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Sustainable forest management from education and community participation

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Abstract

The objective of the study is to design a probabilistic model to estimate the perception of participatory forest management in the Livestock and Agricultural Association EP-15 of La Cruceta, Piura. Inadequate forest management in rural communities leads to the degradation of natural resources; therefore, studies are conducted to promote education and community participation as strategies for sustainable management. The study design is non-experimental, descriptive, causal, with a quantitative approach. A questionnaire validated according to Cronbach's Alpha was used as an instrument, structured in three categories: a) Use of forest resources, b) Satisfaction with participatory management in the use of forests, and c) Benefits of participatory forest management. The socio-demographic characteristics of the respondents show high female participation, a predominance of adults, basic education (completed secondary school), and medium-low income. Households are moderate, reflecting a rural community with limited income and active female participation in agriculture. In conclusion, the design of the logistic regression model is significant, suggesting that gender, education, and income are the main predictors of participatory forest management. The data are crucial for identifying factors affecting the perception of forest management, guiding integrative strategies that balance local development and environmental conservation.

Keywords: Community participation, Environmental education, Forestry policies, Socio-demographic factors, Sustainable forest management.

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1. Introduction

Sustainable forest management faces numerous challenges due to increasing demand for wood products and agricultural conversion [1]. Decades of industrial logging have damaged forest structure and function, increasing the threat of severe fires and social distrust in a changing climate [2]. Anthropogenic threats, such as timber poaching and charcoal manufacture, compound the problem [3]. In addition, misappropriation of sustainability programs and underutilization of local knowledge hinder deforestation mitigation [4]. Local communities perceive soil fertility loss and deforestation as the main environmental problems but lack understanding of how cultural factors, such as superstition, influence their attitudes towards forest restoration [5]. Intensive exploitation of private forests, lack of subsidies and investments, as well as legislative regulation, financial, and technical support, hinder the implementation of sustainable forest management practices and biodiversity conservation [6]. There is also a risk of transferring responsibilities to communities without the necessary capacity to manage them [7]. Therefore, there is a need to improve governance and provide adequate guidance to policymakers, forest managers, and indigenous communities to promote sustainable forest management (SFM) and meet sustainable development goals Akalibey, et al. [8], leaving a legacy for a better world [9].

To date, important advances have been made in sustainable forest management, including research on forest decentralization and the use of traditional knowledge by local farmers for soil conservation and livelihoods [10]. However, a lack of understanding persists regarding the evolution of decentralization policies in terms of rules, discourse, actors, and power. Information on the relationship between traditional ecological knowledge and cultural ecosystem services provided by community forests, which are crucial for human well-being, remains scarce [11]. Although forest certification and management by different groups have made it possible to evaluate various approaches, cultural and situational differences continue to hinder the development of effective and inclusive policies [12]. Despite efforts in forestry education, educational infrastructure, and community participation, current governance systems still fail to fully integrate the unique needs and values of different social groups, evidencing the need for improved coordination and a theoretical approach in sustainable forest management [13].

The neo-tropical seasonally dry forests extend over approximately 520,000 km² in 18 countries of the neotropics, and their high degree of floristic and animal endemism, along with their high diversity of life forms, makes them an important asset of global biodiversity [14]. However, Ferraina, et al. [15] unsustainable logging currently constitutes one of the greatest threats to the biodiversity of these forests [16]. Anthropogenic land use and land cover changes are key factors contributing to environmental degradation and deterioration of soil health, especially in heterogeneous landscapes [17]. These changes have significantly reduced the extent of forests, with conversion to crops generating substantial losses of soil organic carbon and associated ecosystem services. Other changes, such as the conversion of forests to shrublands due to logging and intensified grazing, have also occurred [18]. In addition, various natural and anthropogenic disturbances, such as fires, partial clearing, droughts, and riparian changes, affect aboveground biomass and woody cover [19]. Frequent fires due to traditional practices also pose a risk [20].

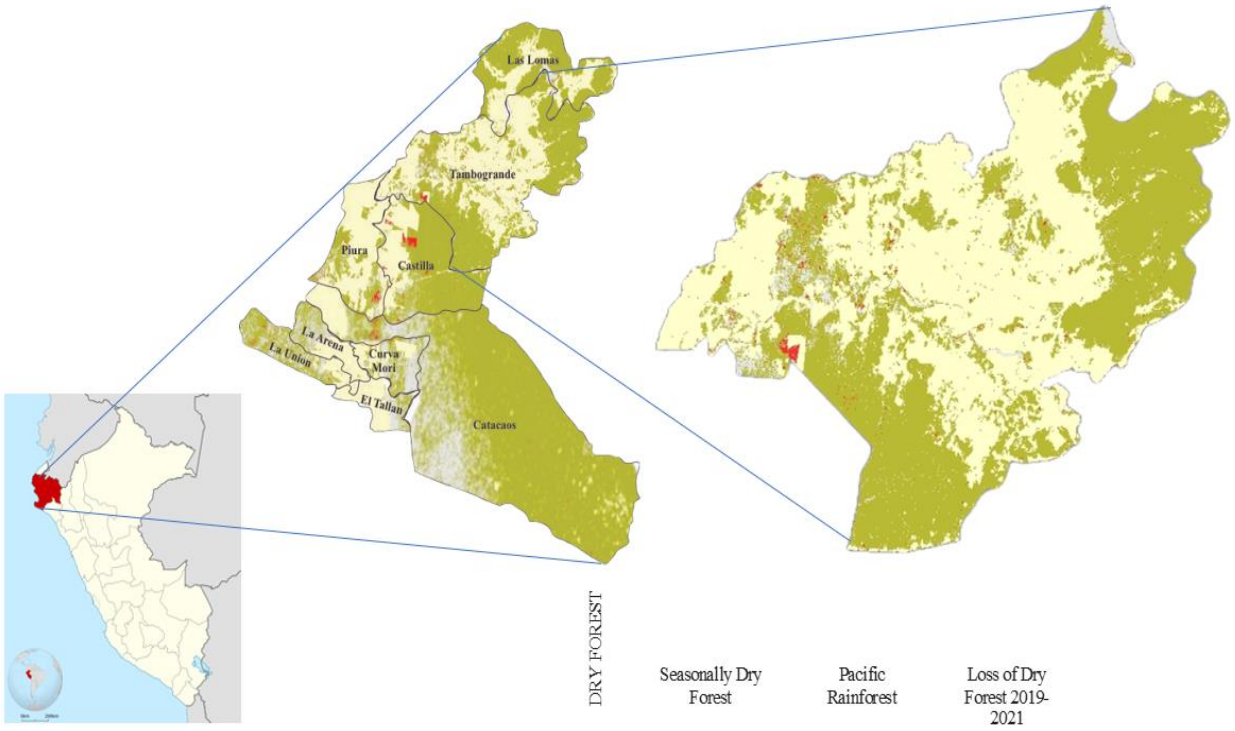

Figure 1.
District of Tambogrande in the province of Piura, Peru.
Source: Ministry of Environment of Peru [21].

In Peru, the political division of the territory is organized into three levels: regions, provinces, and districts. According to the Ministry of Environment of Peru [21], in 2021, a total of 3,314,905 hectares of seasonally dry forest was registered, specifically in the northern part of the country. In the province of Piura, Tambogrande district, a total of 67,854 hectares of seasonally dry forest was recorded. However, in the same year, a loss of 877 hectares of this type of forest was reported due to various factors such as the expansion of agriculture, cattle ranching, illegal exploitation of natural resources, infrastructure construction, climate change, forest fires, and others.

To move towards sustainable forest management, it is crucial to adopt an approach that integrates education and community participation into the forest management system. Based on the data provided, the implementation of techniques with active community participation, along with cross-sectoral coverage and advanced management strategies, can have a positive impact on watershed health and overall water security [22] In addition, it is recommended to establish a clear policy framework that promotes the use of technology in timber, forest science, silviculture, and post-planting management practices to meet the demands for forest products [23]. Also airborne laser scanning (ALS) technology emerges as a key tool to obtain meaningful indicators to support sustainable forest management [24]. Finally, the need to explore the application of community forestry models in urban areas as a way to improve forest management is suggested [25].

Studying sustainable forest management from education and community participation in the participatory forest management system is crucial, as their management decisions directly influence the flow of forest ecosystem services [26]. Communities that implement long-term forest management plans that incorporate conservation values demonstrate a greater capacity to generate sustainable income from a variety of sources [27]. These studies are not only essential for developing more robust theoretical and methodological frameworks that reflect complex dynamics, but also for advancing the theory and practice of enterprise forestry development and sustainable natural resource management, as well as effective policy formulation Masoodi and Sundriyal [28] and sustainable development objectives in rural development [29]. In addition, forestry and forestry education offers great potential for environmental education, making it necessary to review and update related educational contents [30]. Also determining traditions and customs linked to timber through environmental education can be beneficial, as can shared forest management systems, which have the potential to increase knowledge and awareness of environmental and territorial issues [31]. The tropical dry forest is a forest formation that requires greater knowledge of its dynamics and structure for its management and conservation [32].

1.1. Rationale and Research Objectives

The EP-15 Livestock and Agricultural Association is located in the community of La Cruceta, on the northern coast of Peru, within the district of Tambogrande, in the province of Piura. According to data from the National Institute of Statistics and Informatics [33] this community is located 164 meters above sea level (masl) and has a population of 4,597 inhabitants, distributed in 2,276 women and 2,321 men. The association manages a total of 145 hectares of land. Despite the assistance provided by institutions such as the National Forestry and Wildlife Service (SERFOR), which support the cattle ranching association in forest management, there are significant problems in the area, such as environmental contamination from informal and illegal mining. In addition, the local population is engaged in agricultural activities, such as agriculture and cattle ranching, among others [34]. These practices contribute to various environmental problems, such as air, water and soil pollution, deforestation, biodiversity loss and climate change [35]. In this context, participatory forest management emerges as a crucial strategy to mitigate the negative impacts of such activities by involving communities in decision making and sustainable management of natural resources [36].

The main objective of the study is to design a probabilistic model to estimate the level of perception of participatory forest management in the Livestock and Agricultural Association EP-15, La Cruceta, Piura. The specific objectives are: 1) to characterize the socio-demographic factors of the respondents; 2) to analyze the level of perception and attitude of the community towards participatory forest management, broken down according to its dimensions; and 3) to evaluate the influence of socio-demographic characteristics on the perception and attitude of the community towards participatory forest management.

Through these objectives, the study seeks to provide accurate data to the administrative sector of the municipality, facilitating informed decision-making and the implementation of short-, medium-, and long-term actions to improve the sustainable management of resources and environmental quality in the region, as well as to optimize environmental pollution gaps [37].

2. Methodology

The research was descriptive, correlational, causal and quantitative.

2.1. Population, Sample and Sampling

The study population consisted of 65 members, both men and women of the Livestock and Agricultural Association EP-15, belonging to the community of La Cruceta, in the district of Tambogrande, province of Piura, in the year 2024. Non-probabilistic sampling was used, defined by convenience or under the researcher's criteria, as indicated by Ñaupas, et al. [38].

2.2. Methods, Techniques and Instruments

Methods: The study adopted a quantitative approach and used the scientific method. According to Bavaresco [39] this method, characteristic of science, is defined as a rigorous, orderly and systematic procedure that guides thinking in conducting research; in this sense, specific procedures are developed from the identification of the problem to the communication of the results. In addition, the analytical-synthetic method was used, which analyzes the facts by decomposing the object of study

into its parts to examine them separately (analysis) and then integrates these parts to address them in an integral and holistic way (synthesis) [40].

Techniques: Data were collected using the survey technique, through a questionnaire. According to Yuni and Urbano [41] the fundamental characteristic of direct administration questionnaires are those in which the participants under study answer the questions contained in the format in writing. In this study, the data collection instrument was administered with the support of students of the second cycle of the professional career of Forestry Engineering at the National University of Frontera, after prior coordination with the president of the Livestock and Agricultural Association EP-15, corresponding to the community of La Cruceta. In this process, the president called the members to a meeting in the forest area under her management, where each of the members completed the survey in person and voluntarily.

Instrument: To obtain information from the study population, the Tesfaye [42] that evaluates the perception and attitude of the local community towards the participatory forest management system was used as an instrument. This instrument is organized in two sections; the first part assesses sociodemographic factors according to gender, age, occupation, educational level, monthly income, and number of people in the household.

The second part of the questionnaire is organized in 3 sections: a) utilization of forest resources through 7 items. b) Satisfaction of participatory management in forest use, organized in (6 items) and c). Benefits of participatory forest management, organized in (8 items).

The application of the instrument lasted approximately 30 minutes, utilizing Likert-type response scales according to various dimensions: for "Use of forest resources," the scale was as follows: always (4), often (3), seldom (2), rarely (1), and never (0). For “Satisfaction with participatory management in forest use,” the scale used was: very satisfied (2), somewhat satisfied (1), and not satisfied (0). For the dimension "Benefits of participatory forest management," the responses were yes (2), somewhat (1), and no (0). These scores were then categorized on scales according to each dimension: "Benefit from forest resources" (20-28 High, 10-19 Moderate, 0-9 Low); for satisfaction with participatory management in forest use (High 9-12, Moderate 5-8, and Low 0-4); and for satisfaction with participatory management in forest use (High 11-16, Moderate 6-10, and Low 0-5). The value of Cronbach's Alpha statistic was 0.62, which was adequate for further research.

2.3. Data Analysis

The data were organized in Excel sheets version 2019 and processed with the statistical software Minitab v.19 and SPSS-27. Two types of statistical analysis were applied: descriptive statistics were used through the presentation of information in tables and graphs that allow for comparison of the variables and dimensions of the study. On the other hand, inferential statistics were considered; correlation analysis was used to statistically test a dependency relationship between categorical variables, such as the chi-square X^2 statistic, as well as logistic regression to estimate the probability of perception towards participatory forest management. The Pearson test and the Hosmer-Lemeshow test were used to validate the effectiveness and fit of the logistic regression model applied in the study.

3. Results

Figure 1 shows the socio-demographic profile of the respondents of the livestock and agricultural association EP-15 of the community of La Cruceta, Tambogrande District.

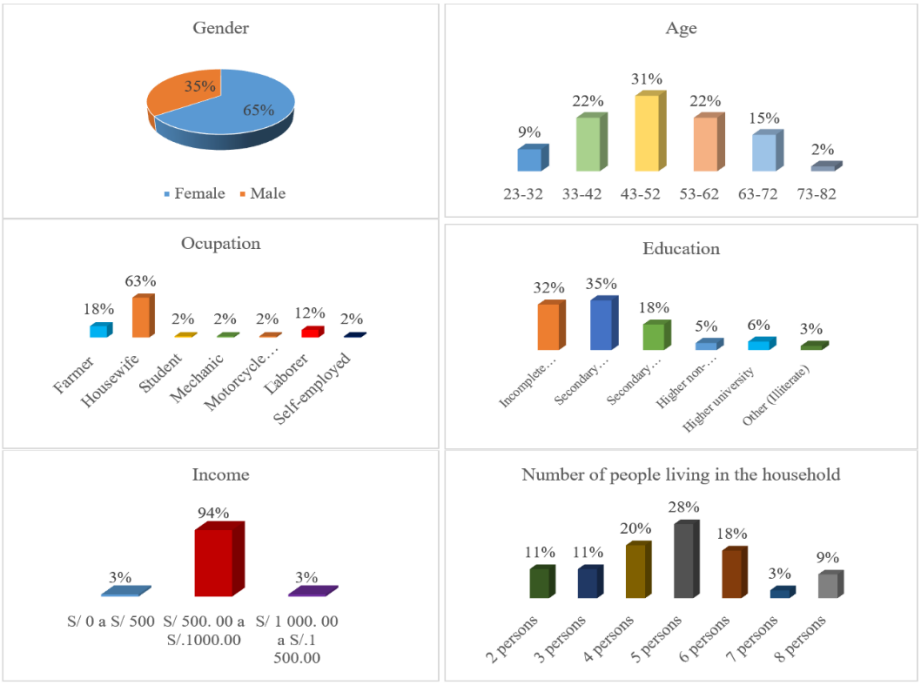

Figure 2.
Sociodemographic profile of respondents of the Livestock and Agricultural Association EP-15 in the community of La Cruceta, Tambogrande District, Province of Piura, 2024.

The majority of the respondents are women (65%) dedicated to agriculture (63%), with a significant representation of housewives (18%) and students (12%). The predominant age group is between 43 and 52 years old (31%), and in terms of education, 35% have completed high school, while 94% have monthly incomes between S/. 500.00 and S/. 1,000.00. The majority live in moderately sized households, with 28% of the families composed of four members, reflecting a community with high female participation and a predominantly secondary and primary education level, along with an average economic situation.

Figure 3 shows the perception and attitude of the community towards participatory forest management, where 58% of the respondents (38 people) have a high perception and attitude, while 42% (27 people) have a moderate perception. In the dimension of forest resource use, only 8% (5 people) have a high perception; 55% (36 people) have a moderate perception and 37% (24 people) have a low perception. All respondents (100%, 65 people) expressed moderate satisfaction with participatory management and consider the benefits of forest management to be high.

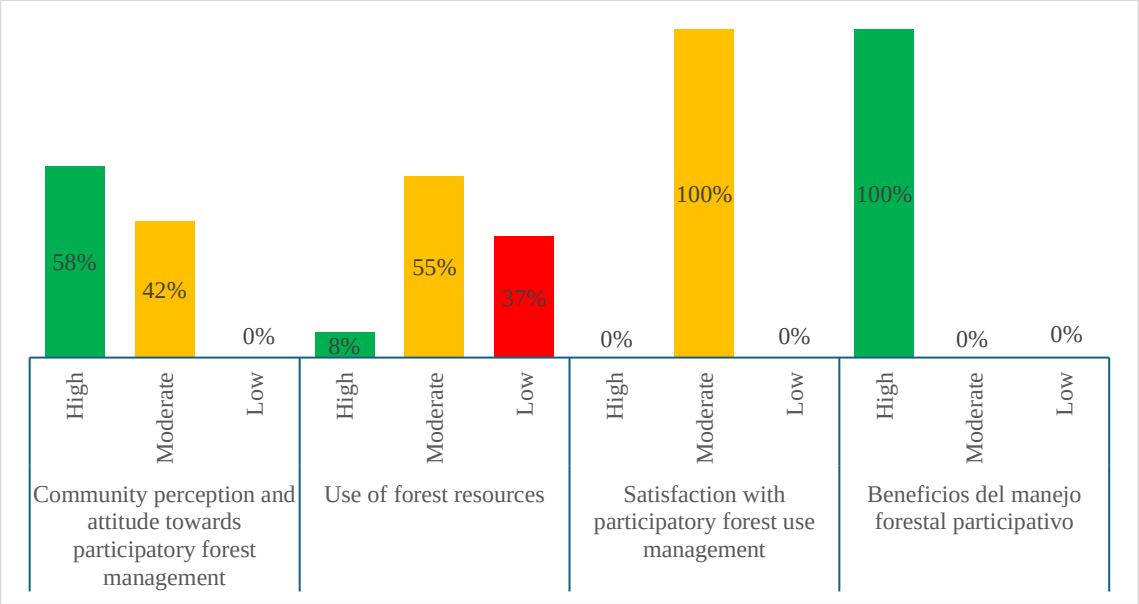

Figure 3.
Level of perception and attitude of the community towards participatory forest management according to dimensions of the variable in respondents of the Livestock and Agricultural Association EP-15, community of La Cruceta, Tambogrande District, Province-Piura, 2024.

In Figure 4 seven attributes are evaluated in relation to the perception and attitude of the community towards participatory forest management, highlighting occupation as the most relevant (information gain: 0.1342), followed by educational level (0.0996), which also showed a good information gain. Gender had the least influence (0.0669), followed by age (0.0508). Income had a low significance (0.0248) and the number of people in the household did not contribute at all (0.0000). These findings suggest that to improve the perception and attitude towards participatory forest management, it is essential to focus educational interventions on specific subgroups of the community, prioritizing those with different occupations and educational levels.

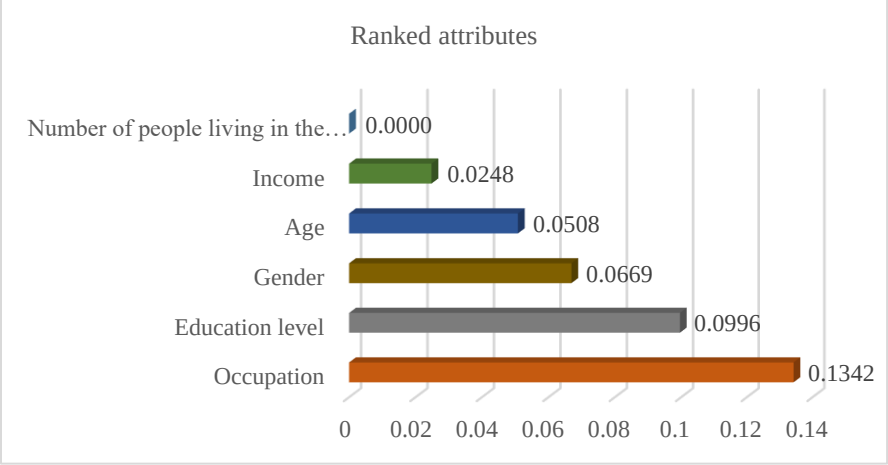

Figure 4.
Level of influence of socio-demographic characteristics on the perception and attitude of the community towards participatory forest management of the Livestock and Agricultural Association EP-15.

The logistic regression model seeks to predict the probability that an individual has a "High" perception of participatory forest management, using gender, age, occupation, education level, income and number of people in the household as predictors. A constant (-8.29) was found, indicating that, in the absence of these factors, the probability of a "High" perception is very low. The results also show that being female (coefficient = 1.574) and having a higher educational level (coefficient = 0.573) significantly increase this probability. Income also has a positive effect (coefficient = 1.73), although not statistically significant. The variables age (coefficient = 0.145), occupation (coefficient = 0.063) and number of people in the household (coefficient = 0.143) have slight positive impacts, but are not determinant. In summary, gender and level of education are the main predictors of a "High" perception. Logistic regression analyses were then conducted to determine the odds ratios between continuous predictors and "High" perception. The results show that the odds ratio for sex was 4.8256, indicating that women are approximately 4.8 times more likely to have a "High" perception compared to men. For age, an odds ratio of 1.1558 was obtained, suggesting that as age increases, the probability of a "High" perception increases slightly. For occupation, the odds ratio was 1.0648, reflecting a moderate positive impact. Educational level presented an odds ratio of 1.7735, indicating that higher levels of education significantly increase the probability of a "High" perception. On the other hand, income showed a strong association, with an odds ratio of 5.6437, evidencing that higher income is strongly related to a "High" perception. Finally, the number of people in the household presented an odds ratio of 1.1542, indicating that an increase in household size is associated with a moderate increase in the probability of a "High" perception.

A fit was made to the model which showed a deviation \(R^2\) of 16.69% and an adjusted \(R^2\) of 9.89%, with values of AIC = 87.51, AICc = 89.48, and BIC = 102.74, and an area under the ROC curve (AUC) of 0.7861, indicating acceptable performance. The Chi-square test yielded a value of 10.71 with a p = 0.098, suggesting that the model is significant overall, although not strongly so. The goodness-of-fit tests performed showed consistent results: Hosmer-Lemeshow (p = 0.115), Pearson (p = 0.109), and deviance (p = 0.082), indicating that there is no significant evidence to reject the model fit, suggesting that the model is reasonably adequate for the data analyzed.

Finally, an analysis of variance was performed for the different dimensions of the study, which revealed significant results. Gender showed statistical significance with a p-value = 0.049, indicating that there is a significant difference in the "High" perception according to the gender of the respondents. Similarly, educational level yielded a p-value = 0.040, suggesting that educational level has a significant impact on the perception of the participants. However, other variables such as age (p = 0.625), occupation (p = 0.799), income (p = 0.297), and number of people in the household (p = 0.506) did not show significant differences, implying that these dimensions do not considerably influence the "High" perception within the model evaluated.

Logistic regression model

$$P(High) = \frac{\exp(Y')}{1 + exp(Y')}$$

$$Y' = -8.29 + 1.574 * \text{Gender} + 0.145 * \text{Age} + 0.063 * \text{Ocupation} + 0.573 * \text{Education level} + 1.13 * \text{Income} + 0.143 * \text{Number of persons}$$

Figure 5 shows the Receiver Operating Characteristic (ROC) curve to evaluate the performance of the predictive model in classifying "High" versus "Not High" perceptions. The ROC curve illustrates the relationship between the true positive rate (sensitivity) and the false positive rate (1 - specificity), allowing to analyze the ability of the model to correctly discriminate between the two classes. The area under the curve (AUC) is 0.7861, indicating an acceptable performance of the model in the classification task. By common standards, an AUC close to 0.8 reflects a good discriminative ability, although there is still room for improvement of the model. In this context, the model achieves a reasonable balance between sensitivity and specificity, suggesting that it is useful for differentiating between target classes.

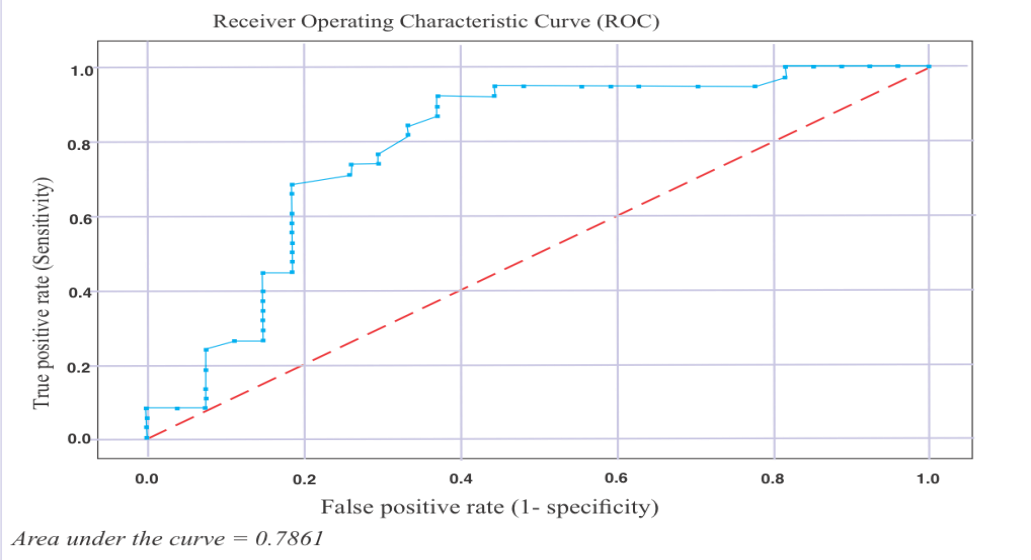

Figure 5.
Area under the curve (AUC).

4. Discussions

The logistic regression model:

$$P(High) = \frac{\exp(Y')}{1 + exp(Y')}$$

$$Y' = -8.29 + 1.574 * \text{Gender} + 0.145 * \text{Age} + 0.063 * \text{Ocupation} + 0.573 * \text{Education level} + 1.13 * \text{Income} + 0.143 * \text{Number of persons}$$

Gender, educational level, and income are shown to be the most influential factors in predicting a high perception of participatory forest management, while age and the number of people in the household have less significant effects. Occupation shows a minimal impact. This finding coincides with the results obtained by Tadesse, et al. [43], who identified that factors such as household size, educational level, income from the forest, and lack of incentives are significant predictors of participation in Participatory Forest Management (PFM). These elements share similarities with the factors highlighted in this study, which reinforces the relevance of these variables in the analysis of community participation. Moreover, Jackson, et al. [44] extend this perspective by employing a logistic regression model to reveal structural constraints in forest governance, such as legislative contradictions, ambiguity in the roles of community associations, and insufficient funding. These conclusions complement the findings of the present study by highlighting that, in addition to socioeconomic characteristics, there are institutional barriers that can influence participation. These models not only provide robust explanations of complex phenomena, as indicated by Thoker, et al. [45], but also allow the evaluation of scenarios through participatory simulations, as proposed by Wimolsakcharoen, et al. [46]. In this context, the model used in this study offers a statistically significant approach to understanding and improving PFM by identifying key factors that influence participation decisions.

When analyzing the socio-demographic characteristics of the families in the community of La Cruceta, it was observed that 65% of the respondents of the livestock and agricultural association EP-15 are women, which highlights a high female participation in local agricultural activities. This finding reinforces the role of women as key agents in decision making and resource management. According to recent research, women in rural settings contribute significantly to the agricultural economy and sustainable natural resource management [47]. The majority of participants are engaged in agriculture (63%), while 18% are homemakers and 12% are students, reflecting a significant commitment to the community economy. These results are consistent with previous studies showing how female participation in agriculture is critical to local economic development and sustainability. In terms of age distribution, 31% of respondents are between 43 and 52 years old, indicating an adult population that could play a crucial role in the transmission of traditional agricultural knowledge and practices. It is important to take advantage of this experience through intergenerational mentoring programs, as suggested by previous studies Son, et al. [48] that highlight the relevance of knowledge transmission from one generation to another to preserve sustainable practices and strengthen productive capacity.

In terms of education, the majority of respondents have incomplete secondary education, suggesting a significant opportunity to implement tailored educational programs, both formal and non-formal. This could enhance women's capacity to manage resources more efficiently, as emphasized by recent studies Begum, et al. [49]. Furthermore, education would not only increase environmental knowledge, but also strengthen the management of ecosystem services and generate new economic opportunities in the community. The economic situation of the community is a major challenge. An alarming 94% of respondents report monthly incomes between S/. 500.00 and S/. 1,000.00, which limits the ability of families to invest in productive improvements. This finding is consistent with previous research that underscores the importance of developing strategies adapted to this economic reality, such as micro-credits or subsidies, to facilitate investment in sustainable agricultural technologies and forest conservation practices. Educational levels and economic constraints are significant barriers to the adoption of sustainable management practices. As suggested by Ahononga, et al. [50] the perception of ecosystem services is influenced by socioeconomic factors, so any intervention must consider these elements to foster effective uptake.

In relation to (SFM), the findings of Savari, et al. [51] highlight several factors that positively impact community participation in conservation activities. Promoting favorable attitudes towards sustainability, improving non-forest income, and expanding information and training channels could significantly increase participation in (SFM) in La Cruceta. These approaches are crucial to strengthen conservation initiatives and improve community resilience to environmental challenges. Finally, strategic investment in educational infrastructure and community awareness programs is required. Experiences in other contexts, such as Kenya, La Fleur, et al. [52] have demonstrated the effectiveness of establishing strong mechanisms for environmental education. This experience could be replicated in La Cruceta to increase awareness of the importance of sustainable natural resource management and foster a broader commitment to conservation.

5. Conclusions

Designing a probabilistic model on the perception of participatory forest management in the Livestock and Agricultural Association EP-15, La Cruceta, Piura, shows that $P(High) = \frac{\exp(Y')}{1+exp(Y')}$ $Y' = -8.29 + 1.574 * \text{Gender} + 0.145 * \text{Age} + 0.063 * \text{Ocupation} + 0.573 * \text{Education} + 1.13 * \text{Income} + 0.143 * \text{Número of persons}$, suggests that gender, education and income are the most influential factors in predicting a high perception of participatory forest management, while age and number of people in the household have less significant effects. Occupation shows minimal impact.

The sociodemographic characteristics of the respondents of the EP-15 Livestock and Agricultural Association in the community of La Cruceta, Tambogrande district, province of Sullana, Piura-2024, show a marked female participation (65%) in agriculture (63%), with a predominantly adult population (31% between 43 and 52 years of age). The educational level is

basic, with a predominance of those who have completed secondary school (35%). The majority have monthly incomes between S/. 500 and S/. 1,000, and households tend to be of moderate size (28% with four members). This reflects a rural community with medium-low income, limited education, and a high contribution of women to the productive sector.

The results of the level of community perception and attitude towards participatory forest management show that 58% of the community has a positive attitude towards this management approach. Regarding the perception of forest resource utilization, 8% consider that utilization is high, while 55% have a moderate perception, and 37% perceive it as low. Despite these differences in the evaluation of resource use, all respondents expressed a moderate level of satisfaction with participatory management, agreeing that forest management generates important benefits for the community. This pattern of results suggests widespread acceptance of the participatory forest management model, although with variations in perceived effectiveness in maximizing forest resource utilization.

The level of influence of socio-demographic characteristics on the perception and attitude of the community towards participatory forest management varied according to the attributes analyzed. Occupation presented the greatest influence (information gain: 0.1342), followed by educational level (0.0996), which also showed a significant gain. To a lesser extent, gender was influential (0.0669), followed by age (0.0508). Income showed low significance (0.0248), while the number of people in the household had no prominent influence (0.0000).

Finally, the main limitations of the study include the sample size, which prevents generalizing the results to larger or more diverse populations. The analysis did not consider in depth the cultural context, which could influence perceptions. In addition, the predictive model showed acceptable but not excellent performance, suggesting that there are uncaptured factors that limit the validity and applicability of the results.

In the future, it is recommended that the sample be expanded to include other communities to improve external validity. In addition, it is suggested to explore more variables, such as socio-cultural attitudes and the long-term effects of forest management. It is also proposed to use advanced statistical techniques, such as multiple regression or machine learning, to improve prediction and obtain more accurate conclusions.

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