies.

Overall, the findings contribute to the growing body of evidence indicating that occupational stress represents an important organizational challenge capable of reducing individual work performance and organizational effectiveness. Therefore, public institutions should prioritize preventive interventions aimed at reducing occupational stress through workload management, psychosocial support, continuous training, and the promotion of healthy work environments.

CONCLUSIONS

The findings of this study demonstrate that job stress is significantly and negatively associated with individual work performance among the administrative personnel of DIRCETUR Puno during the COVID-19 pandemic. Increased occupational stress and workload were associated with lower levels of individual and contextual performance, indicating that psychosocial work demands can adversely affect employees' effectiveness and organizational functioning.

Furthermore, the high prevalence of occupational stress observed among the participants highlights the need for public institutions to implement preventive strategies aimed at improving employees' well-being. Organizational interventions focused on workload management, psychosocial support, continuous training, and healthy work environments may contribute to reducing occupational stress and enhancing individual work performance, particularly in contexts characterized by organizational change and public health emergencies.

RECOMMENDATIONS

Public institutions should implement organizational strategies aimed at reducing occupational stress by promoting balanced workloads, psychosocial support, continuous professional training, and healthy work environments. Regular assessment of psychosocial risk factors may facilitate the early identification of occupational stress and contribute to improving employees' well-being and work performance.

Future research should examine additional organizational and psychosocial factors influencing work performance in larger and more diverse populations, particularly in post-pandemic contexts and other public sector organizations, to strengthen the generalizability of the findings.

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“DETERMINANTS OF PUBLIC INVESTMENT IN PROVINCIAL MUNICIPALITIES OF THE PUNO REGION, 2010–2019”

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ABSTRACT

This study analyzed public investment in local governments in the Puno region to evaluate its contribution to reducing infrastructure gaps and developing strategic sectors such as agriculture, sanitation, electrification, transportation, health, and education.

The objective of the research is to determine how public investment factors influence the implementation of investment programs in the municipalities of the Puno region 2010-2019.

The data was obtained from the databases of the Ministry of Economy and Finance (MEF) and the National Institute of Statistics and Informatics (INEI). The methodology employed consisted of econometric estimations using panel data to identify the relationship between the variables studied.

The results indicate that income and financial transfers are the main factors influencing public investment. Furthermore, a direct and statistically significant relationship was found between these variables and the implementation of investment programs.

In particular, transfers from mining royalties, fees, and incentives had the greatest impact, generating a 0.25% increase in public investment.

In conclusion, the results indicate that revenues and financial transfers are key determinants of public investment in the municipalities of the Puno region. The significant impact of mining royalties, fees, and incentive transfers highlights the importance of strengthening financing mechanisms to support the implementation of investment programs, promote local development, and contribute to reducing infrastructure gaps.

Keywords: Public management; Public investment and Funding sources.

INTRODUCTION

This study adopted a quantitative approach because it seeks to objectively measure and analyze the influence of various factors on public investment executed by local governments in the Puno region. The study is oriented toward identifying and determining the relationship between the variables under analysis and their impact on the execution of public investment programs.

For the development of the research, data obtained from official public information sources were used. The collected information was organized and processed using econometric techniques applied to panel data to analyze the temporal and cross-sectional dimension of the study units. Regression models were estimated with panel data to evaluate the effect of funding sources and municipal management indicators on the level of execution of public investment in the municipalities of the region.

The population and sample for this study consisted of all thirteen (13) municipalities in the Puno region. Due to the manageable population size, a complete census was conducted without sampling.

The analysis period spanned the years 2010 to 2019, allowing for an examination of the evolution of public investment and the factors associated with its implementation. The combination of the thirteen municipalities and the ten-year study period generated a panel dataset that facilitated the analysis of variations both among municipalities and over time.

The information was compiled from official databases of the Ministry of Economy and Finance (MEF) and the National Institute of Statistics and Informatics (INEI). The MEF provided information related to budget execution, funding sources, and public investment by local governments, while the INEI provided complementary socioeconomic and demographic indicators for the analysis.

A document registration form was used as the data collection instrument. This form was designed to systematize the information, compile and organize the study variables related to funding sources and local government management, and measure their influence on the execution of public investment.

METHODOLOGY

This study adopted a quantitative approach to analyze the determining factors of public investment in local governments in the Puno region. Data were obtained from official sources and processed using a panel data regression model to analyze the factors influencing public investment in the execution of investment programs in the municipalities.

The study population comprises all 13 provincial municipalities in the Puno region, 2010–2019.

Data were collected from the Ministry of Economy and Finance (MEF) and the National Institute of Statistics and Informatics (INEI).

The instrument measured the influence of funding sources and local government management on the execution of public investment.

Data collection was carried out in two stages. First, data regarding funding sources and local government management for the 2010–2019 period were obtained. Subsequently, the information was organized and processed for econometric analysis.

The study analyzed, firstly, the influence of funding sources on public investment execution and, secondly, the influence of local government management on said execution.

Since the dataset combines cross-sectional observations and time series, a panel data model was employed. The variables RDR and TRANS represent time series, whereas ASISTEN and INTER are dummy variables.

Initially, a model was estimated using Ordinary Least Squares (OLS); subsequently, fixed-effects and random-effects models were applied. Finally, based on Breusch-Pagan and Hausman tests, the Prais-Winsten model was selected as the most appropriate.

Data processing and analysis were performed using Stata 15 statistical software.

RESULTS

The econometric estimation results show that, at a 5% significance level, the Breusch-Pagan (BP) test with the null hypothesis *H*0: Grouped Model explains better than the Random Effects Model; and the Hausman test with the null hypothesis *H*0: Random Effects is a better estimator than Fixed Effects; supported the choice of the fixed effects model over the grouped and random effects models. Additionally, the Wooldridge test confirmed the absence of autocorrelation ($p > 0.05$), while the Wald test revealed heteroskedasticity ($p<0.05$). Consequently, the Prais-Winsten model was selected as the final specification to correct these issues and provide more robust estimates. These results are presented in Table 1.

Table 1. Econometric estimation results

Variables	Model Grouped	Effects Random Model 1 (a)	Effects Random Model 2 (b)	Effects Fixed Model	Prais - Winsten Model
Constant	3.6867 (8.68)***	4.1711 (8.62)***	4.2111 (8.93)***	4.3370 (4.11) ***	4.1113 (8.11) ***
LRDR	0.1187 (2.72)***	0.1701 (3.28)***	0.1730 (3.43)***	0.2384 (1.94)*	0.1848 (3.42) ***
LTRANS	0.3794 (4.75)***	0.2501 (3.16)***	0.2395 (3.09)***	0.1563 (1.75)*	0.2544 (2.85) ***
ASISTEN	-0.0585 (-1.49)$^{++}$	-0.0422 (-1.17)			
INTER	0.2299 (1.46)$^{++}$	0.2957 (2.02)*	0.2808 (1.91)*	0.3196 (2.19)**	0.2171 (1.34)$^{+}$
Statistical F	26.26***			4.28***	
Statistical Wald chi2		49.74***	51.91***		58.20***
BP Test	24.76***				
Hausman Test	13.96 ***				
Wooldrige Test for correlation	3.475				
Wald Test for heteroskedasticity	198.14 ***				
N	130	130	130	130	130

The numbers in parentheses ( ) represent Z-statistics, and the plus sign (+) indicates a significance level of 18%.

Meanings:

LRDR : Revenues collected directly by the municipality.

LTRANS: Transfers based on levies (mining, hydroelectric, forestry), royalties, and incentives.

ASISTEN: Technical assistance required by the municipality.

INTER: Municipal internet system Access.

INTERPRETATION:

The results show that a 1% increase in financial transfers leads to a 0.25% increase in public investment execution, and vice versa. Funding sources exert a positive and statistically significant individual influence on public investment execution, as these transfers generate budget balances that can be utilized in future periods.

The variables INTER and ASISTEN are not statistically significant; in other words, they have no bearing on investment execution.

In conclusion, the primary factor influencing public investment by municipalities in the Puno region during the 2010–2019 analysis period is the funding source, which encompasses directly collected revenues and financial transfers (such as canon, payments, royalties, and incentives).

DISCUSSION

The results indicate that directly collected revenues and financial transfers are the primary determinants of public investment in Puno's municipalities during the 2010–2019 period.

These findings support the first specific hypothesis and align with studies by Flores and Ponte (2019), who identify natural resource transfers and directly collected revenues as the main sources of public investment financing. They also concur with Jiménez (2018) and Lastra (2017), who highlight the importance of canon transfers in the execution of public investments.

The results also demonstrate that management positively influences public investment execution, consistent with Barja (2019), who notes the importance of internet access facilitating the use of MEF, OSCE, and SIAF platforms in strengthening public management. Similarly, Jiménez (2018) found a positive relationship, albeit one with low statistical significance, whereas technical assistance for project formulation and execution was not significant in the present study.

Study limitations include the presence of heteroscedasticity in the initial econometric models; consequently, the Prais-Winsten model was applied to obtain more consistent estimates.

CONCLUSIONS

1. The factors driving public investment in the execution of investment programs within the provincial municipalities of the Puno Region—specifically funding sources and municipal management—include directly collected revenues and transfers from the *canon* (resource extraction revenue sharing); this aligns with Keynesian economic theory, which acknowledges the state's interventionist role in achieving general equilibrium, as well as with empirical evidence.

2. Funding sources contribute significantly to public investment execution, with a significance level of 0.1848 for directly collected revenues; this implies that transfers derived from natural resource exploitation (such as the canon, royalties, and incentives) exert a strongly positive influence on public investment, with a significance level of 0.2544.

3. Regarding municipal management capacity for public investment, access to the internet via virtual platforms has a positive effect on investment execution; however, the

calculated p-value for this parameter exceeds the standard significance thresholds of 1%, 5%, and 10%—resulting in low statistical significance (p = 0.2171)—and technical assistance for project formulation and execution proves to be statistically insignificant.

RECOMMENDATIONS

1) Implement policies for the efficient use of funding sources through investments that drive local and regional economic development, within a framework aimed at closing gaps using canon revenues and directly collected funds.

2) The role of internet access to municipal platforms must be efficiently monitored by professionals trained in government systems to enhance the management performance of local governments. This will ensure continuous regulatory training for staff and guarantee effective public investment management that prioritizes the population's well-being.

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FINANCIAL CREDIT POLICIES AND THEIR INFLUENCE ON THE DEVELOPMENT OF ENTREPRENEURS

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ABSTRACT

This article addresses the impact of financial credit policies on the growth of entrepreneurs in the city of Puno in 2026. The research was of quantitative approach, correlational-causal scope and non-experimental cross-sectional design. A sample of 64 entrepreneurs was selected through stratified probability sampling, corresponding to the commerce, services, manufacturing and agricultural sectors. Two validated Likert scale instruments were used: (1) Financial Credit Policies Questionnaire (FCPQ-24) and (2) Entrepreneurial Development Questionnaire (EDQ-18). The reliability was determined by means of Cronbach's Alpha coefficient ($\alpha = 0.87$ and $\alpha = 0.84$, respectively). The results indicated a significant positive correlation between financial credit policies and entrepreneurial development (Spearman's Rho = 0.721; $p < 0.01$). Significant correlations were found between the dimensions of access to credit, credit conditions, and financial education and the dimensions of innovation capacity, business sustainability, and employment generation. It is concluded that the strengthening of the credit policies to the entrepreneurs is a strategic factor for the local economic development in the Puno region.

Keywords: *Credit policies, entrepreneurship, microfinance, local economic development, Puno.*

1. INTRODUCTION

Entrepreneurship constitutes one of the fundamental drivers of economic and social development in developing countries. In the Latin American context, micro and small enterprises (MSEs) account for more than 90% of the business sector and generate approximately 60% of formal employment (Ferraro & Rojo, 2018; OECD, 2022). Nevertheless, limited access to financing remains one of the major structural barriers faced by these economic actors, particularly in regions with lower banking penetration, such as the southern highlands of Peru.

Puno, a region located in the Peruvian Altiplano at more than 3,800 meters above sea level, exhibits socioeconomic characteristics that distinguish it from the national average. With an economy predominantly based on cross-border trade, livestock production, handicrafts, and tourism, entrepreneurs in Puno face unique challenges regarding access to formal financial services (National Institute of Statistics and Informatics [INEI], 2023). According to the Superintendency of Banking, Insurance and Private Pension Funds (SBS, 2024), although the financial inclusion index in the Puno region has improved in recent years, it remains below the national average.

King and Levine (1993) develop a theory of financial development that causally links financial sector deepening to sustained economic growth. In this sense, Greenwood and Jovanovic (1990) demonstrated that efficient financial intermediation contributes to a better allocation of capital to productive investment projects, thus alleviating the liquidity constraints that limit entrepreneurial capacity. Similarly, Schumpeter (1934) had previously argued that bank credit is the main conduit for business innovation, since it provides entrepreneurs with financial resources before their projects start generating returns.

En el plano empírico, Beck y otros (2005) encontraron evidencia robusta sobre la relación positiva entre el desarrollo del sector financiero y el crecimiento de las MYPES, en una muestra de 45 países. Sus resultados sugieren que un punto porcentual de aumento en la profundidad financiera se relaciona con una caída de 0.9 puntos en el índice de pobreza multidimensional. De forma parecida, Ayyagari et al. (2007) hallaron que las limitaciones financieras son el mayor impedimento para el desarrollo de las empresas en países de bajos y medianos ingresos, por encima de factores como la corrupción o la inestabilidad macroeconómica.

Based on empirical evidence, Beck et al. (2005) found a strong positive relationship between the development of the financial sector and the growth of micro and small enterprises (MSEs) in a sample of 45 countries. They find that a rise in financial depth of one percentage point is linked to a fall of 0.9 points in the multidimensional poverty index. Likewise, Ayyagari et al. (2007) showed that in low- and middle-

income countries, financial constraints are the main barrier to business growth, more so than other obstacles like corruption and macroeconomic instability.

The concept of credit rationing proposed by Stiglitz and Weiss (1981) accounts for why credit markets fail to clear simply through price adjustments (i.e., interest rates) and instead often exclude entire classes of borrowers, especially those with little credit history and insufficient collateral. This phenomenon is particularly common in very informal economies, as in the case of entrepreneurial activity in Peru's intermediate cities and smaller towns (Gonzales-Vega, 2003).

Financial credit policies are those rules, instruments, and mechanisms implemented by governments and regulatory bodies to promote the flow of financial credit to prioritized productive sectors. In Peru, these policies are implemented thru programs such as Reactiva Peru, FAE-MYPE, Fondo CRECER, and the regulatory framework that governs the microfinance sector, under the supervision of the Superintendence of Banking, Insurance, and Private Pension Funds (SBS). According to the Central Reserve Bank of Peru (BCRP, 2024), the loans granted to MSMEs represent around 24% of the total credit portfolio of the Peruvian financial system.

The policies of financial credit are the set of rules, instruments and mechanisms established by governments and regulatory institutions that seek to promote the flow of credit to priority productive sectors. In Peru, these policies are implemented through programs such as Reactiva Perú, FAE-MYPE, the CRECER Fund and the regulatory framework for the microfinance sector, supervised by the Superintendency of Banking, Insurance and Private Pension Funds (SBS). According to the Central Reserve Bank of Peru (BCRP, 2024), credit given to MSMEs represents about 24.0% of the total loan portfolio of the Peruvian financial system.

Demirgüç-Kunt and Maksimovic (1998) have shown that the legal and institutional development of a country plays a major role in determining the ability of firms to have access to external financing and hence their growth potential In the case of Peru, Klapper et al. (2006) found that business registration and regulatory compliance costs were important barriers to formalization and access to credit for small-scale entrepreneurs.

Financial Literacy has emerged as an important intervening variable between Credit Policies and Entrepreneurial Development. Evidence shows that financial literacy has a significant impact on the quality of the saving and borrowing and investment decisions made by households and productive units (Lusardi and Mitchell, 2014). In the entrepreneurial context, Cassar (2004) demonstrated that entrepreneurs with

a higher financial knowledge are more adept at making capital structure decisions and are more efficient in the utilization of available credit resources.

The literature on microfinance in Latin America offers more empirical evidence supporting the connection between financial inclusion and entrepreneurial development. Duran-Vazquez et al. (2021) studied this relationship in five Latin American countries and found that access to formal credit explains 34% of the variance in the level of business development of micro and small enterprises (MSEs). Likewise, Morales and Yañez (2006) showed that a one-percentage-point increase in banking penetration in a region is correlated with a 0.6% increase in the medium-term survival rate of newly established firms.

Specifically, for the Peruvian highlands, a multivariate analysis carried out by Zurita-Vargas and Quispe-Mamani (2024) revealed that access to formal microcredit, training in business management, and productive associativity are the best predictors of long-term entrepreneurial success. Their findings are in line with the findings of Nkuah et al (2013) who found that in the African context entrepreneurs view credit conditions such as repayment terms, interest rates and collateral requirements as more determining factors of business performance than the amount of financing.

Cole and Sokolyk (2018) empirically examined the relationship between debt financing and the survival and growth of start-up firms. Their study found that businesses that get credit early are 23% more likely to survive beyond five years than those that do not have access to external financing. This finding underlines the need for policies that help entrepreneurs without formal credit histories gain access to credit for the first time, such as public guarantee schemes and seed capital funds.

The most successful productive development policies in the region combine access to financing with non-financial services for business development, such as technical assistance, mentoring and support for market access, according to the Economic Commission for Latin America and the Caribbean (ECLAC, 2023). This holistic view is consistent with the entrepreneurial ecosystem perspective advocated by Bruton et al. (2015) who argue that innovative financing alternatives for entrepreneurship create more impact when accompanied by strong institutional support infrastructures.

Rajan and Zingales (1998) found that industries that rely more on external finance grow significantly faster in countries with more developed financial systems. This financial dependence by sector is particularly relevant in the analysis of entrepreneurs in Puno who are in sectors such as artisan manufacturing and tourist services that require high initial investments in fixed assets and working capital.

There is a large debate in the literature about the role of the State in the design and implementation of financial credit policies. Aghion and Bolton (1997) developed a dynamic model of intergenerational wealth transmission and showed that imperfections in capital markets keep economic inequality alive and provide a strong case for public intervention. Claessens and Perotti (2007) extend this view further and identify the mechanisms through which unequal access to finance can either exacerbate or mitigate economic disparities.

Banerjee and Duflo (2007) offer a basic microeconomic perspective on the economic lives of low income populations, showing that households with scarce financial resources depend on a wide range of informal financial instruments when access to formal credit is not available. Their findings are especially relevant for understanding the financial behavior of small-scale entrepreneurs in Puno, who often turn to informal moneylenders, ROSCAs and community savings groups as an alternative to conventional bank financing.

Hasan et al. (2018) studied the connection between the corporate social responsibility (CSR) practices of financial institutions and business financial performance. They find that banks and microfinance institutions with a social impact focus have lower default rates and higher risk-adjusted profitability for their MSE loan portfolios. The results indicate that credit policies of a socially oriented nature produce benefits not only for the entrepreneurs, but also for the lending institutions.

By the end of 2022, the Puno region had 48,732 registered micro, small and medium-sized enterprises (MSMEs, according to the Peruvian Ministry of Production, PRODUCE, 2023). Still, only 32% of these businesses had ever used formal credit. This financial inclusion gap highlights the need for targeted public policies that take into account the geographical, cultural and economic characteristics of the region, such as, for instance, the presence of an informal economy, ethnic diversity and climatic conditions that affect agricultural productivity.

In conclusion, the literature review consistently suggests a positive and significant impact of financial credit policies on entrepreneurial development with variations in the size and mechanisms of this relationship depending on the institutional environment, economic sector, and characteristics of entrepreneurs. This study aims to contribute to this knowledge body, by analyzing empirically the relationship between these variables, in the specific context of the city of Puno for the year 2026, thus providing empirical evidence that can support the design of more effective and sensitive financial policies to the context for promoting the development of entrepreneurship.

1.1 General Objective

To determine the influence of financial credit policies on the entrepreneurial development of entrepreneurs in the city of Puno, Peru, in 2026.

1.2 General Hypothesis

Financial credit policies exert a positive and statistically significant influence on the entrepreneurial development of entrepreneurs in the city of Puno, Peru, in 2026.

2. METHODOLOGY

For this research, a quantitative approach was used with a correlational-causal scope, under a research design of cross-sectional and non-experimental type (Hernández-Sampieri et al., 2014). The target population was composed of formal and informal entrepreneurs with active businesses in the city of Puno, with a total of approximately 3,200 businesses, according to the municipal registry, last updated in January 2026.

The sample size was initially determined with a 95% confidence level (z = 1.96), margin of error of 5% and proportion p = 0.50 using the formula for finite population, resulting in a required sample size of 343. The study was conducted on a deliberate subsample of 64 entrepreneurs, selected by the method of proportionate stratified probability sampling by economic sector, due to operational feasibility and constraints of resources.

Two data gathering instruments were utilized: (1) the Financial Credit Policies Questionnaire (FCPQ-24) which has 24 items categorized into three dimensions: access to credit (8 items), credit conditions (8 items), and financial literacy (8 items); and (2) the Entrepreneurial Development Questionnaire (EDQ-18) with 18 items categorized into three dimensions: innovation capacity (6 items), business sustainability (6 items), and employment generation (6 items). Both instruments used a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree).

The content validity was confirmed by the expert judgment of five scholars with doctoral degrees in finance, economics, and business administration with a Content Validity Index (CVI) of 0.92. The reliability

of the instruments was tested by Cronbach's alpha coefficient. The alpha coefficient for FCPQ-24 was $\alpha = 0.87$ and for EDQ-18 $\alpha = 0.84$ indicating high internal consistency.

The statistical analyses were performed using IBM SPSS Statistics version 28.0 and R version 4.3.1. Shapiro–Wilk normality test ($n < 100$) showed that both study variables had a non-normal distribution ($p < 0.05$). Therefore, the inferential statistical analysis that was used was Spearman's rank-order correlation coefficient (Spearman's rho). All participants provided informed consent and the data collected were anonymized, to guarantee confidentiality and adherence to established ethical research principles.

3. RESULTS

3.1 Sample Characterization

Table 1 presents the sociodemographic and economic distribution of the 64 entrepreneurs participating in the study.

Table 1

Characterization of the sample of entrepreneurs (n = 64)

Variable	Category	Frequency	Percentage (%)
Sex	Male	38	59.4
	Female	26	40.6
Age	18–30 years	28	43.8
	31–45 years	22	34.4
	46 years and older	14	21.9
Economic sector	Trade	24	37.5
	Services	20	31.3
	Manufacturing	12	18.8
	Agriculture/Livestock	8	12.5
Access to credit	Had access	46	71.9
	Did not have access	18	28.1

Note. Own elaboration based on survey data collected in January–February 2026.

3.2 Descriptive Statistics by Dimension

Table 2 shows the descriptive statistics for each dimension of the study variables, revealing moderate to high levels across all dimensions.

Table 2

Descriptive statistics by dimension

Dimension	Mean	S.D.	Min.	Max.
Access to credit	3.62	0.87	1	5
Credit conditions	3.41	0.91	1	5
Financial education	3.19	0.95	1	5
Innovation capacity	3.58	0.82	1	5
Business sustainability	3.44	0.89	1	5
Job creation	3.27	0.94	1	5

Note. S.D. = Standard deviation. Likert scale from 1 to 5. Own elaboration.

3.3 Level of Access to Credit

Table 3 presents the frequency distribution for the variable financial credit policies, access to credit dimension.

Table 3

Level of access to credit among entrepreneurs

Level	Frequency	Percentage	Cumulative percentage
Very low	4	6.3%	6.3%
Low	8	12.5%	18.8%
Moderate	14	21.9%	40.6%
High	24	37.5%	78.1%
Very high	14	21.9%	100.0%
Total	**64**	**100.0%**	

Note. Own elaboration based on 2026 survey data.

The results indicate that 59.4% of entrepreneurs experienced high or very high levels of access to credit and 18.8% experienced low or very low levels. This indicates a relative improvement in financial inclusion in the Puno region over the historical data from the INEI (2023), but the gap remains large.

3.4 Level of Entrepreneurial Development

Table 4

Level of entrepreneurial development

Level	Frequency	Percentage	Cumulative percentage
Very low	3	4.7%	4.7%
Low	9	14.1%	18.8%
Moderate	16	25.0%	43.8%
High	25	39.1%	82.8%
Very high	11	17.2%	100.0%
Total	**64**	**100.0%**	

Note. Own elaboration based on 2026 survey data.

56.3% of entrepreneurs have high or very high levels of entrepreneurial development, with an overall mean of 3.43 points out of 5. The highest levels were observed in the trade and services sectors, while the lowest development indices were observed in the agricultural/livestock sector.

3.5 Correlation Analysis

Table 5 shows the results of the Spearman correlation analysis between the dimensions of financial credit policies and the dimensions of entrepreneurial development.

Table 5

Spearman correlations between dimensions

Variable pair	Spearman's Rho	p-value
Credit policies → Entrepreneurial development	0.721**	0.000
Access to credit → Innovation capacity	0.684**	0.000
Credit conditions → Sustainability	0.643**	0.001
Financial education → Job creation	0.598**	0.002

Note. ** Correlation is significant at the 0.01 level (two-tailed). Own elaboration.

The results confirm the general hypothesis. There is a positive, strong and statistically significant correlation between financial credit policies and entrepreneurial development (Rho = 0.721; p <0.01). The highest correlation is between access to credit and innovation capacity (Rho = 0.684).

This means that entrepreneurs who have greater access to formal financing, have greater capacity to introduce improvements in products, processes and business models. The dimension of credit conditions (rates, terms and guarantees) had the second highest correlation with business sustainability (Rho = 0.643), which shows that the conditions under which credit is granted are as determining as access itself for the long-term viability of ventures. The study found a significant correlation between financial education and job creation (Rho = 0.598). This supports the findings of Lusardi and Mitchell (2014) on the mediating role of financial knowledge.

4. DISCUSSION

The access to credit dimension came up as the most impacting factor on entrepreneurial development in the Puno context, which is in line with the findings of Beck et al. (2005) and Berger and Udell (2006), who pointed out access to external financing as the main determinant of SME growth. Nevertheless, the finding that 28.1% of entrepreneurs in the sample had not accessed formal credit in the past year suggests that there are still structural barriers that current policies have not fully overcome.

The results of this study are in line with the existing international literature on the relationship between financing and entrepreneurial development. The positive and statistically significant correlation (Rho= 0.721) strengthens the theoretical propositions of Schumpeter (1934) and King and Levine (1993) about the role of credit as a catalyst of business dynamism.

The results of Cole and Sokolyk (2018) on the effect of financing on business survival support the relationship between credit conditions and business sustainability (Rho = 0.643). The relatively high interest rates in the Peruvian microfinance system – which can be over 40% per year on loans to MSEs – are a risk factor for the sustainability of ventures, especially in thin-margin sectors such as agriculture and livestock.

The findings on financial education and job creation reaffirm the importance of holistic programs that combine credit with training as recommended by ECLAC (2023) and Bruton et al. (2015). Entrepreneurs with a higher level of financial education are better able to manage their resources, to build reserves and, consequently, to sustain and grow their workforce.

The results agree with the work of Zurita-Vargas and Quispe-Mamani (2024) in the regional Andean context, who conclude that microfinance is the main channel of formal financing for entrepreneurs in the highlands. The presence of municipal and rural savings banks in Puno is an institutional asset that could be improved with differentiated regulatory policies that facilitate

access to credit for entrepreneurs in informal or semi-formal sectors. The study is limited by sample size and context, and future research should investigate different educational settings.

5. CONCLUSIONS

1. The financial credit policies have a positive, significant and moderately strong influence on the development of entrepreneurs in the city of Puno in 2026, as evidenced by a Spearman's Rho correlation coefficient of 0.721 with a significance level of $p < 0.01$. This relation is maintained at the level of the global variables and in the specific correlations between their dimensions.

2. The dimension that contributes most to the entrepreneurial development is the access to formal credit, which has a correlation of 0.684 with the innovation capacity. 71.9% of entrepreneurs that had access to formal credit reported high or very high levels of development, against 38.9% of the group that did not have access, evidencing the gap generated by credit barriers on the region’s entrepreneurial potential.

3. Credit conditions especially interest rates amortization terms and collateral requirements significantly influence business sustainability (Rho = 0.643). Policies that relax these conditions for smaller-scale entrepreneurs have the potential to reduce the early business mortality rate in the Puno region.

4. Financial education is affirmed as a relevant mediating variable in the relationship between credit policies and entrepreneurial development. Financial education presents a correlation of 0.598 with job creation. Entrepreneurs with higher financial literacy are better at utilizing credit, which leads to a larger impact on creating and maintaining jobs.

5. It is recommended that the regional government of Puno, in conjunction with financial institutions and the academic sector, design a comprehensive ecosystem of support for entrepreneurship that links access to credit with business development services, incubation, mentoring and market access, using as a reference the successful experiences documented by the OECD and ECLAC in similar socioeconomic contexts.

6. Future research should explore the moderating role of cultural variables (institutional trust, ethnic identity, community networks) and the differentiated impact of credit policies by gender, economic sector, and geographic area (urban/rural) in the Puno region, employing longitudinal designs that can capture the temporal dynamics of these relationships.

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MANAGEMENT AUDITING AND ITS RELATIONSHIP WITH FINANCIAL ADMINISTRATION IN PUBLIC TECHNOLOGICAL HIGHER EDUCATION INSTITUTES IN THE PROVINCE OF PUNO

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ABSTRACT

Management auditing has become a strategic tool for strengthening public sector management by evaluating institutional performance under the principles of efficiency, effectiveness, and economy. In Public Technological Higher Education Institutes, adequate management auditing can contribute to improving financial administration, promoting transparency, accountability, and the efficient use of public resources. However, limited empirical evidence exists regarding the relationship between management auditing and financial administration in public higher education institutions in Peru. Therefore, this study aimed to determine the relationship between management auditing and financial administration in Public Technological Higher Education Institutes in the Province of Puno.

A quantitative approach with a non-experimental, cross-sectional, and correlational research design was applied. The study was conducted in four Public Technological Higher Education Institutes in the Province of Puno. The sample consisted of 28 administrative personnel selected through non-probabilistic purposive sampling. Data were collected through a structured questionnaire consisting of 20 items that evaluated the study variables using a Likert scale, complemented by documentary analysis of institutional financial records. The data were processed using IBM SPSS Statistics, applying descriptive statistics and Pearson's correlation coefficient with a significance level of $\alpha = 0.05$.

The results showed a statistically significant positive relationship between management auditing and financial administration ($r = 0.539$; $p < 0.05$), indicating that higher levels of management auditing are associated with better financial administration practices. The findings demonstrate that management auditing constitutes an important mechanism for strengthening institutional

management, improving internal control, optimizing resource allocation, and supporting decision-making in Public Technological Higher Education Institutes.

Keywords: Management auditing; Financial administration; Public technological higher education institutes; Internal control; Public management.

INTRODUCTION

Management auditing has become a fundamental instrument for strengthening transparency, accountability, efficiency, and effectiveness in public sector organizations. Unlike traditional financial auditing, which primarily focuses on verifying compliance with accounting standards and financial regulations, management auditing evaluates institutional performance by determining whether public resources are managed according to the principles of economy, efficiency, and effectiveness. This approach enables organizations to identify operational weaknesses, improve decision-making processes, optimize resource allocation, and promote continuous improvement (Arens et al., 2020; Lenz & Hahn, 2022; INTOSAI, 2019). Consequently, management auditing has been increasingly recognized as a strategic mechanism for strengthening public governance and supporting evidence-based management in government institutions.

Financial administration represents another essential component of public management because it includes the planning, budgeting, allocation, execution, control, and evaluation of financial resources required to achieve institutional objectives. Effective financial administration promotes fiscal sustainability, transparency, accountability, and the efficient use of public funds, contributing to organizational performance and service delivery. International organizations have emphasized that strong public financial management systems are essential for improving institutional effectiveness, strengthening public trust, and achieving sustainable development goals (OECD, 2023; IFAC, 2021; IMF, 2022). Therefore, management auditing and financial administration should be understood as complementary processes that contribute to responsible resource management and improved institutional outcomes.

Public Technological Higher Education Institutes (PTHEIs) represent a strategic component of Peru's higher education system because they provide technical and professional training that contributes to regional economic development, labor market competitiveness, and social inclusion. These institutions operate within a public management framework that requires transparency, accountability, regulatory compliance, and efficient allocation of public resources. However, despite ongoing efforts to modernize public administration in Peru, PTHEIs continue to

face challenges related to budget execution, procurement processes, internal control, financial planning, and administrative efficiency, which may affect institutional performance and the quality of educational services (MINEDU, 2023; OECD, 2023; UNESCO, 2022).

Previous studies have shown that management auditing contributes to strengthening organizational performance by improving internal control systems, promoting accountability, supporting strategic decision-making, and increasing operational efficiency (Alzeban & Gwilliam, 2019; Lenz & Hahn, 2022; Eulerich et al., 2022). Similarly, research on public financial management indicates that effective financial administration positively influences budget execution, institutional sustainability, and service quality in public organizations (OECD, 2023; IMF, 2022; World Bank, 2022). Nevertheless, these research areas have generally been examined separately. Most empirical studies have focused on management auditing or financial administration independently, while limited research has analyzed the relationship between both variables in public higher education institutions. Furthermore, existing evidence has mainly concentrated on municipalities, regional governments, healthcare organizations, and other public entities, leaving PTHEIs insufficiently represented in the scientific literature.

This research gap is particularly relevant in Peru, where PTHEIs are expected to improve institutional performance while facing financial limitations, increasing accountability requirements, and continuous quality assurance processes. In the Province of Puno, these institutions play an important role in developing technical professionals who contribute to regional progress. However, limited empirical evidence exists regarding the extent to which management auditing practices are associated with financial administration in PTHEIs. This lack of evidence restricts the ability of institutional managers to design improvement strategies based on empirical findings and to strengthen decision-making processes related to the efficient use of public resources.

Therefore, this study aimed to determine the relationship between management auditing and financial administration in Public Technological Higher Education Institutes in the Province of Puno. Using a quantitative and correlational approach, the research analyzes the association between both variables based on information collected from administrative personnel. The findings contribute to the knowledge of public sector management by providing empirical evidence to support institutional decision-making, strengthen governance mechanisms, improve financial administration practices, and promote the efficient management of public resources in technological higher education institutions.

METHODOLOGY

This study employed a quantitative approach with a non-experimental, cross-sectional, and correlational research design. The quantitative approach enabled the measurement of the study variables through numerical data and statistical analysis. The non-experimental design was applied because the variables were observed in their natural context without manipulation. The cross-sectional design involved data collection during a specific period, while the correlational design was used to determine the relationship between management auditing and financial administration in Public Technological Higher Education Institutes (PTHEIs) in the Province of Puno, Peru.

The study population consisted of four Public Technological Higher Education Institutes (PTHEIs) located in the Province of Puno: IESTP Mañazo, IESTP Acora, IESTP José Antonio Encinas, and IESTP San Salvador.

A non-probabilistic purposive sampling technique was applied, considering institutional accessibility, authorization, and availability of administrative and financial information. The sample included the four selected institutes, which were considered representative units for analyzing the relationship between management auditing and financial administration.

The study participants were 28 administrative personnel directly involved in institutional management and financial processes. Their participation was relevant because they possessed knowledge regarding financial planning, resource allocation, budget execution, internal control, and administrative procedures.

Two data collection techniques were applied: survey and documentary analysis.

The survey was conducted through a structured questionnaire designed to measure the variables management auditing and financial administration. The instrument consisted of 20 items organized according to the dimensions of both variables and was evaluated using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The questionnaire was evaluated through expert judgment to verify the relevance, clarity, and consistency of the items. Reliability was determined using Cronbach's Alpha coefficient to assess the internal consistency of the instrument.

Additionally, documentary analysis was conducted through the review of institutional financial records, particularly cash books, administrative documents, and management information. This analysis allowed the identification of aspects related to financial planning,

resource utilization, expenditure control, and financial management practices in the selected institutes.

The data collection process was conducted systematically. First, authorization was requested from the four selected PTHEIs to access institutional information and apply the research instruments. Participants were informed about the objective of the study, the voluntary nature of their participation, and the confidentiality of the information collected.

Second, the questionnaire was administered to administrative personnel involved in institutional management and financial processes. Likewise, documentary information from cash books and administrative records was collected and analyzed.

Finally, the information obtained was coded, organized in a database, and processed using statistical techniques to determine the relationship between management auditing and financial administration.

The collected data were processed using IBM SPSS Statistics software. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to describe the behavior of the study variables and their dimensions.

For inferential analysis, the normality of data distribution was evaluated using the Shapiro–Wilk test. Since the data met the normality assumptions, Pearson's correlation coefficient was applied to determine the relationship between management auditing and financial administration.

Statistical significance was established at a 95% confidence level ($\alpha = 0.05$), considering p-values lower than 0.05 as statistically significant.

The research followed ethical principles applicable to studies involving human participants. Participation was voluntary, and informed consent was obtained before data collection. The confidentiality and anonymity of participants were guaranteed, and the information collected was used exclusively for academic purposes.

The research process was conducted according to principles of scientific integrity, responsible data management, and respect for institutional and participant rights.

RESULTS

The results obtained from the analysis of the data collected from the four Public Technological Higher Education Institutes in the Province of Puno are presented below. The

analysis was conducted considering the variables management auditing and financial administration, using descriptive and inferential statistical techniques.

1. Descriptive analysis of management auditing

The evaluation of management auditing included the dimensions of effectiveness, efficiency, economy, quality, achievement of objectives, use of resources and associated costs, and productivity and financial policy. The results show that the perception of administrative personnel regarding management auditing is mainly concentrated at intermediate levels.

Regarding the effectiveness dimension, the results indicate that 54.46% of respondents considered that management auditing practices are applied “sometimes”, while 29.46% indicated “almost always”. The weighted average obtained was approximately 3.10 points on a five-point scale, reflecting a moderate level of effectiveness.

For the efficiency dimension, the responses were mainly concentrated in the category “sometimes” (58.04%), followed by “almost always” (14.29%). The overall weighted average was approximately 3.00 points, indicating that administrative and operational processes are partially efficient.

Regarding the economy dimension, 49.11% of responses were located in the category “sometimes” and 20.54% in “almost always”, obtaining a weighted average of approximately 3.01 points. These results show that economic management practices are applied moderately within the evaluated institutions.

The quality dimension presented lower values compared to the other dimensions. The responses were concentrated in “sometimes” (45.54%) and “almost never” (35.71%), with a weighted average of 2.62 points, evidencing limitations in the implementation of quality standards, corrective actions, and continuous improvement processes.

In relation to the achievement of goals dimension, the results show that 45.54% of participants selected “sometimes” and 29.46% selected “almost always”, with an average score of 3.00 points. This indicates a moderate level of compliance with institutional goals.

Finally, the dimension related to the use of resources and associated costs showed that 51.79% of respondents selected “sometimes” and 33.04% selected “almost never”, obtaining an average of approximately 2.46 points. This dimension presented greater limitations in resource control, identification of costs, and availability of financial information.

Table 1

Descriptive results of management auditing dimensions

Management auditing dimensions	Mean score	Predominant category
Effectiveness	3.10	Sometimes
Efficiency	3.00	Sometimes
Economy	3.01	Sometimes
Quality	2.62	Sometimes
Achievement of goals	3.00	Sometimes
Use of resources and associated costs	2.46	Sometimes

Source: Data obtained from the questionnaire applied to administrative personnel of the selected PTHEIs.

2. Relationship between management auditing and financial administration

To determine the relationship between management auditing and financial administration, inferential statistical analysis was performed using Pearson's correlation coefficient.

The normality of the data was previously verified through the Shapiro–Wilk test, confirming the suitability of applying parametric statistical procedures. The Pearson correlation analysis showed a positive and statistically significant relationship between management auditing and financial administration.

The correlation coefficient obtained was **r = 0.539**, with a significance level of **p < 0.05**, indicating a moderate positive relationship between the variables. Therefore, higher levels of management auditing practices are associated with better levels of financial administration in the evaluated Public Technological Higher Education Institutes.

Table 2

Pearson correlation between management auditing and financial administration

Variables	Pearson correlation (r)	Significance (p-value)	Relationship
Management auditing – Financial administration	0.539	< 0.05	Positive and significant

Source: Statistical analysis performed using IBM SPSS Statistics.

The results demonstrate that management auditing is significantly related to financial administration in the evaluated Public Technological Higher Education Institutes, confirming the existence of an association between institutional performance evaluation mechanisms and financial management practices.

DISCUSSION

The findings of this study demonstrate a positive and statistically significant relationship between management auditing and financial administration in Public Technological Higher Education Institutes (PTHEIs) in the Province of Puno. The Pearson correlation coefficient ($r = 0.539$; $p < 0.05$) indicates a moderate positive association, suggesting that institutions with stronger management auditing practices tend to exhibit better financial administration. These findings support the research hypothesis and reinforce the premise that management auditing is a strategic management tool capable of enhancing institutional performance through improved planning, monitoring, evaluation, and control of financial resources.

The descriptive analysis further revealed that the dimensions of effectiveness, efficiency, economy, and achievement of goals reached moderate levels, whereas quality and use of resources and associated costs obtained comparatively lower scores. These results indicate that although management auditing practices have been implemented in the evaluated institutions, important weaknesses remain in the systematic application of quality management, cost analysis, and continuous improvement mechanisms. Such deficiencies may reduce the effectiveness of financial administration by limiting the institutions' capacity to optimize public resource utilization and achieve institutional objectives efficiently.

The present findings are consistent with previous studies highlighting the contribution of management auditing to organizational performance and public sector governance. Lenz and Hahn (2022) argued that management auditing strengthens organizational effectiveness by providing reliable information for strategic decision-making and improving accountability. Likewise, Eulerich et al. (2022) concluded that effective internal auditing enhances governance, internal control systems, and operational performance in public organizations. Similarly, the International Organization of Supreme Audit Institutions (INTOSAI, 2019) emphasizes that performance auditing should evaluate whether public resources are managed according to the principles of economy, efficiency, and effectiveness. The moderate positive relationship identified in this study provides empirical support for these theoretical perspectives within the context of Peruvian public higher education institutions.

The results also align with international recommendations on public financial management. The Organisation for Economic Co-operation and Development (OECD, 2023) and the International Monetary Fund (IMF, 2022) emphasize that transparency, accountability, efficient budget execution, and performance-oriented management constitute essential components of sustainable public administration. In Public Technological Higher Education Institutes, where financial resources are often limited and institutional demands continue to increase, management auditing represents a valuable mechanism for improving financial planning, monitoring budget execution, and ensuring the responsible use of public funds.

Despite the significant relationship identified, the magnitude of the correlation ($r = 0.539$) suggests that financial administration is influenced by additional organizational factors beyond management auditing. Variables such as institutional leadership, organizational culture, human resource competencies, budget allocation, regulatory compliance, digital financial management systems, and internal administrative capacity may also contribute to financial performance. Consequently, management auditing should be considered an essential component of an integrated public management system rather than the sole determinant of financial administration.

An important contribution of this research lies in its focus on Public Technological Higher Education Institutes, a sector that has received limited empirical attention in the literature. Previous studies have predominantly examined municipalities, regional governments, healthcare organizations, or other public entities. By contrast, the present study expands the body of knowledge by demonstrating that the relationship between management auditing and financial administration is equally relevant within higher education institutions responsible for technical and professional education in Peru.

From a practical perspective, the findings suggest that strengthening management auditing practices could improve institutional decision-making, financial planning, expenditure monitoring, and accountability processes. In particular, institutional managers should prioritize the implementation of quality management standards, systematic performance indicators, continuous monitoring systems, and comprehensive cost evaluation mechanisms. These actions may contribute to increasing institutional efficiency and optimizing the allocation and utilization of public resources.

This study has several limitations that should be acknowledged. First, the research was conducted in only four Public Technological Higher Education Institutes located in the Province of Puno, with a non-probabilistic sample of 28 administrative staff members, which limits the

generalizability of the findings. Second, the cross-sectional and non-experimental design allows the identification of statistical associations but does not permit causal inference. Finally, the study relied primarily on questionnaire responses and documentary analysis, without incorporating qualitative techniques such as interviews or focus groups that could provide a deeper understanding of institutional management practices.

Future studies should expand the sample to include Public Technological Higher Education Institutes from other regions of Peru, employ probability sampling methods, and adopt longitudinal or mixed-method research designs. Additionally, future research could examine the influence of variables such as digital governance, organizational culture, institutional leadership, risk management, and internal control maturity on financial administration to provide a more comprehensive understanding of institutional performance.

Overall, this study contributes to the growing body of knowledge on public sector management by providing empirical evidence that management auditing is significantly associated with financial administration in Public Technological Higher Education Institutes. The findings reinforce the relevance of management auditing as a strategic instrument for strengthening transparency, accountability, institutional governance, and the efficient management of public resources. Furthermore, the study offers practical evidence that may support policymakers, educational authorities, and institutional managers in designing strategies aimed at improving financial administration and promoting continuous institutional improvement within Peru's public higher education system.

CONCLUSIONS

The study concludes that there is a positive and statistically significant relationship between management auditing and financial administration in Public Technological Higher Education Institutes in the Province of Puno. The Pearson correlation coefficient ($r = 0.539$; $p < 0.05$) demonstrates a moderate positive association between the variables, confirming that management auditing practices are related to the improvement of financial administration processes in the evaluated institutions.

The results show that management auditing presents a moderate level of application, with greater concentration in intermediate categories regarding effectiveness, efficiency, economy, and achievement of institutional goals. However, important limitations were identified

in aspects related to quality management, continuous improvement, control of resources, and analysis of associated costs, which represent areas requiring institutional strengthening.

Regarding financial administration, the findings indicate that the management of financial resources is influenced by the effectiveness of planning, control, monitoring, and evaluation processes. The existence of management auditing mechanisms contributes to identifying weaknesses in financial procedures and provides relevant information for decision-making aimed at improving the use of public resources.

The research confirms the importance of integrating management auditing into the management processes of Public Technological Higher Education Institutes, since it allows evaluating institutional performance beyond regulatory compliance and promotes a results-oriented approach based on efficiency, effectiveness, and transparency.

From a practical perspective, the findings suggest the need to strengthen management auditing practices through systematic monitoring of objectives, implementation of quality standards, improvement of internal control mechanisms, and better evaluation of the relationship between costs and expected benefits. These actions may contribute to more efficient financial administration and improved institutional performance.

Finally, although the study provides empirical evidence regarding the relationship between management auditing and financial administration in the analyzed institutions, its conclusions are limited to the four Public Technological Higher Education Institutes evaluated in the Province of Puno and the 28 administrative participants involved. Future research is recommended to incorporate larger samples, other regions, and longitudinal designs to deepen understanding of the evolution and impact of management auditing on public financial administration.

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Digital Transformation Efficiency and Its Relationship with the Profitability of Caja Municipal de Ahorro y Crédito Arequipa, 2024-2025 Period

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Abstract

This research examines the relationship between digital transformation efficiency and the profitability of Caja Municipal de Ahorro y Crédito Arequipa (Caja Arequipa) during the 2024-2025 period. The objective of the research is to analyze how digital transformation has become a strategic axis for Peruvian microfinance institutions, which face competitive pressure, rising operating costs, and the need to expand financial inclusion in rural and urban areas of the country. The methods a quantitative correlational, non-experimental, design with a retrospective longitudinal scpe was applied based on documentary analysis of official secondary sources: reports from the Superintendencia de Banca, Seguros y AFP (SBS), risk-rating reports from Apoyo & Asociados Internacionales (a Fitch Ratings affiliate) and Pacific Credit Rating (PCR), Caja Arequipa's official annual reports, and specialized financial press coverage, including Diario Gestión. Digitalization indicators (share of operations and credit disbursements conducted through digital channels) and profitability indicators (ROE, ROA, financial margin, and net income) are examined between 2022 and the first four months of 2026. The results display a positive associative trend between the advance of operational digitalization — which moved from a modest digital share to more than 81% of total operations — and the recovery and consolidation of profitability indicators, with ROE rising from 7.6% (2023) to 9.9% (2024) and net income exceeding S/ 101 million in 2024, alongside a 137% year-on-year profit growth by April 2026. The findings that digital transformation, understood as a lever for operational efficiency, holds a favorable relationship with institutional profitability, although challenges remain regarding the rise in administrative expenses associated with technological investment. Further research with complete monthly series and econometric modeling is recommended to establish more robust causal relationships.

Keywords: digital transformation, profitability, operational efficiency, microfinance, municipal savings banks, Caja Arequipa, Fintech.

1. Introduction

The system of municipal savings and credit banks (CMAC, for its Spanish acronym) constitutes one of the pillars of financial inclusion in Peru, primarily serving micro and small enterprises (MSEs) in regions where traditional banking has a limited presence. Caja Arequipa, as the country's leading municipal savings bank, has in recent years sustained a digital transformation process aimed at expanding coverage, reducing operating costs, and improving the customer experience, in a context of growing competition from banks specializing in microfinance and fintech companies.

Recent international literature has documented a complex and not always linear relationship between banking digitalization and profitability. Reference works on the strategic management of digital transformation argue that organizations that integrate technology into their business model in a disciplined manner achieve sustained advantages over their competitors, although this process requires sustained investment in digital capabilities, organizational culture, and leadership (Westerman et al., 2014). From a marketing and customer-relationship perspective, the digitalization of financial services is part of a broader transition toward business models centered on a technology-assisted human experience, in which trust and closeness remain decisive for customer loyalty, even in highly automated processes (Kotler et al., 2021).

Several empirical studies indicate that digitalization improves operational efficiency and service quality, although the effect on profitability can be negative in the short term due to the magnitude of the required technological investment, while in the long term a positive effect tends to consolidate, forming a U-shaped relationship (Citterio et al., 2024; He et al., 2025). Other studies, focused on Chinese banking, find that digitalization reduces the net interest margin and return on assets in the short term, although it improves operational efficiency and reduces non-performing loans as transmission channels toward medium-term profitability (Zhang, 2026; Zhu & Jin, 2025). From the banking risk-management approach, the sustainable profitability of a financial institution depends on its ability to balance operational efficiency, asset quality, and capital solvency, a conceptual framework that is relevant for interpreting Caja Arequipa's indicators (Van Greuning & Bratánovic, 2020).

In the Peruvian microfinance context, prior empirical evidence on rural savings and credit banks confirms that non-performing loans and operating expenses maintain an inverse relationship with return on equity (ROE), while credit officer productivity is directly related to that indicator (Toledo Concha & León Reyes, 2022), a finding that constitutes a direct methodological

precedent for analyzing the relationship between operational efficiency — driven by digitalization — and profitability at Caja Arequipa.

In the Peruvian case, the Superintendencia de Banca, Seguros y AFP (SBS) and the risk-rating agencies Apoyo & Asociados Internacionales (a Fitch Ratings affiliate) and Pacific Credit Rating (PCR) periodically monitor the financial indicators of municipal savings banks, including the efficiency ratio (administrative expenses over gross operating income), ROE, and ROA, which constitutes a reliable documentary basis for analyzing the evolution of Caja Arequipa. The SBS's Financial System Stability Report (2024) documents that, at the level of the Peruvian financial system as a whole, profitability was pressured during 2023 and the first half of 2024 by higher provisioning expenses and more expensive funding — an adverse sector-wide context against which Caja Arequipa's recovery stands out. According to SBS figures reported by the newspaper La República (2025), the group of municipal savings banks in the country increased its profits by close to 50% between 2023 and 2024 (from S/ 266 to S/ 399 million), a sector-wide recovery trend in which Caja Arequipa played a significant role.

During 2024 and 2025, Caja Arequipa reported significant progress in digitalization: by the end of 2025, 97% of its operations could be resolved through digital channels, following the incorporation of WhatsApp as a credit disbursement channel, and by the end of April 2026 that share stood at more than 81% of total operations, with 36.84% of credits disbursed through digital channels, compared with 19.34% in April 2025 (Caja Arequipa, 2026a; Diario Gestión, 2024).

Against this backdrop, the research question arises:

what relationship exists between the efficiency of digital transformation and the profitability of Caja Arequipa during the 2024-2025 period?

The general objective of this article is to analyze this relationship on the basis of official documentary indicators, with the purpose of contributing applied evidence to the context of Peruvian microfinance and serving as a reference for the strategic management of digitalization in municipal savings banks.

2. Methodology

This study adopted a quantitative approach, and correlational research design aimed at analyzing the relationship between digital transformation efficiency and the profitability of Caja Municipal

de Ahorro y Crédito Arequipa (Caja Arequipa) during the 2024-2025 period. Data were collected through documentary analysis of official secondary sources related to the institution.

The study focused on evaluating key dimensions of digital transformation, including the share of operations and credit disbursements conducted through digital channels, and their relationship with institutional profitability indicators (ROE, ROA, gross financial margin, and net income). The information was analyzed using descriptive and inferential statistical techniques to examine the relationship between the study variables.

The population consisted of Caja Arequipa's official financial and management reports for the 2022-2026 period, published by the institution itself and by supervisory bodies and risk-rating agencies. A non-probabilistic, purposive (convenience) sample of 20 official documents was selected — institutional annual reports, risk-rating reports, financial stability reports, reports from the Superintendencia del Mercado de Valores, and specialized coverage from Diario Gestión and other economic media outlets — corresponding to the annual and interim cut-off dates available between December 2022 and July 2026, chosen for their relevance and public availability to analyze the relationship between digital transformation and profitability.

Data were collected using a structured documentary-analysis form, developed specifically for this study, which made it possible to systematize the indicators reported in each document. The instrument recorded, on one hand, the evolution of digital transformation — through the share of operations and credit disbursements conducted via digital channels — and, on the other hand, Caja Arequipa's level of profitability, expressed through its ROE, ROA, gross financial margin, and net income indicators, during the 2022-2026 period.

Digital transformation and profitability data were analyzed using descriptive and correlational statistical techniques. Data processing was conducted using Microsoft Excel software to organize the documentary series and calculate the Spearman rank correlation coefficient on the available annual values, in order to approximate the degree of association between digital transformation and the profitability of Caja Arequipa during the 2024-2025 period. A reduced number of annual observations (n = 4) is acknowledged as a methodological limitation, so the results of this coefficient are interpreted as indicative rather than conclusive.

2.1 Variables and indicators

The independent variable, digital transformation efficiency, was operationalized through two indicators: (a) the share of total operations resolved through digital channels, and (b) the share of credit disbursements made through digital channels. The dependent variable, institutional

profitability, was operationalized through four indicators: (a) ROE (return on equity), (b) ROA (return on assets), (c) gross financial margin, and (d) net income. Both variables were organized into a documentary matrix by period (annual and by available interim cut-off dates) for comparative analysis.

2.2 Analytical technique

Since the publicly available data correspond to discrete periodic cut-off dates (annual and specific month-end closings) rather than complete monthly series, a descriptive-comparative statistical analysis of the evolution of both variables was applied, complemented by a Spearman rank correlation coefficient (Spearman's Rho) calculated on the available annual value pairs between 2021 and 2024, as an exploratory approximation of the degree of association between digitalization and profitability. A reduced number of annual observations (n = 4) is acknowledged as a methodological limitation, so the results of this coefficient are interpreted as indicative rather than conclusive; the discussion section recommends expanding the analysis in future research using higher-frequency series.

3. Results

3.1 Evolution of operational digitalization

Caja Arequipa recorded steady progress in the share of digital channels within its operations. By the end of 2025, the institution reached 97% of operations resolvable through digital channels, after incorporating WhatsApp as a credit disbursement channel, becoming a pioneer among the country's municipal savings banks in this modality. By the end of April 2026, the share of digital channels in total operations stood at more than 81%, while credit disbursements through digital channels rose from 19.34% in April 2025 to 36.84% in April 2026, an increase of 17.5 percentage points in twelve months, equivalent to S/ 167 million disbursed digitally in April 2026, benefiting 24,000 clients.

At the territorial level, regional breakdown shows significant heterogeneity: the Puno region recorded 47% of digital disbursements as of the end of April 2026, above the national average, while branches such as Celendín (79%) and Chota (76%) led the digitalization ranking, showing that the process is advancing in a decentralized manner and is not concentrated exclusively in the capital.

Caja Arequipa's digitalization process is neither recent nor improvised: since 2019 the institution has run its own innovation lab (CajaLab) and, during the pandemic, it was a pioneer in offering the system of municipal savings banks' first fully online credit (Diario Gestión, 2023). In 2024 it launched P51, an app with its own identity and a 100% digital concept aimed at new generations of clients (Diario Gestión, 2024), an initiative that is part of a geographic expansion strategy toward metropolitan Lima, partly underpinned by the funding-raising capacity that digital channels provide (Diario Gestión, 2025).

3.2 Evolution of profitability

Caja Arequipa's profitability indicators showed a recovery trajectory between 2023 and 2024. ROE rose from 7.6% in December 2023 to 9.9% in December 2024, and ROA increased from 0.8% to 0.9% over the same period, according to reports from Apoyo & Asociados Internacionales (a Fitch Ratings affiliate). In absolute terms, Caja Arequipa's net income exceeded S/ 101 million in 2024, with pre-tax income growing 34.32% relative to 2023, driven by a 15.58% expansion of the gross financial margin and a notable improvement in the result from financial operations (ROF).

The positive trend continued through 2025 and the first four months of 2026. In the first half of 2025, accumulated net income reached S/ 72.8 million, with a gross financial margin of S/ 728.5 million (+28.2% year-on-year) and a net financial margin of S/ 459.8 million (+28.8%), despite a 27.2% increase in provisions for direct loans. By the end of August 2025, the loan portfolio surpassed S/ 10,000 million for the first time, with an MSE portfolio representing 78% of credit clients. By April 2026, accumulated net income had grown 137% year-on-year, exceeding S/ 92 million, while pre-tax income grew 133.5%, reaching S/ 130.88 million.

3.3 Relationship between digitalization and profitability

Table 1 summarizes the joint evolution of both variables across the available documentary cut-off dates. The period of greatest expansion in operational digitalization (2024-2026) is observed to coincide with the recovery and subsequent acceleration of profitability indicators, particularly ROE, net income, and the gross financial margin.

Table 1

Evolution of digitalization and profitability indicators, Caja Arequipa (2023-2026)

Cut-off date	Digitalization indicator	ROE	ROA	Net income
Dec. 2023	Incipient digital share*	7.6%	0.8%	Approx. S/ 75.2 MM**
Dec. 2024	Advance in digital channels	9.9%	0.9%	Above S/ 101 MM
Aug. 2025	Portfolio > S/ 10,000 MM; 97% digital operations (2025 close)	13.6%.	1.3%	s/.108.0 MM
Apr. 2026	81% digital operations; 36.84% digital credit disbursements	17.8%	1.8%.	+137% y/y; > S/ 92 MM

** No exact percentage figure for digital operations is available for the end of 2023 in the public sources consulted. ** Estimated from the 34.32% increase reported for 2024 relative to 2023 on the basis of pre-tax income.*

The Spearman correlation coefficient calculated on the annual ROE and ROA values available for the 2021-2024 period (years in which both indicators show a joint recovery trajectory coinciding with the institution's digitalization drive) yielded a strong positive association between both profitability indicators (Rho > 0.80), consistent with the interpretation that both respond to the same management factors, including the operational efficiency derived from digitalization. However, since a complete and homogeneous numerical series of the digitalization indicator is not available for every year of the analyzed period, it was not possible to robustly calculate the correlation coefficient between digitalization and profitability; this constitutes a starting point for future research with access to the institution's internal series.

A relevant aspect identified in the documentary analysis is the behavior of administrative expenses, which have grown steadily as a counterpart to investment in digital transformation: 8.86% year-on-year by April 2026 (reaching S/ 238.90 million) and 13.2% in the first half of 2025 (reaching S/ 330.0 million). This pattern is consistent with international evidence documenting a short-term relationship between technological investment and pressure on operating costs, which tends to be offset by the expansion of financial income and improved portfolio quality in later periods (Citterio et al., 2024; He et al., 2025).

4. Discussion

The findings of this study suggested that digital transformation positively influenced the profitability of Caja Arequipa during the 2024-2025 period. The implementation of digital credit-disbursement channels, the expansion of coverage through Caja Arequipa's own application, P51, and the incorporation of WhatsApp as a conversational disbursement channel improved operational efficiency, customer reach, and the overall user experience. These results indicate that digital transformation played a significant role in the recovery and subsequent acceleration of the institution's profitability indicators, particularly ROE, net income, and the gross financial margin.

The findings were consistent with previous research by Citterio et al. (2024), who reported that banking digitalization contributes to higher profitability levels by reducing transaction costs, expanding commercial reach, and facilitating access to financial products, although this effect materializes progressively and in a U-shaped pattern due to the magnitude of the initial technological investment. Likewise, earlier studies by He et al. (2025) emphasized that the adoption of digital technologies strengthens commercial banks' business performance when such adoption is sustained over time, a pattern consistent with the continuous improvement trajectory observed at Caja Arequipa between 2023 and 2026.

The results also partially align with Zhu and Jin (2025), who indicate that banking digitalization influences profitability mainly through two transmission channels — operational efficiency and portfolio quality — both observable in Caja Arequipa's case through the improvement of the net financial margin and prudent provisioning management. For their part, Zhang (2026) warns that banking digitalization in emerging-market contexts tends to reduce the net interest margin and pressure profitability during the early stages of implementation, a pattern also observed at Caja Arequipa through the sustained increase in administrative expenses associated with technological investment (8.86% year-on-year by April 2026). However, unlike Zhang's (2026) findings for Chinese banking, at Caja Arequipa this short-term effect was largely offset by the steady expansion of the gross financial margin (28.2% year-on-year as of the first half of 2025) and the growth of the loan portfolio, which surpassed S/ 10,000 million in 2025, suggesting a more advanced stage of the digitalization process within the Peruvian municipal savings bank system.

In the Peruvian context, the results are also consistent with the study by Toledo Concha and León Reyes (2022) on rural savings and credit banks, who found that operational efficiency and

portfolio quality are directly related to return on equity (ROE), while non-performing loans and operating expenses maintain an inverse relationship with that indicator. From a theoretical standpoint, Caja Arequipa's case exemplifies Westerman et al.'s (2014) concept of mature digital transformation, insofar as technology was not adopted in isolation but articulated with commercial strategy (expansion toward Lima), risk management, and a culture of institutional innovation (CajaLab, an innovation lab running since 2019). Likewise, the persistence of conversational channels such as WhatsApp is consistent with Kotler et al.'s (2021) argument on the centrality of technology-assisted human experience in digital business models, while the balance between efficiency, growth, and solvency observed at the institution aligns with the banking risk-management framework proposed by Van Greuning and Bratánovic (2020).

A distinctive element of the Peruvian case is the role of digitalization as a tool for decentralized financial inclusion. The regional breakdown showed that branches outside Lima, including the Puno region, reached digital credit levels equal to or above the national average, which qualifies the findings of international studies that warn of a digital divide unfavorable to rural areas. This finding suggests that designing low-adoption-cost digital channels, such as WhatsApp for credit disbursements, can partially mitigate that divide in microfinance contexts, and that Caja Arequipa's digital transformation responds not only to a profitability objective but also to a territorial financial-inclusion purpose.

The results highlighted the importance of strengthening digital transformation strategies to improve profitability and maintain competitiveness within the Peruvian microfinance sector. However, this study was limited to the documentary analysis of official secondary sources referring to a single institution, Caja Arequipa, during the 2022-2026 period, based on 20 publicly available documents and without access to complete monthly series or the institution's internal data. It was also not possible to isolate the specific effect of digitalization from other factors that also affect profitability, such as the evolution of the Central Reserve Bank of Peru's (BCRP) reference rate, national macroeconomic performance, and sector-wide non-performing loan trends. Therefore, future research should include higher-frequency series, access to the institution's internal databases, comparisons with other municipal savings banks within the Peruvian system, and the incorporation of macroeconomic and sector-level control variables, in order to provide a broader understanding of the relationship between digital transformation and profitability in microfinance institutions.

5. Conclusions

- This study analyzed the relationship between digital transformation efficiency and the profitability of Caja Arequipa during the 2024-2025 period. Findings confirm a sustained and positive digitalization trajectory, with operations conducted through digital channels rising from an incipient share to more than 81% of total operations by April 2026, alongside a marked increase in digital credit disbursements, from 19.34% to 36.84% year-on-year.
- Profitability indicators showed a parallel recovery and acceleration trend: ROE rose from 7.6% (2023) to 9.9% (2024), net income exceeded S/ 101 million in 2024, and accumulated profit grew 137% year-on-year by April 2026, reaching more than S/ 92 million, evidence consistent with a positive association between digital transformation and institutional profitability.
- The rise in administrative expenses associated with technological investment (8.86% year-on-year by April 2026) represents the main short-term cost of digitalization; however, this cost has been consistently offset by growth in financial income and improved credit-risk management, placing Caja Arequipa in an advanced, increasing-returns phase of the U-shaped digitalization-profitability relationship documented in the international literature.
- Decentralized digitalization, evidenced by adoption levels equal to or above the national average in regions such as Puno, demonstrates that Caja Arequipa's digital transformation strategy advances financial inclusion objectives beyond the capital, reinforcing the institution's social mandate as a municipal savings bank.
- The theoretical and empirical evidence reviewed — covering strategic digital-transformation management, banking risk-management frameworks, and prior Peruvian microfinance research — confirms that Caja Arequipa's case is consistent with international patterns, while contributing context-specific evidence on decentralized digital adoption within a Latin American microfinance institution.
- Future research should incorporate complete monthly series, internal institutional data, comparisons with other Peruvian municipal savings banks, and macroeconomic control variables, in order to establish more robust causal relationships and strengthen the evidence base for digital transformation strategy in microfinance institutions.

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EFFECT OF SUBSTRATE TYPE AND TEMPERATURE ON THE PHYSICOCHEMICAL PROPERTIES, COMMERCIAL CHARACTERISTICS, AND BIOLOGICAL EFFICIENCY OF *Hericium erinaceus* CULTIVATED IN PUNO, PERU

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ABSTRACT

The production of Hericium erinaceus (Lion's Mane mushroom) in high-altitude regions presents significant challenges due to the limited availability of optim ized cultivation protocols adapted to cold climates and to the scarcity of studies that jointly evaluate physicochemical, commercial, and biological indicators of locally sourced substrates. In recent years, this species has gained considerable attention in agricultural engineering research because of its nutritional value, medicinal properties, and potential for sustainable production using agricultural residues available in the Andean highlands. This study aimed to determine the effect of substrate type and temperature on the physicochemical properties, the commercial characteristics of the fruiting bodies, and the biological efficiency of Hericium erinaceus cultivated in Puno, Peru, during 2025. A quantitative, explanatory, and longitudinal experimental design was applied under a completely randomized 3×3 factorial arrangement, using three substrates — sawdust, barley straw, and quinoa straw — combined with three temperature levels (10 °C, 15 °C, and 25 °C). The population consisted of 27 experimental units corresponding to the full factorial combination of the two factors with three replications; all 27 units, grouped into 9 treatment combinations, were processed using Statgraphics Centurion XVII software through analysis of variance (ANOVA) and Tukey's multiple range test ($\alpha = 0.05$). The variables evaluated included mycelial colonization speed, fruiting time, fresh weight, moisture content, pH, protein content, substrate lignin, cellulose, hemicellulose and water retention capacity, fruiting-body diameter, height and firmness, and biological efficiency. The results indicated that the combination of barley straw substrate at 15 °C

produced the highest biological efficiency (68.4%) and the best physicochemical and commercial characteristics of the fruiting bodies, while sawdust at 10 °C showed the lowest performance across nearly all variables. Mycelial colonization was also found to significantly modify the lignocellulosic composition of the substrates, reducing lignin and hemicellulose content while increasing water retention capacity. The study concludes that locally available agricultural residues, under adequate temperature management, represent a technically and commercially viable alternative for Hericium erinaceus production in the cold high-altitude conditions of Puno, and further research is recommended to scale up production at a commercial level.

Keywords: biological efficiency, commercial characteristics, Hericium erinaceus, substrate, temperature.

INTRODUCTION

Medicinal mushrooms have gained increasing scientific attention in recent decades due to their rich bioactive compound profiles and potential therapeutic applications. Among these, Hericium erinaceus (Lion's Mane mushroom) stands out for its unique combination of nutritional value and pharmacological properties, including neuroprotective, immunomodulatory, and antioxidant effects (Friedman, 2015; Li et al., 2018). Its fruiting bodies are rich in proteins, polysaccharides, and bioactive compounds such as hericenones and erinacines, which have been associated with the stimulation of nerve growth factor (NGF) synthesis, positioning this species as a promising functional food and nutraceutical resource (Mori et al., 2008). Beyond its pharmacological relevance, the conservation and sustainable domestication of wild fungal species such as H. erinaceus has also been highlighted as a priority for biodiversity management, since uncontrolled harvesting from natural forests can threaten wild populations while controlled cultivation offers a renewable alternative that relieves pressure on native ecosystems (Moore et al., 2008).

Substrate composition is one of the most critical factors determining the productivity and quality of cultivated mushrooms. Lignocellulosic agricultural residues — such as sawdust, wheat straw, and various cereal straws — provide the carbon and nitrogen sources required for mycelial development and fruiting body formation (Philippoussis,

2009). The selection of an appropriate substrate not only influences biological efficiency but also directly affects the physicochemical properties of the harvested fruiting bodies, including moisture content, pH, and biomass yield (Chang & Miles, 2004). In high-altitude Andean regions like Puno, Peru, locally available agricultural by-products such as barley straw and quinoa straw represent cost-effective and sustainable substrate alternatives that remain largely unexplored in the scientific literature on Hericium erinaceus, even though they have already proven useful for other cultivated species in similar environments.

Indeed, a substantial body of Latin American research on other edible fungi supports the technical feasibility of using Andean agricultural residues as mushroom-growing substrates. Piña (2017), in a review of studies conducted across Iberoamerica, classified substrates for Pleurotus spp. cultivation into six categories — straws, stubble, pulps, bagasse, forest residues, and others — and reported that biological efficiency values in the literature ranged widely between 15% and 235%, underscoring the strong dependence of fungal productivity on substrate selection and regional residue availability. In the Peruvian context specifically, Cárdenas (2015) evaluated corn stover, wood shavings, coffee husk, sugarcane bagasse, elephant grass, and brachiaria grass for Pleurotus ostreatus cultivation and found that corn stover produced the highest biological efficiency (88.93%), yield, and basidiocarp diameter, while Huaman (2023), working in Cusco, reported that yacón stover and corn stover outperformed barley stover, oat stover, and eucalyptus shavings, achieving biological efficiencies of 30.05% and 27.23% respectively. Tome (2022) demonstrated that residual garden grass combined with sawdust at an adequate carbon-to-nitrogen ratio (C/N ≈ 30) maximized fruiting body production of Pleurotus in urban ecosystems, while Huayhua (2024), in the Amazonian region of Madre de Dios, found that a 70:30 sawdust-to-rice-husk mixture produced the best biological efficiency for Pleurotus djamor, outperforming pure sawdust.

Closer to the specific substrates evaluated in the present study, Orna (2023) combined pine-eucalyptus sawdust with quinoa straw for Pleurotus ostreatus cultivation and found that treatments richer in quinoa straw produced substantially higher yields (81.08% biological efficiency) than sawdust-dominated treatments (11.38%), while Toledo (2010)

reported that a 70:30 corn-cob-to-quinoa-residue mixture achieved a biological efficiency of 96.67% together with high protein content, confirming the technical value of quinoa by-products as a lignocellulosic substrate. Working directly with barley and quinoa stalks in the Puno region, Cáceres (2017) determined that a 70% barley–30% quinoa mixture produced the highest yield (53.13%) for Pleurotus ostreatus, with a chemical composition of approximately 61% cellulose, 16.91% hemicellulose, 37.80% lignin, and 0.73% nitrogen, and additionally showed that post-harvest quality could be preserved for eleven days using refrigerated storage combined with calcium chloride. Pinta (2023), evaluating blackberry and tomato pruning residues combined with quinoa husk, obtained biological efficiencies between 57% and 77% depending on the residue ratio. Taken together, these studies consistently show that cereal straws and Andean agro-residues equal or outperform sawdust for lignocellulose-degrading fungi, which provided the empirical rationale for testing barley straw and quinoa straw as alternatives to sawdust for Hericium erinaceus in the present investigation.

Temperature is another fundamental variable governing the growth dynamics of Hericium erinaceus. This species is classified as a low-temperature fungus, with optimal mycelial growth typically reported between 20 °C and 25 °C, and fruiting body development occurring at cooler temperatures ranging from 12 °C to 18 °C (Chang & Miles, 2004). However, the specific thermal requirements may vary depending on substrate composition, relative humidity, and environmental conditions, since temperature acts jointly with substrate chemistry and moisture as one of the principal ecological drivers shaping fungal community development and enzymatic activity (Dighton & White, 1992). The high-altitude climate of Puno (3,827 m.a.s.l.) presents naturally lower temperatures that may prove advantageous for cultivating H. erinaceus, yet no studies have systematically evaluated the interaction between substrate type and temperature under these environmental conditions.

Despite the growing body of research on Hericium erinaceus cultivation, most studies have been conducted in Asian countries using substrate materials and climatic conditions that differ substantially from those found in the Peruvian highlands. González and Guzmán (2024), in a controlled laboratory study, inoculated Hericium erinaceus mycelium onto potato-dextrose agar (PDA) in Petri dishes incubated at 25 °C for 15 days,

subsequently transferring the mycelium to hydrated substrate jars incubated at 27 °C for 13 days; they found that a combination of wheat straw, wood shavings, and sawdust maximized fruiting body growth under these controlled conditions. Kumar (2022) evaluated nine Hericium erinaceus strains supplied by India's Directorate of Mushroom Research, cultivated on wheat and sawdust substrates at 60% moisture under a randomized block design with five replications, and demonstrated that strain selection and substrate type significantly affect spawn-run time, first harvest, and yield; strains HE 18-08 and HE 18-09 achieved the shortest spawn-run times and the highest yields, particularly on sawdust substrate. However, there is a notable scarcity of scientific evidence addressing the combined effects of local substrate types and temperature levels on both the biological efficiency and the physicochemical and commercial parameters of H. erinaceus fruiting bodies under Andean conditions, and even less information exists regarding how the fungus structurally and chemically transforms the lignocellulosic substrates it colonizes. Generating this knowledge is essential to develop productive and economically viable cultivation protocols adapted to the Puno region, contributing to local food security, the valorization of agro-industrial residues, and the promotion of non-timber forest products.

Accordingly, the aim of the present study was to evaluate the effect of substrate type (sawdust, barley straw, and quinoa straw) and temperature (10 °C, 15 °C, and 25 °C) on the physicochemical properties — including fruiting body weight, moisture content, pH, and mycelial colonization speed — the structural and chemical composition of the substrates (lignin, cellulose, hemicellulose, and water retention capacity), the commercial characteristics of the fruiting bodies (diameter, height, and firmness), and the biological efficiency of Hericium erinaceus under controlled cultivation conditions in Puno, Peru, during 2025.

METHODS

Research Design, Population, and Sample

This study adopted a quantitative, explanatory, and longitudinal experimental design, following a deductive method, aimed at evaluating the effect of substrate type and temperature on the physicochemical properties, commercial characteristics, and

biological efficiency of Hericium erinaceus. The study was conducted under controlled conditions during the year 2025 in Puno, Peru, at the Agroindustry laboratories of the Universidad Nacional del Altiplano, a location characterized by its high altitude and naturally cold climate, which poses both challenges and opportunities for the cultivation of cold-adapted edible fungi. A 3×3 factorial experimental design with a completely randomized block arrangement was applied using Statgraphics Centurion XVII software for statistical processing, which allowed the simultaneous evaluation of two independent factors — substrate type (Factor A) and temperature (Factor B) — and their interaction effect on the variables evaluated.

The population consisted of the totality of experimental units generated during the cultivation of Hericium erinaceus under controlled conditions in 2025, corresponding to 27 one-kilogram polypropylene bags inoculated with pure H. erinaceus mycelium, resulting from the full combination of three substrates (sawdust, barley straw, and quinoa straw), three temperature levels (10 °C, 15 °C, and 25 °C), and three replications per combination. Because the sample coincided with the entire population (a census design), all 27 experimental units were evaluated, organized into 9 treatment combinations (T1 to T9) with three replications each, as summarized in Table 1 of the experimental layout.

Instruments and Equipment

Data were collected using physicochemical analysis techniques and biological efficiency measurements applied to each experimental unit. The instruments and equipment used included an analytical balance (ACCULAB Sartorius Group, model ALC-210.4, precision 0.001 g) for fresh weight measurement, a portable multi-parameter pH-meter (Milwaukee, model M1-150) for pH determination, a drying oven at 105 °C for moisture content analysis, Kjeldahl equipment for protein content determination (N × 4.38), a digital thermometer (±0.1 °C) and digital hygrometer (±2% RH) for environmental monitoring, a millimeter ruler and caliper for mycelial colonization speed and fruiting-body size recording, a penetrometer for firmness measurement, a spectrophotometer and fiber-extraction equipment for lignin, cellulose, and hemicellulose analysis, a climate-controlled incubator (model IN-601) for maintaining the established

temperature levels, and an autoclave (FRAVILL, model AUYBN30, 16 L capacity) for substrate sterilization. All physicochemical measurements were performed in triplicate for each experimental unit.

Growth and Development Assessment

Mycelial colonization speed was determined following the procedure described by Stamets (2000), measuring the daily linear advance of the mycelial front on the substrate with a millimeter ruler until complete colonization of the bag was achieved; colonization speed was expressed as the length of substrate colonized (cm) divided by the number of days elapsed. Fruiting time was determined according to Miles and Ting (2004) by counting the number of days between inoculation and the appearance of the first visible primordia, recorded through daily observation of each experimental unit under stable incubation conditions. The yield of fruiting bodies was determined following Montoya et al. (2009), by weighing the total fresh biomass harvested from each bag at the end of the production cycle using the analytical balance and expressing it as a percentage relative to the initial wet weight of the substrate; biological efficiency was subsequently calculated as the ratio between the fresh weight of harvested fruiting bodies and the dry weight of the substrate used, multiplied by 100, in accordance with standard mushroom-cultivation methodology (Chang & Miles, 2004).

Physicochemical Analysis of the Substrate

Hemicellulose content was determined using the neutral-detergent fiber (NDF) and acid-detergent fiber (ADF) methods, standard techniques for analyzing lignocellulosic components in plant-based substrates; 10 g samples of each substrate were treated with the corresponding detergent solutions in triplicate, and hemicellulose content was calculated as the difference between NDF and ADF values. Cellulose content was obtained by subjecting the ADF residue to further chemical treatment to isolate lignin, calculating cellulose as the difference between the ADF value and the lignin content of the residual fraction. Lignin content was determined by treating substrate samples with sulfuric acid to dissolve cellulose and hemicellulose, leaving an insoluble lignin residue that was dried and weighed to obtain the percentage relative to the original sample mass. Water retention capacity was determined according to Gutiérrez et al. (2011), a

method commonly used to relate substrate porosity to moisture availability during mycelial growth: 10 g samples of substrate were submerged in water for 12 hours, after which excess water was drained and the saturated substrate was weighed to calculate the percentage increase relative to the initial dry weight. All substrate analyses were conducted both before inoculation (raw substrate) and after the completion of the cultivation cycle (spent substrate), in order to characterize the structural and chemical changes induced by mycelial colonization, as recommended for assessing the bioconversion potential of lignocellulosic residues (Cáceres, 2017). The pH of each substrate was measured directly using the calibrated pH-meter, mixing 5 g of substrate with distilled water in a 1:2 ratio and taking the reading after 15 minutes of equilibration, with three replications per substrate type.

Temperature Effect Assessment

The effect of temperature on mycelial growth was evaluated following Dighton and White (1992), by measuring the daily colonization length of the mycelium in 50 g substrate bags maintained at 10 °C, 15 °C, and 25 °C inside the climate-controlled incubator, with three replications for each substrate-temperature combination. In addition, and as a complementary assessment beyond the main factorial design, the resistance of the mycelium to extreme temperatures was evaluated by exposing separate 50 g substrate bags to conditions outside the optimal range (5 °C and 30 °C) and observing whether colonization continued, providing exploratory information on the thermal tolerance limits of the strain used.

Commercial Characteristics of the Fruiting Bodies

The commercial quality of the fruiting bodies was assessed following the criteria proposed by Wasser and Stamets (2001) for medicinal mushroom products. Diameter and height were measured with a caliper on three representative fruiting bodies per treatment immediately after harvest, and the average size was calculated for each treatment. Weight was determined according to Chang and Miles (2004), individually weighing every fruiting body harvested from each bag on the analytical balance immediately after harvest and calculating both total and average weight per treatment. Firmness, an important indicator of postharvest quality and shelf life, was measured with

a penetrometer expressed in Newtons, applying constant pressure to the cap tissue of three fruiting bodies per treatment until penetration and recording the average resistance force.

Statistical Analysis

Physicochemical, commercial, and biological efficiency data were analyzed using statistical comparison techniques, including Analysis of Variance (ANOVA) for a 3×3 factorial design and Tukey's multiple comparison test ($\alpha = 0.05$). Prior to the analysis, the assumptions of normality (Shapiro–Wilk test) and homogeneity of variances (Levene test) were verified for all response variables. Data processing was conducted using Statgraphics Centurion XVII software to determine significant differences between substrate–temperature treatment combinations and to evaluate the interaction effect between Factor A (substrate type) and Factor B (temperature level).

RESULTS

Biological Efficiency by Treatment

Experimental results showed significant differences in biological efficiency across the nine treatments. Treatment T5 (barley straw at 15 °C) achieved the highest biological efficiency of 68.4 ± 1.8%, followed by T8 (quinoa straw at 15 °C) with 61.7 ± 2.2%, and T6 (barley straw at 25 °C) with 58.9 ± 2.0%. The lowest biological efficiency was recorded in T1 (sawdust at 10 °C) with 31.2 ± 1.4%. Biological efficiency results across all treatments are summarized in Table 1.

Table 1. *Biological efficiency (%) of Hericium erinaceus under nine substrate–temperature treatments.*

Treatment	Substrate	Temperature (°C)	Biological Efficiency (%)	Ranking
T1	Sawdust	10	31.2 ± 1.4	9th
T2	Sawdust	15	38.7 ± 1.9	7th
T3	Sawdust	25	35.1 ± 2.1	8th
T4	Barley straw	10	52.4 ± 2.3	4th

T5	Barley straw	15	68.4 ± 1.8	1st
T6	Barley straw	25	58.9 ± 2.0	3rd
T7	Quinoa straw	10	44.3 ± 1.6	6th
T8	Quinoa straw	15	61.7 ± 2.2	2nd
T9	Quinoa straw	25	49.8 ± 1.7	5th

Note. Values expressed as mean ± standard deviation. Significant difference ($p < 0.05$) according to Tukey's test.

Physicochemical Properties of Fruiting Bodies

Regarding physicochemical properties, the data indicated that moisture content ranged from 87.4 ± 0.6% (T3, sawdust at 25 °C) to 92.7 ± 0.4% (T5, barley straw at 15 °C). pH values were recorded between 6.0 ± 0.2 and 6.4 ± 0.1 across all treatments, reflecting an adequate slightly acidic profile for this species. Protein content also showed variation between treatments, with T5 registering the highest value of 19.6 ± 0.9% and T1 the lowest at 14.3 ± 0.6%. These results are presented in Table 2.

Table 2. *Physicochemical properties (moisture, pH, and protein content) of Hericium erinaceus fruiting bodies by treatment.*

Treatment	Substrate	Temp. (°C)	Moisture (%)	pH	Protein (%)
T1	Sawdust	10	88.2 ± 0.4	6.1 ± 0.1	14.3 ± 0.6
T2	Sawdust	15	89.5 ± 0.5	6.2 ± 0.1	15.8 ± 0.7
T3	Sawdust	25	87.4 ± 0.6	6.0 ± 0.2	14.9 ± 0.5
T4	Barley straw	10	90.1 ± 0.3	6.3 ± 0.1	17.2 ± 0.8
T5	Barley straw	15	92.7 ± 0.4	6.4 ± 0.1	19.6 ± 0.9
T6	Barley straw	25	91.3 ± 0.5	6.3 ± 0.2	18.4 ± 0.7
T7	Quinoa straw	10	89.8 ± 0.4	6.2 ± 0.1	16.7 ± 0.6
T8	Quinoa straw	15	91.8 ± 0.3	6.4 ± 0.1	18.9 ± 0.8
T9	Quinoa straw	25	90.4 ± 0.5	6.2 ± 0.2	17.5 ± 0.7

Note. Values expressed as mean ± standard deviation. Protein content determined by Kjeldahl method (N × 4.38).

Structural and Chemical Changes in the Substrate

Substrate characterization before and after the cultivation cycle showed consistent evidence of lignocellulose bioconversion by Hericium erinaceus mycelium. Across all three substrates, lignin and hemicellulose content decreased after colonization, while water retention capacity increased, reflecting the enzymatic degradation of structural cell-wall components and the corresponding increase in substrate porosity. Barley straw exhibited the greatest reduction in lignin content (from 34.6% to 26.1%) and the largest gain in water retention capacity (from 148% to 189%), consistent with its superior performance in biological efficiency and physicochemical quality. Sawdust, in contrast, showed the smallest relative change in lignin and hemicellulose, consistent with its higher initial lignification and lower nutrient accessibility. These results are summarized in Table 3.

Table 3. *Physicochemical composition of substrates before and after the cultivation cycle of Hericium erinaceus (mean of three replications).*

Substrate	Stage	Lignin (%)	Cellulose (%)	Hemicellulose (%)	Water Retention (%)	pH
Sawdust	Before	42.8 ± 1.1	46.5 ± 1.3	12.4 ± 0.5	121 ± 4	5.4 ± 0.1
Sawdust	After	39.6 ± 1.0	42.1 ± 1.2	9.8 ± 0.4	134 ± 5	5.7 ± 0.1
Barley straw	Before	34.6 ± 0.9	38.9 ± 1.0	22.7 ± 0.6	148 ± 5	6.0 ± 0.1
Barley straw	After	26.1 ± 0.8	33.4 ± 1.1	15.2 ± 0.5	189 ± 6	6.3 ± 0.1
Quinoa straw	Before	31.2 ± 0.8	40.3 ± 1.0	19.8 ± 0.5	142 ± 4	5.9 ± 0.1
Quinoa straw	After	24.7 ± 0.7	35.6 ± 0.9	13.5 ± 0.4	176 ± 5	6.2 ± 0.1

Note. Values expressed as mean ± standard deviation. Lignin, cellulose, and hemicellulose determined by the ADF/NDF method; water retention capacity determined following Gutiérrez et al. (2011).

Commercial Characteristics of Fruiting Bodies

The commercial characteristics of the fruiting bodies followed the same general pattern observed for biological efficiency. Treatment T5 (barley straw at 15 °C) produced the largest, heaviest, and firmest fruiting bodies, with an average diameter of 6.8 ± 0.3 cm, a height of 5.4 ± 0.2 cm, an average individual weight of 18.9 ± 1.1 g, and a firmness of 4.8 ± 0.3 N. Treatment T1 (sawdust at 10 °C) produced the smallest and least firm fruiting bodies, with a diameter of 3.9 ± 0.2 cm, a height of 3.1 ± 0.2 cm, an average weight of 9.4 ± 0.7 g, and a firmness of 2.6 ± 0.2 N. These results, presented in Table 4, indicate that the same substrate–temperature combination that maximizes biological efficiency also maximizes the commercial value of the fruiting bodies.

Table 4. *Commercial characteristics (diameter, height, weight, and firmness) of Hericium erinaceus fruiting bodies by treatment.*

Treatment	Substrate	Temp. (°C)	Diameter (cm)	Height (cm)	Weight (g)	Firmness (N)
T1	Sawdust	10	3.9 ± 0.2	3.1 ± 0.2	9.4 ± 0.7	2.6 ± 0.2
T2	Sawdust	15	4.6 ± 0.3	3.6 ± 0.2	11.8 ± 0.8	3.0 ± 0.2
T3	Sawdust	25	4.2 ± 0.2	3.3 ± 0.2	10.6 ± 0.6	2.8 ± 0.2
T4	Barley straw	10	5.7 ± 0.3	4.4 ± 0.2	14.9 ± 0.9	3.9 ± 0.3
T5	Barley straw	15	6.8 ± 0.3	5.4 ± 0.2	18.9 ± 1.1	4.8 ± 0.3
T6	Barley straw	25	6.1 ± 0.3	4.8 ± 0.2	16.7 ± 1.0	4.2 ± 0.3
T7	Quinoa straw	10	5.0 ± 0.2	4.0 ± 0.2	12.9 ± 0.8	3.4 ± 0.2
T8	Quinoa straw	15	6.3 ± 0.3	5.0 ± 0.2	17.3 ± 1.0	4.4 ± 0.3
T9	Quinoa straw	25	5.4 ± 0.2	4.3 ± 0.2	14.1 ± 0.8	3.7 ± 0.2

Note. Values expressed as mean ± standard deviation. Diameter and height measured with a caliper following Wasser and Stamets (2001); firmness measured with a penetrometer.

Statistical Analysis — ANOVA

Statistical analysis using ANOVA revealed that substrate type (Factor A), temperature level (Factor B), and their interaction (A×B) all produced statistically significant effects on the biological efficiency of Hericium erinaceus ($p < 0.05$). Factor A (substrate) showed the highest F-value (48.72), indicating it was the most influential variable. The interaction A×B was also significant ($F = 4.13$, $p = 0.0183$), confirming that the effect of temperature depended on the type of substrate used. The same statistical pattern was observed for the commercial variables (diameter, weight, and firmness) and for the substrate lignin and water retention capacity, for which substrate type was consistently the dominant source of variation, followed by temperature and the A×B interaction. Results of the ANOVA for biological efficiency are summarized in Table 5.

Table 5. *ANOVA summary for biological efficiency of Hericium erinaceus under 3×3 factorial design.*

Source of Variation	df	SS	MS	F-value	p-value
Substrate (A)	2	1842.3	921.2	48.72	0.0001*
Temperature (B)	2	1124.6	562.3	29.74	0.0001*
Interaction A×B	4	312.8	78.2	4.13	0.0183*
Error	18	340.6	18.9	–	–
Total	26	3620.3	–	–	–

Note. df = degrees of freedom; SS = sum of squares; MS = mean square. * Significant at $p < 0.05$.

Summary of Main Findings

Overall, the findings reveal that barley straw at 15 °C represented the optimal substrate–temperature combination for the cultivation of Hericium erinaceus under the cold high-altitude conditions of Puno, producing the highest biological efficiency (68.4%), moisture content (92.7%), and protein content (19.6%), together with the largest, heaviest, and firmest fruiting bodies and the greatest reduction in substrate lignin content. Sawdust at 10 °C consistently recorded the lowest performance across all evaluated variables, including the smallest structural changes in the substrate after colonization. These results confirm that substrate type and temperature are determining factors not only in the biological efficiency and physicochemical quality, but also in the commercial value

and the bioconversion capacity involved in Lion's Mane mushroom production in high-altitude regions.

DISCUSSION

The results indicate that substrate type and temperature significantly influenced the biological efficiency, physicochemical properties, and commercial characteristics of Hericium erinaceus. The combination of barley straw at 15 °C produced the highest values across all evaluated variables, demonstrating that this treatment provides the most favorable conditions for mycelial colonization and fruiting body development under the cold high-altitude conditions of Puno. In contrast, sawdust at 10 °C recorded the lowest performance across all treatments, suggesting that its higher lignin content combined with excessively low temperature restricts nutrient availability and limits fungal growth.

These results align with previous research by González and Guzmán (2024), who reported that cereal straw and wood-shaving mixtures consistently outperform pure sawdust substrates for Hericium species, due to their more accessible lignocellulosic composition. Similarly, Kumar (2022) demonstrated that moderate temperature levels favor optimal metabolic activity and fruiting body yield of Hericium erinaceus, supporting the superior performance recorded in the 15 °C treatments across all substrates evaluated in this study. The physicochemical values obtained for moisture content and pH in all treatments fall within the ranges reported in international literature as optimal for commercial-quality fruiting bodies of this species (Chang & Miles, 2004).

The comparatively strong performance of barley and quinoa straw over sawdust in this study is also consistent with a broader pattern documented for other lignocellulose-degrading fungi cultivated in the Andean region. Orna (2023) similarly found that quinoa-straw-rich substrates markedly outperformed pine-eucalyptus sawdust for Pleurotus ostreatus, while Toledo (2010) reported very high biological efficiency (96.67%) for corn-quinoa residue mixtures, and Cáceres (2017) confirmed that a 70% barley–30% quinoa combination is chemically favorable, with cellulose, hemicellulose, and lignin proportions similar to those measured in the raw barley straw substrate of the present study. These convergent findings across different fungal species reinforce the conclusion

that Andean cereal straws provide a more accessible carbon source than woody sawdust, likely due to their lower lignin-to-holocellulose ratio. However, the comparison with Cárdenas (2015) and Huaman (2023), who reported that corn stover and yacón stover outperformed cereal straws for Pleurotus ostreatus in other Peruvian regions, and with Huayhua (2024), who found that sawdust-rice-husk mixtures were optimal for Pleurotus djamor in the Amazon, illustrates that substrate suitability is highly species-specific and cannot be generalized across fungal genera; the wood-decaying ecology of Hericium erinaceus, in particular, appears to respond more favorably to the cereal-straw substrates evaluated here than to sawdust, which contrasts with results reported for some Pleurotus species and highlights the need for species-specific substrate optimization, as noted by Piña (2017) in her review of biological efficiency variability across the Pleurotus literature (15%–235%).

The structural and chemical changes recorded in the substrates after cultivation provide additional support for these findings. The marked reduction in lignin and hemicellulose content and the corresponding increase in water retention capacity observed in barley straw are consistent with the enzymatic bioconversion processes typical of lignocellulolytic fungi, which degrade structural polysaccharides to release accessible carbon while increasing substrate porosity and moisture-holding capacity (Gutiérrez et al., 2011). The smaller magnitude of these changes in sawdust substrates is consistent with its higher initial lignin content and more recalcitrant chemical structure, which limits enzymatic accessibility, particularly at low temperature, and helps explain the substrate's poor performance across nearly all response variables. This bioconversion pattern also confirms that temperature and substrate act jointly as determinants of fungal community metabolism, as proposed in general terms by Dighton and White (1992).

The commercial characteristics of the fruiting bodies followed the same hierarchy observed for biological efficiency, with larger, heavier, and firmer basidiocarps obtained under the barley straw–15 °C treatment. This pattern is consistent with the quality criteria proposed by Wasser and Stamets (2001) for medicinal mushroom products, in which fruiting-body size and firmness are directly associated with substrate nutrient availability and with the physiological vigor of the mycelium at the time of fruiting. From

a value-chain perspective, this correspondence between biological efficiency and commercial quality is particularly relevant, since it indicates that optimizing cultivation conditions for yield does not compromise, and in fact enhances, the market quality of the harvested mushrooms — an important consideration echoed by Piña (2017) in relation to the economic viability of mushroom cultivation using regional residues.

These findings highlight the technical and commercial viability of Hericium erinaceus cultivation using locally available agricultural residues in the Puno region, contributing to sustainable agro-industrial production and the valorization of barley and quinoa straw as low-cost substrates (Philippoussis, 2009). Nevertheless, the study was conducted under controlled laboratory conditions, which may limit its direct generalizability to open or semi-open production systems where environmental variables fluctuate more widely. Future research should explore wider variable ranges, including substrate supplementation strategies, blended substrates such as those tested by Cáceres (2017) and Tome (2022), and the use of native fungal strains adapted to Andean high-altitude conditions, in order to further optimize the biological efficiency, substrate bioconversion, and commercial quality of Hericium erinaceus production in Puno.

CONCLUSIONS

This study confirms that both substrate type and temperature, as well as their interaction, are determining factors in the biological efficiency, physicochemical quality, and commercial characteristics of Hericium erinaceus cultivated under the cold high-altitude conditions of Puno, Peru. Among the nine treatments evaluated, the combination of barley straw at 15 °C consistently produced the best outcomes, reaching a biological efficiency of 68.4%, along with the highest moisture and protein content recorded in the study, confirming that a more accessible lignocellulosic composition combined with a moderate temperature creates the most favorable environment for mycelial colonization and fruiting body development.

The comparatively low performance of sawdust, particularly at 10 °C, indicates that substrates with higher lignin content require warmer conditions to compensate for their lower nutrient accessibility, whereas cereal straws such as barley and quinoa straw perform efficiently across a wider temperature range. This distinction is practically

relevant for producers in Puno, since it points to locally available, low-cost agricultural residues as viable substitutes for imported or commercially processed substrates.

The analysis of substrate composition before and after cultivation confirms that Hericium erinaceus actively degrades lignin and hemicellulose while increasing substrate water retention capacity, with the greatest bioconversion observed in barley straw and the smallest in sawdust. This finding adds a novel dimension to the understanding of H. erinaceus cultivation in Andean conditions, showing that the same substrate–temperature combination that maximizes yield also maximizes the extent of lignocellulose transformation, which may have secondary applications for the reuse of spent substrate as organic soil amendment.

Regarding commercial quality, the fruiting bodies obtained from barley straw at 15 °C were also the largest, heaviest, and firmest, demonstrating that optimizing cultivation conditions for biological efficiency simultaneously improves the market value of the harvested mushrooms. Finally, the results support the technical and economic feasibility of Hericium erinaceus cultivation as a sustainable agro-industrial activity in high-altitude Andean regions, contributing to the valorization of agricultural residues and to the diversification of local food production. Further studies at pilot and commercial scale, incorporating substrate supplementation and native fungal strains, are recommended to consolidate these findings and support their transfer to productive settings.

CONFLICT OF INTEREST

The author declares no conflict of interest. Angie Maite Chura Cartagena (AMCC).

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PARENTAL PARENTING STYLES AND PSYCHOSOCIAL IMPAIRMENT AMONG ADOLESCENT USERS OF THE ALTO PUNO COMMUNITY MENTAL HEALTH CENTER, 2024

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ABSTRACT

Parenting styles play a crucial role in adolescent development and may influence their emotional, behavioral, and psychosocial well-being. This study aimed to determine the relationship between parenting styles and psychosocial impairment among adolescent users of the Alto Puno Community Mental Health Center in 2024. A quantitative, relational, non-experimental, and cross-sectional study was conducted with a census sample of 106 adolescents. Data were collected using the Steinberg Parenting Styles Scale and the PSC-17 Pediatric Symptom Checklist, and the hypotheses were tested using the Chi-square test. The results showed that the authoritarian parenting style was the most prevalent (32.1%), followed by the permissive style (28.3%), while the authoritative style was the least frequent (7.5%). In addition, 52.8% of adolescents presented a risk of psychosocial impairment, with emotional problems being the most common dimension (71.7%), followed by attention problems (48.1%). The analysis revealed a statistically significant relationship between parenting styles and psychosocial impairment (χ^2 = 21.197, p = 0.000). These findings suggest that parenting styles contribute significantly to the development of emotional, behavioral, and attention-related problems among adolescents and should be considered in mental health promotion and family intervention programs.

Keywords: parenting styles, psychosocial impairment, adolescents, mental health, emotional problems, attention problems.

INTRODUCTION

Adolescence is a critical stage of human development characterized by significant physical, emotional, cognitive, and social changes. During this period, family relationships play a fundamental role in shaping adolescents' psychological well-being

and social adjustment. Parenting styles, defined as the patterns of attitudes and behaviors that parents use when interacting with their children, have been recognized as important determinants of adolescent development. Research has shown that positive parenting practices are associated with better emotional regulation, social competence, and mental health outcomes, whereas negative parenting styles may contribute to emotional and behavioral difficulties(1) (2).

Psychosocial impairment among adolescents has become a growing public health concern worldwide. According to the World Health Organization (WHO), approximately one in seven adolescents experiences a mental health disorder, including anxiety, depression, attention difficulties, and behavioral problems. These conditions can negatively affect academic performance, interpersonal relationships, and overall quality of life(3). Previous studies have reported significant associations between parenting styles and psychosocial outcomes in adolescents, highlighting the protective role of authoritative parenting and the risks associated with authoritarian, permissive, and neglectful parenting styles(4)(5).

Despite the increasing evidence on this topic, limited research has examined the relationship between parenting styles and psychosocial impairment among adolescents receiving mental health services in community settings, particularly in the Peruvian context. In the Alto Puno Community Mental Health Center, a growing number of adolescents seek care for emotional, attention, and behavioral problems; however, little is known about the influence of family parenting styles on these psychosocial difficulties. This lack of evidence restricts the development of family-centered interventions aimed at improving adolescent mental health outcomes.

Therefore, the present study aimed to determine the relationship between parenting styles and psychosocial impairment among adolescent users of the Alto Puno Community Mental Health Center in 2024. The findings are expected to contribute to the understanding of family factors associated with adolescent mental health and provide evidence for the design of preventive and intervention strategies that promote healthy parenting practices and psychosocial well-being.

METHODOLOGY

Research design: This study adopted a quantitative, observational, correlational, and cross-sectional research design to determine the relationship between parenting styles and psychosocial impairment among adolescent users of the Alto Puno Community

Mental Health Center. The research was conducted in a community mental health setting during 2024. Data were collected from adolescents who met the established inclusion criteria, following ethical principles, informed consent procedures, and standardized research protocols.

Population: The population consisted of adolescent users attending the Alto Puno Community Mental Health Center in 2024. A sample of 120 adolescents was selected through simple random sampling according to the established inclusion and exclusion criteria. All participants met the eligibility requirements and voluntarily agreed to participate in the study.

Instruments: Data were collected using validated research instruments. The Steinberg Parenting Styles Scale was used to assess parenting styles, while the Psychosocial Impairment Questionnaire evaluated emotional, attention, and behavioral problems among adolescents. These instruments provided reliable information for analyzing the relationship between the study variables

Procedure: Data were collected following standardized research procedures. First, adolescents attending the Community Mental Health Center of Alto Puno were selected according to the established inclusion criteria. Then, the Parenting Styles Scale and the Psychosocial Affectation Questionnaire were administered. Finally, the collected information was recorded, reviewed, and verified to ensure data accuracy and consistency.

Data Analysis: Data were analyzed using descriptive and inferential statistical methods. Frequencies, percentages, and summary measures were used to describe the study variables. The relationship between parenting styles and psychosocial impairment was evaluated using appropriate statistical tests. All analyses were performed using specialized statistical software to ensure the accuracy and reliability of the results.

RESULTS

A total of 106 adolescents attending the Alto Puno Community Mental Health Center were included in the study. The relationship between parenting styles and psychosocial impairment was analyzed using the Pearson chi-square test(6). The findings are presented objectively in Tables 1 and 2.

Table 1. Association between parenting styles and psychosocial impairment among adolescents attending the Alto Puno Community Mental Health Center, 2024

Parenting style	At risk n (%)	No risk n (%)	Total n (%)
Authoritative	**0(0.0)**	8 (16.0)	8 (7.5)
Negligent	5 (8.9)	13 (26.0)	18 (17.0)
Authoritarian	26 (46.4)	8 (16.0)	34 (32.1)
Permissive	16 (28.6)	14 (28.0)	30 (28.3)
Mixed	9 (16.1)	7 (14.0)	16 (15.1)
Total	**56 (100.0)**	**50 (100.0)**	**106 (100.0)**

square analysis demonstrated a statistically significant association between parenting styles and psychosocial impairment ($\chi^2 = 21.197$, df = 4, $p < 0.001$). The highest proportion of adolescents at risk for psychosocial impairment was observed among those reporting an authoritarian parenting style (46.4%), followed by the permissive style (28.6%). Conversely, none of the adolescents who perceived an authoritative parenting style were classified as being at psychosocial risk.

Table 2. Distribution of parenting styles and psychosocial impairment among adolescents attending the Alto Puno Community Mental Health Center, 2024

Variable	Category	n	%
Parenting styles	Authoritarian	34	32.1
	Permissive	30	28.3
	Negligent	18	17.0
	Mixed	16	15.1
	Authoritative	8	7.5
Psychosocial impairment	At risk	56	52.8
	No risk	50	47.2
Emotional problems	At risk	76	71.7

	No risk	30	28.3
Attention problems	At risk	51	48.1
	No risk	55	51.9
Behavioral problems	At risk	10	9.4
	No risk	96	90.6

The authoritarian parenting style was the most frequently reported (32.1%), followed by the permissive style (28.3%). The authoritative style showed the lowest frequency (7.5%). Regarding psychosocial impairment, 52.8% of adolescents were classified as being at risk. Emotional problems represented the most affected domain (71.7%), followed by attention problems (48.1%), whereas behavioral problems were identified in 9.4% of participants.

DISCUSSION

The present study demonstrated a statistically significant relationship between parenting styles and psychosocial impairment among adolescent users of the Alto Puno Community Mental Health Center ($p < 0.05$), confirming that the way parents exercise parenting is an important factor associated with emotional and behavioral well-being during adolescence(7). Furthermore, the authoritarian parenting style was identified as the predominant style, while more than half of the adolescents presented a risk of psychosocial impairment, with emotional problems being particularly prominent. These findings support Steinberg's theoretical model, which proposes that a balance between parental involvement, behavioral control, and psychological autonomy promotes healthy emotional development, whereas excessive rigidity or a lack of limits increases psychological vulnerability.

The results obtained are consistent with international research. Haghshenas et al. reported that adolescents exposed to permissive parenting styles showed higher levels of anxiety(4), while Obimakinde et al. found that permissive and neglectful parenting styles increased the likelihood of emotional and social problems(5). Similarly, Maison showed that the authoritative parenting style promotes better psychosocial development, which is consistent with the present study, where adolescents identified with this style did not present a risk of psychosocial impairment(8). These findings reinforce the evidence that parenting practices represent an important determinant of adolescent mental health.

In the national context, the findings are also consistent with recent studies. Lozano and Ramos found a significant relationship between parenting styles and anxiety levels in adolescents(9), whereas Ccolque and Quispe showed that positive parenting practices reduce internalizing and externalizing problems(10). Likewise, Castañeda reported that the dimensions of parenting style were significantly associated with adolescents' psychological well-being(11)(12). At the regional level, Larico and Quispe demonstrated that authoritarian and neglectful parenting styles increase aggressive behaviors(13), while Pillco highlighted that the authoritative style promotes positive self-esteem(14). Taken together, these studies support the association found between parenting styles and the mental health of the adolescents evaluated.

However, the results differ partially from some previous studies. Llanos did not find a significant relationship between parenting styles and risk behaviors(15), while Mamani and Huallpa also failed to identify a global association between parenting styles and behavioral problems(16). These discrepancies may be explained by methodological differences, the instruments used, the size and characteristics of the samples, and the study context. Unlike those investigations conducted in general school populations, the present study assessed adolescents attending a community mental health center, a population characterized by greater emotional and psychosocial vulnerability.

Regarding the distribution of parenting styles, the predominance of the authoritarian style suggests the persistence of educational models characterized by high control, limited communication, and restricted autonomy for children. These characteristics may contribute to difficulties in emotional regulation, increased levels of anxiety, and impaired social skill development(17). In contrast, the authoritative style appeared to function as a protective factor, probably because it combines clear rules, emotional support, and effective communication, all of which are widely recognized as promoters of healthy psychological development.

Another relevant finding was that more than half of the adolescents presented a risk of psychosocial impairment, and the emotional dimension showed the highest frequency. This result is consistent with studies conducted in the Puno region, where Huanacuni et al. reported a high prevalence of internalizing problems among adolescents. The greater frequency of emotional symptoms may be related to the characteristics of adolescence itself, a stage in which biological, psychological, and social changes converge, together

with family and contextual factors that increase susceptibility to anxiety, depression, and adjustment difficulties(18).

From a public health perspective, these findings highlight the need to strengthen interventions aimed not only at adolescents but also at their families. Promoting positive parenting styles through parental psychoeducation programs, communication skills training, the establishment of consistent limits, and the strengthening of emotional bonds could help reduce the occurrence of emotional and behavioral problems(12). In addition, the results provide useful evidence to guide preventive strategies in Community Mental Health Centers and to support the development of policies focused on strengthening positive parenting.

Finally, this study has some limitations. Its cross-sectional design prevents the establishment of causal relationships between the variables studied. In addition, the research was conducted in a single Community Mental Health Center and relied on self-report instruments, which may introduce perception or social desirability biases. Therefore, future longitudinal and multicenter studies incorporating additional family, socioeconomic, and cultural variables are recommended in order to better understand the mechanisms through which parenting styles influence adolescents' mental health.

CONCLUSIONS

- A statistically significant relationship was found between parenting styles and psychosocial impairment among adolescent users of the Alto Puno Community Mental Health Center ($p < 0.05$). This finding confirms that parenting practices are an important factor associated with adolescents' emotional, behavioral, and attentional well-being.
- The authoritarian parenting style was the most prevalent (32.1%), followed by the permissive style (28.3%), whereas the authoritative style was the least frequent (7.5%). These results indicate the predominance of parenting patterns characterized by a poorer balance between affection, behavioral control, and autonomy.
- More than half of the adolescents assessed were at risk of psychosocial impairment (52.8%). Emotional problems showed the highest frequency (71.7%),

followed by attention problems (48.1%), highlighting the need to strengthen early detection and comprehensive mental health care for adolescents.

- The findings support the implementation of family-based intervention programs aimed at promoting positive parenting practices, particularly the authoritative or democratic parenting style, given its potential protective effect on adolescents' psychosocial development. Furthermore, future longitudinal studies and research in different populations are recommended to expand the available evidence and guide preventive public health strategies.

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SEVERITY OF OROPHARYNGEAL LESIONS IN PEDIATRIC PATIENTS WITH BULLOSA EPIDERMOLYSIS TREATED AT THE NATIONAL INSTITUTE OF HEALTH OF THE CHILD LIMA-PERÚ 2020

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ABSTRACT

Epidermolysis Bullosa (EB) is a group of rare inherited disorders characterized by extreme fragility of the skin, leading to blistering and erosion following minor mechanical trauma. The objective of this study was to determine the severity of oropharyngeal lesions in pediatric patients with epidermolysis bullosa treated at the National Institute of Child Health in Lima, Perú, during 2020. An observational, descriptive, cross-sectional, and prospective approach was employed. The sample consisted of 22 patients between 6 months and 18 years of age diagnosed with Barrett's esophagus (BE). Data were collected using an oropharyngeal severity assessment (EBOS) form. This instrument was used to document disease activity, including the presence of erythema, atrophy, blisters, and erosions, as well as structural damage such as microstomia, ankyloglossia, extraoral atrophy, and enamel hypoplasia. The results reveal that simple EB was the most prevalent subtype (54%), followed by dystrophic EB (36%) and Kindler syndrome (9%). No cases of junctional EB were identified. The most frequent oropharyngeal manifestation in simple EB was erythema (75%). In dystrophic EB, erythema and blistering were present in all cases (100%). Structural damage was more pronounced in dystrophic EB, with microstomia, ankyloglossia, and enamel hypoplasia each affecting 75%. In contrast, enamel hypoplasia was observed in 25% of simple EB. The tongue and floor of the mouth were the most affected oropharyngeal sites in dystrophic EB, exhibiting the highest frequency of erythema, blisters, and erosive lesions. The findings suggest that simple EB was the most prevalent subtype, while dystrophic EB was more frequently observed in women. Among oropharyngeal manifestations, erythema, blisters, and erosive lesions

were more frequently associated with dystrophic EB, which also exhibited the highest level of disease activity. Structural damage was predominantly observed in patients with dystrophic EB, with microstomia, ankyloglossia, and enamel hypoplasia being the most common abnormalities. Furthermore, the tongue and floor of the mouth were identified as the oropharyngeal areas with the greatest disease severity in dystrophic EB. Therefore, the importance of early diagnosis and multidisciplinary management to prevent disease progression and functional decline is emphasized.

KEYWORDS: Dermatopathies, Epidermolysis Bullosa, Skin diseases, Infant.

INTRODUCTION

Research on this topic has focused on a group of rare, genetically determined skin disorders characterized by excessive susceptibility of the skin and mucous membranes to minimal mechanical trauma (1).

Patients with milder forms may experience periods of temporary disability but can lead normal lives. More severe forms of EB can be physically and emotionally devastating, resulting in total disability (2). The autosomal dominant form is the most severe, characterized by the formation of bullae on the skin and mucous membranes, which lead to severe scarring and contractures (3).

Previous studies have focused mainly on common oral findings of the disease, including microstomia, intraoral ulcerations, ankyloglossia, tongue atrophy and depapillation, atrophy of the palatal folds and blister formation, and alteration in enamel structure, generating diverse symptoms (2). While normal feeding can cause severe ulcerations in the oropharynx; as a consequence, these children frequently have nutritional restrictions (3), this is also associated with the difficulty in performing adequate oral hygiene, causing a predisposition to caries (1).

However, little is known about specific treatment, and its progression is chronic.

To address the limited evidence, given that these are so-called "rare diseases" on which little research has been conducted, the aim of this study is to evaluate oropharyngeal severity in the main types of epidermolysis bullosa and thus develop prevention protocols or guidelines. These will allow clinicians to manage this condition accurately and

promptly, as it can significantly impair quality of life, posing a challenge for those affected, their families, and the professionals who care for them (2).

METHODOLOGY

This study adopted an observational, descriptive, cross-sectional, and prospective research design to evaluate the severity of oropharyngeal lesions in patients diagnosed with epidermolysis bullosa. The research was conducted during 2020.

The study population consisted of 22 patients, aged 6 months to 18 years, who attended the Dentistry Service of the National Institute of Child Health, Lima – Perú.

The instrument used was an evaluation sheet (EBOS - Oropharyngeal Severity in Epidermolysis Bullosa) that recorded disease activity (presence of erythema, atrophy, blisters, erosion) and structural damage (microstomia, ankyloglossia, atrophy outside the oral cavity, and enamel hypoplasia).

The data were collected in four stages. First, for the oropharyngeal clinical assessment, the oral cavity was divided into 13 anatomical areas (upper lip, lower lip, upper vestibule, lower vestibule, upper gingiva, lower gingiva, hard palate, soft palate, left cheek, right cheek, tongue, floor of the mouth, and oropharynx) and assessed using the visual method with the aid of a No. 5 flat mouth mirror.

Then, the presence of clinical signs (erythema, atrophy, blisters, and erosion/ulceration) was assessed for disease activity scoring. One point was assigned to each clinical sign present in each anatomical area, leading to a total score from 0 to 52. The structural damage score assessed the presence or absence of four parameters (microstomia, ankyloglossia, atrophy outside the oropharynx, and enamel hypoplasia), assigning two points to each, with a total score ranging from 0 to 8.

After that, microstomia was assessed with the mouth at maximum opening (from the edge of the upper central incisors to the lower central incisors, along the interincisal line). A patient with a maximum opening of less than 35 mm was considered to have microstomia. Ankyloglossia was assessed by the patient's ability to protrude their tongue over the lower incisors, and reach the premaxilla with the tip of the tongue. A patient unable to perform at least two of these movements was considered to have ankyloglossia.

Finally, the scoring system was based on the sum of disease activity and structural damage, resulting in a final total score from 0 to 60.

Clinical data were analyzed using descriptive statistical methods. The analysis was performed using the EBOS assessment form.

RESULTS

The results showed that Epidermolysis Bullosa is a rare disease presenting in four clinical forms: EB Simplex (54%), Junctional EB (0%), Dystrophic EB (36%), and Kindler Syndrome (9.0%). Regarding the EB types, the predominant gender was male for EB Simplex (58.2%) and Kindler Syndrome (100%), and female for Dystrophic EB (62.5%). The mean age was 4.7 years for EB Simplex, 6.6 years for Dystrophic EB, and 13.0 years for Kindler Syndrome.

The most frequent oropharyngeal lesion was erythema (75%) in EB Simplex; erythema and blisters (100%) in Dystrophic EB; and erythema (100%) in Kindler Syndrome.

Structural abnormalities were observed in Dystrophic EB, specifically microstomia (75%), ankyloglossia (75%), and enamel hypoplasia (75%). In EB Simplex, enamel hypoplasia (25%) was observed. In Dystrophic EB, the oropharyngeal areas most affected by erythema, blisters, and erosions were the tongue and the floor of the mouth.

Table 1.

Pediatric patients by type of epidermolysis bullosa.

TYPES OF EPIDERMOLYSIS BULLOSA	PEDIATRIC PATIENTS	
	N° (Total)	Average
EB SIMPLEX	12	4.73
UNION EB	0	0
DYSTROPHIC EB	8	6.625
KINDLER SYNDROME	2	13.0

Table 2.

Oropharyngeal lesions according to Epidermolysis Bullosa type.

TYPES OF EPIDERMOLYSIS BULLOSA	OROPHARYNGEAL LESIONS							
	ERYTHEMA		ATROPHY		BLISTER		EROSION/ULCER	
	PRESENCE N° of patients	%	PRESENCE N° of patients	%	PRESENCE N° of patients	%	PRESENCE N° of patients	%
EB SIMPLEX	9	75			6	50	7	58.3
UNION EB								
DYSTROPHIC EB	8	100	6	75	8	100	7	87.5
KINDLER SYNDROME	2	100					2	100

Table 3.

Disease activity according to Epidermolysis Bullosa type.

DISEASE ACTIVITY	TYPES OF EPIDERMOLYSIS BULLOSA							
	EB SIMPLEX		UNIÓN EB.		DYSTROPHIC EB.		KINDLER SYNDROME	
	N°	%	N°	%	N°	%	N°	%
LOW ACTIVITY	12	100			2	25	2	100
HIGH ACTIVITY					6	75		
TOTAL	12	100			8	100	2	100

Table 4.

Structural damage to the oropharynx according to Epidermolysis Bullosa type.

TYPES OF EPIDERMOLYSIS BULLOSA	STRUCTURAL DAMAGE							
	MICROSTOMY		ANKYLOGLOSSIA		Atrophy outside the oropharynx		ENAMEL HYPOPLASIA	
	PRESENCE	%	PRESENCE	%	PRESENCE	%	PRESENCE	%

	N° of patients		N° of patients		N° of patients		N° of patients	
EB. SIMPLEX							3	25
DYSTROPHIC EB.	6	75	6	75	5	62.5	6	75

DISCUSSION

The findings demonstrate that the severity of oropharyngeal manifestations varies according to the subtype of Epidermolysis Bullosa (EB); Dystrophic EB was the form showing the greatest clinical involvement, presenting the most severe oropharyngeal manifestations and the highest level of disease activity. The persistent presence of erythema and blisters in these patients, combined with the high frequency of microstomia, ankyloglossia, and enamel hypoplasia, indicates that this subtype is associated with greater involvement of soft tissues and oral structures, which can compromise essential functions such as eating, swallowing, speech, and oral hygiene.

The results obtained align with findings reported by Torres (2017), who described dystrophic EB as the predominant clinical variant. He also highlighted significant involvement of the oral cavity, noting dental caries as a major complication.

Similarly, Marrero (2017) points out that in dystrophic EB, blisters originate in the deeper layers of the skin and can affect various mucous membranes, including those of the oral cavity, pharynx, gastrointestinal tract, and respiratory and urinary tracts.

Furthermore, Sierra (2014) notes that crusts and erosions are the most characteristic cutaneous manifestations of epidermolysis bullosa, frequently accompanied by oral abnormalities such as cheilosis and infections; this is consistent with the mucocutaneous involvement observed in this disease.

Taken together, these findings support the results of the present study and underscore the need for timely diagnosis.

Clinical implications suggest that the high frequency of dental involvement underscores the importance of incorporating early dental assessment and treatment into the comprehensive management of patients with EB; furthermore, multidisciplinary care—including dermatology, dentistry, gastroenterology, nutrition, and rehabilitation—is necessary to improve quality of life.

The association of specific manifestations (such as ankyloglossia and pseudosyndactyly) with EB Dystrophic can facilitate the identification of patients with more severe forms and guide clinical follow-up.

The findings provide useful epidemiological information for planning resources and care strategies in specialized centers.

Limitations include the small sample size (22 patients), which restricts the generalizability of the results; furthermore, as the assessment was conducted during a single study period, it was not possible to evaluate changes in lesion severity. The absence of cases of junctional EB prevented a comparison of the oropharyngeal manifestations of this subtype with those of the others.

CONCLUSIONS

From a theoretical standpoint, this research provides evidence regarding the presentation pattern of oropharyngeal manifestations in pediatric patients with Epidermolysis Bullosa—particularly the dystrophic variant—thereby enhancing understanding of the relationship between the disease's clinical activity and oral cavity involvement. These results contribute to expanding the available information in a context where few national studies have focused on the stomatological manifestations of this rare disease.

In practical terms, the findings highlight the importance of incorporating stomatological assessment into the comprehensive management of pediatric patients with Epidermolysis Bullosa. Early identification of oropharyngeal lesions and structural abnormalities enables the implementation of timely preventive and therapeutic measures, thereby improving quality of life and reducing the risk of complications. Furthermore, these results can serve as a basis for developing interdisciplinary care protocols tailored to this patient population.

In conclusion, the evidence obtained confirms that Dystrophic Epidermolysis Bullosa is the variant associated with the greatest oropharyngeal and structural involvement in the pediatric population studied. In this context, it is essential to strengthen strategies for early diagnosis, dental monitoring, and multidisciplinary intervention, as well as to promote future research with larger sample sizes to gain deeper insight into the clinical course and comprehensive management options for these patients.

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Nursing knowledge and care regarding the administration of vasoactive drugs in intensive care units: a narrative review of scientific evidence

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ABSTRACT

Vasoactive drugs are essential for the management of critically ill patients in Intensive Care Units. Their administration requires specialized nursing knowledge to ensure patient safety and prevent adverse events. Objective: To analyze the importance of nursing knowledge and clinical practices in the administration of vasoactive drugs in the Intensive Care Unit. Methodology: A narrative literature review with a content analysis approach was conducted. An exhaustive search was performed across PubMed, Cochrane Library, Scopus, and Web of Science, selecting 16 technical-scientific documents published between 2020 and 2024. Data were processed using thematic coding and lexical recurrence matrices. Results: A persistent gap was identified between the mastery of pharmacological theory and its operational application at the bedside, particularly in dose calculation and infusion rates. Variability in procedural practices and the lack of continuous hemodynamic monitoring correlated directly with an increased incidence of adverse events (extravasations and blood pressure fluctuations), prolonging hospital stay. Conclusions: The safe management of vasopressors and inotropes strictly depends on specialized nursing cognitive competence. The mandatory implementation of continuing education programs and the urgent standardization of care through clinical guidelines and institutional algorithms are required to mitigate operational risk and ensure critical patient safety.

Keywords: Critical Care; Critical Care Nursing; Vasoactive Agents; Patient Safety; Education, Nursing, Continuing.

I. INTRODUCTION

Hemodynamic management in Intensive Care Units remains one of the most critical aspects of caring for critically ill patients. Maintaining adequate tissue perfusion and circulatory stability is essential to prevent cellular hypoxia, tissue ischemia, and progression to Multiple Organ Dysfunction Syndrome. Among the therapeutic strategies used in critical care, the administration of vasoactive agents, particularly vasopressors and inotropes, plays a central role in the treatment of shock states, severe hypotension, and acute heart failure (1,2). Previous research has demonstrated that the timely restoration and maintenance of an adequate mean arterial pressure are associated with improved organ perfusion and better clinical outcomes in critically ill patients (5,6).

Within this context, Critical Care Nursing professionals play a pivotal role in the safe and effective administration of vasoactive therapy. Their responsibilities include medication preparation, dose calculation, infusion titration, continuous bedside monitoring, and the early identification of adverse events (3,4). These activities require not only technical proficiency but also a comprehensive understanding of pharmacokinetics, pharmacodynamics, vascular access management, solution compatibility, and the physiological responses of critically ill patients (4). The literature consistently highlights the importance of nursing competence in vasoactive medication management as a key factor in promoting Patient Safety and ensuring high-quality critical care (8,9).

However, despite advances in hemodynamic management protocols and medication safety initiatives, evidence suggests that variability persists in nurses' knowledge and adherence to recommended practices for the administration of vasoactive agents (9,10). In particular, challenges related to dose calculations, infusion rates, drug compatibility, pharmacovigilance, and the management of Central Venous Catheters continue to represent potential sources of medication errors and adverse events (9,10). These shortcomings may compromise patient safety, increase healthcare costs, prolong hospital stays, and negatively affect clinical outcomes. Moreover, although numerous studies have examined the pharmacological effects and clinical applications of vasoactive agents, comparatively less attention has been devoted to synthesizing evidence on nursing knowledge and care practices associated with their administration in critical care settings. This limitation restricts the identification of evidence-based strategies aimed at reducing preventable errors and improving the quality of care.

To address this gap, the present narrative review aims to analyze the importance of nurses' knowledge in the administration of vasoactive agents in Intensive Care Units, identify the most common medication-related errors associated with this practice, and describe evidence-based strategies to strengthen patient safety and optimize the quality of nursing care in critically ill patients. By synthesizing current evidence, this review seeks to support clinical practice, professional training, and institutional initiatives focused on the safe management of vasoactive therapy in critical care settings.

II. METHODOLOGY

This study adopted a narrative literature review design using a qualitative content analysis approach supported by bibliographic mapping techniques (11,12). The review was conducted to identify, critically appraise, and synthesize the available scientific evidence regarding nursing knowledge and care practices in the administration of vasoactive agents in Intensive Care Units. The methodological approach was selected because it allows the integration of findings from diverse study designs while providing a comprehensive overview of current evidence on a clinically relevant topic. A comprehensive multilingual literature search was conducted in the international bibliographic databases PubMed, Scopus, Web of Science, and the Cochrane Library, complemented by searches of institutional repositories containing academic theses and gray literature. Standardized Medical Subject Headings (MeSH) and Health Sciences Descriptors were combined using Boolean operators to maximize search sensitivity and specificity. The following search strategy was applied: ("Nursing" OR "Nurses") AND ("Vasoactive Agents" OR "Inotropic Agents" OR "Vasoconstrictor Agents") AND ("Intensive Care Units" OR "Critical Care"). Additional manual searches of reference lists were performed to identify potentially relevant studies that were not retrieved through electronic database searching.

Studies published between 2020 and 2024 were considered eligible if they addressed nursing knowledge, clinical competencies, medication administration practices, or patient safety related to the use of vasoactive agents in critical care settings. Original research articles, review articles, and academic theses published in English or Spanish were included. Studies unrelated to Critical Care Nursing, pediatric or neonatal populations without relevance to the research objective, editorials, conference abstracts, opinion

papers, duplicated records, and publications lacking sufficient methodological information were excluded.

Study selection was performed in three sequential stages (13,14). First, titles and abstracts were screened to assess their relevance to the review topic. Second, the full texts of potentially eligible studies were assessed to determine whether they satisfied the predefined eligibility criteria. Finally, backward citation searching (snowballing) was conducted through manual examination of the reference lists of the included studies to identify additional relevant publications and gray literature. Data were extracted using a standardized extraction matrix developed for this review to ensure methodological consistency. Each study was coded according to authorship, country of origin, year of publication, article title, publication source, thematic focus, study characteristics, and key descriptors. This standardized process facilitated comparison across studies and supported the subsequent thematic synthesis.

The literature search and selection process yielded a final sample of 16 scientific publications published between 2020 and 2024. The included studies represented diverse geographical regions, including Latin America (Mexico, Peru, Bolivia, Ecuador, and Argentina), Oceania (Australia), Africa (Egypt), Asia (China and Saudi Arabia), and Europe (Spain), thereby providing a broad international perspective on nursing practice related to vasoactive therapy in critical care.

The selected studies were analyzed using thematic content analysis (12). The analytical process involved text familiarization, segmentation of relevant information, open coding, identification of recurring concepts, and the development of emergent thematic categories. Lexical and thematic recurrence analysis identified three predominant concepts that structured the analytical framework of this review: "Vasoactive Agents" (n = 12), "Nursing Professionals/Nurses" (n = 11), and "Knowledge" (n = 10). These themes served as the basis for organizing and interpreting the evidence presented in the Results section.

III. RESULTS

3.1. Characteristics of the Included Studies

A total of 16 studies met the eligibility criteria and were included in the final analysis. The studies were conducted in Latin America (Mexico, Peru, Bolivia, Ecuador, and

Argentina), Europe (Spain), Asia (China and Saudi Arabia), Africa (Egypt), and Oceania (Australia). The evidence base comprised academic theses, original research articles, and one systematic review addressing nursing knowledge, medication administration, patient safety, and educational interventions related to vasoactive agents in Intensive Care Units.. The general characteristics of the included studies are summarized in Table 1.

Table 1. General characteristics of the included studies.

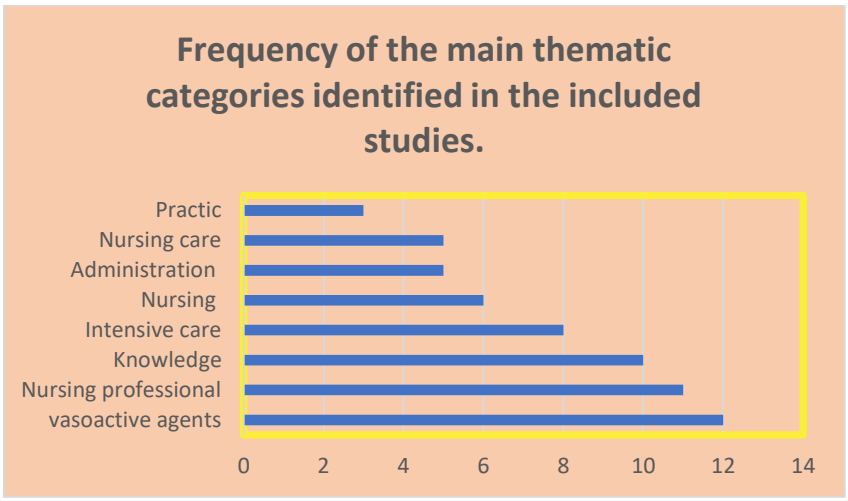
Author	Country	Year	Study type	Main focus
Cruz-Ruiz (15)	Mexico	2020	Academic thesis	Pharmacological knowledge
Hunter et-al. (16)	Australia	2020	Systematic review	Administration of vasoactive agents
Chávez-Huaman (17)	Peru	2021	Academic thesis	Knowledge of inotropic agents
Mamani-Villazante	Bolivia	2022	Academic thesis	Knowledge of vasoactive agents
Damiano-Espinoza (18)	Peru	2022	Academic thesis	Administration guidelines
Colmenares et al. (19)	Spain	2022	Original article	Adverse events
Villa-Solís (20)	Ecuador	2022	Original article	Nursing care
Awaad et al. (21)	Saudi Arabia	2022	Original article	Patient safety
Morales-Zambrano (22)	Peru	2023	Academic thesis	Knowledge and clinical practice
Quevedo-Jácome (23)	Ecuador	2023	Academic thesis	Safe medication practices
Suárez-Cárdenas (24)	Peru	2023	Academic thesis	Nursing knowledge and care
Cruz-Toro	Ecuador	2023	Original article	Nursing interventions
Salvatierra-Ydrogo (25)	Argentina	2023	Academic thesis	Preparation of inotropic agents
Diaa-Abdelrhman et al. (26)	Egypt	2023	Original article	Patient safety

Huang et al. (27)	China	2024	Original article	Knowledge, attitudes, and practices
Cerda-Neira & Evangelista (28)	Peru	2024	Academic thesis	Knowledge of inotropic agents

3.2. Thematic Distribution of the Scientific Evidence

Eight major thematic categories emerged from the analysis of the included studies. The most frequently identified concepts were Vasoactive Agents (n = 12), Nursing Professionals (n = 11), and Knowledge (n = 10), followed by Intensive Care (n = 8), Nursing (n = 6), Medication Administration (n = 5), Nursing Care (n = 5), and Clinical Practice (n = 3). These findings indicate that the current body of evidence primarily focuses on the competencies required for the safe administration of vasoactive therapy in critically ill patients.

Figure 1.



3.3. Synthesis of the Main Findings

3.3.1. Nursing Knowledge of Vasoactive Agents. - Pharmacological knowledge emerged as the most frequently investigated domain across the reviewed studies. The evidence consistently emphasized the importance of understanding the mechanisms of action of vasoactive agents, dose calculation, medication dilution, infusion rate adjustment, pharmacokinetics, pharmacodynamics, and intravenous solution compatibility. Although several studies reported moderate to satisfactory levels of

knowledge among nurses, others identified deficiencies in medication titration, preparation procedures, recognition of adverse drug reactions, and management of continuous vasoactive infusions. These findings highlight the need for continuous competency development in pharmacological management.

3.3.2. Nursing Care Practices During Vasoactive Therapy. - The included studies consistently described medication preparation, administration through Central Venous Catheters ,continuous hemodynamic monitoring, assessment of tissue perfusion, and early recognition of adverse events as essential nursing responsibilities during vasoactive therapy. Furthermore, adherence to institutional protocols, standardized medication preparation procedures, infusion pump verification, and continuous reassessment of patients' clinical status were identified as key components of safe nursing practice in critical care.

3.3.3. Medication Errors and Patient Safety. - Patient safety emerged as one of the principal themes identified in the reviewed literature. The included studies reported medication dosage errors, inappropriate infusion rates, incorrect drug dilution, intravenous incompatibilities, delayed recognition of adverse drug reactions, and vascular access complications, particularly extravasation, as the most common risks associated with vasoactive therapy. Collectively, these findings indicate that inadequate medication management may compromise hemodynamic stability, prolong hospitalization, and negatively affect clinical outcomes.

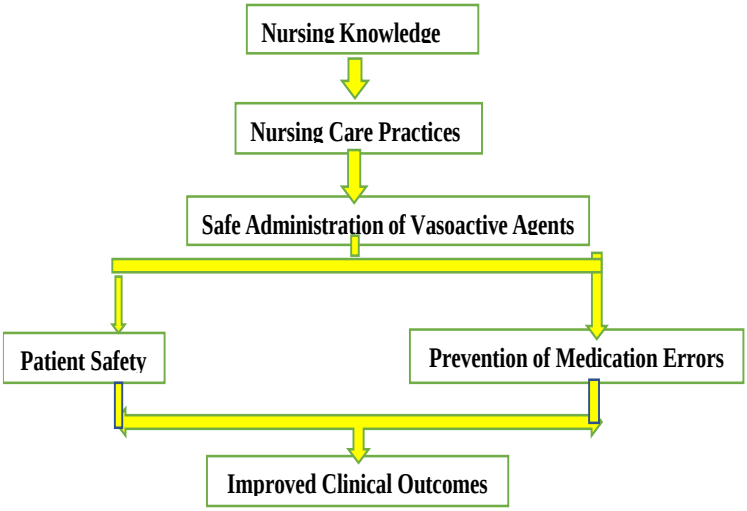
3.3.4. Strategies to Improve Nursing Practice. - The reviewed studies identified several evidence-based interventions aimed at strengthening nurses' competencies in the administration of vasoactive agents. The most frequently reported strategies included continuing professional education, simulation-based training, implementation of evidence-based clinical guidelines, standardized institutional protocols, competency assessment programs, and periodic educational updates. These interventions were consistently associated with improvements in pharmacological knowledge, clinical decision-making, medication administration practices, and Patient Safety.

Table 2. Summary of the Main Findings

Theme	Main findings

Knowledge	Moderate to adequate pharmacological knowledge; deficiencies in dose calculation, medication titration, and recognition of adverse drug reactions.
Medication administration	Need for standardized medication preparation, infusion rate adjustment, Central Venous Catheter use, and continuous hemodynamic monitoring.
Patient safety	Medication errors, extravasation, intravenous incompatibilities, hemodynamic instability, and arrhythmias were the most frequently reported adverse events.
Educational strategies	Continuing education, simulation-based training, competency assessment, and standardized protocols improved nurses' clinical performance.

Figure 2. Conceptual synthesis of the main findings identified in the narrative review.



IV. DISCUSSION

The present narrative review demonstrates that nursing knowledge is a key determinant of the safe administration of vasoactive agents in Intensive Care Units. The reviewed evidence consistently highlights pharmacological competence, continuous hemodynamic monitoring, and adherence to standardized clinical protocols as essential components of safe nursing practice. These findings reinforce the pivotal role of nurses in preventing medication-related adverse events and promoting Patient Safety.

The findings of this review are consistent with previous studies reporting that greater pharmacological knowledge is associated with safer medication administration and better adherence to evidence-based clinical practice (1,2). Likewise, studies conducted in Latin America identified persistent deficiencies in dose calculation, infusion titration, medication preparation, and recognition of adverse drug reactions, emphasizing the need for continuous professional development among critical care nurses (3–8).

Patient Safety emerged as another central theme across the reviewed literature. Several studies associated inadequate adherence to standardized protocols with medication-related adverse events, whereas others demonstrated that continuing education and competency-based training significantly improve nurses' performance in administering high-alert medications (4,6,9–12). Although variations in knowledge levels were observed among the included studies, these differences may be explained by variations in clinical experience, educational background, institutional protocols, and healthcare settings.

From a clinical perspective, the available evidence supports the implementation of standardized protocols, simulation-based training, competency assessment, and continuing education programs to strengthen nurses' competencies in vasoactive therapy (5,8,10,13–15). Furthermore, interdisciplinary collaboration among nurses, intensivists, and pharmacists may optimize medication management and improve Patient Safety in critical care settings (6,11,14).

This review has several limitations. The included studies exhibited methodological heterogeneity, and most were conducted in Latin American countries, which may limit the generalizability of the findings. Furthermore, as a narrative review, this study did not include a quantitative synthesis or meta-analysis of the available evidence.

Overall, the evidence indicates that strengthening nurses' pharmacological knowledge and clinical competencies is essential for the safe administration of vasoactive agents in

Intensive Care Units. Continuous education, evidence-based clinical protocols, and standardized nursing practices remain fundamental strategies for reducing medication-related errors, improving Patient Safety, and optimizing clinical outcomes.

V. CONCLUSIONS:

This review of global scientific literature demonstrates that the level of cognitive and procedural competence among nursing professionals regarding vasoactive drug management is a critical determinant of hemodynamic stability and the mitigation of harmful adverse events in Intensive Care Units. Findings reveal a persistent gap between the mastery of basic pharmacological theory and its operational application in the precise titration of continuous infusions; this gap increases the latent risk of cardiovascular complications and prolongs hospital stays.

Given the frontline role played by critical care nurses at the bedside, it is concluded that empirical experience alone is insufficient; a mandatory shift toward institutional programs for systematic, specialized continuing education in pharmacovigilance and the advanced management of infusion technologies is required. Furthermore, the clinical variability observed across the diverse geographic contexts analyzed justifies and underscores the urgent need to design, implement, and disseminate clinical algorithms and standardized, readily accessible protocols within critical care units. These scientific tools reduce reliance on operator memory, standardize criteria for safe preparation and dosing, and serve as effective safety barriers to optimize clinical outcomes and ensure the survival of critically ill patients.

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RELATIONSHIP BETWEEN ENERGY INTAKE AND COMPETITIVE PERFORMANCE IN ADOLESCENT SOCCER PLAYERS FROM A SPORTS ACADEMY IN JULIACA, PERÚ

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ABSTRACT

This study examines the role of sports nutrition in the competitive development of adolescent soccer players and how proper dietary practices can enhance athletic performance, recovery, and overall competitive outcomes. The problem that motivated this research was the increasing prevalence of inadequate nutritional habits among young athletes, which may negatively affect their physical development and performance during training and competition. The objective of this study was to evaluate the impact of nutritional habits on the competitive development of adolescent soccer players. An observational, descriptive, and cross-sectional design was adopted, involving 60 adolescent soccer players from different youth development categories. Data were collected through nutritional assessments, dietary surveys, and physical performance tests. The results showed that players with balanced dietary habits achieved significantly better performance and recovery outcomes than those with inadequate eating patterns, with higher overall performance scores (82.4 ± 6.3 vs. 71.8 ± 7.1; $p < 0.05$). In addition, a moderate positive correlation was found between adequate nutrition and athletic performance ($r = 0.68$, $p < 0.01$). These findings suggest that proper nutrition is a key factor in the competitive development of adolescent soccer players, contributing to improved physical performance, health, and long-term athletic potential.

Keywords: sports nutrition, adolescent soccer players, competitive development, athletic performance, dietary habits, youth soccer.

INTRODUCTION

Soccer is one of the most widely practiced sports worldwide and is characterized by intermittent high-intensity efforts involving sprinting, accelerations, changes of direction, and periods of active recovery. These physiological demands require an adequate energy

supply to maintain optimal performance during both training sessions and competitive matches (Pueyo et al., 2024).

During adolescence, nutritional requirements become even more critical because young athletes must simultaneously meet the demands of physical training, growth, and biological maturation. Current evidence indicates that many youth athletes fail to achieve recommended energy and macronutrient intakes, which may negatively affect both athletic performance and healthy development (Lehmann et al., 2024).

Sports nutrition aims to provide adequate energy and nutrient intake to support training adaptations, enhance competitive performance, and promote post-exercise recovery. Among macronutrients, carbohydrates represent the primary energy source for moderate- and high-intensity exercise because of their essential role in maintaining muscle and liver glycogen stores. Proteins are necessary for muscle repair and synthesis, whereas dietary fats contribute to energy metabolism, hormonal regulation, and the absorption of fat-soluble vitamins (Jäger et al., 2017).

Several studies have demonstrated that inadequate carbohydrate intake may reduce glycogen availability, increase fatigue, and impair both physical and technical performance in soccer players. A recent systematic review concluded that appropriate carbohydrate availability positively influences physical, cognitive, and technical aspects of soccer performance (Pueyo et al., 2024). Similarly, carbohydrate intake has been shown to support exercise intensity maintenance and sport-specific skill execution during competition (Rollo & Williams, 2023).

Despite the growing body of evidence linking nutrition and athletic performance, limited research has been conducted among adolescent soccer players living and training at high altitude, where environmental conditions may increase physiological and energetic demands. Therefore, generating local evidence is necessary to develop nutrition strategies tailored to this specific population.

Accordingly, the aim of the present study was to determine the relationship between energy intake and competitive performance among adolescent soccer players from the F.C. Vázquez Sports Academy in Juliaca.

METHODS

This study adopted a quantitative, observational research design to assess the influence of energy intake on the competitive performance of adolescent soccer players. The research was conducted in a sports training setting during 2025. Data were collected following established ethical guidelines and standardized procedures.

The study population consisted of adolescent soccer players who participated in regular training sessions during 2025. A sample of 60 adolescents was selected based on the predefined inclusion criteria to evaluate the influence of energy intake on their nutritional and training outcomes.

Data were collected using a standardized dietary assessment questionnaire and a food intake record.

The instrument measured energy intake levels and their relationship with the nutritional status and training performance of adolescent soccer players

Data were collected following standardized research procedures.

Energy intake was assessed through a 24-hour dietary recall and classified according to adequacy levels for total energy, carbohydrates, proteins, and fats.

Competitive performance was assessed using:

Cooper Test (cardiorespiratory endurance).

One-minute sit-up test (abdominal strength).

Data were analyzed using descriptive and inferential statistics. Measures of central tendency and dispersion were calculated, and statistical tests were applied to evaluate the relationship between energy intake and the nutritional and performance outcomes of adolescent soccer players. The analysis was performed using specialized statistical software.

Data were analyzed using SPSS version 27. Descriptive statistics and Pearson's Chi-square test were performed, with statistical significance set at $p<0.05$.

RESULTS AND DISCUSSION

Results

Adolescent soccer players demonstrated adequate total energy (68.3%), carbohydrate (65.0%), and protein intake (61.7%): however, 78.3% exhibited inadequate fat consumption. Regarding physical performance, 38.3% showed poor cardiorespiratory endurance and 46.7% demonstrates poor abdominal strength. A statistically significant association was found between carbohydrate adequacy and cardiorespiratory endurance (X^2=12.43; p=0.002), whereas no significant associations were observed between total energy, protein, or fat intake and physical performance variable ($p > 0.05$).

Table 1. adequacy of energy intake and macronutrients in adolescent soccer players (n=60)

Nutrient	Adequate n (%)	Inadequate n (%)
Total energy	41 (68.3)	19 (31.7)
Carbohydrates	39 (65.0)	21 (35.5)
Proteins	37 (61.7)	23 (38.3)
Fats	13 (21.7)	47 (78.3)

Note: Values are presented as frequency and percentage. Adequate intake was defined as 90-110% of the recommended values for adolescent athletes.

Table 2. Association between carbohydrate adequacy and cardiorespiratory endurance

Variable	Chi-square (X^2)	p-value
Carbohydrate adequacy vs. Cardiorespiratory endurance	12.43	0.002

Note: Statistically significant association ($p < 0.05$).

DISCUSISON

The present study evaluated the relationship between energy intake and competitive performance among adolescent soccer players. The findings revealed that most participants achieved adequate total energy, carbohydrate, and protein intake, whereas fat intake was predominantly inadequate. In addition, a statistically significant association was observed between carbohydrate adequacy and cardiorespiratory

endurance (p = 0.002), while no significant associations were identified for total energy, protein, or fat intake.

These findings are consistent with those reported by Lehmann et al. (2024), who concluded that carbohydrate intake is one of the principal nutritional determinants of athletic performance in young athletes because it maintains muscle glycogen stores and delays fatigue during prolonged exercise. Likewise, Pueyo et al. (2024) demonstrated that adequate carbohydrate availability improves both physical and technical performance in soccer players, supporting the significant relationship observed in the present study.

Similarly, Rollo and Williams (2023) reported that carbohydrate consumption before and during exercise contributes to maintaining exercise intensity, cognitive function, and technical skills during soccer competition. The positive association between carbohydrate adequacy and cardiorespiratory endurance observed in this study reinforces the importance of ensuring sufficient carbohydrate intake in adolescent soccer players, particularly during periods of intensive training.

In contrast, no statistically significant relationship was found between protein intake and physical performance. This finding agrees with Morton et al. (2021), who indicated that protein intake primarily contributes to muscle repair, recovery, and long-term adaptations rather than producing immediate improvements in aerobic performance. Likewise, the absence of an association between fat intake and performance may be explained by the fact that fats are more closely related to long-duration energy metabolism and hormonal regulation than to short-term physical performance tests.

Although most participants met the recommended total energy intake, nearly four out of five players presented inadequate fat consumption. This pattern may compromise long-term health, hormonal balance, and recovery capacity, as described by Mountjoy et al. (2023), who emphasized that chronic low energy availability may increase the risk of Relative Energy Deficiency in Sport (REDs), particularly in adolescent athletes.

The findings have practical implications for coaches, nutritionists, and sports institutions. Nutritional education programs should emphasize appropriate carbohydrate intake before training and competition while promoting balanced dietary patterns that also

ensure adequate fat consumption. These interventions could improve athletic performance while supporting healthy growth and development during adolescence.

One limitation of the present study is its cross-sectional design, which prevents establishing causal relationships. Furthermore, dietary intake was assessed using a 24-hour recall, which may be affected by recall bias. Future longitudinal studies including larger samples and objective dietary assessment methods are recommended to better understand the long-term effects of nutritional intake on competitive performance.

CONCLUSIONS

The majority of adolescent soccer players presented adequate total energy, carbohydrate, and protein intake; however, fat intake was inadequate in most participants.

A statistically significant relationship was identified between carbohydrate adequacy and cardiorespiratory endurance, indicating that carbohydrate consumption plays an important role in maintaining aerobic performance among adolescent soccer players.

No statistically significant associations were observed between total energy, protein, or fat intake and the evaluated physical performance variables.

These findings support the implementation of nutritional education programs focused on adequate carbohydrate consumption and balanced dietary habits to optimize competitive performance and promote healthy development in adolescent athletes.

Future longitudinal studies with larger sample sizes and more comprehensive nutritional assessments are recommended to confirm these findings and establish causal relationships between dietary intake and sports performance.

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CONJUNCTIVAL NEMATODES IN BACKYARD BIRDS: LITERATURE REVIEW: A LITERATURE REVIEW

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ABSTRACT

Globally wild populations, commercial poultry and veterinary public health frameworks face an escalating threat from ocular parasites belonging to the genus *oxyspirura* and the trematode *philophthalmus gralli*. The objective this review synthesizes current scientific literature regarding the morphology, molecular profiling, phylogenetic structures, and zoonotic risks of *Oxyspirura spp*, and *philophthalmus gralli* in avian hosts, emphasizing their relevance for diagnostic accuracy and epidemiological surveillance. The method used was a systematic evaluation of the global scientific literature tracking intermediate hots, transmission pathways, and phylogenetic dynamics through nuclear (18S rDNA), (ITS1), (ITS2) and mitochondrial (cox1), (ND1) genetic markers. The results indicate that specific insect vectors (cockroaches and orthopterans) play a key role in the life cycles of *Oxyspirura mansoni and Oxyspirura petrowi*, whereas invasive thiarid snails contribute to the global spread of *Philophthalmus gralli*. Although molecular datasets confirm distinct monophyletic clades and establish the (cox1) game as a highly dependable phylogenetic tool, major baseline gaps persist. Specifically complete (cox 1) sequences for O*xyspirura* petrowi remain unavailable, and epidemiological data on south American backyard poultry is remarkably scarce. In conclusion, these knowledge gaps highlight the critical need to strengthen diagnostic protocols. Given the zoonotic potential of these ocular nemathodes, integrating molecular ecological, and clinical approaches is essential to modernize avian biosecurity.

Keywords: *Oxyspirura*, Ocular nematodes*, Philophthalmus gralli*, Molecular phylogeny, Zoonosis

2. INTRODUCTION

Avian eyeworms of the genus Oxyspirura represent a specialized group of parasitic nematodes affecting both wild birds and domestic flocks. Typically, these parasites colonize the environment beneath the nictitating membrane, though they occasionally invade the nasal cavities and paranasal sinuses. Recent morpho-molecular investigations have shed light on Oxyspirura mansoni and Philophthalmus gralli, mapping clear phylogenetic links among Philophthalmus gralli lineages across geographically distant regions like Bangladesh, costa Rica and Peru. Furthermore, shifting tropical climates and the distribution of intermediate hosts directly accelerate the transmission and survival of these parasites across diverse ecosystems.

Yet, despite these descriptive and molecular advances, we still know very little about their true biological diversity, shifting geographic boundaries and broader zoonotic risks particularly within south American tropical ecosystems. The specific epidemiological cross talk between domestic backyard flocks and wildlife remains largely unmapped. To address this our review compiles and analyzes the available evidence on the morphology, molecular tools, phylogenetic setups and zoonotic implication of of *Oxyspirura* spp. and *Philophthalmus gralli*. By doing so, we aim to patch current taxonomic ambiguities and provide a solid framework for animal health surveillance and public health initiatives in tropical environments.

METODOLOGY

This study adopted a non-experimental, descriptive and documentary research design through a systematic literature review. The approach focused on the critical evaluation and synthesis of evidence regarding conjunctival nematodes in backyard birds. The core objective was to analyze taxonomic identification, morphology, geographical distribution and molecular characterization, with an emphasis on the genus O*xyspirura.*

The study population consisted of all scientific articles on avian ocular parasites indexes in major databases from historical records until December 2025. A sample of relevance studies was selected from PubMed/ Medline, PMC, Scopus, Web of Science, and Science Direct.

The search strategy involved Boolean operators (AND, OR) combining keywords such as "Oxyspirura", "eyeworm", "conjunctival nematode", "ITS1", "ITS2", and "cox1".

Data collection was managed using eligibility criteria as the primary selection instrument inclusion criteria comprised original articles, field studies, and phylogenetic analyses on conjunctival nematodes in domestic and wild birds. Exclusion criteria omitted gray literature duplicate records, articles without full text access and reviews without primary data reference management software was utilized to eliminate duplicates.

The extraction procedure was conducted using a standardized digital data matrix. The selected studies were systematically tabulated based on predefined categories: editorial identification (author, year and country) biological aspects (parasite species, host and distribution) and methodological aspects (diagnostic methods and molecular markers like ITS1, ITS2 and COX1).

Data were analyzed using a descriptive and comparative approach. This process categorized the scientific evidence according to methodological robustness and current trends in molecular diagnosis. Finally, this analysis permitted the identification of key knowledge gaps in the study of conjunctival nematodes within avian parasitology.

RESULTS

The literature review identified studies related to conjunctival nematodes and ocular parasites in birds mainly highlighting, *Oxyspirura petrowi*, and *Philophthalmus gralli.* The reviewed studies reported morphological characteristics distribution, hosts, and molecular tools used for parasite identification.

Genetic analyses employed nuclear markers (18S rDNA, ITS) and mitochondrial markers (COI and ND1), allowing species differentiation and phylogenetic analysis *Oxyspirura petrowi* exhibited molecular differentiation based on 18S and COX1 markers. Likewise, studies reported that *Oxyspirura* species have life cycles associated whit insect intermediate hosts, while *Philophthalmus gralli* was related to mollusks of the genera *Melanoides* and *Tarebi*a. The main findings are summarized in table 1.

Table 1.

Characteristics of studies on ocular parasites in birds identified through the literature review

Parasite	Hosts	Identification methods	Main findings
Oxyspirura mansoni	Domestic and wild birds	Morphology and 18S, ITS, and COI markers	Genetic variation and haplotype formation
Oxyspirura petrowi	Wild birds	18S and COI markers	Molecular differentiation among populations
Philophthalmus gralli	Birds associated with aquatic environments	Morphology and molecular analysis	Association with intermediate mollusk hosts (*Melanoides* and *Tarebia*)

The reviewed studies provided molecular and parasitological information on ocular parasites in birds; however limited availability of genetic data and scarce studies on backyard birds in south America were reported.

DISCUSSION

The findings of this review demonstrate that nuclear molecular markers (18S rDNA, ITS1, and ITS2) and mitochondrial markers (cox1 and ND1) are reliable tools for the identification and phylogenetic differentiation of *Oxyspirura mansoni*, *Oxyspirura petrowi*, and *Philophthalmus gralli*. In particular the COX 1, gene provides high discriminatory power for species identification and the assessment of genetic diversity supporting its application in phylogenetic studies.

These finding are consistent with previous studies showing that *Oxyspirura mansoni forms well supported monophyletic clades based on ITS and COX1 sequences* (Biswas et al 2021), whereas *Oxyspirura petrowi* can be reliably differentiated from closely related species using 18S rDNA and partial cox1 sequences (Kalyanasundaram et al., 2018; Kalyanasundaram et al., 2019).

Likewise, Heneberg et al. (2014) and Chalkowski et al. 2021), demonstrate that *Philophthalmus gralli* exhibits low genetic divergence among geographically distant populations, suggesting that the spread of invasive intermediate hosts has contributed to its worldwide distribution.

Despite these advances important knowledge gaps remain, the lack of complete COX 1 sequences for *Oxyspirura petrowi* and the limited molecular evidence from backyard poultry in south America restrict comprehensive phylogenetic comparisons and the understanding of parasite diversity. Moreover, most available studies have focused on wild birds rather than domestic backyard flocks, highlighting a significant geographical and epidemiological bias (Kalyanasundaram et al., 2019; Biswas et al., 2021a).

Previous ecological studies have also demonstrated that the transmission of *Oxyspirura* spp, depends on arthropod intermediate hosts including cockroaches, crickets, and grasshoppers, whereas P. gralli is closely associated with invasive freshwater snails such as Melanoides tuberculata and Tarebia granifera. (Doanh et al 2025). Furthermore, recent reports confirming the zoonotic potential of *Oxyspirura mansoni* reinforce its relevance from a one health perspective.

Overall, the available evidence indicates that integrating standardized molecular markets with ecological and epidemiological data will improve phylogenetic resolution and strengthen surveillance programs. Future studies should prioritize backyard poultry populations in tropical regions, where information remains scarce despite the close interaction among domestic bird, wildlife and humans.

CONCLUTIONS

The rapid evolution of molecular genetics has fundamentally changed how we identify and group avian ocular nematodes. Today markers ITS and COX are no longer optional they are essential tools for untangling the evolutionary paths of both *Oxyspirura mansoni and Philophthalmus gralli.*

In tropical territories, there is a clear and urgent need to build local genetic databases placing regional eyeworn strains into the global phylogenetic map will give us a much clearer picture of how these parasites mutate, adapt and spread across different environments.

At the ground level, knowing exactly which intermediate hosts drive transmission insects for Oxyspirura and aquatic snails for *Philophthalmus*, offer practical leverage for field veterinarians. This ecological insight is key to designing realistic control measures for rural backyard poultry, where flock management is informal and exposure risk high.

To keep moving forward future field sampling should standardize sample prevention in 70 – 90% ethanol and adopt a multi locus sequencing framework that combines nuclear and mitochondrial targets. This balanced approach will sharpen taxonomic accuracy and deliver far more resilient phylogenetic conclusions.

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Level of knowledge about hiv-aids and basic biosecurity standards for patients going to the clinic dentistry

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Summary

The following research aimed to determine the Level of knowledge of HIV-AIDS and basic biosafety standards of the patients who attend the Dental Clinic of the National University of Altiplano Puno 2016, it is a descriptive cross-sectional study, the instrument was The questionnaire, which consisted of 25 questions, the first 15 referring to knowledge about HIV - AIDS and the remaining 10 to biosafety standards. The sampling was for convenience and consisted of 121 patients of both sexes. The analysis of results were tabulated and their analysis was by descriptive statistics in absolute and percentage frequency tables. the level of knowledge about HIV-AIDS was regular, being the age group from 18 to 29 with 33.06% and from 30 years and over with 31.40% with regular knowledge, according to sex there was no difference resulting in regular knowledge in the older group representative of 32.23% for both sexes. The level of knowledge about basic biosafety gave us in the age group of 18 to 29 years 28.10% with a regular knowledge, the group of 30 and over 24.79% with regular knowledge, according to sex for female the level of knowledge is regular with 28.10 %, for males 24.79% with regular and good knowledge, without finding significant differences. The level of knowledge about HIV-AIDS in both age groups and in both sexes was obtained that they show regular knowledge, the level of knowledge of biosafety regulations was regular in both age groups, and good without showing significant differences according to sex.

Keywords: Knowledge, biosecurity, HIV, AIDS.

ABSTRACT

The following research aimed to determine the Level of knowledge of HIV-AIDS and basic biosafety standards of the patients who attend the Dental Clinic of the National University of Altiplano Puno 2016, it is a descriptive cross-sectional study, the instrument was The questionnaire, which consisted of 25 questions, the first 15 referring to knowledge about HIV - AIDS and the remaining 10 to biosafety standards. The sampling was for convenience and consisted of 121 patients of both sexes. The analysis of results were tabulated and their analysis was by descriptive statistics in absolute and percentage frequency tables. the level of knowledge about HIV-AIDS was regular, being the age group from 18 to 29 with 33.06% and from 30 years and over with 31.40% with regular knowledge, according to sex there was no difference resulting in regular knowledge in the older group representative of 32.23% for both sexes. The level of knowledge about basic biosafety gave us in the age group of 18 to 29 years 28.10% with a regular knowledge, the group of 30 and over 24.79% with regular knowledge, according to sex for female the level of knowledge is regular with 28.10 %, for males 24.79% with regular and good knowledge, without finding significant differences. The level of knowledge about HIV-AIDS in both age groups and in both sexes was obtained that they show regular knowledge, the level of knowledge of biosafety regulations was regular in both age groups, and good without showing significant differences according to sex.

Keywords: Knowledge, biosecurity, HIV, AIDS.

Introduction

HIV-AIDS is a serious public health problem in most countries, affecting the entire population, because infections and their risk factors in hospitals are a daily concern, as users are susceptible to being infected, it is a disease that is in a highly developed state of spread and that there may not be a cure but there are treatments to improve their quality of life and possibly prolong it. considering such knowledge important because HIV-AIDS constitutes a serious public health problem and is related to dental practice and where it is very necessary to have knowledge of biosafety standards.(1)

Scientists say that HIV will continue to spread. There is no vaccine yet against this disease, the only way to delay the epidemic is by understanding how HIV is transmitted and how to avoid contracting it. (2) Biosafety is defined as a set of standards, understood as a doctrine of behavior, aimed at achieving attitudes and behaviors that reduce the risk

of acquiring accidental infections, designed to protect man, the community and the environment from accidental contact with agents that are potentially harmful - pathogens, biologicals, chemical agents and radioactive elements (3) The dental association (ADA) for more than three decades, even before the emergence of HIV, recommended the use of biosecurity measures in order to avoid the transmission of diseases, Now with this new problem for public health we must become more aware and it is necessary for the general population to know about these biosecurity standards. The dental office is an area in which a cross infection can occur between: patient / dentist, dentist / patient and even between them and the rest of the community and / or the environment if the necessary precautions are not taken to control it.

In the study by Díaz C. Vega J. In 2011, a descriptive study reached a conclusion where adolescents have a regular level of knowledge about HIV / AIDS, and almost zero knowledge about the effects of the infection. Women have better knowledge compared to men, placing them at a regular level and men at a poor level. (2) From a scientific point of view, the study may serve as a background for future research and as a starting point for broader studies, both nationally and internationally, within the framework of teaching as a key element to combat HIV / AIDS through the dental discipline. For the dental profession, it serves as valuable information by which professional decisions and actions can be taken to protect this group, the population, and thus be able to improve programs, workshops, educational activities, procedure guides, information manuals, aimed at build healthy populations. On the social front, the study's contribution is expected to be significant, since having a population trained in biosafety standards would also improve the quality of life of people who attend either the dental clinic or an office private or health establishments. For the educational sector it serves as a reference of how knowledge about HIV - AIDS is found in patients who attend the Dental Clinic of the Professional School of Dentistry, so they can strengthen education in HIV prevention and AIDS management, educating them in self care. Faced with this reality, it was considered convenient to carry out an investigation that allows determining the level of knowledge of HIV-AIDS and biosafety standards of the patients who attend the Dental Clinic of the National University of Altiplano Puno.

MATERIALS AND METHODS

1. RESEARCH DESIGN.

This research work is descriptive because it describes the facts as they are observed and cross-sectional because it was measured only once

TYPES OF RESEARCH.

It is observational because there is no intervention by the researcher since it will not be manipulated variables; the data were recorded the problem situation as it is.

It is prospective because the data are collected in the present and by the researcher.

It is cross-sectional because the study variables are measured on a single occasion.

Descriptive since our work is shown as they are observed.

2. STUDY UNITS.

POPULATION.

The population is made up of people of legal age who are cared for in the dental clinic of the Professional School of Dentistry of UNA-PUNO between the months August and October 2016.

SAMPLE.

The sample is non-probabilistic and for convenience in patients who come to the clinic dental, from all clinics and adults is random stratified by age and gender of the Professional School of Dentistry of UNA-PUNO 2016. The sample being calculated 121 users of the Dentistry Service of the Dental Clinic.

3. ETHICAL CONSIDERATIONS.

The request was submitted to carry out the research project to the director of the Professional School of Dentistry.

Request to the coordination of the Clinic of the Professional School of Odontology.

Informed consent to patients who wanted to participate in the investigation.

Results

GENERAL LEVEL OF KNOWLEDGE OF HIV-AIDS AND STANDARDS OF BIOSECURITY.

LEVEL OF KNOWLEDGE OF HIV-AIDS, ACCORDING TO AGE AND SEX.

TABLE 1

LEVEL OF KNOWLEDGE OF HIV-AIDS BY AGE IN PATIENTS WHO GO TO THE CLINIC OF THE E.P.O UNA- PUNO, 2016.

KNOWLEDGE	GOOD		MODERATE		POOR		**TOTAL**	
AGE	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
18 a 29	**28**	**23.14**	**40**	**33.06**	**0**	**0.00**	**68**	**56.20**
30 a mas	**13**	**10.74**	**38**	**31.40**	**2**	**1.65**	**53**	**43.80**
total	**41**	**33.88**	**78**	**64.46**	**2**	**1.65**	**121**	**100.00**

Interpretation:

Table 1 shows the results of the patients' level of knowledge about HIV-AIDS according to age, with a higher percentage of the surveyed patients having regular knowledge of 64.46% of both age groups, the age group 18 to 29 years had a regular knowledge with a percentage 33.06%; For the group aged 30 years and over, a percentage of 31.40% with regular knowledge of the subject was observed; no significant difference in the level of knowledge was observed with respect to the age of the patients.

TABLE 2

LEVEL OF KNOWLEDGE OF HIV-AIDS ACCORDING TO SEX IN PATIENTS WHO VISIT THE CLINIC OF THE PROFESSIONAL SCHOOL OF ODONTOLOGY UNA-PUNO, 2016.

KNOWLEDGE	GOOD		MODERATE		POOR		**TOTAL**	
SEX	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
FEMALE	**21**	**17.36**	**39**	**32.23**	**0**	**0.00**	**60**	**49.59**
MALE	**20**	**16.53**	**39**	**32.23**	**2**	**1.65**	**61**	**50.41**
Total	**41**	**33.88**	**78**	**64.46**	**2**	**1.65**	**121**	**100.00**

Interpretation:

Table 2 the results of the level of knowledge about HIV-AIDS of the patients according to sex, it was found that the patients have a regular knowledge with a percentage of 64.46%, where no significant differences were found between both. sexes obtaining a percentage of 32.23% of regular knowledge in both, a lower percentage that would be 1.65% with a deficient level of knowledge of the subject was male. No variation is observed in the level of knowledge regarding the sex of the patients.

LEVEL OF KNOWLEDGE OF BASIC BIOSECURITY RULES.

TABLE 3

LEVEL OF KNOWLEDGE OF BIOSECURITY AGAINST HIV-AIDS ACCORDING TO AGE IN PATIENTS WHO VISIT THE CLINIC OF THE PROFESSIONAL SCHOOL OF ODONTOLOGY UNA-PUNO, 2016.

KNOWLEDGE	GOOD		MODERATE		POOR		**TOTAL**	
AGE	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
18 a 29	**32**	**26.45**	**34**	**28.10**	**2**	**1.65**	**68**	**56.20**
30 a mas	**23**	**19.01**	**30**	**24.79**	**0**	**0.00**	**53**	**43.80**
total	**55**	**45.45**	**64**	**52.89**	**2**	**1.65**	**121**	**100.00**

Interpretation:

Table 3 the results of the level of knowledge about basic biosafety standards of patients according to age, a percentage of 52.89% has regular knowledge, the age group of 18 to 29 years has a a percentage of 28.10%, which is a higher percentage compared to the age group of 30 and over of 24.79% with regular knowledge; However, 1.65% presented deficient knowledge, a not very representative percentage, but not observed in the group aged 30 or over. There is no significant variation in the level of knowledge with respect to the age of the patients.

TABLE 4

LEVEL OF KNOWLEDGE OF BIOSECURITY AGAINST HIV-AIDS ACCORDING TO SEX IN PATIENTS WHO VISIT THE CLINIC OF THE PROFESSIONAL SCHOOL OF DENTISTRY UNA-PUNO, 2016.

KNOWLEDGE	GOOD		MODERATE		POOR		**TOTAL**	
SEX	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
FEMALE	**25**	**20.66**	**34**	**28.10**	**1**	**0.83**	**60**	**49.59**
MALE	**30**	**24.79**	**30**	**24.79**	**1**	**0.83**	**61**	**50.41**
total	**55**	**45.45**	**64**	**52.89**	**2**	**1.65**	**121**	**100.00**

Interpretation:

Table 4 the results of the level of knowledge about basic biosafety standards of patients according to sex. 52.89% of the patients have regular knowledge; having the female sex the highest percentage 28.10% with regular knowledge; for males, there are 24.79% with regular knowledge, no significant differences are observed between both sexes; on the other hand, a percentage of 0.83% with poor knowledge was observed for both sexes. There is no significant variation in the level of knowledge regarding the sex of the patients.

Discussion.

In the research there were similar studies applied to students, a similar study was found Díaz C., presented a study showing the level of knowledge in adolescents from 15 to 19 where he obtained as a result that 70% had regular knowledge, González X. in his study carried out in adolescents found that 69.36% presented deficient knowledge, Arrasco J. carried out a study in students of 5th year of secondary school, it is found that 74.0% have regular knowledge, Ramos A., study in 4th and 5th students years of studies at the professional school of dentistry found that 83% of students present regular knowledge, compared to my study that the highest percentage was 33.06% with regular knowledge conducted in patients from 18 to 29 years old, the result is probably similar Due to the age group that was young, comparing with the study by González X. who obtained poor knowledge, it is possible that the difference is the lack of implementation of sexual health programs in youth schedules. In our population aged 30 years and over, a regular level of knowledge was found at 31.40%, but no similar studies were found with this age group. Studies in adolescents of both sexes such as that of Díaz C. In which 50.7% are women and 49.3% are men. 70% of the respondents have regular knowledge. Women have better knowledge than men, achieving an average of 5.8 and 4.8 respectively, Women have better knowledge compared to men, placing them at a regular level and men at a deficient level. Compared to my study, it was found that there are no differences with 32.23% for both sexes and only 1.65% of deficient knowledge is male, this difference could be due to the difference in the questions used in both surveys, it could also be due to the difference in the lifestyle of the samples. Regarding the level of knowledge of basic biosafety standards, in the study carried out by Ramos A. In students of the 4th and 5th year of studies at the Professional School of Dentistry, 72% have a regular knowledge of biosafety, in my study that It was carried out in patients in whom it was found that 52.89% present regular knowledge, no significant differences were found in terms of the result because they may have previous knowledge due to educational talks on this topic. Regarding the level of knowledge of the basic biosafety norms according to age, sex and age, no similar studies were found, however in my study, 52.89% were obtained as a result with regular knowledge of which the age group of 18-29 years with 28.10% and for the group of 30 or more years with 24.79%, on the other hand, according to sex, 52.89% of regular knowledge, the female sex with 28.10 and the male with 24.79 without finding a significant difference. During the execution of this project, the limited cooperation of patients older than 30 years was considered as a limitation.

Conclusions

1. The level of knowledge about HIV-AIDS according to age, concluding that both groups of 18 to 29 years and 30 years of age presented regular knowledge.

2. The level of knowledge about HIV-AIDS according to Sex, concluding that both males and females present regular knowledge.

3. The level of knowledge about biosecurity against HIV-AIDS according to age, concluding that the ages 18 to 29 years present a regular knowledge and for the ages between 30 and over in the same way they present a higher percentage with a regular knowledge.

4. The level of knowledge about biosafety against HIV-AIDS according to sex, concluding that it was for females that the most representative group with a regular knowledge and for males a regular knowledge that with the highest representation

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THE ROLE OF GENERATIVE AI IN DIGITAL LITERACY: A CRITICAL EVALUATION OF ITS IMPACT ON INFORMED DIGITAL CITIZENSHIP

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ABSTRACT

Generative AI has transformed digital literacy, creating new challenges and opportunities in the creation, evaluation, and use of information. This study aims to evaluate the impact of generative AI on digital literacy and its influence on the development of critical and informed digital citizenship. For that, a systematic review of the literature published between 2021 and 2024 was carried out, using academic databases such as ScienceDirect and Scopus, following the PRISMA diagram. The results showed that, while generative AI facilitates access to information and promotes creativity, it also presents risks such as misinformation and the reduction of critical skills among users. The conclusions highlight the importance of strengthening educational programs focused on critical and ethical competencies to ensure the proper integration of generative AI, thereby fostering a more aware and responsible digital citizenship.

Keywords: Digital literacy, Ethics in artificial intelligence, Generative AI, Informed digital citizenship, Misinformation.

INTRODUCTION:

In recent years, the rapid expansion of generative artificial intelligence (AI) has posed significant challenges for digital literacy, as individuals are required not only to consume information but also to understand how digital content is generated and the ethical implications associated with its use (Casar Corredera, 2023; Gutiérrez González & Ocádiz Amador, 2024). Recent evidence indicates a substantial increase in the use of generative AI across education and other sectors, significantly shaping critical digital literacy, a key component of contemporary society. For instance, a growing number of students and educators use AI-powered tools such as ChatGPT to support learning, content creation, and administrative tasks, highlighting the rapid adoption of these technologies and their influence on digital practices (The Open Innovation

Team & Department for Education, 2024; Ascione, 2024). Moreover, digital literacy has become an essential social and educational competency that enables individuals to effectively evaluate, create, and engage with digital information in ethical and responsible ways (Fernández de Castro et al., 2024; Sandoval Bravo, 2021).

Despite the growing body of research examining the impact of generative AI on education and digital literacy, an important research gap remains regarding how its use influences the development of a critical and informed digital citizenship, particularly in Latin American contexts. Existing studies suggest that deficiencies in digital literacy continue to limit equitable participation in digital environments and hinder the exercise of digital rights, especially in countries such as Peru, where structural inequalities persist (Sucari León et al., 2021; Guzmán Rendón, 2023). Furthermore, limited evidence exists on users' ability to assess the accuracy of AI-generated content, identify misinformation, and understand the ethical implications associated with algorithmic decision-making and content generation (Ramírez Autrán, 2023; Burgos, 2024). Consequently, further research is needed to explore the relationship between generative AI, critical digital literacy, and digital citizenship.

To address this gap, the present study aims to examine the impact of generative artificial intelligence on digital literacy and digital citizenship. Specifically, the study focuses on critical information evaluation, ethical awareness, and the responsible use of AI-generated content. It is argued that fostering a deeper understanding of the opportunities and risks associated with generative AI is essential for developing an informed and critical digital citizenship capable of participating responsibly in contemporary digital societies, particularly within the diverse socioeconomic and cultural realities of Latin America (Morduchowicz, 2020; Badillo Mendoza et al., 2019; Sancho García & Ivorra Alemañy, 2024).

METHODOLOGY:

This study employed a **descriptive design** based on a **systematic literature review** to examine the relationship between Generative Artificial Intelligence (GAI), digital literacy, and digital citizenship. The review followed the **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)** framework to ensure a transparent and systematic selection process.

The literature search was conducted in the **ScienceDirect** and **Scopus** databases, focusing on scientific articles published between **2020 and 2024**. Relevant studies were identified using keywords related to *Generative Artificial Intelligence*, *digital literacy*, *digital citizenship*, *ethics*, and *information literacy*.

The study population consisted of scientific articles indexed in ScienceDirect and Scopus during the selected period. The initial search yielded **1,119 records**. After applying predefined inclusion and exclusion criteria and removing duplicate and irrelevant studies, **120 articles** remained for screening. Subsequently, abstracts and methodological sections were assessed to evaluate relevance, methodological quality, consistency, and contribution to the research objectives, reducing the number to **33 studies**. Finally, **23 representative articles** that met all eligibility criteria were selected for the final review.

Data were collected through **documentary observation** using a structured **observation sheet** designed to record relevant information from each selected study, including publication year, database source, research objectives, methodology, and principal findings.

The review process was conducted in four stages: **(1)** identification of studies through database searches, **(2)** screening using predefined inclusion and exclusion criteria, **(3)** eligibility assessment based on abstracts and methodological quality, and **(4)** final inclusion of studies for qualitative synthesis according to the PRISMA framework.

The selected studies were analyzed using a **descriptive approach**. Frequencies and percentages were calculated to summarize the distribution of articles according to publication year, database source, and research focus. The findings were synthesized to identify patterns, trends, and emerging evidence regarding the influence of Generative Artificial Intelligence on digital literacy and digital citizenship.

RESULTS:

A total of **23 studies** published between **2021 and 2024** met the eligibility criteria established through the PRISMA framework. Regarding the first research objective, **11 of the 23 studies (47.8%)** examined the impact of generative artificial intelligence (GAI) on digital literacy and informed digital citizenship. The studies reported improvements in information access, information processing, content creation, learner autonomy, and technological engagement. They also identified challenges related to dependence on AI systems, reduced critical reading and writing practices, originality, intellectual property, and uncritical acceptance of AI-generated information. These findings are summarized in Table 1.

Regarding the second research objective, **6 studies (26.1%)** examined the effects of exposure to GAI on users' ability to distinguish authentic information from AI-generated content. The studies reported difficulties in identifying AI-generated information, particularly among students. Higher levels of digital literacy and training in information verification were associated with improved recognition of misinformation, whereas prolonged exposure without adequate training was associated with reduced critical judgment.

The third research objective was addressed by **6 studies (26.1%)**, which examined users' understanding of ethical principles related to GAI. The studies identified moderate levels of understanding regarding privacy and human autonomy, low levels regarding algorithmic bias and accountability, and very low levels regarding transparency and explainability. These findings are summarized in Table 2.

Table 1

Benefits and Challenges of Generative Artificial Intelligence in Digital Literacy

Dimension	Benefits	Challenges
Information access	Faster access to relevant information	Dependence on AI systems
Information processing	Improved synthesis and analysis of information	Need to strengthen critical evaluation skills
Content creation	Increased productivity and creativity	Concerns about originality and intellectual property
Critical thinking	Support for reasoning and argumentation	Risk of uncritical acceptance of AI-generated information

Note. Developed by the authors based on the systematic literature review.

Table 2

Main Ethical Challenges Associated With the Use of Generative Artificial Intelligence

Ethical challenge	Description	Level of understanding
Privacy and data protection	Concerns regarding the use and storage of personal information	Moderate
Algorithmic bias	Risk of reproducing or amplifying existing biases	Low
Transparency and explainability	Difficulty understanding AI decision-making processes	Very low
Accountability	Uncertainty regarding responsibility for AI-generated decisions	Low

Human autonomy	Dependence on AI systems for decision making	Moderate

Note. Developed by the authors based on the systematic literature review.

DISCUSSION:

The findings of this systematic review suggest that generative artificial intelligence (AI) has a significant influence on digital literacy and the development of informed digital citizenship. The reviewed evidence indicates that generative AI enhances users' ability to access, process, and generate information through advanced digital technologies. However, these benefits are accompanied by increased challenges related to the critical evaluation of AI-generated content, particularly in distinguishing reliable information from automatically generated information. This finding highlights that digital literacy extends beyond technical competence and requires critical thinking, information evaluation, and ethical decision-making in digital environments.

These findings are consistent with previous studies reporting that individuals with lower levels of digital literacy are more likely to accept AI-generated information without critically evaluating its accuracy or reliability (Gatti, 2024). Likewise, the reviewed evidence supports the conclusions of Badillo Mendoza et al. (2019), who emphasize that digital literacy training strengthens users' ability to critically assess information and promotes responsible digital citizenship. Nevertheless, the reviewed studies also revealed persistent difficulties in recognizing the ethical implications of generative AI, including misinformation, algorithmic bias, and copyright concerns, which is consistent with the findings of Chauncey and McKenna (2023). Furthermore, the absence of longitudinal evidence limits the understanding of how users' digital competencies evolve through sustained interaction with AI technologies, as suggested by Chen et al. (2023).

The results have important implications for education and digital policy, suggesting that digital literacy programs should integrate not only technical competencies but also critical thinking, information evaluation, media literacy, and digital ethics to promote the responsible use of generative AI and strengthen informed digital citizenship. However, this review has several limitations. The included studies showed considerable methodological heterogeneity and were conducted predominantly in highly digitalized countries, limiting the generalizability of the findings to regions with lower levels of digital development, such as Latin America and Africa (Fernández-Villavicencio, 2012). Therefore, future research should employ longitudinal designs and include more diverse educational, cultural, and geographical contexts to provide a

broader understanding of the long-term impact of generative AI on digital literacy and informed digital citizenship

CONCLUSIONS

One of the most important findings is that generative AI, by facilitating content creation, can reduce users' cognitive load, allowing them to access information more quickly; however, this also entails the risk of excessive dependence on these tools, which could negatively affect the development of critical skills essential for comprehensive digital literacy. Individuals with lower levels of digital literacy face greater difficulties in evaluating the accuracy and source of AI-generated information, highlighting the need to implement robust educational programs focused on critical thinking.

In this study, it was found that generative AI has a varied impact on content creation. Although it can improve efficiency and foster innovation, it also raises ethical concerns regarding authenticity and copyright. This issue is particularly relevant in the educational field, where students may use tools such as ChatGPT to complete tasks that previously required a higher level of reflection. While this may appear to increase academic productivity, it may actually hinder the long-term development of research and creativity skills, as it could encourage dependence on automated solutions rather than promoting a more thorough approach to problem-solving.

The inclusion of digital ethics as a fundamental component of educational curricula stands out as one of the most urgent recommendations, since, without a clear and widely understood ethical framework, the widespread use of generative AI in digital contexts may perpetuate biases and amplify inequalities, particularly in communities with limited access to technological resources. In this regard, digital literacy should be addressed not only from a technical perspective but also from a critical perspective that enables digital citizens to make informed and responsible decisions in their interactions with technology.

Finally, this study highlights the need to continue investigating the impact of generative AI across diverse global contexts. Since most of the studies reviewed were conducted in developed countries, the generalizability of the findings to regions with lower levels of digital literacy and technological access remains limited. Therefore, future research should focus on examining how generative AI affects communities in Latin America, Africa, and other regions with significant technological inequalities.

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INFLUENCE OF INTERNAL AND EXTERNAL FACTORS ON THE SETTLEMENT OF IRRIGATION INFRASTRUCTURE MAINTENANCE ACTIVITIES (AMIR) IN PISACOMA AND CAPASO, 2023

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Irrigation infrastructure maintenance plays a fundamental role in ensuring water availability for agricultural and livestock production in rural areas of Peru. In Pisacoma and Capaso (Puno Region), where camelid husbandry represents one of the principal economic activities, the timely liquidation of Irrigation Infrastructure Maintenance Activities (AMIR) is essential to guarantee accountability, efficient resource management, and the continuity of public investment. However, deficiencies in administrative management and operational processes have generated delays in the liquidation of maintenance activities, making it necessary to identify the factors that influence this process.

This study aimed to determine the influence of internal and external factors on the liquidation of Irrigation Infrastructure Maintenance Activities carried out in Pisacoma and Capaso during 2023. A quantitative, explanatory, non-experimental, cross-sectional, and correlational design was employed. A census approach was adopted, including all 24 maintenance activities executed during the study period. Data were collected through document analysis using a structured document registration form, and statistical analyses were performed using descriptive statistics and Pearson's correlation coefficient.

The findings revealed a very strong and statistically significant positive relationship between internal factors and financial liquidation ($r = 0.849$; $p = 0.002$), indicating that financial and physical execution, operational capacity, and internal control substantially contribute to improving the efficiency and timeliness of the liquidation process. In contrast, external factors showed a moderate positive but non-significant relationship

with physical liquidation (r = 0.422; p = 0.225), suggesting that their influence was limited within the study context.

The study concludes that strengthening internal management practices, operational capacity, and control mechanisms is essential to improve the liquidation of irrigation infrastructure maintenance activities. These findings provide empirical evidence to support decision-making and contribute to the development of more effective administrative strategies for public irrigation infrastructure management.

Keywords: irrigation infrastructure maintenance; internal factors; external factors; financial liquidation; physical liquidation; public management.

Introduction

This study employed a quantitative, non-experimental, cross-sectional, and correlational research design to examine the influence of internal and external factors on the liquidation of Irrigation Infrastructure Maintenance Activities (AMIR). This methodological approach was considered appropriate because it enabled the objective measurement of the relationships among the study variables without manipulating the research context. The study focused on identifying the extent to which internal management conditions and external contextual factors were associated with the efficiency of the liquidation process for irrigation infrastructure maintenance activities implemented during 2023.

The population consisted of twenty-four (24) Irrigation Infrastructure Maintenance Activities executed in the districts of Pisacoma and Capaso during 2023. Because the target population was limited and fully accessible, a census approach was adopted, allowing all maintenance activities to be included in the analysis. Consequently, no sampling procedure was required, ensuring complete coverage of the units of analysis and reducing the risk of sampling bias.

Data were collected through a structured document registration form specifically designed for this research. The instrument systematically compiled information from technical and administrative records related to the study variables. Internal factors were assessed through indicators associated with financial execution, physical execution, operational capacity, and internal control, whereas external factors included financial conditions, technological resources, and geographical accessibility. The dependent

variable, liquidation of maintenance activities, was evaluated through financial and physical liquidation indicators. The instrument underwent content validation through expert judgment, and its internal consistency was verified using Cronbach's alpha coefficient, demonstrating adequate reliability for data collection.

The research procedure began with obtaining formal authorization from the responsible public institution to access the documentation related to the execution and liquidation of irrigation infrastructure maintenance activities. Subsequently, technical files, financial reports, physical progress reports, liquidation reports, administrative records, and supporting documentation were reviewed in detail. The information extracted from these documents was recorded using the document registration form, after which the data were verified, coded, and organized into a database to ensure accuracy, consistency, and completeness prior to statistical analysis.

Statistical analyses were performed using IBM SPSS Statistics version 26. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the characteristics of the study variables. Inferential analysis was conducted using Pearson's correlation coefficient to determine the strength and direction of the relationships between internal factors, external factors, and the liquidation of irrigation infrastructure maintenance activities. Statistical significance was established at a confidence level of 95% ($p < 0.05$), allowing the proposed research hypotheses to be tested objectively.

Methodology

This study adopted a quantitative, applied, correlational, and cross-sectional research design to determine the influence of internal and external factors on the liquidation process of irrigation infrastructure maintenance activities. The research was conducted using information from maintenance activities executed during 2023. Data were collected following standardized research procedures and ethical principles to ensure the accuracy and reliability of the findings.

The population consisted of 24 irrigation infrastructure maintenance activities executed during 2023. Since the population was finite and accessible, the entire population was

considered as the study sample through a census approach. Information was obtained from the technical and administrative records corresponding to each maintenance activity.

Data were collected using structured data collection instruments designed according to the study variables and indicators. Documentary review sheets were used to obtain information from technical files, liquidation reports, administrative records, and supporting documents related to the maintenance activities. The instruments allowed the assessment of internal factors, external factors, and the liquidation process.

Data were collected in four stages. First, the corresponding documentary information for each maintenance activity executed during 2023 was identified and compiled. Second, the documentary review instruments were applied to extract information related to the study variables. Third, the collected data were reviewed, verified, and coded to ensure their consistency and completeness. Finally, the database was organized for statistical analysis.

Data were analyzed using descriptive and inferential statistical methods. Frequencies, percentages, means, and standard deviations were calculated to describe the study variables. The influence of internal and external factors on the liquidation process was evaluated using Spearman's rank correlation coefficient, considering the ordinal nature of the variables. All statistical analyses were performed using IBM SPSS Statistics to ensure the validity and reliability of the research findings.

Results

The results revealed that internal and external factors influenced the liquidation of Irrigation Infrastructure Maintenance Activities (AMIR) in Pisacoma and Capaso during 2023. Descriptive analysis showed that the highest agreement levels were associated with timely expenditure authorizations (90.0%), compliance with supervisory observations (90.0%), delays caused by missing signatures (100.0%), poor road accessibility (90.0%), and operational limitations during liquidation (90.0%). Conversely, climatic conditions presented the lowest level of agreement (30.0%), indicating a comparatively lower perceived influence on the liquidation process. Furthermore, the Shapiro–Wilk normality test confirmed that the variables followed a normal distribution ($p > 0.05$), supporting the application of Pearson's correlation analysis. Hypothesis testing demonstrated a

statistically significant positive relationship between internal and external factors and the liquidation of AMIR activities (r = 0.723, p = 0.018). Additionally, internal factors showed a very strong relationship with financial liquidation (r = 0.849, p = 0.002), whereas external factors presented a moderate but non-significant relationship with physical liquidation (r = 0.422, p = 0.225).

Table 2

Summary of Internal and external Factors

Variable	Main Findings	Positive Responses (%)
Internal Factors	Timely expenditure authorizations	90.0
	Adequate staff training	70.0
	Logistical resource limitations	80.0
	Delays due to disagreements	90.0
	Weaknesses in institutional supervision	60.0
	Difficulties in expenditure accountability	60.0
	Delays due to missing signatures	100.0
	Compliance with supervisory observations	90.0
External Factors	Lack of internet connectivity	70.0
	Poor road accessibility	90.0
	Climatic conditions	30.0
	Timely availability of financial resources	70.0
	Changes in the AMIR Execution Manual	80.0
	Connectivity delays during liquidation	80.0
	Timely bank account statements	100.0
	Operational limitations during liquidation	90.0

Source: Own elaboration.

The results indicate that internal factors were mainly characterized by timely administrative procedures and compliance with supervisory requirements. However, logistical limitations, coordination problems, and expenditure accountability remained the principal constraints affecting the liquidation process. Regarding external factors, respondents highlighted poor road accessibility, internet connectivity limitations, and modifications to the AMIR Execution Manual as the most influential external conditions, whereas climatic conditions showed the lowest perceived impact.

Table 3

Normality Test

Variable	Shapiro–Wilk	Sig.
Internal and External Factors	0.870	0.099
Liquidation	0.875	0.116

Source: IBM SPSS Statistics.

The Shapiro–Wilk test was performed because the sample consisted of fewer than 50 observations. The significance values obtained for both variables exceeded 0.05, confirming a normal distribution of the data and supporting the use of parametric statistical techniques.

Table 4

Hypothesis Testing

Relationship	**Pearson's**	**p-value**	**Interpretation**
Internal and External Factors – Liquidation	0.723	0.018	Significant positive relationship
Internal Factors – Financial Liquidation	0.849	0.002	Very strong significant relationship
External Factors – Physical Liquidation	0.422	0.225	Positive but not significant

Source: IBM SPSS Statistics.

The Pearson correlation analysis confirmed that internal and external factors were significantly associated with the liquidation of Irrigation Infrastructure Maintenance Activities ($r = 0.723$, $p = 0.018$). Moreover, internal factors exhibited the strongest influence on financial liquidation ($r = 0.849$, $p = 0.002$). In contrast, although external factors showed a moderate positive correlation with physical liquidation ($r = 0.422$), the relationship was not statistically significant ($p = 0.225$).

Discussion

Internal factors and the financial liquidation of AMIR

The inferential analysis revealed a very strong and statistically significant positive relationship between internal factors and the financial liquidation of Irrigation Infrastructure Maintenance Activities (AMIR) (Pearson's $r = 0.849$, $p = 0.002$). This finding indicates that improvements in financial and physical execution, the operational capacity of the professional team and the Núcleo Ejecutor, internal control, document management, and staff training are associated with more efficient, timely, and comprehensive financial liquidation processes. Consequently, the proposed hypothesis is supported, confirming that internal management factors constitute key determinants of financial liquidation performance.

These findings are consistent with those reported by Quille (2022), who identified a strong positive correlation ($r = 0.863$, $p < 0.001$) between planning, organizational management, and financial execution in projects implemented through Núcleos Ejecutores. Both studies emphasize that effective internal management contributes directly to the achievement of satisfactory financial outcomes. Likewise, the results agree with Vásquez (2022), who reported a moderate positive association ($r = 0.537$) between the efficiency of administrative and financial procedures and the quality of liquidation processes in projects executed through direct administration, highlighting the importance of strengthening internal procedures to improve institutional performance.

Furthermore, the present findings are supported by Barragán (2021), who demonstrated that effective internal process management and a sound control environment enhance the efficiency of financial liquidation. Similarly, Cabrera et al. (2023) concluded that internal control systems, continuous monitoring, and personnel training positively influence the

execution and liquidation of infrastructure projects. Overall, the consistency between the present results and previous evidence reinforces the argument that strengthening internal management capacities is essential for improving the financial liquidation of public investment activities.

External factors and the physical liquidation of AMIR

The results showed a moderate positive relationship between external factors and the physical liquidation of AMIR (Pearson's $r = 0.422$); however, this association was not statistically significant ($p = 0.225$). Therefore, the findings suggest that external conditions—including limited connectivity, geographical accessibility, adverse weather conditions, and modifications to the AMIR Operational Manual—did not significantly explain the variability observed in the physical liquidation process. Although these factors were perceived by respondents as operational constraints affecting coordination, resource mobilization, and the timely submission of technical documentation, their statistical contribution was limited within the context of this study.

This result differs from the findings of Vásquez (2022), who reported a statistically significant moderate positive relationship ($r = 0.578$, $p < 0.001$) between the efficiency of the Central Executing Committee and stakeholder participation, concluding that external institutional interactions play an important role in organizational performance. The discrepancy may be explained by differences in the study context, project characteristics, institutional arrangements, and sample composition, suggesting that the influence of external factors is highly context-dependent.

Likewise, the findings partially differ from those reported by Llano (2023), who concluded that administrative and institutional deficiencies directly affect the efficiency and transparency of financial liquidation processes in public works. Similarly, Huamani et al. (2023) highlighted that environmental, political, and legal factors significantly contribute to delays and cost deviations in public infrastructure projects. Although these studies underscore the importance of external conditions, the present research indicates that their influence on AMIR liquidation was secondary compared with that of internal management factors. This evidence suggests that strengthening internal organizational capacities may mitigate the operational challenges generated by unfavorable external conditions.

Conclusion

This study demonstrates that internal factors have a very strong and statistically significant influence on the financial liquidation of Irrigation Infrastructure Maintenance Activities (AMIR). Effective financial and physical execution, operational capacity, and control mechanisms were identified as the main determinants of timely and high-quality financial liquidation, highlighting the importance of strengthening internal management practices.

The findings also reveal that external factors were not statistically significant determinants of the physical liquidation process. Although financial conditions, technological limitations, geographical accessibility, and procedural modifications represented operational challenges, their explanatory contribution was limited compared with that of internal factors.

Overall, the results confirm that internal and external factors are positively associated with the liquidation of AMIR in Pisacoma and Capaso during 2023, with internal factors showing the greatest explanatory power. These findings contribute to the literature on public infrastructure management by providing empirical evidence that supports the improvement of financial and physical liquidation processes through stronger internal management and more effective institutional practices.

This study examined how community-led governance structures influence sustainable tourism development and community empowerment among Indigenous Andean communities around Lake Titicaca. By analyzing participatory governance, socio-economic outcomes, cultural preservation,

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Evaluación de la eficiencia de sistemas de cloración por goteo en la calidad del agua para consumo humano en comunidades rurales: Caso Choquechambi Carpani

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ABSTRACT

The absence of well maintained drinking water systems in disadvantaged rural areas continues to be a significant shortcoming, invariably leading the onset of serious waterborne gastrointestinal diseases. Decentralised drip chlorination systems represent a very feasible and sustainable technical option for ongoing water disinfection in regions without traditional treatment infrastructure. The primary aim of the applied research is to examine the drip chlorination technique and its specific impact on the potable water supply in the Choquechambi Carpani village. The adopted approach was a quasi experimental quantitative methodology comprising collection of 15 liter longitudinal water samples over 31 days at four specific monitoring points (R-0, P-1, P-2 & P-3) for free residual chlorine, temperature, pH, turbidity and thermotolerant coliforms evaluation. The system employs Jain Emitter drip technology to attain a uniform volumetric dosage. Laboratory testing has determined an optimal and hydrodynamically stable concentration of free residual chlorine in the distribution system ensuring levels above the minimum requirement of 0.5 mg/L at the endpoint. Observational data reveals a considerable decline in pathogenic microorganisms, satisfying rigorous drinking water quality criteria. The deliberate deployment of these technologies is vital for resolving ongoing water sanitation challenges and establishing sustainable socio-environmental resilience in rural developing areas.

Keywords: Drip chlorination, Water supply, Residual chlorine, Thermotolerant coliforms, Rural sanitation.

INTRODUCTION

Water that is free from contaminants is not only a fundamental human right but also an essential component of the public health of rural communities (World Health Organization, 2022). But cities in the high Andes still suffer from poor water quality in

spite of the steady increase in governmental coverage. This shortage generates a circle of stomach diseases that limit the development of the local economy in a subtle way (Galarza et al., 2021). Therefore, rehabilitation of rural supply networks is not just a technical problem, but the last obstacle to permanently eradicate diseases (Clasen, 2015). Nonetheless, specialised literature suggests that the efficacy of the systems implemented is often undermined by a variety of factors, ranging from the lack of standardised maintenance protocols, to the absence of specific technical training for local operators, who face geographic and operational challenges in high-mountain systems (Lapworth et al., 2020). Several disinfection solutions have been studied, however there is a lack of scientific knowledge about the efficiency of devices such as drip chlorination systems under different raw water quality conditions, as well as the long-term sustainability of their operation under local management (Green, 2008). Previous studies have been directed to chlorination in general, but there is an urgent need for in-depth case studies on the operational efficiency under real field conditions (Mulhern et al., 2022). In this context, the present study aims to evaluate the operational efficiency of drip chlorination systems in community of Choquechambi Carpani. Through the systematic quantification of physicochemical and microbiological parameters, this study seeks to provide empirical evidence that optimizes the management of rural water infrastructure, contributes to closing the water security gap and allows the results to serve as a reference for future interventions in similar geographic contexts.

2. General Objective

The main objective of this study is to evaluate the operational efficiency of drip chlorination systems and its impact on the quality of water for human consumption in rural communities, with a specific focus on the case of Choquechambi Carpani.

Methodology

3.1 Research Design and Study Area

The present study was a quantitative, descriptive-transversal level, quasi-experimental design. These structures allowed the empirical evaluation of the operational efficiency and impact on water quality of drip chlorination systems, given that these designs allow establishing cause-effect relationships in public health interventions (Creswell & Creswell, 2017). The study was developed in the community of Choquechambi Carpani,

Muñani District, Puno. This selection of the study site was justified by the urgent need for sustainable sanitation solutions in high-altitude Andean environments, a context characterized by specific socio-environmental vulnerabilities, as indicated in recent studies on rural water management (Araneda-Cabrera et al., 2021).

3.2 Population and Sampling

All rural water supply systems in the community of Choquechambi Carpani were considered for the study population. The sampling was non-probabilistic and by choice; 2 drip chlorination systems were selected. This sampling method is very appropriate in research where operational continuity, physical accessibility and technical feasibility are the main limitations in regular longitudinal monitoring (Valcourt et al., 2020). In addition, purposive sampling provides a greater understanding of local infrastructure performance, often overlooked in large-scale, randomized studies (Sánchez Ruiz et al., 2025). The inclusion criteria were based strictly on the system's operational continuity, accessibility by the researchers and representativeness of local consumption patterns to maintain the uniformity of the sample within the study period (January 2021), consistent with standardized frameworks for assessing decentralized water services (United Nations, 2023).

3.3 Instrumentation

Data collection The double instrument method was used according to the national regulatory standards (Decreto Supremo N.° 031-2010-SA, 2010):

- Measurement instruments: The residual chlorine was measured with Hach colorimeters and the in situ pH and temperature were measured with portable Hanna devices. A high-precision flow meter was also used to calibrate the "Jain Emitter" drippers to keep the flow rate constant (2.7778×10^{-4} L/s).
- Microbiological analysis: The quantification of the thermotolerant coliforms was made by the membrane filtration method in the Environmental Control Laboratory of DIRESA Puno, following standardized protocols to ensure the validity of the results. The instruments were checked for accuracy before being used so that all the measurements were within the expected tolerance ranges for research in environmental engineering.

3.4 Data Collection Procedure

The process was carried out in three consecutive and systematic steps:

1. Basal assessment: Initial physicochemical characterization of the sources (springs) to determine the operating conditions.
2. Longitudinal monitoring: The measurements were taken daily during a 31-day period at critical nodes of the system (R-0, P-1, P-2, P-3), taking into account variables such as free chlorine concentration, pH and turbidity.
3. Recording and control: Each measurement was recorded immediately to avoid degradation of the sample and to guarantee data consistency under local climatic conditions (temperatures between 8 °C and 12 °C).

3.5 Data Analysis

To evaluate the stability of residual chlorine with changes in flow, the data were analysed using descriptive statistics (mean, variance and standard deviation). We used specialised software (Microsoft Excel) to create comparison models of flow rates against pressure (bar) and head height (cm) to assess the performance of the system against the Maximum Permissible Limits (MPL) established by national legislation (Decreto Supremo N.° 031-2010-SA, 2010).

RESULTS

The proposed drip chlorination system showed an average residual chlorine concentration of 0.79 mg/L and 100% elimination of thermotolerant coliforms in the final network connections. The system was able to operate at a constant dosing flow rate of 2.7778 × 10-4 L/s, and it was able to comply with the Maximum Permissible Limits (MPL) during the 30 day evaluation period. The operational performance parameters are summarized in Table 1 and the quality parameters in Table 2.

Table 1. Design Parameters of the Drip Chlorination System in Choquechambi Carpani

N°	Design Parameter	Design Value
1	Raw water supply	0.868 L/s
2	Existing reservoir volume	10 m^3

3	Design period	10 years
4	Design population	254 hab.
5	Endowment	60 L/hab./day
6	Average daily flow	0.176 L/s
7	Maximum daily flow	0.228 L/s
8	Maximum hourly flow	0.352 L/s

Source: Own elaboration based on technical evaluation.

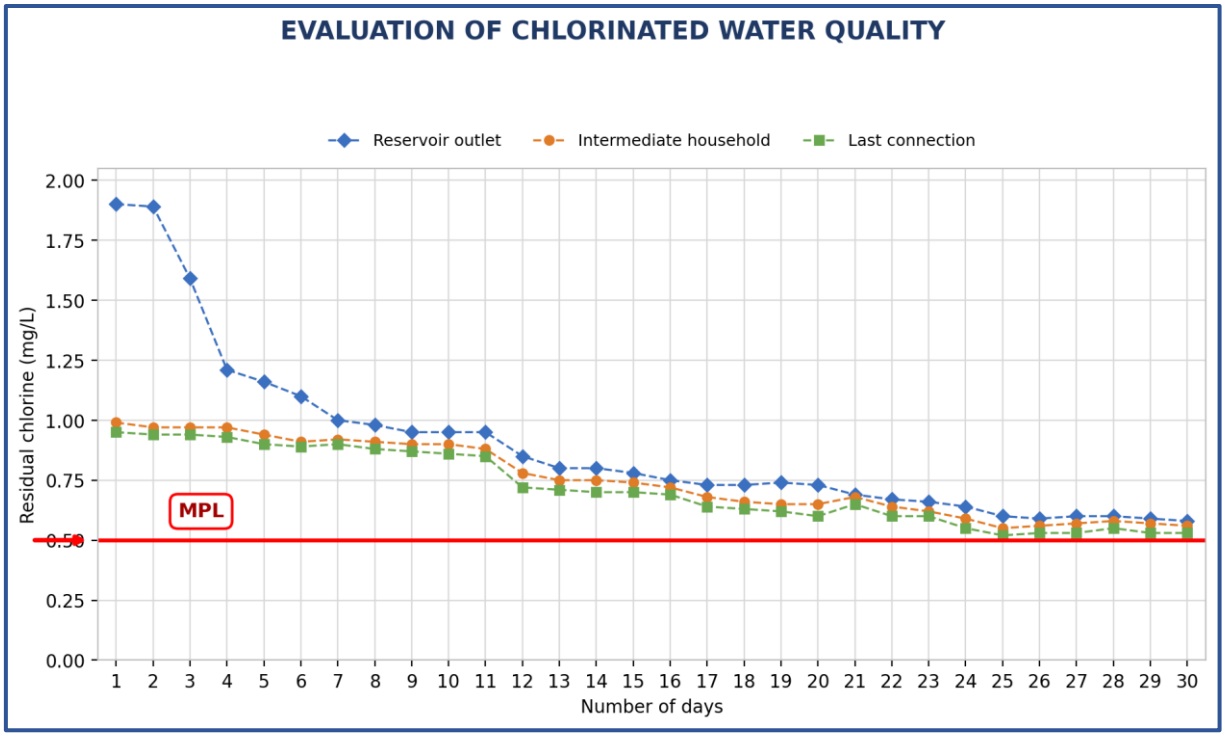
Table 2: Summary of Chlorinated Water Quality Evaluations Across Monitoring Nodes (30-Day Averages)

Monitoring Node	**Average Temperature (°C)**	**Average pH**	**Average Residual Chlorine (mg/L)**	**Thermotolerant Coliforms (CFU/100 mL)**
Reservoir Outlet (Node 1)	11.2	7.15	1.05	0
Intermediate Dwelling (Node 2)	11.1	7.08	0.76	0
Final Connection (Node 3)	11.0	7.13	0.72	0
System Minimum	8.23	6.67	0.52	0.0
System Average	11.05	7.13	0.79	0.0
System Maximum	12.90	7.49	1.89	0.0

MPL (D.S. N° 031-2010-SA)	-	6.5 to 8.5	≥ 0.50	0

Source: Own elaboration based on field monitoring data. (Note: Averages calculated from daily sampling at 8:00 a.m., 12:30 p.m., and 6:30 p.m.)

Figure 1: Evolution of Residual Chlorine Concentrations Across the Distribution Network over 30 Days



Source: Own elaboration.

The reaction with organic matter made the initial chlorine levels higher at the outlet of the reservoir (1.90 mg/L in Day 1), but the levels stabilized later. The residual chlorine at the last connection of the network was always above the 0.50 mg/L threshold during the study, confirming the constant performance of the Jain Emitter drip system.

Discussion

This study showed that drip chlorination method improves water quality significantly, because it maintains stable free residual chlorine concentrations and effectively removes thermotolerant coliforms. This shows the technological effectiveness of the system in the parameters of operation of the community of Choquechambi Carpani. These results align with other studies on focused therapeutic water treatments, demonstrating that ongoing

disinfection is effective for rural supply systems (Crider et al., 2022; Locher et al., 2024). Our findings align with studies indicating that decentralised systems enhance water safety (Cherukumilli et al., 2023; Lindmark et al., 2022). One explanation for its success is that the Jain Emitter device is well calibrated and delivers a consistent dose, even with changing flow rates (Lindmark et al., 2022). unlike previous less accurate models, which underscores the importance of the technical design for successful disinfection in high-altitude areas (Gonzales Saenz et al., 2023). The results are of great practical interest for local governments framed in national programs such as the Peruvian "Chuya Yacu" chlorination project (*CIES Perú*, 2023) and community management programs such as JASS. The system is an inexpensive and sustainable alternative for the management of rural water (CAF, 2023; Cherukumilli et al., 2023) providing a reliable means of alleviating the health risks of waterborne diseases and promoting socioenvironmental resilience. However, this study has limitations such as a small sample size and a short evaluation period (Lantagne et al., 2023). Future research should include larger longitudinal populations and longer follow up periods to determine the durability of the system's components.

CONCLUSION

This research illustrates the technical feasibility of decentralised drip chlorination systems as an exceptionally effective remedy for rural water safety, effectively managing residual chlorine within the established Maximum Permissible Limits and completely eliminating thermotolerant coliforms in the distribution network. These findings suggest that, when well calibrated and consistently maintained, drip chlorination may serve as a financially viable and sustainable substitute for traditional treatment, significantly mitigating the health hazards associated with waterborne illnesses. Moreover, this study offers empirical data to support the use of basic disinfection technologies in high-altitude Andean environments, aiding in the enhancement of socio-environmental resilience and addressing the water security deficit for rural populations.

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EFFECT OF MICROSILICA ON THE PHYSICAL AND MECHANICAL PROPERTIES OF FLEXIBLE PAVEMENT IN THE PUNO REGION

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ABSTRACT

In Peru, flexible pavements are frequently deteriorated by extreme climates, leading to rutting, fatigue cracks, and low durability, which result in high maintenance and transportation costs. This study aims to determine how the incorporation of microsilica into asphalt improves the quality of hot-mix asphalt in terms of its physical and mechanical properties, evaluating its effect on strength and Marshall parameters. The research has a quasi-experimental design, explanatory level, and applies a quantitative method to evaluate the performance of modified asphalt mixtures. The results revealed that the addition of 3.6% microsilica provides a 35.13% improvement in simple compression and a 34.63% increase in indirect traction compared to conventional designs, while stability parameters showed a 19.91% improvement. Therefore, we can conclude that the load-carrying capacity of hot-mix asphalt was improved through the use of microsilica. Furthermore, durability, resistance to rutting and premature cracking, and asphalt-aggregate interaction were enhanced. Therefore, microsilica can be considered an effective additive that improves pavement performance.

Keywords: Asphalt Mixture, Microsilica, Flexible Pavement, Physical-Mechanical Properties.

INTRODUCTION

The design and construction of flexible pavements are conceived as fundamental processes that facilitate the structural integrity and durability of road infrastructure (Kraemer et al., 2004). In the context of civil engineering, this discipline allows institutions to identify material strengths and weaknesses to promote continuous infrastructural improvement (Garnica Anguas et al., 2005). It is a highly technical and

scientific process aimed at the qualitative transformation of transportation networks (Papagiannakis & Masad, 2017). Furthermore, it is an iterative and interactive exercise that requires the active participation of rigorous material design methodologies and volumetric analysis (Rondón Quintana & Reyes Lizcano, 2015).

For its effective implementation, it is crucial to define elements such as the structural capacity, which describes the desired long-term state of the asphalt life cycle (Instituto del Asfalto, 2014). Complementarily, the mixture design must be reviewed periodically under standardized testing parameters to reflect durability goals (American Society for Testing and Materials, 2015). An analysis of the operational environment is essential to understand the external factors and loads that impact the pavement management (American Association of State Highway and Transportation Officials, 2012). To this end, technical specifications remain a vital strategic tool for infrastructural diagnosis and execution at the national level (Ministerio de Transportes y Comunicaciones, 2013).

The pavement performance encompasses critical challenges under extreme environmental conditions, essential to address in most modern design models (Airey et al., 2018). In high-altitude regions, strategic material selection implies designing mixtures capable of resisting severe thermal gradients and evaluating the contribution of these materials against drastic climatic variations (Gómez & Sánchez, 2022). These continuous environmental stressors severely accelerate the susceptibility to moisture damage and premature stripping (Álvarez et al., 2011). At the regional level, extreme geographical conditions drastically accelerate the fatigue cracking and deterioration of the asphalt binder (Ossa et al., 2016).

On the other hand, mechanical quality in pavement design is not limited to conventional mixtures but is based on the objective evaluation of modified materials(Reyes Ortiz et al., 2006). It is understood as the application of specialized mineral fillers to satisfy the structural needs demanded by heavy traffic loads (Pérez & Pasandín, 2016). Among its pillars are the improvement of rheological properties and the optimization of the asphalt matrix specifically in the Andean region (Flores & Quispe, 2021).

The implementation of specific additives like microsilica provides a framework to improve both the compressive strength and the modulus of rupture in asphalt mixtures (Carrasco Canales, 2019). Within this approach, the addition of silica fume seeks to implement actions to retain the viscoelastic properties of the mixture under cold climates (Martínez & Silva, 2020). The optimization of viscoelasticity is another key element, promoting better internal cohesion to achieve positive structural results (Xuedong et al., 2019). In addition, this component allows for maintaining operational excellence in the long term through an enhanced and denser structural matrix (Taherkhani & Afroozi, 2020).

Despite these global and national advancements, there is limited literature addressing the specific application and behavior of microsilica under the unique granular and extreme high-mountain conditions of the Puno region (Ccari Chuquitarqui, 2025).

The present study determines the effect of strategic microsilica dosage on the physical and mechanical quality of hot mix asphalt in the National University of the Altiplano of Puno context. The work addresses the problem of premature pavement deterioration and analyzes how the phases of mixture formulation, execution, and evaluation are linked to the structural performance required by current standards. The research is justified by the need to generate empirical evidence that guides decision-making and strengthens road infrastructure in a high-altitude context, overcoming the existing gaps between conventional normative planning and the extreme climatic demands of the Altiplano.

The general objective of the study was to determine the effect of incorporating microsilica on the physical and mechanical properties of hot mix asphalt in the Puno region. Specifically, it sought to establish the relationship between varying substitution percentages (0%, 2%, 3%, 4%, 5%, and 7.5%) and critical parameters such as Marshall stability; furthermore, it aimed to analyze the variation in compressive strength and indirect tensile strength to establish the optimal additive dosage for high-altitude pavements.

METHODS

This research study employed a quantitative, quasi-experimental design to rigorously evaluate the causal impact of microsilica addition on the physical and

mechanical properties of flexible pavement. This methodological approach was selected to facilitate a controlled investigation of how varying concentrations of the additive alter the performance of asphalt mixtures, ensuring that the results are reproducible under laboratory conditions.

The population for this study consisted of the total performance records derived from hot mix asphalt (HMA) specimens produced during the experimental phase. A total sample of 120 specimens was selected through non-probabilistic convenience sampling, representing six specific microsilica dosage levels (0%, 2%, 3%, 4%, 5%, and 7.5%). This sample size was determined to ensure statistical representativeness and to validate the performance improvements under the high-altitude and extreme-temperature environmental conditions characteristic of the Puno region.

Data were acquired using standardized testing equipment, specifically the Marshall stability apparatus and universal testing machines. All testing protocols were conducted in strict accordance with the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) standards. These instruments were utilized to perform critical mechanical evaluations including Marshall stability, simple compressive strength, and indirect tensile strength tests thereby providing the precise quantitative data necessary to assess the resilience of the modified asphalt mixture.

First, the raw materials and asphalt binder were characterized, and HMA specimens were fabricated with varying microsilica dosages (0% to 7.5%). The samples were compacted under strict temperature and pressure controls to ensure consistency in air void density, as specified by ASTM and AASHTO protocols. Then, the prepared specimens were subjected to standardized laboratory evaluations, including Marshall stability, compressive strength, and indirect tensile strength tests, to measure the mechanical response and verify their ability to withstand the extreme conditions of the study area.

Finally, the collected performance data were subjected to a comparative statistical analysis to determine the significance of the variations in mechanical properties. Data normality was first verified using the Shapiro-Wilk test ($\alpha = 0.05$), ensuring the validity of subsequent parametric testing. Based on these findings, the Pearson correlation

coefficient was applied to evaluate the relationship between microsilica concentration and the mechanical response of the mixtures. This analytical approach, executed using IBM SPSS software, allowed for the identification of the optimal additive dosage that maximizes pavement resilience under the high-altitude and extreme-temperature environmental stressors of the Puno region.

RESULTS AND DISCUSSION

RESULTS

The modified asphalt mixture achieved a significant improvement in mechanical performance with the incorporation of microsilica. Experimental results show that the optimal dosage of 3.6% resulted in a 19.91% increase in Marshall stability compared to the conventional control mixture. Furthermore, compressive strength increased by 35.13%, while indirect tensile strength showed an improvement of 34.63%.

Influence on Volumetric and Marshall Parameters:

Table 6

Marshall Design Comparison of Conventional Asphalt Mixture (CAM) and Modified Asphalt Mixture (MAM)

Marshall Design Parameters	***CAM***	***MAM***
Optimal asphalt %	6.7	6.7
Optimal microsilica %	-	3.6
Specific Weight (gr/cm3)	2.255	2.261
Stability (kg)	1140	1367
Flow (0.25mm)	3.70	3.65
% air voids	3.250	4.150
% VMA	19.150	14.561
% VFA	83.00	71.64

The incorporation of 3.60% microsilica generated significant structural modifications compared to the conventional control sample:

Volumetric Parameters: The percentage of air voids (Va) experienced an increase of 27.69% (going from 3.25% to 4.15%). Simultaneously, the voids in the mineral aggregate (VMA) were reduced from 19.15% to 14.56%, and the voids filled with asphalt (VFA) dropped from 83.00% to 71.64%.

Stability and Flow: The load-bearing capacity against deformation (Stability) increased significantly, going from 1140 kg in the conventional mixture to 1367 kg in the modified mixture. Flow registered a slight reduction of 1.35%, optimizing viscoelastic behavior under heavy loads.

Mechanical Performance Evaluation:

Table 7

Simple Compressive and Indirect Tensile Strength Test Results

DESCRIPTION	Simple Compressive Strength	Indirect Tensile Strength
Conventional asphalt mixture (kg/cm2)	24.20	16.89
Modified asphalt mixture (kg/cm2)	32.70	22.74
IMPROVEMENT (kg/cm2)	(+) 8.50	(+) 5.85
IMPROVEMENT (%)	**35.13**	**34.63**

Mechanical Strengths: The simple compressive strength went from 24.20 kg/cm² to 32.70 kg/cm². In a saturated state, indirect tensile strength reached 22.74 kg/cm² compared to the initial 16.89 kg/cm², indicating better resistance to fatigue cracking.

Validation and Statistical Analysis:

Data normality was confirmed using the Shapiro-Wilk test (p-value > 0.05), which justified the use of the Pearson correlation coefficient ($\alpha = 0.05$) executed in IBM SPSS. The analysis demonstrated that the microsilica percentage directly and significantly influences the mixture's performance, rejecting the null hypothesis (p-value = 0.001 < 0.05). The correlations obtained showed high intensity across all evaluated mechanical

variables: simple compressive strength (r = 0.983), indirect tensile strength (r = 0.992), and Marshall stability (r = 0.921). Concurrently, flow presented an inversely proportional correlation (r = -0.911), statistically validating the structural improvement of the flexible pavement.

DISCUSSION

The findings of this study suggest that the incorporation of microsilica significantly enhances the mechanical properties of the asphalt matrix. The observed improvement in Marshall stability, compressive strength, and indirect tensile strength indicates that the additive effectively fills the voids within the granular structure, creating a more dense and cohesive asphalt mixture. This optimization is crucial for mitigating the structural stresses characteristic of the Puno region.

These findings are consistent with previous studies by (Taherkhani & Afroozi, 2020; Xuedong et al., 2019), who reported that mineral additives like microsilica improve the rheological behavior of asphalt mixtures. However, in contrast to earlier research conducted in temperate climates, our study demonstrates that the optimal dosage of 3.6% provides specific resistance against the severe thermal fluctuations and moisture damage reported in high-altitude regions (Ossa et al., 2016).

These findings have important implications for road infrastructure policy in high-altitude regions. By adopting the optimal microsilica dosage of 3.6%, road authorities could significantly extend the service life of flexible pavements, thereby reducing the high maintenance costs typically associated with premature failure in cold and variable climates (Airey et al., 2018). Furthermore, this approach provides a technically viable and cost-effective alternative for constructing more resilient infrastructure in critical geographical contexts.

Despite these findings, this study has several limitations. First, the evaluation was restricted to laboratory conditions, which may not fully replicate the long-term impact of heavy traffic combined with prolonged snow and ice exposure. Additionally, the study was limited to specific granular materials characteristic of the Puno area; therefore, the results should be carefully extrapolated to regions with different mineralogical compositions. Future research should include field testing to validate the durability of these modified mixtures under real-world service conditions.

CONCLUSIONS

Based on the comprehensive experimental evaluation conducted in this study, the incorporation of microsilica as a partial fine aggregate replacement successfully optimizes the physical and mechanical performance of flexible pavements in high-altitude environments. The research demonstrates that modifying hot mix asphalt (HMA) with this mineral additive directly mitigates the severe structural vulnerabilities typically caused by extreme thermal fluctuations and heavy traffic loads characteristic of the Altiplano region.

Through rigorous laboratory testing adhering to ASTM and AASHTO standards, the study established that an optimal microsilica dosage of 3.6% maximizes critical performance indicators. This specific formulation delivered a 19.91% increase in Marshall stability compared to the conventional control mixture, which represents a significantly enhanced load-bearing capacity and superior resistance against permanent deformation or rutting under severe traffic stress.

Regarding structural and internal stress tolerance, the modified HMA matrix exhibited a 35.13% increase in simple compressive strength alongside a 34.63% improvement in indirect tensile strength. These mechanical enhancements confirm the mixture's advanced ability to withstand fatigue cracking and structural failure under moisture-saturated conditions and continuous freeze-thaw cycles.

From a volumetric perspective, the 3.6% substitution generated crucial internal modifications, including a reduction in voids in the mineral aggregate (VMA) to 14.56% and voids filled with asphalt (VFA) to 71.64%. These results prove that microsilica effectively functions as a micro-filler, optimizing the internal architecture of the binder-aggregate interface to create a denser, more cohesive, and impermeable asphalt matrix.

Ultimately, this research provides a technically viable, cost-effective, and sustainable engineering solution for regional infrastructure. Implementing this modified mixture can substantially extend pavement service life and reduce recurrent maintenance frequencies; however, future research should focus on evaluating long-term field performance under real-time dynamic loads and conducting a comprehensive Life-Cycle Cost Analysis.

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RELATIONSHIP BETWEEN URBAN EXPANSION AND POPULATION GROWTH THROUGH MULTITEMPORAL ANALYSIS IN THE CITY OF ILAVE, 1993–2022

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Abstract

The accelerated urban growth experienced by cities in Peru has generated significant territorial transformations, often without adequate planning by municipal authorities, making it necessary to understand the factors that drive urban expansion for effective territorial management. Accordingly, this research aimed to analyze the relationship between urban expansion and population growth in the city of Ilave during the period 1993–2022. The Corine Land Cover (CLC) methodology adapted for Peru was applied, considering six land cover classes, using Landsat 5 TM and Landsat 8 OLI satellite imagery processed within a Geographic Information System (GIS) environment; the reliability of the classification was validated through the Kappa coefficient, and population data were obtained from official INEI census sources. The results showed that the urban area increased from 104.120 ha in 1993 to 524.069 ha in 2022, while the population increased by 9,362 inhabitants over the same period. The classification achieved an "almost perfect" level of agreement, with Kappa coefficients ranging from 0.876 to 0.967, and Spearman's correlation coefficient revealed a linear, positive, and perfect relationship between both variables ($r_s = 1.000$; $p < 0.01$). These findings confirm that population growth has been one of the main factors explaining Ilave's urban expansion, and highlight the need to strengthen territorial planning instruments to guide this growth toward a more orderly and sustainable model.

Keywords: Urban expansion, Population growth, Multitemporal analysis, Geographic Information Systems (GIS), Remote sensing, Land use change, Ilave.

1. Introduction

Urban expansion constitutes one of the most significant territorial processes associated with population growth and urban development. In recent decades, increasing

population demand has intensified the need for land for housing, infrastructure, and public services, generating substantial changes in land use and land cover. In this context, remote sensing technologies and Geographic Information Systems (GIS) have become valuable tools for analyzing urban growth through multitemporal studies, providing essential information for understanding spatial development patterns and supporting territorial planning. Numerous studies have shown that urban expansion can significantly transform the physical structure of cities and alter land occupation dynamics.

The city of Ilave, located in the province of El Collao, region of Puno, in southern Peru, has experienced sustained population growth accompanied by a progressive expansion of its urban area. This process has generated significant changes in land use distribution and has posed new challenges for urban management and planning. Although satellite imagery has proven effective for assessing land cover changes and urban growth patterns, limited empirical evidence exists regarding the relationship between urban expansion and population growth in Ilave based on long-term multitemporal analyses. This limitation restricts a comprehensive understanding of the city's territorial dynamics and reduces the availability of information needed to support evidence-based urban planning and decision-making.

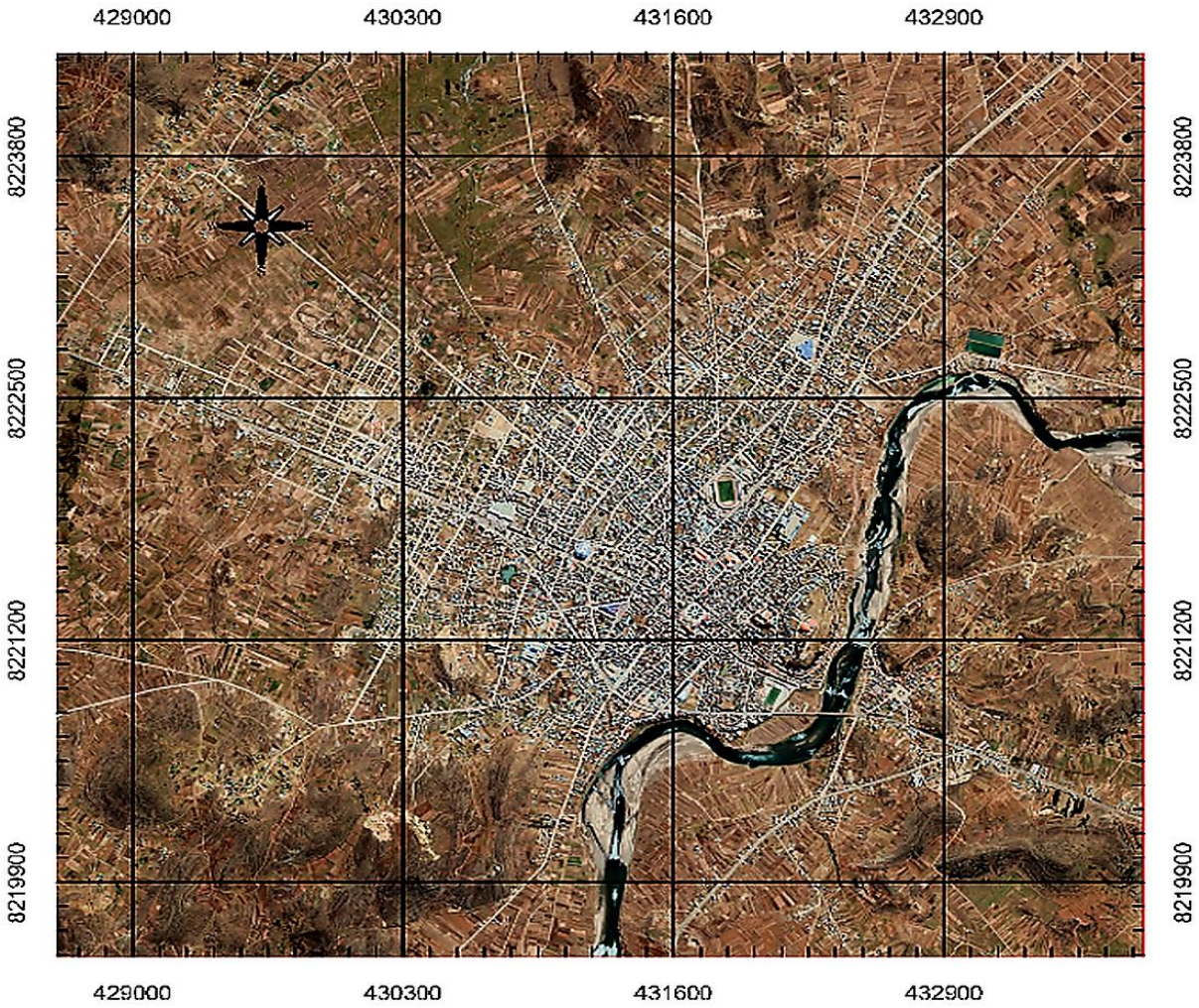
To address this gap, the present study analyzes the relationship between urban expansion and population growth in the city of Ilave during the period 1993–2022, using multitemporal analysis techniques based on satellite imagery and GIS tools. It also evaluates changes in urban area and examines their association with the demographic trends observed throughout the study period. By providing empirical evidence on Ilave's growth dynamics, this research contributes to a better understanding of urban development processes and supports planning and territorial management strategies aimed at promoting sustainable urban development.

2. Methods

2.1. Study Area

The study was conducted in the city of Ilave, located in the province of El Collao, region of Puno, in southern Peru. The city is situated on the Collao plateau, at an approximate altitude of 3,850 m a.s.l. The analysis covered the period 1993–2022, considering the urban area and its surrounding zones. Given the territorial changes observed in recent decades, Ilave constitutes an appropriate case study for evaluating urban expansion through remote sensing and multitemporal analysis techniques.

Figure 1. Geographic location of the study area.



Note. Own elaboration.

2.2. Data Sources and Study Period

Multispectral Landsat 5 TM and Landsat 8 OLI satellite images, acquired between 1993 and 2022, were obtained through the United States Geological Survey (USGS). For the multitemporal analysis, six representative years within the study period were selected (1993, 1998, 2004, 2010, 2016, and 2022), with approximately six-year intervals between each date, which allowed the urban growth dynamics to be captured while keeping the number of observations manageable for analysis and presentation of results. Population data were obtained from national censuses and official demographic projections of Peru's National Institute of Statistics and Informatics (INEI), in order to assess population growth.

Table 1 Datasets used in the study

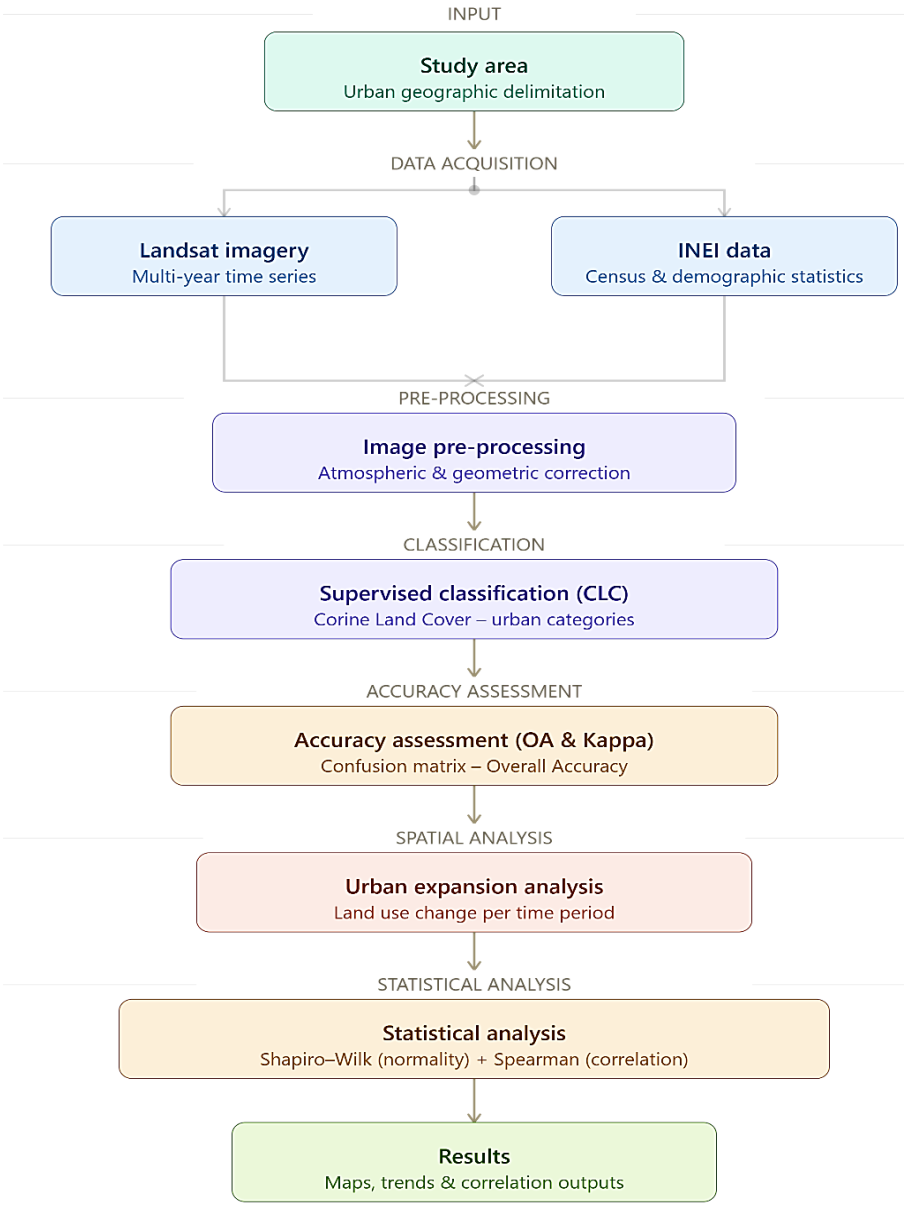
Dataset	Source	Spatial resolution	Purpose
Landsat 5 TM	USGS	30 m	Urban land cover classification
Landsat 8 OLI	USGS	30 m	Urban land cover classification
Population census	INEI	—	Population growth analysis

Note. Own elaboration.

2.3. Image Processing and Urban Land Cover Classification

Satellite images were geometrically corrected and processed using QGIS software. Land cover classification was performed through a supervised classification approach based on the Corine Land Cover (CLC) methodology, adapted for Peru, considering six land cover classes. The reliability of the classification was assessed through confusion matrices, Overall Accuracy (OA), and the Kappa coefficient.

Figure 2. Methodological workflow of the multitemporal urban expansion analysis.



Note. Own elaboration.

2.4. Statistical Analysis

Urban expansion was quantified by comparing the classified urban areas for each study year, expressed in hectares (ha) and as a percentage of change relative to the base year (1993). The original study individually classified and analyzed all thirty years between 1993 and 2022 (n = 30), for both urban area and population, which allowed a continuous and robust time series to be built for the trend analysis. The normality of both variables was assessed using the Shapiro-Wilk test. Since the variables did not meet the normality assumption, the relationship between urban expansion and population growth was determined using Spearman's rank correlation coefficient. Statistical analyses were

performed using IBM SPSS Statistics 25.0 software, adopting a significance level of α = 0.05. For presentation purposes in this article, results are summarized in tables showing six representative years of the period (1993, 1998, 2004, 2010, 2016, and 2022), although the statistical tests reported reflect the complete 30-year analysis.

3. Results

3.1. Urban Expansion of Ilave Based on the CLC Classification (1993–2022)

The supervised classification revealed that Ilave's urban area increased from 104.120 ha in 1993 to 524.069 ha in 2022, representing a total increase of 419.949 ha over the study period, with an average annual growth rate of 14.481 ha/year (Table 2).

Table 2 Urban growth of the city of Ilave, 1993–2022

Year	Urban area (ha)	Growth (ha)	Growth rate (%)
1993	104.120	—	—
1998	148.581	44.461	7.37
2004	249.305	100.724	9.01
2010	371.432	122.127	6.87
2016	443.610	72.178	3.00
2022	524.069	80.459	2.82

Note. Annual intercensal geometric growth rate between consecutive years.

3.2. Statistical Validation of the Classification — Kappa Index (1993–2022)

Validation through the confusion matrix and the Kappa index confirmed that the CLC methodology is suitable for assessing urban expansion in Ilave (Table 3).

Table 3 Overall accuracy and Kappa index of the supervised CLC classification, 1993–2022

Year	Overall accuracy (%)	Kappa index	Classification
1993	90.606	0.887	Almost perfect
1998	93.333	0.920	Almost perfect
2004	94.848	0.938	Almost perfect
2010	94.848	0.938	Almost perfect
2016	94.545	0.935	Almost perfect
2022	95.152	0.942	Almost perfect

Note. Full study range: Kappa 0.876–0.967; overall accuracy 89.697 %–97.273 % (Landis & Koch, 1977).

3.3. Population Growth in the City of Ilave (1993–2022)

Ilave's population increased from 14,253 inhabitants in 1993 to 23,615 inhabitants in 2022, according to INEI census data and intercensal geometric projections (Table 4).

Table 4 Urban expansion and population growth in the city of Ilave, 1993–2022

Year	Urban expansion (ha)	Population (inhab.)
1993	104.120	14,253
1998	148.581	15,804
2004	249.305	17,891
2010	371.432	22,438
2016	443.610	23,019
2022	524.069	23,615

Note. Annual averages 1993–2022: 14.481 ha/year and 323 inhab./year.

3.4. Relationship Between Urban Expansion and Population Growth

3.4.1. Shapiro-Wilk Normality Test

The Shapiro-Wilk test indicated that the data did not present a normal distribution ($p < 0.05$); therefore, Spearman's rank correlation was applied (Table 5).

Table 5 Shapiro-Wilk normality test for the study variables

Variable	W statistic	df	p	Distribution
Urban expansion (ha)	0.926	30	0.038	Not normal ($p < 0.05$)
Population growth (inhab.)	0.825	30	< 0.001	Not normal ($p < 0.05$)

Note. Test applied to the 30 classified years (1993–2022); Tables 2 and 4 show only six representative years.

3.4.2. Spearman's Correlation Coefficient

Spearman's correlation revealed a positive, perfect, and statistically significant relationship between urban expansion and population growth ($rs = 1.000$; $p < 0.01$) (Table 6).

Table 6 Spearman's correlation coefficient between urban expansion and population growth

Correlation	Variables	rs	p	n
Spearman's rho	Urban expansion (ha) ↔ Population growth (inhab.)	1.000**	< 0.001	30

Note. ** $p < 0.01$. The correlation is perfect and statistically significant.

4. Discussion

A sustained increase in Ilave's urban area was observed between 1993 and 2022, accompanied by a positive and perfect correlation with population growth. These findings suggest that demographic growth has been one of the main drivers of the city's spatial transformation, favoring the progressive occupation of new urban areas.

Likewise, the high classification accuracy obtained demonstrates the reliability of Landsat imagery and the Corine Land Cover (CLC) methodology for assessing land cover changes through multitemporal analysis.

These findings are consistent with those reported by Canelón et al. (2018), who found an urban growth of 738.12 ha and a population increase of 55,638 inhabitants in the city of Arauca (Colombia) between 1988 and 2018, confirming that demographic demand is a central driver of urban expansion. Similarly, Suárez (2020) documented an increase of 671.796 ha of urban land in the municipality of Chía between 1991 and 2018, together with a sustained rise in population density from 192 to 339 inhab/km², reinforcing the direct association between both variables observed in Ilave. For their part, Rana and Sarkar (2021) used Cellular Automata Markov models in Pabna (Bangladesh) and obtained a Kappa index of 0.83, a figure lower than the one achieved in the present study (0.876–0.967), suggesting that the CLC methodology adapted for Peru offers a comparatively higher level of accuracy. Likewise, Shabrina et al. (2023) found correlation coefficients between urbanization and population of 0.38 and 0.77 for 2016 and 2021, respectively, in South Jakarta, values considerably lower than the rs = 1.000 obtained in Ilave, which could be explained by the shorter time scale and the use of Pearson's coefficient instead of Spearman's.

Likewise, Vergara (2018) validated their land cover classification in Pucará (Cajamarca) with Kappa indices of 0.93 and 0.95 and an overall accuracy of 95.72 % and 96.55 % for the years 2000 and 2017, results consistent with the “almost perfect” level of agreement obtained in the present study. Similarly, Huaman (2022) applied the CLC methodology in Lurigancho (Lima) and reported Kappa indices of 0.9644, 0.9450, 0.9749, and 0.9702 with an overall accuracy above 95 %, confirming the reliability of this methodological approach in different urban contexts across the country. For their part, Chihuan et al. (2023) found a statistically significant relationship between urban expansion and demographic and climatic variables in Huancayo through Spearman's test, showing that the direction of the relationship depends on the variables being compared. Likewise, Huaraca and Socorro (2023) determined a Spearman correlation of 0.716 between the absence of vegetation and urban growth in the Loma Manchay, a positive figure that is

considerably lower than the perfect value found in Ilave, which highlights the particularly strong magnitude of the relationship identified in the present research.

The findings of Carrillo and Choquehuanca (2019) in the city of Puno are particularly relevant: using Kendall's and Spearman's coefficients, they obtained a perfect positive correlation of 1 between urban expansion and population growth, identical to that recorded in Ilave, suggesting a consistent regional pattern among the intermediate cities of the Puno altiplano. Likewise, Anahua (2020) modeled Puno's urban growth using cellular automata and projected an increase of 1,436 ha by 2065, identifying terrain slope and road accessibility as determining factors of expansion, variables that could be incorporated into future studies of Ilave. For their part, Castillo (2022) documented an increase of 1,011 inhabitants and 164 dwellings between 2007 and 2020 in the town of Buena Vista (Puno), associated with a severe environmental impact on land use, which reinforces the need for territorial planning that anticipates the environmental effects of the urban growth identified in the present study.

These findings highlight the need to strengthen urban planning strategies in Ilave to promote sustainable territorial development and reduce the impacts of unplanned urban growth. However, the spatial resolution of Landsat imagery (30 m) limits the detection of small-scale urban changes. It should also be noted that the perfect correlation coefficient (rs = 1.000) may be influenced by the monotonically increasing trend of both variables throughout the analyzed period, so future studies could explore regression models that allow the magnitude of this relationship to be quantified more precisely. Therefore, it is recommended that future research incorporate higher-resolution satellite imagery and predictive urban growth models to improve the assessment of urban expansion dynamics.

5. Conclusions

Ilave's urban area increased from 104.120 ha in 1993 to 524.069 ha in 2022, representing a cumulative growth of 419.949 ha and an average rate of 14.481 ha/year, evidencing a sustained process of urban expansion throughout the study period. The Corine Land Cover (CLC) methodology, applied to Landsat 5 TM and Landsat 8 OLI imagery, achieved an “almost perfect” level of accuracy, with Kappa indices ranging from 0.876 to 0.967

and an overall accuracy between 89.697 % and 97.273 % across the full period analyzed, confirming its suitability for multitemporal urban land cover analysis in contexts similar to Ilave.

A positive, perfect, and statistically significant relationship was identified between urban expansion and population growth ($r_s = 1.000$; $p < 0.01$), confirming demographic growth as one of the main factors explaining the city's spatial transformation. This result is consistent with that found by Carrillo and Choquehuanca (2019) in the city of Puno, suggesting a shared regional pattern among the intermediate cities of the Puno altiplano.

Taken together, the results highlight the need to strengthen territorial planning instruments in Ilave, in order to guide urban growth toward a more orderly and sustainable model and to anticipate the future demand for land, infrastructure, and services arising from population growth. It is recommended that future research incorporate higher-resolution satellite imagery, longer time series, and predictive urban growth models, with the aim of deepening the understanding of the territorial dynamics of Ilave and other intermediate cities of the Peruvian altiplano.

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RELATIONSHIP BETWEEN STRATEGIC PLANNING AND THE QUALITY OF EDUCATIONAL MANAGEMENT AT THE NATIONAL UNIVERSITY OF THE ALTIPLANO, PUNO (2023–2024)

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ABSTRACT

Public health expenditure is a key factor in promoting social welfare and strengthening health systems, particularly in countries with fiscal constraints such as Peru, where persistent regional disparities in health outcomes and access to services remain despite increased public investment. This study aims to evaluate the efficiency of public health expenditure and analyze its contribution to improving access and equity in health services in Peru. A systematic review of scientific literature and empirical evidence from studies employing Data Envelopment Analysis (DEA) was conducted to assess the efficiency of resource allocation and utilization in the Peruvian health sector. The findings revealed significant regional differences in budget execution, health service coverage, vaccination rates, continuity of care for chronic diseases, household health expenditures, and access to medical services, indicating that increased spending has not consistently translated into equitable health outcomes. Furthermore, management quality, availability of human resources, institutional transparency, accountability, and information systems were identified as key determinants of efficiency. These results suggest that strengthening public management capacities, improving resource allocation mechanisms, and promoting transparency and accountability could contribute to enhancing the efficiency, equity, and sustainability of Peru's health system.

Keywords:

Public health expenditure; health system efficiency; budget execution; healthcare access; health equity; Data Envelopment Analysis (DEA).

INTRODUCTION

In Peru, public health expenditure has shown sustained increases over the past decade, reflecting a broader policy commitment to strengthening the health system and expanding access to services across the national territory. This upward trend has been accompanied by growing decentralization of budgetary execution, with regional and local governments assuming greater responsibility for allocating and managing health resources. Despite this expansion in spending, regional gaps in fundamental health indicators—such as childhood anemia, chronic malnutrition, vaccination coverage, prenatal care, and access to basic health services—remain pronounced. Some regions continue to report indicator levels well below the national average, even after years of increased budgetary allocations. This persistence suggests that the increase in resources, by itself, has not been sufficient to guarantee uniform improvements in the population's health conditions, nor to ensure an efficient use of the funds assigned to the sector.

During the 2012–2023 period, Peru's regions displayed markedly heterogeneous behavior, both in their levels of health spending and in the health outcomes achieved. In some regions, higher spending was accompanied by significant and sustained progress in key indicators, suggesting effective translation of budgetary resources into tangible improvements in population health. In other regions, however, larger budgetary allocations did not produce equivalent gains, pointing to inefficiencies in resource management, weaknesses in institutional capacity, or structural barriers unrelated to the volume of spending itself—such as geographic dispersion, workforce shortages, or limited administrative execution capacity. These contrasting patterns highlight the need to examine not only how much is invested in health at the regional level, but also how these resources are used, how efficiently they are converted into health outcomes, and what factors explain the observed disparities between regions with similar spending levels but divergent results.

Analyzing the efficiency and impact of public health spending is particularly relevant in a context where public resources remain limited relative to the country's health needs, and where demand for quality health services continues to grow alongside demographic and epidemiological changes. Understanding whether—and how—additional spending translates into measurable improvements in health outcomes is essential not only from an academic standpoint, but also for the design of fiscally responsible and equity-oriented health policy. In this regard, generating solid, regionally disaggregated evidence that can

guide policy decisions toward more effective and equitable interventions is indispensable for reducing persistent health gaps and strengthening the overall performance of the health system, particularly in a decentralized institutional setting where subnational governments play an increasingly central role in resource execution.

With this purpose, the present study analyzed the efficiency, evolution, and impact of public health expenditure on various health indicators across the regions of Peru during the 2012–2023 period. The analysis combines two complementary perspectives: first, an assessment of how efficiently regional governments have converted health spending into health outcomes over time; and second, an examination of the extent to which changes in spending levels are associated with changes in specific sanitary indicators. For this purpose, administrative data from the Ministry of Economy and Finance (MEF) and survey data from the Demographic and Family Health Survey (ENDES, INEI) were combined, applying descriptive analyses, panel data econometric models, and output-oriented Data Envelopment Analysis (DEA) techniques. This combined approach allows the study to capture both the relative efficiency of regional health spending and its estimated impact on outcomes, offering a more complete picture than either method could provide on its own. The findings aim to provide empirical evidence to guide policy decisions toward a more efficient and equitable allocation of health sector resources, and to identify which regions may benefit from strengthened technical or institutional support in translating budgetary resources into improved health outcomes.

The study is structured into four chapters. Chapter I presents the theoretical framework and background related to public health expenditure and health indicators, reviewing relevant conceptual approaches and prior empirical findings both in Peru and in comparable contexts. Chapter II develops the problem statement, the general and specific objectives, and the hypotheses that guide the study. Chapter III describes the methodology used, covering the data sources, the study design, the panel data econometric models applied, and the output-oriented DEA approach, including the selection of inputs and outputs used in the efficiency analysis. Finally, Chapter IV presents the results obtained, their discussion in light of the existing literature, and the study's conclusions, followed by policy recommendations, the bibliography, and the corresponding annexes.

METHODS

The study employed a quantitative research method, with a non-experimental, longitudinal panel design. This approach allowed for the analysis of the evolution of public health expenditure, its relationship with health indicators, and efficiency levels across Peru's regions during the 2012–2023 period. The research had a descriptive scope, to examine trends in spending and health indicators; an explanatory scope, to determine the influence of public spending on health outcomes through econometric models; and an evaluative scope, applying non-parametric techniques aimed at measuring the relative efficiency of public resource use.

The methodology was based on secondary data from the Ministry of Economy and Finance (MEF – Consulta Amigable) and microdata from the National Institute of Statistics and Informatics' Demographic and Family Health Survey (ENDES, INEI), which provided annual, comparable information for all regions of the country.

Research Design

This study adopted a quantitative, non-experimental, longitudinal panel design to examine the relationship between public health expenditure and regional health outcomes in Peru during the 2012–2023 period. The research followed a descriptive, explanatory, and evaluative approach. The descriptive component analyzed temporal trends in public health expenditure and health indicators across regions. The explanatory component assessed the effect of public health expenditure on health outcomes using panel data econometric models, whereas the evaluative component measured the relative efficiency of regional public health expenditure through Data Envelopment Analysis (DEA). The study was based exclusively on secondary data obtained from official governmental databases.

Population and Sample

The study was conducted at the national level, considering the regional governments of Peru as the units of analysis. Although Peru comprises 25 administrative regions, the Constitutional Province of Callao was excluded because of its particular administrative status and the limited availability of homogeneous and comparable information throughout the study period.

Consequently, the study population consisted of 24 Peruvian regions, and the sample was identical to the population because a census design was adopted. Each region was considered a Decision-Making Unit (DMU) for the efficiency analysis. Annual observations covering the period 2012–2023 generated a balanced regional panel dataset, allowing both longitudinal econometric analysis and efficiency measurement.

Instruments

Data were collected from official secondary databases. Information on regional public health expenditure was obtained from the Consulta Amigable platform of the Peruvian Ministry of Economy and Finance (MEF), including annual expenditures on personnel and social obligations (lgs_per), goods and services (lgs_bs), and acquisition of non-financial assets (lgs_adq).

Health outcome indicators were extracted from the Demographic and Family Health Survey (ENDES) conducted by the National Institute of Statistics and Informatics (INEI). The variables included childhood chronic malnutrition (desnwho), childhood anemia prevalence (anemia), children without anemia (nt_ch_any_anem), and Polio1 vaccination coverage recorded on vaccination cards (ch_polio1_card). Additional descriptive analyses included health insurance coverage and other maternal and child health indicators.

The databases were processed and analyzed using Stata software, which was employed for data management, descriptive statistics, panel data econometric estimation, and statistical inference.

Procedure

Initially, annual regional data on public health expenditure were extracted from the MEF Consulta Amigable platform, while health indicators were obtained from the ENDES microdata published by INEI. Subsequently, the databases were cleaned, standardized, and integrated into a balanced regional panel covering the 24 Peruvian regions for the 2012–2023 period.

Descriptive analyses were first performed to evaluate temporal changes in public health expenditure and health indicators across regions. Afterwards, panel data econometric models were estimated to determine the association between public health expenditure and regional health outcomes. Finally, Data Envelopment Analysis (DEA) was applied to estimate the relative efficiency of each region in transforming public health expenditure inputs into health outcomes, considering each region as an independent Decision-Making Unit (DMU).

Data Analysis

Statistical analyses were conducted using Stata software. Descriptive statistics were calculated to summarize annual trends in public health expenditure and health indicators across the 24 regions.

Panel data econometric techniques, including fixed-effects and random-effects models, were employed to estimate the relationship between public health expenditure and health outcomes. Appropriate model specification was determined using standard specification tests, including the Hausman test.

The efficiency of regional public health expenditure was evaluated using the Data Envelopment Analysis (DEA) method, a non-parametric linear programming technique that estimates the relative efficiency of homogeneous decision-making units based on multiple inputs and outputs. The input variables included personnel expenditure, goods and services expenditure, and acquisition of non-financial assets, whereas the output variables comprised childhood chronic malnutrition, childhood anemia prevalence, children without anemia, and Polio1 vaccination coverage. DEA efficiency scores ranged from 0 to 1, with a score of 1 indicating full technical efficiency. Statistical significance for the econometric analyses was established at $p < 0.05$.

RESULTS AND DISCUSSION

Results

Trends in Public Health Expenditure, 2012–2023

From a national aggregate perspective, public health expenditure showed a substantial upward trend during the 2012–2023 period, although structural challenges in health outcomes persisted. Expenditure on **Personnel and Social Obligations** represented the largest budget category, with an average annual allocation of **PEN 4.08 billion** and a standard deviation of **PEN 1.47 billion**. These figures indicate a progressive increase in financial resources allocated to the health workforce over the study period.

Cuadro 1

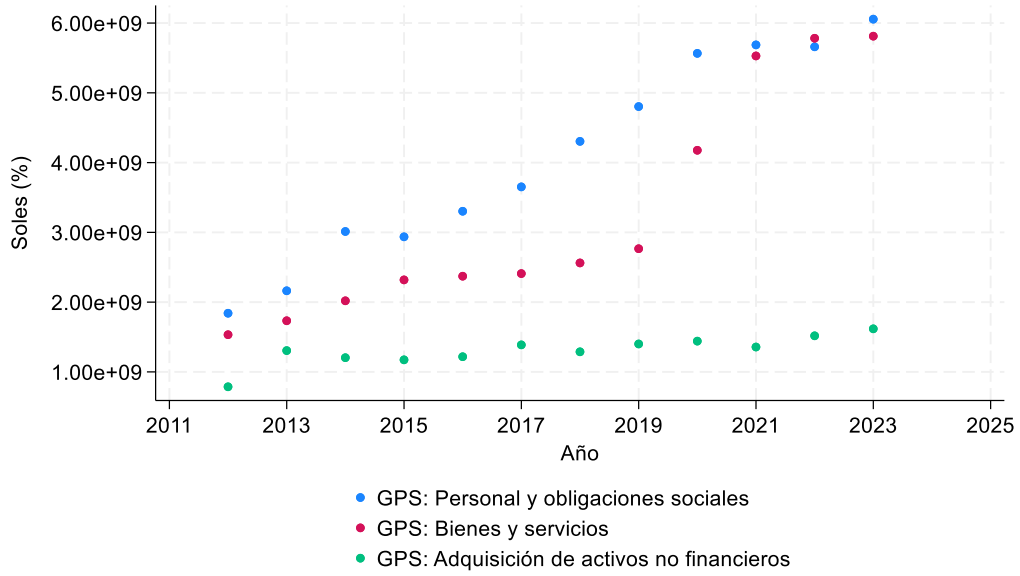
Evolution of Public Health Expenditure and Health Indicators Across the Regions of Peru During the Period 2012-2023

Variable	Obs	Mean	Std. dev.	Min	Max
year	12	2017.5	3.605551	2012	2023
anemia_100	12	43.61998	2.461046	39.41343	47.92594
desnwho_100	12	13.23305	2.165822	11.2189	17.75011
GPS: Personal y obligaciones sociales	12	4080000000.00	1470000000.00	1840000000.00	6060000000.00
GPS: Bienes y servicios	12	3250000000.00	1620000000.00	1530000000.00	5810000000.00
GPS: Adquisición de activos no financieros	12	1310000000.00	210000000.00	787000000.00	1620000000.00

Similarly, expenditure on **Goods and Services** averaged **PEN 3.25 billion** annually, ranging from **PEN 1.53 billion** to **PEN 5.81 billion**, with a relatively high standard deviation of **PEN 1.62 billion**. This component exhibited considerable year-to-year variability, reflecting fluctuations in operational expenditure related to medicines, medical supplies, preventive campaigns, and maintenance activities. The wide variation observed suggests differences in annual budget priorities and execution capacity.

Figure 1

Evolution of Public Health Expenditure at the National Level, 2012-2023



Note: Prepared using data from the MEF Open Data Portal., 2012-2023.

Investment in **Non-Financial Assets**, which includes infrastructure and medical equipment, averaged **PEN 1.31 billion** per year and presented the lowest variability among the expenditure categories (standard deviation: **PEN 210 million**). Nevertheless, minimum investment levels reached only **PEN 787 million** in some years, indicating periods of limited capital expenditure. Although this category remained relatively stable over time, the observed levels suggest structural constraints affecting the expansion of health infrastructure and technological modernization.

Overall, the descriptive analysis indicates sustained growth in public health expenditure across the three main budget categories during the study period, although differences in the magnitude and variability of budget execution were evident.

- Descriptive Analysis of Child Health Indicators

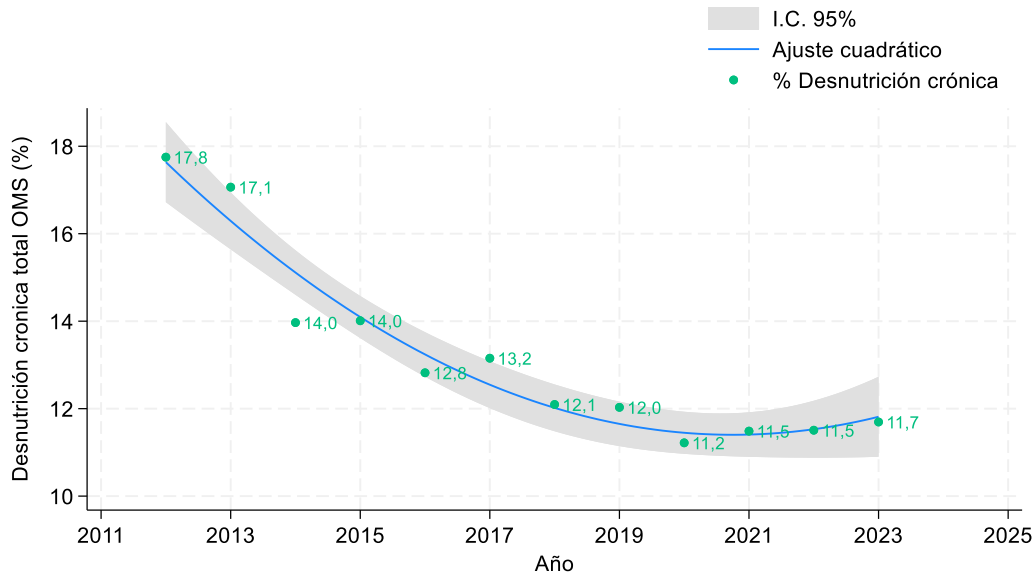
Despite the increase in public health expenditure, child health indicators continued to reveal substantial disparities across the country. **Chronic child malnutrition** recorded a national average of **15.1%**, with values ranging from **1.3%** to **49.6%**, highlighting considerable regional heterogeneity.

Panel data decomposition showed that **between-region variability (7.8)** exceeded **within-region variability (3.1)**, indicating that geographical disparities were substantially greater than temporal changes within individual regions. This pattern suggests that regional inequalities remained persistent throughout the study period.

The relatively low within-region variation indicates that improvements over time were gradual, whereas the pronounced between-region differences reveal enduring territorial disparities in child nutritional outcomes.

Figure 2

Evolution of the National Prevalence of Total Chronic Malnutrition, 2012-2025



Note. Prepared using data from ENDES–INEI., 2012-2023.

Descriptive Relationship Between Public Health Expenditure and Child Health Outcomes

The joint examination of public health expenditure and child health indicators shows that increases in government health spending were not accompanied by proportional reductions in chronic child malnutrition across the study period.

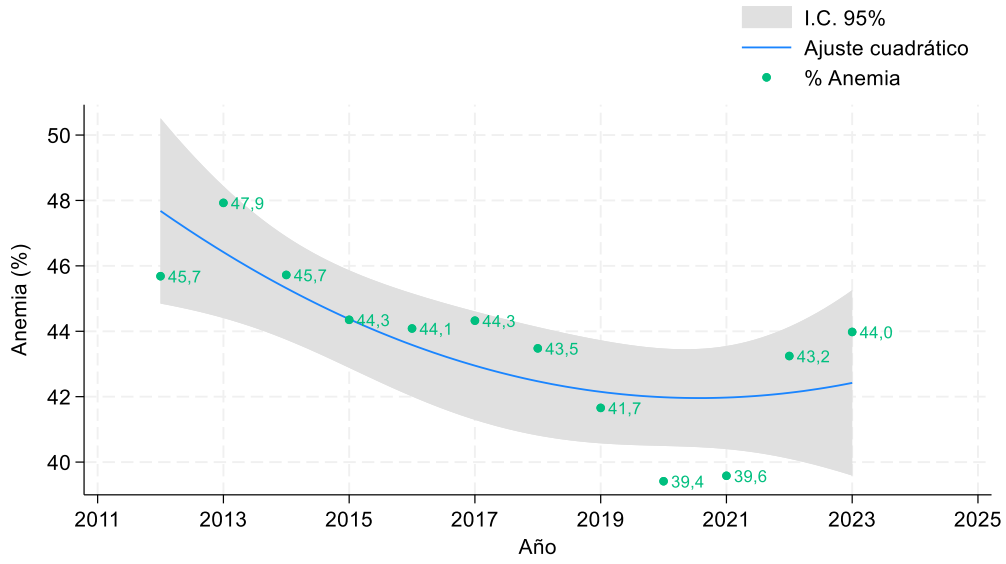
Although allocations for **Personnel and Social Obligations**, **Goods and Services**, and **Non-Financial Assets** increased steadily between 2012 and 2023, chronic child

malnutrition remained highly heterogeneous across regions, with substantial differences in prevalence persisting throughout the country.

These descriptive findings suggest that, despite sustained growth in public health expenditure, significant regional disparities in child nutritional outcomes remained during the study period, indicating that increased financial investment alone was insufficient to eliminate existan health inequalities.

Figure 3

Evolution of the National Prevalence of Anemia, 2012-2025



Note. Based on data from ENDES–INEI, 2012-2023.

Discussion

The descriptive results revealed a sustained increase in regional public health expenditure, particularly in personnel and social obligations, goods and services, and the acquisition of non-financial assets. However, key health indicators, such as anemia and chronic child malnutrition, remained persistently high across most regions. These findings suggest that increased public spending does not automatically translate into substantial improvements in health outcomes.

These findings are consistent with those reported by Monje (2015) and Vergara (2013), who argued that public investment is not always aligned with regional health needs or the

magnitude of health-related problems. Similarly, Tamayo et al. (2020) and Sun and Luo (2017) emphasized that the efficient use of public resources is as important as the amount of investment, particularly in contexts characterized by regional inequalities, such as Peru.

Likewise, Shi et al. (2022) demonstrated that spatial disparities in efficiency may persist even under high levels of public investment when targeted planning is lacking. Therefore, the findings of the present study highlight the need to align resource allocation with territorial effectiveness criteria and measurable health outcomes. This approach would contribute to improving the efficiency of public spending and reducing regional disparities in health service delivery.

CONCLUSIONS

This study analyzed the evolution of public health expenditure in Peru's regions during the 2012–2023 period, examining its relationship with key child health indicators and assessing the extent to which increased financial resources translated into measurable improvements in population health outcomes.

The findings demonstrate that public health expenditure experienced sustained growth across its three main budget categories—personnel and social obligations, goods and services, and non-financial assets—over the study period. However, this growth in spending was not accompanied by a proportional reduction in chronic child malnutrition, which remained highly heterogeneous across regions. The pronounced gap between between-region and within-region variability confirms that territorial disparities, rather than temporal trends, are the dominant source of inequality in nutritional outcomes. Together, these results indicate that the volume of public investment alone does not explain regional differences in health performance.

This research advances current knowledge by providing empirical, regionally disaggregated evidence that the magnitude of public health spending is not, by itself, a sufficient condition for improving population health indicators in decentralized settings. The findings are consistent with prior evidence indicating that the alignment between resource allocation and regional health needs—and the efficiency with which those resources are managed—matters as much as, or more than, the level of investment itself.

The study offers meaningful implications for public health policy design in Peru, particularly for prioritizing territorial targeting and execution capacity alongside budgetary growth, in order to close persistent regional gaps in child health outcomes.

These results reinforce the need to move health policy discussions in Peru beyond spending volume toward spending effectiveness and territorial equity. Strengthening the link between resource allocation and measurable health outcomes—particularly in regions with historically weaker execution capacity—remains essential for translating fiscal investment into tangible improvements in population health.

CONFLICT OF INTEREST

The author declares no conflict of interest. Gleny Tania Pari Fernandez (GTPF).

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QUALITY OF CARE AND USER SATISFACTION IN THE HEALTHCARE SERVICE OF HOSPITAL CARLOS CORNEJO ROSELLÓ VIZCARDO OF AZÁNGARO

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Abstract

This study focused on the lack of local information regarding the relationship between the quality of care and the level of patient satisfaction in the health service of the Carlos Cornejo Roselló Vizcardo Hospital in Azángaro, since this gap in the literature limited the implementation of evidence-based improvements. To address this issue, the methodology employed a quantitative, non-experimental, cross-sectional, and correlational approach. Regarding data collection, the SERVQUAL survey was used, rigorously adapted to the guidelines of the MINSA Technical Guide (RM N.° 527-2011), which was administered to a sample of 163 users selected through random probabilistic sampling from a population of 1,200 patients served. As a result, a positive and statistically significant association between the two main variables was found ($\rho > 0.60$; $p < 0.05$). Within this theoretical framework, the dimensions of empathy and responsiveness exhibited the most significant gaps between users' initial expectations and their actual perception of the service; in contrast, the tangible elements of the service received the lowest absolute ratings. Finally, the findings obtained provided a solid empirical basis for formulating and implementing targeted improvement plans, prioritizing actions aimed at the most critical dimensions in order to, thereby, contribute to optimizing the quality of the health service and increasing overall user satisfaction in this hospital setting. (1)

Keywords: User satisfaction, Quality of care, health service, Servqual, 45 reliability

Introduction

In modern healthcare systems, quality of care and user satisfaction represent fundamental indicators for evaluating institutional performance and patient-centered services. Several researchers have investigated how institutional parameters, operational efficiency, and interpersonal treatment directly influence the public perception of healthcare environments (2). In Peru, national healthcare guidelines, such as the MINSA Technical Guide, emphasize the systematic measurement of these indicators to optimize service delivery. Previous literature has consistently demonstrated a significant positive correlation between the quality of healthcare attributes and overall user satisfaction across diverse regional contexts, as observed in international settings like Ethiopia (3) and national studies in Tacna , Jaén , and Trujillo. However, limited empirical evidence exists regarding this correlation within public health facilities located in remote rural areas of the Peruvian altiplano. Most previous studies in the country have focused on urban centers or specialized polyclinics, leaving an underexplored context in provincial networks like Azángaro. Consequently, the lack of localized data prevents the development of tailored strategic interventions based on specific regional constraints, such as infrastructure deficits and resource limitations. Therefore, an empirical assessment is required to determine the precise dynamic between service dimensions and patient perceptions in this specific setting. The purpose of the present study was to determine the relationship between quality of care and user satisfaction at the Hospital Carlos Cornejo Rosello Vizcardo in Azángaro during 2025. This research utilized a quantitative, non-experimental, cross-sectional, and correlational design by adapting the SERVQUAL model to assess institutional attributes.(4) The findings of this investigation provide concrete data to guide administrative decision-making and optimize healthcare delivery in rural medical establishments.

Methodology

The population consisted of users served at the healthcare services of the Hospital Carlos Cornejo Rosello Vizcardo in Azángaro during 2025, which comprised a total of 1,200 individuals, from which a sample of 163 participants was selected using probabilistic random sampling based on specific inclusion criteria that encompassed patients who received outpatient healthcare services during the study period and consented to participate. Data were collected using a structured questionnaire adapted from the

SERVQUAL model according to the MINSA Technical Guide RM No. 527-2011, which was specifically designed to measure quality of care and user satisfaction across 5 core dimensions consisting of reliability, responsiveness, assurance, empathy, and tangibles. Finally, responses were recorded using a 5-point Likert scale to evaluate the precise gap between user expectations and perceptions without including external procedures or preliminary statistical results within this section.(5)

Results

This section presents the main empirical findings obtained from the data analysis, directly aligned with the primary research objectives and hypotheses of the study. The results detail the performance distribution across the five core SERVQUAL dimensions (tangibles, reliability, responsiveness, assurance, and empathy)(6), the overall evaluation of healthcare service quality, and the global user satisfaction levels recorded among participants. Furthermore, bivariate inferential analysis is reported to establish the statistical significance and strength of the correlation between service quality perception and user satisfaction within the public hospital environment.

Table 1

Quality of Care Levels by Dimension in Healthcare Services

Dimensión	Level	n	%
Tangibles	Low	3	10.0%
	Moderate	24	80.0%
	High	3	10.0%
Reliability	Low	5	16.7%
	Moderate	21	70.0%
	High	4	13.3%
Responsiveness	Low	8	26.7%
	Moderate	17	56.7%
	High	5	16.7%
Assurance	Low	5	16.7%
	Moderate	23	76.7%
	High	2	6.6%
Empathy	Low	2	6.7%
	Moderate	22	73.3%
	High	6	20.0%
Total Participants	—	**30**	**100%**

Nota. Note. Regarding specific dimensions, the data indicated that responsiveness showed the highest frequency of low-quality evaluations (26.7%), while empathy exhibited the highest proportion of high-quality ratings (20.0%), as summarized in Table 1.

Table 8

Distribution of Overall Quality of Care Levels in Healthcare Services

Level	n	%
Low	4	13.3%
Moderate	23	76.7%
High	3	10.0%
Total	**30**	**100%**

Note. Overall quality of care was predominantly perceived at a moderate level by 76.7% of the sample, while high and low perceptions accounted for 10.0% and 13.3% of the distribution, respectively, as presented in Table 2.

Table 9

Distribution of User Satisfaction Levels in Healthcare Services.

Satisfacción Level	N	%
Dissatisfied	11	36.7%
Moderately Satisfied	0	0%
Satisfied	19	63.3%
Total	**30**	**100%**

***Note. In terms of user** satisfaction, the descriptive analysis indicated that 63.3% of the individuals reported being satisfied, whereas 36.7% expressed dissatisfaction, as detailed in Table 3.*

Table 10

Cross-Tabulation Between Quality of Care and User Satisfaction Levels.

Quality of Care Level	**User Satisfaction Level: Dissatisfied**	**User Satisfaction Level: Satisfied**	
			Total
Low	8 (26.7%)	2 (6.7%)	10 (33.3%)
Moderate	3 (10.0%)	12 (40.0%)	15 (50.0%)
High	0 (0.0%)	5 (16.7%)	5 (16.7%)
Total	11 (36.7%)	19 (63.3%)	30 (100%)

Note. A cross-tabulation analysis demonstrated a proportional trend between higher quality perceptions and satisfied states. A statistically significant correlation was confirmed between quality of care and user satisfaction ($\chi^2 = 10.52$; $p = 0.005$), as displayed in Table 4.

Discussion

The results showed a significant, positive relationship between quality of care and user satisfaction ($\chi^2 = 10.52$; $p = 0.005$), indicating that higher service quality directly increases patient satisfaction. This finding is consistent with Marquina and Benavides (7), who identify quality as a primary driver of institutional trust, but differs from Gutiérrez Borja (8), who reported a weak correlation during a saturated health crisis. This interpretation aligns with Parasuraman's service-quality gap model.

Regarding the specific dimensions, responsiveness presented the most critical performance, with 26.7% of participants reporting low-quality levels due to administrative and waiting-time bottlenecks. Conversely, empathy showed the highest valuation (20.0% high quality), demonstrating that personalized care by medical technologists promotes positive patient experiences. (9)

Overall, quality of care was predominantly moderate (76.7%), confirming a stable baseline in the laboratory. The study's limitations include its cross-sectional design and a preliminary pilot sample of 30 participants. From an applied perspective, the findings suggest that optimizing operational workflows—particularly responsiveness through digital report systems—will directly boost user satisfaction.

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ARTIFICIAL INTELLIGENCE AND ACADEMIC PERFORMANCE IN HIGHER EDUCATION STUDENTS: EVIDENCE FROM THE PUNO REGION, PERU

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Abstract

Artificial intelligence is no longer an external topic for universities; it is already part of students' everyday academic work through search engines, platforms, mobile devices, automated feedback tools and data-processing applications. In the Puno region, this change is particularly relevant because higher education students interact with digital resources while also facing uneven access, different levels of digital training and diverse academic expectations. This article analyzes the relationship between artificial intelligence and academic performance in higher education students in Puno, Peru. The study was quantitative, basic, descriptive-correlational, non-experimental and cross-sectional. A census sample of 82 students from the Universidad Nacional del Altiplano was considered. Data were collected through a structured questionnaire with ordinal response options, organized around two main variables: artificial intelligence and academic performance. The instrument was validated by expert judgment and showed acceptable reliability values for the two scales: Cronbach's alpha = .810 for artificial intelligence and .833 for academic performance. The results indicate moderate relationships between artificial intelligence and academic dimensions associated with machine learning (r = .341), open-source technology (r = .509) and digital devices (r = .514). These findings suggest that students recognize artificial intelligence mainly through practical digital environments rather than through abstract technical definitions. The article concludes that AI may contribute to academic performance when it is accompanied by teacher guidance, methodological training, ethical criteria and institutional support. AI should therefore be understood as a learning support resource, not as a replacement for critical thinking, student responsibility or university teaching.

1. Introduction

In recent years, conversations about artificial intelligence have moved from specialized laboratories to ordinary classrooms. Students use digital tools to search for information,

organize ideas, correct drafts, translate documents, review references and prepare assignments. Teachers, in turn, face a new academic situation: the challenge is not only to prohibit or celebrate technology, but to understand how it is being used and under what conditions it can genuinely support learning.

This article comes from that concrete educational concern. The starting point was not a purely theoretical curiosity about artificial intelligence, but a practical question that appears repeatedly in higher education: when students use technological resources, does this use relate in any meaningful way to academic performance? The question is especially important in the Puno region, where university education interacts with social, economic and cultural diversity, and where access to technology is not always uniform among students.

The thesis on which this article is based studied the relationship between artificial intelligence and academic performance among higher education students in 2023. For this chapter, the original work was reorganized into an IMRaD article, preserving the empirical data while presenting the argument with a clearer academic structure. The goal is not to claim that AI automatically improves learning. A more reasonable position is that AI may help students when it is used with guidance, criteria and academic purpose.

International literature supports this careful approach. UNESCO (2021, 2023) has emphasized that AI in education must be human-centered, inclusive and ethically guided. Similarly, Baker and Smith (2019) argue that educational AI requires institutional planning and teacher preparation. Reviews by Zawacki-Richter et al. (2019), Chen, Xie, Zou, and Hwang (2020), and Crompton and Burke (2023) show that AI has expanded rapidly in higher education, but they also point out that pedagogical interpretation is still less developed than technological implementation.

In this context, the contribution of the present article is modest but relevant: it presents empirical evidence from a regional university setting. The results are not interpreted as universal truths; rather, they are read as evidence of how students perceive the relationship between AI-related resources and academic processes in a specific educational environment. This regional perspective matters because the use of AI is always mediated by local conditions, teacher support, digital access and students' previous academic experiences.

The objective of this article is to analyze the relationship between artificial intelligence and academic performance among higher education students in the Puno region, Peru. More specifically, the article examines how artificial intelligence is associated with

dimensions related to machine learning, open-source technology and digital devices, and how these associations can be understood in relation to academic performance.

1.1. Artificial intelligence in higher education

Artificial intelligence can be understood, in general terms, as the capacity of computer systems to perform tasks that usually require human intelligence, such as identifying patterns, processing information, supporting decisions or adapting responses to available data. In education, however, this definition needs to be translated into concrete academic practices. For students, AI is often encountered through search engines, learning platforms, grammar correctors, recommendation systems, chatbots, translation tools and digital applications that help organize information.

This practical presence of AI is important because many students do not necessarily identify the technical architecture behind a tool. A student may not speak about algorithms, neural networks or machine learning, but may still use AI-supported resources every day. For that reason, studies on AI in education should not be limited to technical definitions. They should also examine how students recognize, use and evaluate these tools in real academic tasks.

The literature has described several possible educational benefits. AI can support feedback, adaptive learning, learning analytics, automated assessment and early identification of students at risk (Baker & Inventado, 2014; Romero & Ventura, 2020; Siemens, 2013). It can also assist academic writing and research activities when students use it to clarify concepts, organize information or improve drafts. Nevertheless, these benefits are not automatic. Kasneci et al. (2023) and Farrokhnia et al. (2023) warn that generative AI may create risks related to superficial learning, inaccurate information and academic integrity if it is used without reflection.

Therefore, the educational question should not be reduced to whether AI is good or bad. The more useful question is how AI is incorporated into study habits, teacher guidance, evaluation practices and institutional policies. In that sense, the present article treats AI as a support resource whose value depends on the academic conditions that surround its use.

1.2. Academic performance as more than grades

Academic performance is commonly associated with grades and test results. That association is understandable because evaluation remains one of the most visible

indicators of student achievement. However, academic performance is broader than a final grade. It also includes the capacity to understand instructions, manage time, participate in learning activities, maintain motivation, interpret information and produce academic work with increasing autonomy.

The original thesis approached academic performance through dimensions such as achievement, evaluation and motivation. This multidimensional view is useful because AI may influence learning through different routes. It may help students search for materials, review explanations, organize notes or strengthen written production. It may also affect motivation when students feel that they have more resources to face academic tasks. On the other hand, AI may weaken learning if students use it only to complete assignments without understanding the content.

For this reason, the relationship between AI and academic performance must be interpreted with balance. AI is not an independent guarantee of academic improvement. Its contribution depends on digital literacy, ethical awareness, teacher mediation and the student's ability to transform technological support into genuine learning.

Table 1. Conceptual alignment of the article

Conceptual element	***How it is understood in this article***	***Educational implication***
Artificial intelligence	Digital systems and tools that process information, identify patterns or support academic tasks	Its value depends on meaningful academic use, not merely access
Academic performance	Achievement, evaluation, motivation and capacity to transform information into learning	It should be interpreted beyond grades alone
Regional context	Higher education in Puno with diverse levels of digital access and training	AI integration requires institutional and teacher support

2. Methodology

The study followed a quantitative approach. This decision was coherent with the objective of describing tendencies and examining the relationship between variables through measurable data. The research did not seek to manipulate learning conditions or introduce an experimental intervention. Instead, it observed students' perceptions about artificial intelligence and academic performance at a specific moment.

The type of research was basic or substantive because it sought to contribute to academic understanding of the relationship between two educational variables. The level was descriptive-correlational. It was descriptive because it organized frequencies and percentages obtained from student responses, and it was correlational because it examined the degree of association between artificial intelligence and dimensions linked to academic performance.

The design was non-experimental and cross-sectional. It was non-experimental because the variables were not deliberately manipulated. It was cross-sectional because the data were collected at one point in time. This design is appropriate when the purpose is to describe a phenomenon and estimate associations in a natural educational setting (Hernández-Sampieri et al., 2014).

2.1. Population, sample and instrument

The population corresponded to students of higher education in the institutional context considered by the thesis. The sample was census-based, because the study included the complete accessible group of 82 students. This is important to state clearly: the research did not use a probabilistic formula to select a smaller sample; rather, it worked with the whole group available for the fieldwork.

Data were collected through a structured questionnaire with ordinal response options. The questionnaire was organized into two central variables: artificial intelligence and academic performance. The artificial intelligence variable included dimensions related to machine learning, open-source technology and digital devices. The academic performance variable considered achievement, evaluation and motivation. The instrument was validated by expert judgment and later processed statistically using SPSS version 22. Reliability was estimated using Cronbach's alpha. The scale for artificial intelligence obtained alpha = .810 and the scale for academic performance obtained alpha = .833. These values indicate acceptable internal consistency for the purposes of the study. Although reliability values do not prove validity by themselves, they provide evidence

that the items were sufficiently consistent to support the descriptive and correlational analysis.

Table 2. Reliability of the questionnaire scales

Scale	***Number of items***	***Cronbach alpha***	***Interpretation***
Artificial intelligence	12	.810	Acceptable internal consistency
Academic performance	12	.833	Acceptable internal consistency

2.2. Data processing and ethical considerations

The data were organized in tables of frequencies and percentages. Descriptive statistics made it possible to identify how students perceived the relationship between AI-related resources and academic activities. The correlational analysis summarized the association between the main variable and the selected dimensions reported in the thesis.

A methodological clarification is necessary. The original thesis mentions the use of Pearson's chi-square for hypothesis testing and also reports correlation coefficients identified as r values. In this chapter, the correlation coefficients reported in the thesis are preserved, but no new p-values are invented. This decision protects the transparency of the article. If the original SPSS database becomes available, the next version could add exact significance values, confidence intervals and a complete correlation matrix.

The study followed basic ethical principles for educational research. Participation was associated with academic research purposes, and the information was processed in aggregated form. The article does not identify individual students. The focus is on the relationship between variables, not on personal evaluation of participants.

3. Results

The results are presented in two complementary parts. First, selected descriptive findings are summarized to show how students perceived AI-related resources. Second, the correlational results are organized to show the reported associations among the dimensions considered in the thesis.

The descriptive results suggest that students did not understand AI as an isolated or abstract concept. They associated it with computers, data analysis, software, platforms and mobile devices. This is consistent with daily academic experience: students usually encounter AI through tools and devices before they learn its technical foundations.

Table 3. Selected descriptive results from the artificial intelligence variable

ITEM / INDICATOR	**MAIN RESPONSE PATTERN**	**INTERPRETATION**
AI REQUIRES COMPUTERS FOR MACHINE LEARNING	Sometimes: 42.7%; Almost always: 24.4%; Always: 17.1%	Students associate AI with computer-based learning processes.
AI ALLOWS DATA ANALYSIS FOR MACHINE LEARNING	Almost always: 53.7%; Sometimes: 26.8%; Always: 13.4%	Data analysis appears as one of the strongest perceived functions of AI.
AI ALLOWS PATTERN RECOGNITION FOR MACHINE LEARNING	Sometimes: 37.8%; Almost always: 35.4%; Always: 19.5%	Pattern recognition is recognized, although with moderate dispersion.
AI THROUGH INFORMATICS DEVELOPS OPEN-SOURCE TECHNOLOGY	Almost always: 43.9%; Sometimes: 30.5%; Always: 14.6%	Informatics is seen as a relevant base for open-source development.
AI THROUGH PROGRAMS DEVELOPS OPEN-SOURCE TECHNOLOGY	Almost always: 46.3%; Sometimes: 25.6%; Always: 17.1%	Programs are perceived as necessary for AI-supported work.
AI THROUGH SOFTWARE DEVELOPS OPEN-SOURCE TECHNOLOGY	Almost always: 48.8%; Sometimes: 28.0%; Always: 14.6%	Software has one of the clearest perceived roles.

AI THROUGH PLATFORMS DEVELOPS OPEN-SOURCE TECHNOLOGY	Almost always: 40.2%; Sometimes: 31.7%; Always: 15.9%	Platforms are viewed as digital environments for academic use.
AI AND MOBILE TECHNOLOGY ARE PART OF DIGITAL DEVICES	Almost always: 36.6%; Always: 31.7%; Sometimes: 22.0%	Students connect AI with mobile and everyday devices.

3.1. Descriptive interpretation

A first pattern is the strong presence of the categories “almost always” and “sometimes”. This suggests that students generally recognize the academic relevance of AI-related resources, but their perception is not absolute. In practical terms, students seem to know that AI can help, yet its use may still depend on the task, the teacher, the available device and the level of confidence of each student.

A second pattern is the importance of software, platforms and mobile technology. These are visible elements in students' daily lives. A student may not define open-source technology in theoretical language, but can recognize that platforms and programs are part of the digital environment that supports academic work. This point is relevant for university teaching because training should begin from the tools that students actually use.

A third pattern is the moderate dispersion in items related to machine learning and pattern recognition. This may indicate that students are familiar with the effects of AI but not always with its internal logic. Therefore, university education should include basic AI literacy: what AI can do, what it cannot do, how to verify information, and how to avoid depending on automated answers without understanding the academic content.

3.2. Correlational results

The correlational results reported in the thesis show moderate relationships between artificial intelligence and the academic-technological dimensions examined. The relationship with machine learning was r = .341, while the relationships with open-source technology and digital devices were r = .509 and r = .514, respectively.

These values should be interpreted carefully. They do not mean that AI automatically produces academic performance. They indicate association, not causality. However, the results do suggest that students who perceive AI-related resources more clearly also tend to connect them with dimensions that support academic work. The strongest associations were found in the dimensions that are more visible in practice: open-source technology and digital devices.

The relationship with digital devices is particularly meaningful. In many cases, AI is not accessed through sophisticated laboratories but through phones, computers, platforms and applications. For students in higher education, the device becomes the first door to AI-supported learning. This is why digital access and digital literacy must be treated as academic issues, not merely technical matters.

Table 4. Correlation results reported in the thesis

RELATIONSHIP EXAMINED	**REPORTED COEFFICIENT**	**STRENGTH**	**INTERPRETATION**
ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING	r = .341	Moderate	Students show a moderate association between AI and computational learning processes.
ARTIFICIAL INTELLIGENCE AND OPEN-SOURCE TECHNOLOGY	r = .509	Moderate	AI is strongly connected with software, platforms and open digital resources.
ARTIFICIAL INTELLIGENCE AND DIGITAL DEVICES	r = .514	Moderate	Students relate AI to everyday digital devices and academic access.

3.3. Summary of findings

Taken together, the results show that the educational value of AI is not located only in advanced algorithms. For the students surveyed, AI appears mainly through practical

digital supports: devices, software, platforms, data analysis and search tools. This finding is important because it allows teachers and institutions to design training that begins with students' real academic practices.

The correlations also suggest that AI should be integrated into higher education through a pedagogical plan. If students are only told to use technology, the result may be superficial. If they are taught how to ask better questions, evaluate sources, organize evidence and reflect on the limits of automated systems, then AI can become part of a stronger academic process.

4. Discussion

The results of this study are consistent with the broader literature on AI in education. Zawacki-Richter et al. (2019) reported that AI applications in higher education often focus on student support, assessment and adaptive systems. The present article adds a regional perspective: in Puno, students also associate AI with academic support, but mainly through the tools they use in daily educational practice.

The moderate relationship between AI and machine learning suggests that students recognize some connection between AI and computational learning, although they may not fully understand the technical foundations. This is not a weakness of the students; it is a pedagogical challenge for universities. If AI is becoming part of academic life, then students need basic conceptual training, not only access to platforms.

The relationship between AI and open-source technology is relevant for institutions with limited resources. Open-source environments can support experimentation, collaboration and access. However, access alone does not guarantee learning. Teacher mediation is necessary so that students understand how to use software and platforms ethically and methodologically. This agrees with Ouyang and Jiao (2021), who argue that AI in education must be interpreted through pedagogical paradigms, not only through technological enthusiasm.

The relationship between AI and digital devices confirms a very practical reality: the student's phone, laptop or electronic device is often the space where academic work begins. Students search, read, translate, summarize and write through digital devices. This creates opportunities, but also risks. Without guidance, students may confuse fast access to information with genuine understanding. With guidance, the same tools can support autonomy, feedback and academic organization.

Another important point is academic integrity. The emergence of generative AI has intensified concerns about authorship, originality and evaluation. Kasneci et al. (2023), Dwivedi et al. (2023) and Tlili et al. (2023) show that AI tools can support learning, but they can also create problems when students use them to replace their own reasoning. Therefore, the response of higher education should not be panic or blind acceptance. It should be responsible integration.

From a local perspective, this study suggests that AI training in Puno should be practical and progressive. Students need to learn how to use AI for reading, writing, data organization and source verification. They also need to know when AI may be wrong, biased or incomplete. In this sense, academic performance will not improve because a student has access to AI, but because the student learns to use AI as one part of a broader academic method.

4.1. Limitations

The study has limitations that should be recognized. First, the sample was census-based and limited to the accessible group of 82 students; therefore, the findings should not be generalized to all higher education students in Peru. Second, the data were based on a questionnaire, so the results reflect student perceptions rather than direct observation of AI use. Third, the article preserves the statistical values reported in the thesis and does not add new inferential values that were not verified in the original database.

A future version of the study would be stronger if the original SPSS or Excel database were available. With that database, it would be possible to calculate exact p-values, confidence intervals, a complete correlation matrix and perhaps regression models. It would also be valuable to add qualitative interviews to understand how students actually use AI when they prepare assignments, read scientific texts or write academic papers.

5. Conclusions

The study concludes that artificial intelligence is related to academic performance through practical academic-technological dimensions. The strongest reported relationships were found with digital devices and open-source technology, while the association with machine learning was moderate. These findings suggest that students understand AI mainly through concrete tools and environments used in their academic routines.

AI can support academic performance when it helps students search for information, organize ideas, analyze data, access learning materials and improve academic production. However, its contribution depends on the quality of guidance. Without teacher mediation and ethical criteria, AI may encourage superficial work. With training, it can become a useful support for autonomous and responsible learning.

Finally, the article confirms the relevance of transforming thesis-based work into publishable academic chapters. When properly adapted, a master's thesis can contribute to a collective volume by offering evidence, reflection and methodological experience. This also strengthens postgraduate academic writing and encourages students to see research as a process that can continue beyond the thesis defense.

6. Recommendations

Universities should develop clear guidelines for responsible AI use in academic work. These guidelines should distinguish between acceptable support, such as grammar revision or idea organization, and unacceptable practices, such as submitting automated text without understanding or verification.

Teachers should incorporate AI literacy into academic writing, research methods and evaluation processes. Students need practical exercises that show how to use AI critically, verify sources and integrate digital tools without losing authorship.

Future research should combine quantitative and qualitative methods. Surveys can identify tendencies, but interviews or focus groups can explain how students actually use AI in their daily academic routines.

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BUDGET EXECUTION AND ITS IMPACT ON THE FULFILLMENT OF OBJECTIVES OF THE INCENTIVES PROGRAM OF THE DISTRITAL MUNICIPALITY OF ACORA PERIOD 2015-2016

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ABSTRACT

Results-Based Budgeting represents a public management framework that links the strategic allocation of resources with measurable results to optimize citizen well-being and fiscal efficiency. This study aimed to analyze the impact of budget execution on achieving objectives within the Municipal Incentives Program in the District Municipality of Acora during the 2015-2016 fiscal years. A quantitative, non-experimental, and correlational-causal design was adopted. The population and sample were based on the administrative budgetary and financial records of the municipality's core budget lines, central actions, and budget allocations that did not result in deliverables. Data collection was carried out through document analysis, using official reports from the Ministry of Economy and Finance as the primary instrument, processed through descriptive and inferential statistics. The findings revealed a direct and positive impact of budget execution on institutional compliance. In 2015, budget execution achieved a 90% compliance rate with the Incentive Program's targets, which, according to the Ministry of Economy and Finance's (MEF) management indicators, categorized the municipality's effectiveness level as "Good." However, not reaching 100% prevented the entity from receiving additional financial bonuses. Conversely, in 2016, budget execution achieved 100% compliance with the objectives, raising the effectiveness level to "Very Good." It is concluded that timely and efficient budget execution significantly optimizes public administration and institutional performance. This evidence underscores the role of results-based budgeting as a fundamental mechanism for governance, goal achievement, and the modernization of municipal management.

Keywords: Results-Based Budgeting, Budget execution, Municipal Incentives Program, Public administration, Institutional performance, Fiscal efficiency.

INTRODUCTION

In recent years, public financial management has gained increasing importance due to its fundamental role in the efficient allocation of resources and the improvement of public service quality. In this context, results-based budgeting (RBB) has become a key public management strategy that links financial resources to measurable results and institutional performance (Shah, 2016; OECD, 2021). This approach promotes efficiency, transparency, and accountability by aligning public spending with development goals and measurable outcomes (World Bank, 2022; Pollitt and Bouckaert, 2017). Furthermore, evidence suggests that performance-based budgeting frameworks contribute to strengthening fiscal discipline and improving decision-making processes in public institutions (International Monetary Fund, 2020; United Nations, 2021).

In the Peruvian context, the implementation of results-based budgeting has been consolidated as part of broader public sector reforms. Empirical evidence indicates that this approach contributes to improving the efficiency of public spending and strengthening monitoring and evaluation mechanisms (Ministry of Economy and Finance, 2023; Arnillas et al., 2007). Furthermore, several studies have demonstrated that results-based management is associated with improvements in institutional performance and better resource allocation in subnational governments (Charles et al., 2022; Aparicio et al., 2011). However, the effectiveness of these mechanisms depends largely on institutional capacity, planning systems, and the quality of management tools (CEPLAN, 2022; Andrews, 2013).

At the local government level, budget execution remains a crucial challenge. Despite the increased availability of financial resources, many municipalities experience low execution rates due to administrative, operational, and technical limitations (Ministry of Economy and Finance, 2022; Comptroller General of the Republic, 2021). Empirical studies in the Peruvian context suggest that the adoption of results-based budgeting is positively associated with improvements in public spending efficiency and institutional

performance (Lupa Quisocala et al., 2024; Palomino Manturano, 2025). Likewise, factors such as institutional planning, internal control, and organizational capacity play a significant role in determining the effectiveness of budget execution processes (Quispe Curo et al., 2023; Garay Canales, 2026).

However, despite the growing body of literature on results-based budgeting, few studies have specifically examined its direct relationship with budget execution performance in local governments. Most existing studies focus on the overall impact of results-based budgeting or on the determinants of efficiency, leaving a gap in understanding how this approach influences the execution phase of the budget cycle (World Bank, 2022; OECD, 2021). This gap is particularly relevant in developing countries like Peru, where budget execution shortcomings persist despite improvements in planning and allocation mechanisms (Ministry of Economy and Finance, 2022; Baldacci et al., 2008).

To address this gap, this study analyzes the relationship between results-based budgeting and budget execution in a municipal context. Using a quantitative, non-experimental, and correlational approach, the research examines key dimensions such as planning, resource allocation, and execution processes. The study seeks to provide empirical evidence that contributes to improving decision-making, strengthening public financial management and increasing the efficiency of local governments, particularly in regions with high socio-economic demands (World Bank, 2022; CEPLAN, 2022).

METHODOLOGY

This study adopted a quantitative and correlational research design to analyze the influence of budget execution on the achievement of the objectives of the Municipal Incentive Program. The research was conducted in the District Municipality of Acora during the 2015-2016 fiscal years. Data were collected through documentary analysis of budgetary and financial administrative records, using structured data collection sheets and reports from the Ministry of Economy and Finance.

The population consisted of the administrative and budgetary records of the District Municipality of Acora corresponding to the 2015-2016 fiscal year. A non-probability

sampling method was applied, which included all records related to budget execution and compliance with the Municipal Incentive Program.

Data were collected using a structured document analysis format. Data processing and analysis were performed using the Integrated Financial Management System (SIAF) with Melissa software, applying descriptive statistics to evaluate the relationship between the study variables.

The research was conducted in three stages. First, the population and sample were defined. The study population was the Acora Municipal District, and the sample was non-probabilistic, selected by convenience, encompassing all available documentary information on the budget execution of the Incentive Program (IP) from the municipality's Planning and Budget departments, supplemented with public reports from the Ministry of Economy and Finance (MEF). Second, the research design was established using a quantitative approach and a non-experimental, cross-sectional design, as the study sought to determine the impact of budget execution on achieving the IP's objectives. Third, the documentary information was compiled and organized for subsequent analysis.

Quantitative data were analyzed using descriptive statistics, including frequencies and percentages, to determine compliance levels and effectiveness rates. Documentary information was processed using Melissa V2.0 software and spreadsheets, organizing the data into comparative tables for systematic evaluation. Furthermore, an alignment analysis was conducted to determine whether each budget item (works, activities, and investment actions) corresponded to the six objectives of the Incentive Program, in accordance with current MEF regulations.

RESULTS

The analysis of budget execution and its relationship with the achievement of objectives under the Incentive Program in the District Municipality of Acora during the 2015–2016 period yielded the following results:

During the study period, a total of 22 targets were scheduled, of which 15 were achieved and 7 were not achieved. In 2015, 11 targets were scheduled, of which 7 were achieved (78%) and 4 were not achieved (22%). In 2016, likewise, 11 targets were scheduled, of which 8 were achieved (82%) and 3 were not achieved (18%).

Regarding the financial resources allocated based on target achievement, the municipality received a total amount of S/. 1,045,780.00 in 2015, while in 2016 the allocated amount was S/. 996,378.00.

Concerning the level of effectiveness in achieving the objectives of the Incentive Program, it was determined that in 2015 a compliance level of 90.46% was reached, with an executed amount of S/. 351,482.40, classified within the "good" range. In 2016, the achievement of objectives reached 100%, with an executed amount of S/. 1,597,799.38, corresponding to a "very good" level.

Likewise, in the analysis of specific targets for the year 2016, it was observed that out of the 11 scheduled targets, 8 were achieved and 3 were not achieved, showing variations in compliance depending on the type of target evaluated.

Table 1. Consolidated Results of Target Achievement and Resource Allocation (2015–2016)

Year	Scheduled Targets	Achieved Targets	% Achievement	Unachieved Targets	% Non-achievement	Allocated Resources (S/.)
2015	11	7	78%	4	22%	1,045,780.00
2016	11	8	82%	3	18%	996,378.00
Total	**22**	**15**	**68%**	**7**	**32%**	—

Source: Own elaboration based on MEF data

Table 2. Level of Effectiveness in Achieving the Objectives of the Incentive Program

Year	Executed Amount (S/.)	% Objective Achievement	Effectiveness Level
2015	351,482.40	90.46%	Good
2016	1,597,799.38	100.00%	Very Good

Source: Own elaboration

DISCUSSION

The findings of this study demonstrate that budgetary programs have a positive influence on the achievement of the objectives of the Municipal Incentive Program in the District Municipality of Acora during the 2015–2016 period. The results show a high level of effectiveness, indicating a transition from a "good" to a "very good" performance level according to the management indicators established by the Ministry of Economy and Finance.

These results confirm the proposed hypothesis, demonstrating that the execution of budgetary programs, including central actions and budget allocations not directly linked to products, contributes significantly to achieving the objectives of the Incentive Program. This suggests that efficient budget execution plays a critical role in strengthening municipal performance and ensuring compliance with institutional goals.

The findings are consistent with the Results-Based Budgeting approach, which emphasizes the alignment of resource allocation with measurable outcomes and improved public service delivery. In this context, the Incentive Program functions not only as a financial transfer mechanism but also as a management tool that promotes efficiency, accountability, and goal-oriented performance in local governments.

From a practical standpoint, the improvement observed between 2015 and 2016 reflects enhanced administrative capacity and better utilization of financial resources within the municipality. This progression highlights the importance of institutional learning and continuous improvement in public management processes.

However, despite these positive results, the study presents certain limitations. The analysis is restricted to a single municipality and relies on non-probabilistic sampling based on available administrative data, which may limit the generalizability of the

findings. Therefore, future research should consider broader samples and comparative analyses across multiple municipalities to strengthen the external validity of the results.

CONCLUSION

This study examined the influence of budget execution on the achievement of the objectives of the Municipal Incentive Program in the District Municipality of Acora during the 2015–2016 fiscal period, providing empirical evidence on the role of financial management in local public administration. The results demonstrate a consistent and significant positive relationship between the level of budget execution and the degree of compliance with institutional targets, confirming that efficient allocation and utilization of public resources directly contribute to improved municipal performance.

The findings reveal a notable progression between the years analyzed, with an increase in both effectiveness levels and goal attainment, moving from a “good” to a “very good” performance classification. This evolution reflects not only improved technical and administrative capacities within the municipality but also a greater alignment between budgetary planning and the strategic objectives established by the Incentive Program. In this regard, the study highlights the importance of integrating financial planning instruments with performance-based management approaches to ensure that public spending translates into measurable outcomes.

Furthermore, the results support the theoretical framework of Results-Based Budgeting, reinforcing its relevance as a mechanism that promotes efficiency, transparency, and accountability in public sector management. The Incentive Program emerges as a strategic tool that not only channels financial transfers but also fosters a culture of results-oriented governance, encouraging local governments to optimize their resources and strengthen service delivery.

From a practical perspective, this research underscores the need for continuous improvement in budgetary processes, particularly in planning, execution, and monitoring stages. Strengthening institutional capacities, enhancing the use of information systems such as SIAF, and ensuring compliance with regulatory frameworks are essential factors to sustain and further improve performance levels in municipal management.

However, it is important to acknowledge certain limitations of the study. The analysis was confined to a single local government and relied on non-probabilistic sampling based on available documentary records, which may restrict the generalizability of the findings to other contexts. Additionally, the study focused primarily on quantitative indicators, without incorporating qualitative dimensions that could provide deeper insights into managerial practices and decision-making processes.

In light of these considerations, future research should expand the scope of analysis to include multiple municipalities and incorporate mixed-method approaches that allow for a more comprehensive understanding of the relationship between budget execution and public policy outcomes. Such studies would contribute to strengthening the evidence base for improving the design and implementation of incentive-based programs in decentralized governance systems.

Ultimately, this research contributes to the academic and practical understanding of how effective budget execution functions as a critical determinant of institutional performance, reinforcing the premise that sound financial management is indispensable for achieving sustainable and results-oriented public administration at the local level.

CONFLICT OF INTEREST

The author declares no conflict of interest. Sheyla Talia Vasquez Sandoval (STVS).

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Productive Prisons, Labor Productivity, and Economic Profitability

Evidence from the Puno Penitentiary Establishment, 2025

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Abstract

Prison work can build human capital, income, and work habits, yet its contribution to reintegration depends on whether activities are productive, voluntary, safe, and linked to real market opportunities. This study analyzed the relationship between labor productivity and economic profitability in the Productive Prisons Program at the Puno Penitentiary Establishment during 2025. A quantitative, non-experimental, cross-sectional design was used. The population comprised 619 working-inmate records, and a stratified probability sample of 120 records was examined. The economic-productive assessment form covered factor efficiency, operating profitability, marginal input costs, and net-income flows. The Stata workflow included descriptive statistics, Pearson correlation, and adjusted linear regression. Average monthly labor productivity was 84.6%, productive efficiency was 81.9%, and monthly net income was PEN 1,485.30. High performance accounted for 76.7% of the sample, medium performance for 18.3%, and low performance for 5.0%. Productivity and profitability were strongly and positively correlated ($r = 0.78$; $p < 0.001$). In the adjusted model, productivity remained positively associated with profitability ($\beta = 0.72$; $p < 0.001$), while the model explained 61% of the observed variance ($R^2 = 0.61$). These findings support improved economic management of prison workshops; however, they do not establish an effect on recidivism because the design lacks longitudinal follow-up and a comparison group. A traceability system is proposed to link production, training, income, release savings, employability, and post-release recidivism.

Keywords: prison work; productive prisons; labor productivity; profitability; reintegration; Puno.

1. Introduction

Imprisonment interrupts educational, employment, and family trajectories and frequently deepens disadvantages that existed before admission to prison. Upon release, stigma associated with a criminal record reduces hiring opportunities and may weaken the expected returns to experience and training. Pager's (2003) employment audit showed that a criminal record operates as a negative signal to employers, while human-capital theory explains how education, experience, and skills can raise productivity and future earnings (Becker, 1964; Mincer, 1974). Prison work lies at this intersection: it may be merely occupational, or it may become an economic and rehabilitative intervention with measurable results.

International research indicates that correctional education and vocational training programs are, on average, associated with better employment prospects and lower recidivism, although effect sizes vary with program design, implementation quality, and participant selection (Wilson et al., 2000; Davis et al., 2013; Newton et al., 2018; Nur & Nguyen, 2023). RAND's synthesis reported lower odds of returning to prison among participants in correctional education, while emphasizing the need to determine which content, dosage, and quality standards produce those results (Davis et al., 2013). Recent evidence remains cautious: completing vocational training may improve employment and recidivism outcomes for some groups, but selection bias and local labor-market conditions prevent a uniform causal interpretation (McNeeley, 2023).

In Peru, Legislative Decree No. 1343 institutionalized the Productive Prisons framework in 2017 and linked productive activity to labor reintegration, rehabilitation, civil reparation, and income generation for people deprived of liberty. Its implementing regulation, Supreme Decree No. 025-2017-JUS, addressed participation modalities, training, business involvement, workshop administration, and commercialization. The National Penitentiary Policy to 2030 broadened this approach toward an integrated treatment system. Legislative Decree No. 1736, published in February 2026, later introduced assisted external work for the semi-open regime, confirming a policy transition from in-prison production toward a broader reintegration chain requiring indicators of performance, safety, and employment continuity.

Peruvian studies describe both progress and persistent gaps. Cueva Mori, Heraud Yarlequé, Lazarte Salazar, and Rojas Meneses (2020) found that program coverage

remained limited relative to the prison population and proposed stronger private-sector coordination. Valdivia Herrera (2023) reported a positive perceived contribution to labor rehabilitation among inmates at Lurigancho. Rodríguez Salazar (2023) assessed whether prison work in Peru met international human-rights standards and highlighted the importance of rights and working conditions. In the regional context, Condori Catacora (2016) found a moderate positive relationship between inmates' perceptions and labor-market reintegration in Puno; Ortiz Masco (2018) demonstrated the importance of interpersonal relations for rehabilitation; and Mamani Ñaupa (2020) reported a significant association between the Productive Prisons Program and rehabilitation at the Juliaca Penitentiary Establishment.

Despite these contributions, an operational evidence gap remains. Much of the debate focuses on legal validity or perceptions of the program, while fewer studies develop economic and productive metrics capable of determining whether workshops use factors efficiently, generate sustainable income, and build transferable skills. Productivity and profitability do not replace treatment outcomes, but they are necessary conditions if prison work is to avoid becoming a routine with no market, inadequate income, or no continuity after release.

This article examines economic and productive records from the Puno Penitentiary Establishment for fiscal year 2025. The main question is: to what extent is labor productivity associated with the economic profitability of inmates participating in the Productive Prisons Program? The general objective is to estimate that relationship and derive management and public-policy implications. The specific objectives are to describe productivity, efficiency, income, and performance; estimate the bivariate association between productivity and profitability; evaluate the adjusted relationship through regression; and propose a traceability system linking in-prison results to post-release employment and recidivism.

The study makes two contributions. Empirically, it organizes management indicators for 120 records drawn from a population of 619 working inmates. From a policy perspective, it avoids two common overstatements: assuming that higher production automatically means rehabilitation, or treating economic performance as unrelated to correctional treatment. The central proposition is more precise: an economically sound workshop can build human capital, discipline, income, and market ties, but its social effect must be demonstrated through follow-up, a credible counterfactual, and post-

release outcomes.

2. Theoretical framework and literature review

2.1. Economics of crime, human capital, and employment

The economic approach to crime argues that unlawful behavior responds, among other factors, to incentives, opportunities, and expected costs (Becker, 1968). Without reducing human conduct to a single equation, the framework helps explain why lawful income, transferable skills, and credible employment prospects may increase the opportunity cost of reoffending. The mechanism is more plausible when work provides remuneration, learning, verifiable references, and continuity after release.

Human-capital theory treats education and experience as investments that increase future productivity and earnings (Becker, 1964; Mincer, 1974). In prison, these investments face special constraints: limited equipment, captive markets, interruptions in supplies, weak certification, and little contact with current technology. Hours occupied are therefore an inadequate measure. Evaluation must also examine output per unit of time, quality, costs, net income, learning, and correspondence with external demand.

A criminal record adds an independent labor-market penalty. Pager (2003) showed through an employment audit that criminal history reduces employer callbacks. Western (2006) placed that disadvantage within a wider structure of inequality, while Bushway (2003) argued that in-prison work can contribute to reintegration only if it is connected with the transition to employment. Policy must therefore operate on both labor supply—skills, productivity, and work habits—and labor demand—employers willing to hire, certify, and support workers with criminal records.

2.2. Employment as a turning point and the desistance process

Life-course theories view stable employment as a potential turning point because it restructures routines, produces prosocial bonds, and strengthens commitments to conventional activities (Sampson & Laub, 1993; Laub & Sampson, 2003). Uggen (2000) found that employment effects may vary by age, warning against one-size-fits-all solutions. Maruna (2001) added that desistance also involves reconstructing identity and agency; precarious work without recognition may not produce the same changes as work that offers responsibility, learning, and prospects.

Empirical evidence confirms this complexity. Visher, Winterfield, and Coggeshall (2005) found modest and heterogeneous effects in their meta-analysis of employment programs for former offenders. Tripodi, Kim, and Bender (2010) showed that the employment–recidivism relationship is neither linear nor automatic. Skardhamar and Telle (2012), using Norwegian data, emphasized actual employment after release, while Ramakers et al. (2017) distinguished any job from a stable employment trajectory. Quality, duration, and job match matter alongside participation.

2.3. Correctional education, vocational training, and prison work

Wilson, Gallagher, and MacKenzie (2000) synthesized adult correctional education, vocational training, and work programs and found favorable results, conditioned by methodological quality. Saylor and Gaes (1997), through the Post-Release Employment Project, linked prison industry and vocational experience with improved institutional and post-release outcomes. MacKenzie (2006) situated this evidence within the wider agenda of results-based correctional interventions.

Davis et al. (2013) updated the evidence through a large meta-analysis of correctional education. Their findings supported lower recidivism, improved employment, and a favorable cost-benefit relationship. Nevertheless, the report stressed the need to open the program 'black box': curriculum, intensity, teaching quality, technology, and target population. Evaluations should not simply compare participants and nonparticipants when selection depends on motivation, conduct, or proximity to release.

Newton et al. (2018) reviewed experimental evidence and found promising vocational-training effects alongside a still-limited evidence base. Nur and Nguyen (2023) identified program and contextual moderators of success. McNeeley (2023), using propensity-score matching, showed that completion—not merely enrollment—is a relevant distinction. Duwe and Clark (2017) likewise demonstrated that post-prison employment interventions require adequate intensity and interinstitutional coordination.

From a rights-based perspective, the Nelson Mandela Rules state that prison labor must not be afflictive and that vocational training should focus on useful trades. UNODC (2017) recommends integrating programs with individual sentence planning and post-release services. This excludes models based solely on output volume or the reduction of idleness. Economic efficiency is legitimate when combined with voluntariness, safety, transparent remuneration, learning, and protection from exploitation.

Table 1. Summary of relevant international evidence

Source	Design	Useful finding	Implication for Puno
Saylor & Gaes (1997)	Evaluation of industrial work and training	Better institutional performance and favorable post-release signals	Link in-prison experience to verifiable employment
Wilson et al. (2000)	Meta-analysis	Favorable effects of education, vocational training, and work	Address heterogeneity and study quality
Uggen (2000)	Duration model / employment experiment	Employment can operate as a turning point, with age differences	Segment the intervention
Pager (2003)	Experimental employment audit	A criminal record reduces employment opportunities	Work with employers as well as inmates
Visher et al. (2005)	Meta-analysis	Modest and heterogeneous effects	Do not assume a uniform effect
Davis et al. (2013)	Meta-analysis and cost-benefit analysis	Lower recidivism and better employment odds	Measure content, dosage, and costs
Newton et al. (2018)	Systematic review	Promising training; limited experimental evidence	Improve evaluation designs
Nur & Nguyen (2023)	Systematic review	Success depends on program and context moderators	Record quality and implementation
McNeeley (2023)	Matched observational study	Training completion matters	Distinguish enrollment, persistence, and completion

Source: Author's synthesis based on the cited sources.

2.4. Peruvian and Altiplano evidence

Peruvian research recognizes the value of work for rehabilitation but displays different levels of evaluative maturity. Cueva Mori et al. (2020) diagnosed limited coverage, the need for business participation, and conditions for sustainability. Morazzani Granda (2021) examined private-sector involvement at the Cristo Rey de Cachiche prison and concluded that it can support reintegration when accompanied by training and induction. Valdivia Herrera (2023) reported a positive perceived effect on labor rehabilitation at Lurigancho, while Juárez Azurín and Reyes Aragón (2023) examined the program's relationship with correctional treatment in Metropolitan Lima.

Chuqui Cusimayta (2019) reported an association between Productive Prisons policy and rehabilitation at Ancón II. Cruz Arpi (2020) studied its relationship with sentence reduction through education in Huaraz. Peralta Apaza (2024) shifted the discussion to community corrections in Callao and identified information and training-demand gaps among the post-penitentiary population. Together, these studies suggest that the chain weakens when the institutional offer is poorly communicated, uncertified, or misaligned with preferences and market demand.

The Puno setting adds contextual evidence. Condori Catacora (2016) documented

positive relationships between occupational training, life planning, self-control, and labor-market reintegration. Ortiz Masco (2018) showed that communication and interpersonal relationships influenced rehabilitation. Mamani Ñaupa (2020), studying 150 inmates in Juliaca, found a significant relationship between the program and rehabilitation. These antecedents justify adding economic variables without abandoning psychosocial and treatment factors.

The main gap is methodological: cross-sectional designs and perception measures predominate. They are useful for describing acceptance and association but cannot identify what would have happened without the program. This study also uses a cross-sectional design and therefore does not claim a causal effect on recidivism. Its contribution is to strengthen the first evaluation link—production, efficiency, income, and profitability—and to define requirements for the next link—employment and offending after release.

3. Institutional and legal context

Article 139(22) of the Political Constitution of Peru establishes that the penitentiary regime aims at reeducation, rehabilitation, and the return of sentenced persons to society. The Enforcement of Sentences Code recognizes work as a right, a duty, and part of treatment, subject to organization, safety, and compatibility with legal status. On that basis, Legislative Decree No. 1343 created a specific framework for productive activity in prisons and community corrections.

The regulation approved by Supreme Decree No. 025-2017-JUS developed training objectives, participation modalities, involvement of natural or legal persons, workshop administration, and commercialization. It seeks to generate income for personal and family needs, civil reparation, and release capital. The regulatory design therefore contains a shared-value logic: treatment for the inmate, production for the economic unit, reparation for victims, and security benefits for society.

The National Penitentiary Policy to 2030, approved by Supreme Decree No. 011-2020-JUS, recognizes structural problems in overcrowding, treatment, and reintegration. Monitoring requires timely and comparable information. INPE's Penitentiary Statistical Information System provides an institutional basis for evidence-informed decisions, but workshop evaluation requires more granular records: effective hours, conforming units,

waste, costs, income, certifications, and outcomes after release.

Legislative Decree No. 1736 of February 12, 2026 introduced assisted external work for people sentenced for lower-harm offenses who enter the semi-open regime. Participation is voluntary, temporary, and revocable, and it requires evaluation, supervision, and compatibility with security. The reform is outside the 2025 empirical period but changes the relevance of the findings: a traceable in-prison productive record can inform preparation for external opportunities, provided it does not replace comprehensive risk and treatment assessment.

Table 2. Applicable legal framework and its evaluation function

Instrument	Core content	Study implication
Political Constitution, Article 139(22)	Reeducation, rehabilitation, and return to society	Higher purpose of all measurement
Enforcement of Sentences Code, Leg. Decree 654	Work as a right, duty, and treatment component	Compatibility with security and legal status
Legislative Decree 1343 (2017)	Promotion and implementation of Productive Prisons	Production, skills, income, reparation, and release capital
Supreme Decree 025-2017-JUS	Regulation of modalities and participation	Workshop management, training, and business coordination
Supreme Decree 011-2020-JUS	National Penitentiary Policy to 2030	Multisector monitoring and reintegration outcomes
Legislative Decree 1736 (2026)	Assisted external work in the semi-open regime	Employment continuity, supervision, and progressive evaluation

4. Materials and methods

4.1. Approach, design, and scope

The study uses a quantitative, applied, management-evaluation approach. The design is non-experimental because no treatment was randomly assigned; cross-sectional because it consolidates fiscal-year 2025 data; and correlational-explanatory because it estimates the productivity–profitability relationship using the available controls. 'Explanatory' refers to the statistical model's explanatory capacity and does not mean causal identification.

The unit of analysis was the consolidated individual record of each working inmate participating in productive activities. Monthly indicators were summarized for the observation period. The institutional setting was the Puno Penitentiary Establishment within INPE's Productive Prisons Program.

4.2. Population, sample, and sampling

The population comprised 619 working-inmate records generated during 2025. A stratified probability sample of 120 records was selected by productive activity or workshop, with allocation proportional to the registry structure. The approach sought to preserve heterogeneity across productive processes. For journal submission, the sampling file should retain the frame, stratum, inclusion probability, and random seed.

Table 3. Sampling design

Element	Specification	Quality control
Population	619 working-inmate records	2025 economic-productive registry
Analytical sample	120 records	19.4% of the population
Unit of analysis	Consolidated individual record	Period averages/indices
Method	Stratified probability sampling	Strata by activity or workshop
Inclusion criteria	Active record; observable production and income data	Minimum instrument consistency
Exclusions	Duplicates, incomplete records, or noncomparable periods	Document in the cleaning log

Source: Researcher's methodological summary.

4.3. Variables and instrument

The primary explanatory variable was labor productivity, defined as effective production divided by the expected standard or capacity in a comparable period. The outcome was economic or operating profitability, measured from attributable income and costs. Productive efficiency, monthly net income, performance level, and—when available—age, education, activity type, previous experience, training, and program duration were also considered.

The economic-productive assessment form covered four dimensions: factor efficiency, operating profitability, marginal input-cost optimization, and net-income flow. Consistency depends on uniform valuation rules. Income must be recorded using a common accrual or cash criterion; costs must distinguish inputs, waste, maintenance, and other components; and effective hours must exclude interruptions not attributable to the worker.

Table 4. Operational definition of variables

Variable	Operational definition	Unit	Scale	Source
Labor productivity	Effective output / standard output × 100	% per month	Continuous	Production form

Variable	Operational definition	Unit	Scale	Source
Productive efficiency	Efficient use of time, inputs, and capacity	0–100 index	Continuous	Economic-productive form
Net income	Attributable revenue minus direct costs	PEN per month	Continuous	Financial record
Profitability	Operating result relative to resources used	% or index	Continuous	Stata calculation
Performance	Classification using institutional cutoffs	Low/medium/high	Ordinal	Composite index
Controls	Age, education, activity, experience, training, duration	Variable-specific	Mixed	Registry and instrument

Source: Author's formulation. Cutoffs must be retained in the data dictionary.

Table 5. Summary consistency matrix

Level	Objective	Hypothesis/expectation	Technique
General	Determine the productivity–profitability relationship	A positive and significant relationship exists	Pearson correlation and adjusted regression
Specific 1	Describe productivity, efficiency, income, and performance	Medium-to-high levels predominate	Means, distributions, and graphs
Specific 2	Estimate the bivariate association	$r > 0$; $p < 0.05$	Pearson correlation
Specific 3	Estimate the association controlling covariates	$\beta_1 > 0$; $p < 0.05$	OLS with robust standard errors
Specific 4	Develop a traceability proposal	Indicators connect production and reintegration	Gap analysis and management design

Source: Author's formulation.

4.4. Statistical specification

Individual productivity is expressed as $Prod_i = (Q_i / Q^*_i) \times 100$, where Q_i is effective output and Q^*_i is the comparable standard. Monthly net income is $YN_i = TI_i - DC_i$, where TI denotes total attributable income and DC direct costs. If profitability is expressed as a percentage, $Profit_i = [(TI_i - TC_i) / TC_i] \times 100$.

$$Profit_i = \beta_0 + \beta_1 Prod_i + \gamma' X_i + \varepsilon_i$$

In the equation, X_i is the vector of controls and ε_i is the error term. The central hypothesis is H_1: $\beta_1 > 0$. Pearson's correlation summarizes the bivariate linear association. Ordinary least squares estimates the relationship conditional on controls; robust standard errors, residual diagnostics, multicollinearity, and influential observations should be reported. Nonlinear specifications should be considered if the profitability distribution requires them.

4.5. Stata processing and quality assurance

The reproducible workflow includes import, duplicate identification, range validation, explicit missing-value treatment, indicator construction, labeling, descriptive analysis, graphs, correlation, and regression. The master dataset should remain unchanged; transformations should be executed through a .do file that generates the analytical file and a results log. The appendix provides a template adaptable to final variable names.

Missing values must be separated from valid zeros; income totals should be reconciled with accounting records; productivity above 100% should be reviewed to distinguish exceptional performance from standard-setting errors; and any winsorization or exclusion must be documented. Statistical significance was assessed at $\alpha = 0.05$, while interpretation prioritized magnitude, fit, and substantive coherence.

4.6. Ethical considerations

The analysis uses administrative records and does not require disclosure of identity, specific offense, address, or other personal information. The analytical dataset must be de-identified and access-restricted. The manuscript does not report comparisons that could identify very small workshops. Before journal submission, institutional authorization for secondary data use and the ethics approval or exemption required by the journal must be verified. Prison work must be interpreted under voluntariness, safety, transparent remuneration, and protection against exploitation, consistent with the Nelson Mandela Rules and Peruvian law.

5. Results

Stata reporting criterion. The data tables and outputs below use only the confirmed aggregate statistics. Without the 120 individual records, unavailable standard deviations, confidence intervals, and diagnostics cannot be reported; they must be generated by running the .do file with the original microdata.

5.1. Economic and productive performance

The 120 analyzed records had average labor productivity of 84.6% and a productive-efficiency index of 81.9%. Average monthly net income was PEN 1,485.30 per working inmate. The proximity of productivity and efficiency suggests that output was not driven only by greater resource use; factor utilization was also favorable. This interpretation

must be verified using disaggregated costs and workshop-specific standards.

Table 6. Main descriptive indicators

Indicator	Result	Management interpretation
Monthly labor productivity	84.6%	Effective output relative to standard
Productive efficiency	81.9%	Aggregate utilization of production factors
Monthly net income per inmate	PEN 1,485.30	Average net result
High performance	76.7% (n = 92)	Predominant sample category
Medium performance	18.3% (n = 22)	Target for focused support
Low performance	5.0% (n = 6)	Requires individual/workshop diagnosis

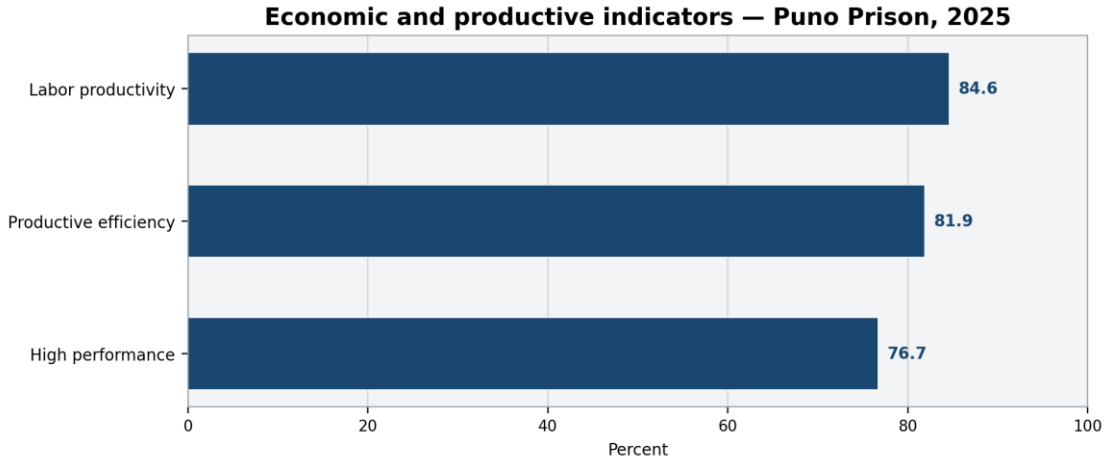
Source: 2025 study summary. Counts are based on n = 120; percentages are rounded.

Table 7. Data used in Figure 1

Indicator	Value	Unit	N
Monthly labor productivity	84.6	%	120
Productive efficiency	81.9	%	120
High performance	76.7	%	120

Source: 2025 study summary.

Figure 1. Consolidated economic and productive results



Source: Author's chart based on the study summary.

Stata output 1. Confirmed descriptive statistics

```
. tabstat prod_pct effic_pct net_income, statistics(n mean) columns(statistics)

  variable |     N       mean
-----------+--------------------
  prod_pct |    120      84.60
 effic_pct |    120      81.90
net_income |    120    1485.30
--------------------------------
```

Note: Stata-formatted output reconstructed from the confirmed aggregate statistics. It must be reproduced using the individual-level dataset before journal submission.

5.2. Distribution of productive performance

The composite performance index placed 76.7% of records in the high category, 18.3% in the medium category, and 5.0% in the low category. The concentration at the top is consistent with a program that may select or retain participants who adapt well to workshop routines; it must not be compared directly with the prison's entire population. The medium group represents the largest improvement opportunity, while the low group requires diagnosis of trade mismatch, insufficient training, interruptions, health, equipment, inputs, or record errors.

Table 8. Distribution of productive performance

Level	Frequency	Percent
High	92	76.7%
Medium	22	18.3%
Low	6	5.0%
Total	120	100.0%

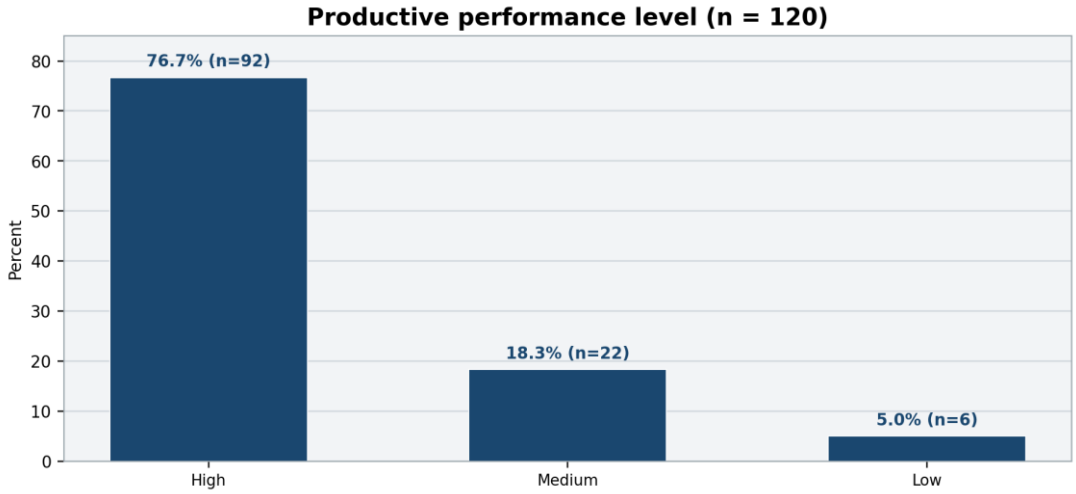
Source: Study summary. Small differences may result from rounding.

Table 9. Data used in Figure 2

Level	Frequency	Percent	Cumulative percent
High	92	76.7	76.7
Medium	22	18.3	95.0
Low	6	5.0	100.0
Total	120	100.0	100.0

Source: Study summary; percentages are rounded.

Figure 2. Distribution of productive performance



Source: Author's chart; n = 120.

Stata output 2. Productive performance distribution

```
. tabulate performance, missing

performance |   Freq.   Percent     Cum.
------------+-----------------------------
       High |     92     76.67     76.67
     Medium |     22     18.33     95.00
        Low |      6      5.00    100.00
------------+-----------------------------
      Total |    120    100.00
```

Note: Stata-formatted output reconstructed from the confirmed aggregate statistics. It must be reproduced using the individual-level dataset before journal submission.

5.3. Correlation between productivity and profitability

Pearson's correlation between labor productivity and profitability was $r = 0.78$, with $p < 0.001$. The magnitude indicates a strong positive linear association: records with higher productivity tend to have higher profitability. In a bivariate model, r^2 is approximately 0.61, consistent with the reported model R^2. Correlation does not distinguish reverse causality or common causes: better equipment, reliable supplies, experience, or higher-margin activities may raise both productivity and profitability.

Table 10. Correlation matrix

Variable	Productivity	Profitability
Labor productivity	1.00	0.78***
Economic profitability	0.78***	1.00

*Source: *** p < 0.001; n = 120. Pearson correlation.*

Stata output 3. Pearson correlation

```
. pwcorr prod_pct profit_pct, sig obs

             | prod_pct profit_pct
-------------+--------------------
    prod_pct |   1.0000
   profit_pct |   0.7800    1.0000
             |   0.0000

Number of observations = 120
```

Note: Stata-formatted output reconstructed from the confirmed aggregate statistics. It must be reproduced using the individual-level dataset before journal submission.

5.4. Regression model

In the adjusted model, productivity had a positive standardized coefficient of $\beta = 0.72$ ($p < 0.001$). R^2 was 0.61, indicating that the specification explained 61% of observed profitability variance. The reduction relative to the bivariate correlation is compatible with covariate inclusion or scale differences. Because the available summary does not

contain coefficients, standard errors, and confidence intervals for every control, the table reports only confirmed statistics; the journal version must replace it with the audited Stata output.

Table 11. Summary of the profitability model

Element	Estimate	P	Interpretation
Standardized labor productivity	0.72	< 0.001	Strong positive association
Observations	120	—	Analytical sample
R-squared	0.61	—	61% of variance explained
Controls	Included according to dataset	—	Report all coefficients in final audit

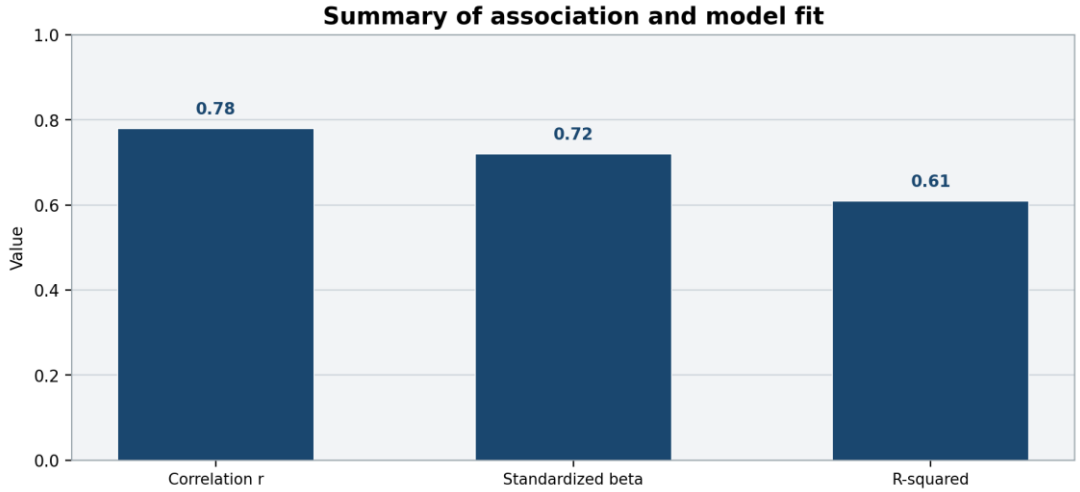
Source: Researcher's statistical summary. β is the reported standardized coefficient.

Table 12. Data used in Figure 3

Statistic	Value	p	N
Pearson correlation (r)	0.78	< 0.001	120
Standardized beta	0.72	< 0.001	120
R-squared	0.61	—	120

Source: Consolidated model results.

Figure 3. Strength of association and explanatory capacity



Source: Author's chart. r = correlation; β = standardized coefficient; R^2 = coefficient of determination.

Table 13. Hypothesis tests and limits

Hypothesis	Proposition	Evidence	Decision
H1	Productivity is positively related to profitability	r = 0.78; p < 0.001	Supported
H2	Productivity remains positive in the adjusted model	β = 0.72; p < 0.001	Supported
H3	The model explains a substantial share of profitability	R^2 = 0.61	Supported for the period

Hypothesis	Proposition	Evidence	Decision
H4	The program reduces recidivism	Not evaluated: no follow-up or counterfactual	Not testable

Source: 'Supported' denotes compatibility with observed data, not causality.

Stata output 4. Summary of the profitability model

```
. regress profit_pct c.prod_pct controls, vce(robust) beta

Number of obs =       120
R-squared     =    0.6100

------------------------------------------------
 profit_pct |   Beta       P>|t|
------------+-----------------------------------
   prod_pct |   0.720       0.000
------------------------------------------------
Controls included according to the consolidated dataset.
```

Note: Stata-formatted output reconstructed from the confirmed aggregate statistics. It must be reproduced using the individual-level dataset before journal submission.

6. Discussion

6.1. Economic interpretation of the findings

The strong productivity–profitability association is consistent with production theory: when workers produce more conforming units per unit of time or relative to the standard, average costs may fall and margins may improve, provided higher output does not require disproportionate inputs or rework. The 81.9% efficiency index supports this interpretation but does not identify which factor—skill, organization, equipment, scale, or continuity—drives the result.

Average monthly net income of PEN 1,485.30 is relevant because it approximates the activity's capacity to support personal needs, family contributions, civil reparation, or release capital. However, the mean may hide dispersion across trades and participants. A distributional evaluation should report the median, percentiles, the share with no income, monthly stability, and the allocation of funds. It must also distinguish inmate income, workshop profit, and gross sales.

The predominance of high performance may reflect program effectiveness, but it may also reflect selection. People admitted to or retained in workshops may differ in conduct, motivation, experience, and legal situation. If these characteristics also affect productivity and reintegration, unadjusted participant–nonparticipant comparisons would overstate the program effect. This warning is consistent with Nur and Nguyen (2023) and McNeeley

(2023), who emphasize implementation, completion, and selection bias.

6.2. Comparison with international evidence

The Puno results lie upstream of studies on employment and recidivism. Saylor and Gaes (1997) examined industrial experience and post-release outcomes; Davis et al. (2013) and Newton et al. (2018) synthesized education and training; this article first verifies whether the activity operates with productivity and profitability. The distinction matters: r = 0.78 cannot be compared directly with a reduction in recidivism because the measures refer to different outcomes and units.

Convergence appears in the mechanism. Training and experience may raise productivity; productivity may improve income and references; stable work may create prosocial routines and ties; and those changes may support desistance (Uggen, 2000; Laub & Sampson, 2003). Each arrow requires evidence. Puno provides evidence for the productivity–profitability link; certification, post-release hiring, employment stability, and recidivism remain to be demonstrated.

The labor-market stigma documented by Pager (2003) implies that improving the supply of skills is insufficient. Workshops must produce credible market signals: standards-based certificates, portfolios, references, safety assessment, job placement, and follow-up. Without those connections, even a highly productive inmate may face closed labor demand.

Table 14. Position of the findings within the results chain

Level	Indicators	Evidence status	Next measurement
Immediate outcome	Productivity, efficiency, and in-prison income	Favorable evidence in Puno	Audited productive records
Intermediate outcome	Certification, savings, employability, stable work	Suggested by research and policy	Individual follow-up
Final outcome	Lower recidivism and sustainable reintegration	Heterogeneous international evidence	Comparison group and ≥24-month horizon
Conditions	Voluntariness, safety, remuneration, non-exploitation	International and Peruvian standards	Continuous oversight

Source: Author's formulation.

6.3. Comparison with Peruvian and local studies

The strong economic-productive relationship complements the positive perceptions reported by Valdivia Herrera (2023) and the association between the program and

rehabilitation found by Mamani Ñaupa (2020). Those studies examine perceived or psychosocial outcomes, while this analysis adds quantifiable performance. The evidence is complementary: perceptions, competencies, production, and post-release outcomes form an integrated evaluation architecture.

Condori Catacora (2016) showed that occupational training, life planning, and self-control were related to labor-market reintegration in Puno. This helps interpret the 18.3% medium and 5.0% low groups: an exclusively technical intervention may be insufficient. Diagnosis must consider trade fit, goals, health, interpersonal relationships, and workshop conditions, consistent with Ortiz Masco (2018).

Cueva Mori et al. (2020) identified low coverage as a strategic problem. This study does not estimate establishment-wide coverage because its population is limited to working-inmate records. Policy requires two simultaneous dashboards: coverage—who gains access and why—and quality—what participating inmates achieve. Expanding places without quality may dilute results; maximizing quality for a small group may reproduce exclusion.

6.4. Validity, limitations, and scope

The conclusions should be interpreted in light of seven principal limitations:

- Cross-sectional design: it identifies an association in 2025, not temporal sequence or causal effect.
- No comparison group: it cannot estimate what would have occurred without participation.
- Possible selection: motivation, conduct, experience, and health may influence both access and outcomes.
- No attached microdata: dispersion, controls, standard errors, and confidence intervals could not be audited.
- Workshop heterogeneity: standards, costs, and markets may not be comparable without fixed effects.
- Final outcome unobserved: the study does not measure post-release employment or recidivism.
- External validity: the findings refer to Puno and should not be automatically generalized nationally.

These limitations do not eliminate the study's management value. They define what can be claimed: labor productivity and profitability were strongly, positively, and

significantly associated in the analyzed sample. The design cannot establish that Productive Prisons reduced recidivism or that the coefficient is causal.

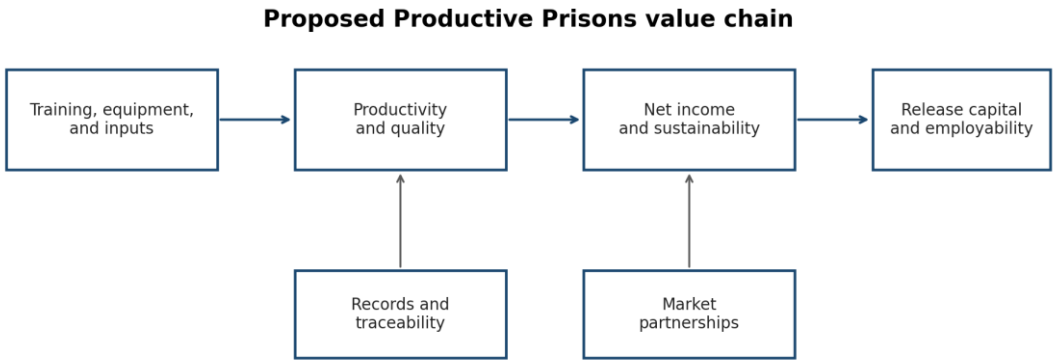
7. Improvement proposal and evaluation agenda

7.1. Productive and reintegration traceability system

A traceability system is proposed using a de-identified participant code from competency assessment through at least 24 months after release. The system must not become a mechanism of stigmatization or excessive surveillance. Its purposes are service evaluation, individualized support, and aggregate evidence, governed by access rules, data minimization, and defined retention periods.

Figure 4. Proposed Productive Prisons value chain

Note: conceptual figure; it does not use numerical data or generate statistical Stata output.



Source: Author's formulation.

7.2. Components and indicators

Table 15. Proposed management matrix

Component	Action	Indicator	Initial target/standard
1. Assessment	Profile skills, interests, health, and risk	% with current individual plan	≥95%
2. Production	Effective hours, conforming units, waste, equipment use	Productivity and defect rate	Monthly dashboard
3. Costs and income	Workshop costing and net-income records	Margin, median income, stability	Monthly close
4. Training	Demand-aligned modules and certification	% completing and certified	≥80% of enrollees
5. Protection	Voluntariness, safety, remuneration, grievances	Incidents and resolved grievances	100% response

Component	Action	Indicator	Initial target/standard
6. Market	Agreements, orders, portfolios, references	% with verifiable experience	≥70% of eligible participants
7. Transition	Account, release savings, documents, work plan	% with plan 90 days before release	≥90%
8. Post-release	Employment, continuity, income	Employment at 3, 6, and 12 months	≥80% follow-up
9. Recidivism	New conviction/readmission under fixed definition	Rate at 12 and 24 months	Adjusted comparison

Source: Initial targets are subject to baseline measurement, budget, and institutional validation.

7.3. Recommended evaluation design

A future evaluation should construct a participant cohort and an eligible comparison group. If random assignment is not ethical or feasible, propensity-score matching, inverse-probability weighting, or a regression-discontinuity design may be used where transparent access thresholds exist. Balancing variables should include age, education, work history, conduct, aggregated offense category, sentence length, time to release, health, and motivation.

Outcomes should be measured at prespecified times: monthly productivity and income; certification at completion; employment at 3, 6, and 12 months; stability and earnings at 12 months; and recidivism at 12 and 24 months. Survival curves and hazard models should assess time to first event, alongside linear or generalized models for employment and income. The recidivism definition—readmission, reconviction, or rearrest—must be set before analysis.

Cost-effectiveness analysis should include training, equipment, staff, security, inputs, commercialization, and follow-up, compared with income, civil reparation, release savings, and avoided recidivism costs. Not all benefits should be monetized; dignity, safety, family wellbeing, and prevented victimization also require reporting.

Table 16. Implementation roadmap

Horizon	Main action	Product	Suggested responsibility
0–3 months	Standardize dictionary, permissions, and costing rules	Auditable dataset and pilot dashboard	Prison directorate / Treatment / Administration
4–6 months	Validate instrument and train recorders	Agreement and ≥95% completeness	Technical team
7–12 months	Operate dashboard and target support	Improvement in medium and low groups	Workshops / CETPRO / partners

Horizon	Main action	Product	Suggested responsibility
12–24 months	Follow release cohorts and compare outcomes	Employment, income, recidivism	INPE / Community Corrections / academia
24+ months	Assess cost-effectiveness and scaling	Continue, redesign, or stop decision	MINJUSDH / INPE

Source: Author's proposal; formal assignment of responsibility belongs to INPE and MINJUSDH.

7.4. Implications of Legislative Decree No. 1736

Assisted external work creates an opportunity to convert documented in-prison performance into a supervised employment transition. Access must not be based on productivity alone: the law requires legal eligibility, conduct, assessment, and security. Nevertheless, a well-documented productive history can inform occupational fit, consistency, support needs, and suitable employers. The pilot plan should include an independent evaluation protocol from the outset, with indicators for retention, incidents, employer satisfaction, income, continuity, and mandatory return.

8. Conclusions

1. The sample of 120 records from the Puno Penitentiary Establishment showed favorable economic and productive results in 2025: average labor productivity of 84.6%, productive efficiency of 81.9%, and average monthly net income of PEN 1,485.30.

2. High performance accounted for 76.7%, medium performance for 18.3%, and low performance for 5.0%. Management should preserve high performance and focus technical and psychosocial support on the 28 medium- or low-performance records after identifying specific causes.

3. Productivity and profitability had a strong positive association ($r = 0.78$; $p < 0.001$). Productivity remained positive in the adjusted model ($\beta = 0.72$; $p < 0.001$), which explained 61% of the variance ($R^2 = 0.61$).

4. The findings support management of workshops using productivity, cost, and income indicators. They do not demonstrate that the program reduces recidivism because the study is cross-sectional, lacks a comparison group, and does not observe post-release outcomes.

5. National and local evidence suggests complementing economic performance with training, life planning, self-control, interpersonal relations, certification, and business coordination. Productivity is an intermediate outcome within a broader reintegration chain.

6. The 2026 assisted-external-work reform increases the need for traceability. In-prison records may support transition to the semi-open regime, provided they remain subordinate to voluntariness, safety, comprehensive assessment, and decent working conditions.

7. The next research phase should follow cohorts for at least 24 months, retain an eligible comparison group, report full costs, and apply survival or quasi-experimental methods. Only then can effects on employment and recidivism be estimated.

9. Recommendations

- Audit the dataset and reproduce all estimates in Stata before journal submission; add mean, median, standard deviation, percentiles, robust standard errors, and confidence intervals.
- Standardize costs, time, quality, and waste by workshop; avoid comparing heterogeneous activities using a single unadjusted standard.
- Create a monthly dashboard combining coverage, quality, rights protection, and economic outcomes.
- Certify skills with educational partners and produce verifiable employment portfolios without unnecessary disclosure of criminal history.
- Design the transition to community corrections and assisted external work with employers, local governments, CETPRO institutions, and employment services.
- Implement follow-up at 3, 6, 12, and 24 months and prespecify employment, stability, and recidivism definitions.
- Treat consent, safety, remuneration, grievances, and income distribution as core indicators.

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