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Analyzing Internal and External Factors for Ecological Preservation in San Juan de Pastocalle: A Combined SWOT and Neutrosophic AHP Approach

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Abstract. This study aimed to analyze the role of Community Circles in preserving the ecological link in the rural parish of San Juan de Pastocalle, identifying both the factors that enhance and those that limit this process. The SWOT analysis combined with the neutrosophic AHP method was applied to evaluate the key elements that affect ecological sustainability in the community. The results revealed that the main weaknesses were the lack of training in adequate recycling and the poor infrastructure for waste management. Strategic actions focused on strengthening local capacities and ensuring economic support were proposed. The use of decision-making methods applying neutrosophic logic allowed for a more precise and objective evaluation. The importance of neutrosophy in addressing uncertainty in the management of complex problems is highlighted.

Keywords: ecological sustainability, decision-making, Neutrosophy, SWOT, AHP.

1 Introduction

The relationship between human communities and their ecological environment has garnered increasing interest in recent decades due to the environmental impacts arising from urbanization, climate change, and the degradation of natural resources. In this context, the preservation of local ecological areas emerges as a key challenge for rural communities, where the integration of inhabitants with their natural environment remains essential for ensuring the sustainability of ecosystems [1]. In many of these communities, Community Circles play a fundamental role by promoting ecological awareness and facilitating active citizen participation in environmental protection.

Community Circles are spaces where community members gather to discuss topics of common interest, with the relationship between humans and the ecological environment occupying a central place. In the rural parish of San Juan de Pastocalle, these activities have proven to be an effective vehicle for raising awareness among residents about the importance of respecting nature, managing waste, and exercising environmental rights. However, there remains concern about the lack of practical application of these values in the community's daily life, limiting the effectiveness of local environmental conservation initiatives. This disconnection between theory and practice, between ecological awareness and real action, represents a key challenge facing the parish in its attempt to preserve the ecological bond with its environment. [2]

The ecological bond is understood as the intrinsic relationship between people and the ecosystems in which they live. The conservation of this bond is essential to ensure that communities can manage their natural resources sustainably. Various studies have shown that local communities, particularly those in ecologically valuable areas, are the best managers of their natural resources due to their traditional knowledge and practices passed down over time [3], [4]. In this regard, the role of Community Circles in San Juan de Pastocalle is crucial, as these initiatives promote the transmission of traditional knowledge and practices that strengthen the bond between inhabitants and their natural environment, while also fostering community cooperation around common environmental goals.

However, in a context where decision-making is characterized by uncertainty and complexity, it is necessary to employ analytical methods that allow for addressing problems in a structured and systematic way [5]. In this regard, the use of decision-making tools presents itself as a convenient option to evaluate the various factors affecting the effectiveness of Community Circles in preserving the ecological bond. In this framework, the SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) can help identify strengths to be leveraged, weaknesses to be addressed, opportunities to be explored, and threats to be mitigated. [6]

However, SWOT analysis alone cannot provide a quantitative evaluation or effectively resolve the contradictions and imprecision inherent in decisions that need to be made in situations of uncertainty [7]. In this context, the integration of the AHP (Analytic Hierarchy Process) method in its neutrosophic variant emerges as a solution to address these limitations [8]. AHP is a multi-criteria decision-making technique that allows for ranking different alternatives according to established criteria. Its combination with neutrosophic set theory overcomes problems of indeterminacy and lack of precision in evaluations; as this approach considers not only the truth and falsehood of options but also the degrees of indeterminacy that often characterize real-world situations. [9]

Neutrosophic theory is particularly useful in contexts where evaluation criteria are ambiguous or uncertain [10], [11], such as environmental management in rural communities. By incorporating the notion of indeterminacy, this approach allows for a more accurate representation of the complexity of decisions that must be made in ecological and social fields [12], [13].

The objective of this study is to analyze how Community Circles contribute to the preservation of the ecological bond in the rural parish of San Juan de Pastocalle, evaluating both the factors that enhance and those that limit this process. By applying SWOT analysis combined with neutrosophic AHP, the study seeks to identify the most effective strategies for optimizing the impact of Community Circles on the ecological and social environment of the community.

2 Preliminaries

2.1 Definitions

Definition 1: A Neutrosophic set N is defined by three membership functions: the truth-membership function T_A, the indeterminacy-membership function I_A, and the falsehood-membership function F_A. These functions are applied to the universe of discourse U where for any element $x \in U$, $T_A(x)$, $I_A(x)$, and $F_A(x)$ belong to the interval $]-0,1+[$, and the following condition holds: $-0 \leq \inf T_A(x) + \inf I_A(x) + \inf F_A(x) \leq \sup T_A(x) + \sup I_A(x) + \sup F_A(x) \leq 3+$. [14]

It is important to note that according to this definition, the membership functions, $T_A(x)$, $I_A(x)$, and $F_A(x)$ are real standard or non-standard subsets of $]-0,1+[$ implying that these functions can be subintervals of $[0,1]$.

Definition 2: The Single-Valued Neutrosophic Set (SVNS) N over U is $A = \{< x;\, T_A(x), I_A(x), F_A(x) >: x \in U\}$, where $T_A: U \to [0,1], I_A: U \to [0,1]$, and $F_A: U \to [0,1]$, with the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The Single-Valued Neutrosophic Number (SVNN) is represented by $N = (t, i, f)$, such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3: According to [15], the single-valued trapezoidal neutrosophic number, $\tilde{a} = \langle (a_1, a_2. a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, where the truth, indeterminacy, and falsehood membership functions are defined as follows:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, \quad a_2 \leq x \leq a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), a_3 \leq x \leq a_4 \\ 0, \quad otherwise \end{cases} \tag{1}$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2 - x + \beta_{\tilde{a}}(x - a_1))}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{(x - a_2 + \beta_{\tilde{a}}(a_3 - x))}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2 - x + \gamma_{\tilde{a}}(x - a_1))}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \gamma_{\tilde{a}}, & a_2 \leq x \leq a_3 \\ \frac{(x - a_2 + \gamma_{\tilde{a}}(a_3 - x))}{a_3 - a_2}, & a_3 \leq x \leq a_4 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0,1]$, $a_1, a_2, a_3, a_4 \in \mathbb{R}$ and $a_1 \leq a_2 \leq a_3 \leq a_4$.

Definition 4: given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$ (4)

Subtraction: $\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$ (5)

Inversion: $\tilde{a}^{-1} = \langle (a_4^{-1}, a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, where $a_1, a_2, a_3, a_4 \neq 0$. (6)

Multiplication by a scalar number: $\lambda\tilde{a} = \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases}$ (7)

Division by a scalar number: $\frac{\tilde{a}}{\lambda} = \begin{Bmatrix} \langle (\frac{a_1}{\lambda}, \frac{a_2}{\lambda}, \frac{a_3}{\gamma\lambda}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle \ if\ (\lambda > 0) \\ \langle (\frac{a_3}{\gamma\lambda}, \frac{a_2}{\lambda}, \frac{a_1}{\lambda}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \beta\gamma_{\tilde{a}} \rangle \ if\ (\lambda < 0) \end{Bmatrix}$ (8)

Division: $\frac{\tilde{a}}{\tilde{b}} = \{ \begin{matrix} \langle (\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \theta\beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 > 0, b_3 > 0) \\ \langle (\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 < 0, b_3 > 0) \\ \langle (\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle \ if\ (a_3 < 0, b_3 < 0) \end{matrix}$ (9)

2.2 Neutrosophic SWOT-AHP basics

The application of the Neutrosophic Analytic Hierarchy Process (N-AHP) allows the use of a linguistic scale instead of a numerical one, offering a more intuitive approach for experts [16]. The original numerical scale proposed by Saaty is adapted into a linguistic framework, as illustrated in Table 1. This adaptation enables experts to evaluate elements, such as ethical considerations in supply chains, using linguistic terms rather than numerical values, which is often more natural for subjective assessments.

Table 1: Saaty's scale translated into a Triangular Neutrosophic Scale. Source: [8]

Definition	Triangular Neutrosophic Scale
Equally influential	$\tilde{1} = \langle (1,1,1); 0.50, 0.50, 0.50 \rangle$
Slightly influential	$\tilde{3} = \langle (2,3,4); 0.30, 0.75, 0.70 \rangle$
Strongly influential	$\tilde{5} = \langle (4,5,6); 0.80, 0.15, 0.20 \rangle$
Very strongly influential	$\tilde{7} = \langle (6,7,8); 0.90, 0.10, 0.10 \rangle$
Absolutely influential	$\tilde{9} = \langle (9,9,9); 1.00, 1.00, 1.00 \rangle$

Definition	Triangular Neutrosophic Scale
Intermediate values	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$ $\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$ $\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$ $\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

The SWOT-AHP involves the execution of the following procedures:

Step 1: Form a team of experts familiar with SWOT analysis. This team identifies internal and external factors essential to the analysis through methods such as surveys or interviews.

Step 2: Establish a hierarchical framework for the problem. This hierarchy typically has four levels:

1. The organizational goal or primary objective.
2. Strategic criteria identified by the SWOT framework (Strengths, Weaknesses, Opportunities, and Threats).
3. Sub-criteria, which detail the elements within each strategic criterion.
4. Strategies or alternatives to be evaluated.

Step 3: Develop a neutrosophic pairwise comparison matrix to assess the relative importance of criteria, sub-criteria, and alternatives. Linguistic terms (from Table 1) are used to quantify the relationships, capturing expert judgments effectively. The neutrosophic scale is attained according to expert opinion. The neutrosophic pairwise comparison matrix of factors, sub-factors, and strategies are as follows:

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} \cdots & \tilde{1} \end{bmatrix} \quad (10)$$

The matrix satisfies the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, b based on inversion principles.

Step 4: Ensure consistency in the pairwise comparison matrix. Consistency is evaluated by verifying if the transitive relationship $a_{ik} = a_{ij a_{jk}}$ holds for all combinations of i, and k. This analysis focuses on the lower, middle, and upper bounds of the triangular neutrosophic numbers.

Step 5: Calculate weights for factors (S, W, O, T), sub-factors, and alternatives. This is achieved by converting the neutrosophic pairwise comparison matrix into deterministic values using equations for scoring and accuracy:

Let $\tilde{\alpha}\_ij = \langle(a_1, b_1, c_1), \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle$ represent a singular triangular neutrosophic number; then,

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (11)$$

and

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (12)$$

Which are the score and accuracy degrees of $\tilde{a}_{ij}$ respectively.

To get the score and the accuracy degree of $\tilde{a}_{ij}$, following equations are used:

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \quad (13)$$

$$A(\tilde{a}_{ji}) = 1/A(\tilde{a}_{ij}) \quad (14)$$

Through the evaluation and scoring of each triangular neutrosophic number within the neutrosophic pairwise comparison matrix, the subsequent deterministic matrix is obtained:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (15)$$

Determine the order of precedence, denoted as the Eigen Vector X, from the preceding matrix, through the following steps:

1. Standardize the values within each column by dividing each entry by the sum of the respective column.

2. Calculate the cumulative average for each row.

Step 6: Determine the overall priority of strategies by aggregating weights using Equation (16). The overall weight value for alternative j (j=1,…,) can be expressed as follows:

$$Tw_{\text{Alt}_j} = w_S * \sum_{i=1}^{n} w_{S_i} * w_{\text{Alt}_j} + w_W * \sum_{i=1}^{n} w_{W_i} * w_{\text{Alt}_j} + w_O * \sum_{i=1}^{n} w_{O_i} * w_{\text{Alt}_j} + w_T * \sum_{i=1}^{n} w_{T_i} * w_{\text{Alt}_j} \quad (16)$$

where (i=1,…,n) and (wS,wW,wO,wT) are the weights of Strengths, Weaknesses, Opportunities, and Threats; (wSi,wWi,wOi,wTi) are the sub-factor weights; and $w\text{Alt}j$ is the weight of the alternative j, corresponding to its sub-factor.

3 Results

The data collection was based on a sample of 100 individuals with direct connections to elements related to environmental impact and the ecological bond in their surroundings. Through interviews and surveys, internal and external factors were identified that explain how Community Circles influence this bond in the rural parish of San Juan de Pastocalle, evaluating both strengths and limitations. Subsequently, the information was refined with the collaboration of five experts. The identified factors are presented below:

Table 2: Identified internal and external factors

Internal Factors		External Factors	
Strengths	**Weaknesses**	**Opportunities**	**Threats**
Active participation in ecological activities (51.85% are willing to participate in environmental volunteering)	Lack of knowledge about the concept of ecological bond (19.37% of respondents do not understand it well)	Growth of environmental awareness at national and global levels	Disinterest in the impact of climate change (53.33% consider climate change not a priority for many)
Interest in environmental conservation (72.59% of respondents support conservation)	Low infrastructure for waste management (34.81% disagree with the existence of collection points)	Recent alliances between public and private sectors for sustainability projects	Destruction of habitats due to human activities (55.56% point to deforestation as a threat)
Community commitment to ecological care (45.93% engage in waste collection)	Lack of training in proper recycling (problems with waste classification)	Strengthening teamwork through Community Circles to implement ecological measures	Lack of financial support for high-impact environmental activities
Support from local authorities for ecological projects (52.22% support governmental conservation initiatives)	Limited participation from certain sectors in decision-making (some voices are not heard in community processes)		
Existence of organized environmental groups (38.89% of the population belongs to an ecological group)			

The identified elements formed the basis of the study, which was developed according to the proposed methodology. After determining the internal and external factors influencing the system, the next step was to evaluate them in order to identify those with the greatest impact on its functioning, based on expert judgment. The analysis was carried out sequentially, starting with the evaluation of the components of the SWOT matrix, as detailed in Table 3, followed by the ranking of the factors according to their relative importance.

Table 3: Evaluation Matrix of the SWOT Criteria (S, W, O, T). Source: Own elaboration.

	S	O	W	T
S	(1,1,1); 0.5, 0.5, 0.5	(2, 3, 4); 0.3, 0.75, 0.7	(4, 5, 6); 0.8, 0.15, 0.2	(2, 3, 4); 0.3, 0.75, 0.7
O	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1,1,1); 0.5, 0.5, 0.5	(1,1,1); 0.5, 0.5, 0.5	(4, 5, 6); 0.8, 0.15, 0.2
W	(1/6, 1/5, 1/4); 0.8, 0.15, 0.2	(1,1,1); 0.5, 0.5, 0.5	(1,1,1); 0.5, 0.5, 0.5	(2, 3, 4); 0.3, 0.75, 0.7
T	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1/6, 1/5, 1/4); 0.8, 0.15, 0.2	(1/4, 1/3, 1/2); 0.3, 0.75, 0.7	(1,1,1); 0.5, 0.5, 0.5

After performing the corresponding calculations with the data presented in Table 3, a numerical matrix was generated to undergo the standard AHP Method process. This procedure included verifying the consistency ratio and obtaining the weight matrix associated with the analyzed criteria, W = (0.22; 0.10; 0.49; 0.19). Similarly, this analysis was applied to each criterion of the SWOT diagnosis, allowing for the derivation of the weight vector for the identified internal and external factors. Table 4 summarizes the obtained results.

Table 4: Evaluation matrix of SWOT criteria. Source: Own elaboration

	Factors	**Global Weight Vector**
Strengths	Active participation in ecological activities	0.03
	Interest in environmental conservation	0.02
	Community commitment to ecological care	0.06
	Support from local authorities in ecological projects	0.02
	Existence of organized groups in favor of the environment	0.09
Opportunities	Growth of environmental awareness at national and global levels	0.05
	Recent alliances between public and private sectors for sustainability projects	0.01
	Strengthening teamwork through Community Circles for ecological measures	0.04
Weaknesses	Lack of knowledge about the concept of ecological link	0.08
	Low infrastructure for waste management	0.16
	Lack of training in proper recycling	0.20
	Limited participation of certain sectors in decision-making	0.06
Threats	Disinterest in the impact of climate change	0.04
	Habitat destruction due to human activities	0.04
	Lack of financial support for high-impact environmental activities	0.11

The SWOT analysis applied to the system revealed a predominance of weaknesses over other evaluated elements. The factors with the highest global weight were the *Lack of training in proper recycling* (0.20) and the *Low infrastructure for waste management* (0.16). This highlighted that, according to expert judgment, these weaknesses represented the main barriers to preserving the ecological link in the rural parish of San Juan de Pastocalle.

Additionally, the threat related to the lack of economic support for high-impact environmental activities (0.11) also received a significant weight. This result emphasized the need to implement survival strategies to mitigate the negative effects of these weaknesses and threats. Although the strengths and opportunities had less influence, it is important to highlight that the *Existence of organized groups in favor of the environment* (0.09) was the main strength. Although this element carried less weight, it could be key in promoting collective and sustainable actions.

In this context, the study underscored the urgency of prioritizing actions that strengthen local capacities in recycling and infrastructure, as well as ensuring adequate economic support. These measures would optimize the impact of the Community Circles in preserving the ecological link.

Additionally, a PEST analysis [17] was conducted based on the detected elements. Table 5 summarizes the main elements developed.

Table 5: PEST analysis for the solution of detected elements

Dimension	Context	Proposed Actions
Political	Insufficient support from local and national authorities for sustainability projects.	Promote public policies that fund waste management infrastructure.
	Incorporate the parish into national sustainability and ecological linkage programs.	
Economic	Limited financial support for high-impact environmental initiatives.	Establish public-private partnerships to finance recycling projects and ecological activities.
	Scarcity of investment in infrastructure for waste management.	Create microcredit programs and specific subsidies to improve community facilities.
Social	Lack of training in recycling and low participation from specific sectors.	Implement educational workshops on recycling within the Community Circles.
	Weak awareness of the importance of ecological linkage.	Develop awareness campaigns through local media and school activities.
Technological	Lack of appropriate infrastructure for waste management.	Introduce accessible technologies for waste separation and recycling.
	Train residents in sustainable technological practices through interactive workshops.	

4 Conclusion

The conducted study demonstrated that the use of the SWOT analysis combined with the neutrosophic AHP method effectively identified the weaknesses limiting the preservation of the ecological linkage in the rural parish of San Juan de Pastocalle. The application of Neutrosophy, in particular, proved essential for managing the inherent uncertainty in the expert evaluation of the factors, providing a clearer and more objective view of the influence of the various elements. This methodological approach enabled a thorough analysis, facilitating strategic decision-making to strengthen the most critical areas of the system.

The results underscore the importance of addressing weaknesses related to waste management infrastructure and recycling training as priorities to optimize the impact of the Community Circles. Moreover, the application of these decision-making methods highlighted the need for comprehensive solutions that include inter-institutional cooperation and economic strengthening, in order to ensure the sustainability of ecological activities within the community. The study opens new research opportunities, highlighting how multicriteria methods can be valuable tools in managing complex problems in community contexts.

References

[1] C. Mestanza-Ramón *et al.*, "A review to update the Protected Areas in Ecuador and an analysis of their main impacts and conservation strategies," *Environments*, vol. 10, no. 5, p. 79, 2023

[2] S. Kanwal, M. I. Rasheed, A. H. Pitafi, A. Pitafi, and M. Ren, "Road and transport infrastructure development and community support for tourism: The role of perceived benefits, and community satisfaction," *Tour. Manag.*, vol. 77, p. 104014, 2020

[3] L. C. Kluger, P. Gorris, S. Kochalski, M. S. Mueller, and G. Romagnoni, "Studying human–nature relationships through a network lens: A systematic review," *People Nat.*, vol. 2, no. 4, pp. 1100–1116, 2020

[4] E. S. Brondízio *et al.*, "Locally based, regionally manifested, and globally relevant: Indigenous and local knowledge, values, and practices for nature," *Annu. Rev. Environ. Resour.*, vol. 46, no. 1, pp. 481–509, 2021,.

[5] M. Abdar *et al.*, "A review of uncertainty quantification in deep learning: Techniques, applications and challenges," *Inf. fusion*, vol. 76, pp. 243–297, 2021.

[6] A. Stacchini, A. Guizzardi, and A. Mariotti, "Smoothing down arbitrariness in planning: From SWOT to participatory decision making," *Land use policy*, vol. 119, p. 106213, 2022.

[7] H. Aghasafari, A. Karbasi, H. Mohammadi, and R. Calisti, "Determination of the best strategies for development of organic farming: A SWOT–Fuzzy Analytic Network Process approach," *J. Clean. Prod.*, vol. 277, p. 124039, 2020.

[8] M. Abdel-Basset, M. Mohamed, and F. Smarandache, "An extension of neutrosophic AHP–SWOT analysis for strategic planning and decision-making," *Symmetry (Basel).*, vol. 10, no. 4, p. 116, 2018.

[9] M. Junaid, Y. Xue, M. W. Syed, J. Z. Li, and M. Ziaullah, "A neutrosophic ahp and topsis framework for supply chain risk assessment in automotive industry of Pakistan," *Sustainability*, vol. 12, no. 1, p. 154, 2019.

[10] N. Olgun and A. Hatip, "The effect of the neutrosophic logic on the decision tree," *Quadruple Neutrosophic Theory Appl. Pons Ed. Brussels, Belgium, EU*, vol. 17, pp. 238–253, 2020.

[11] F. Smarandache, "Introduction to NeutroAlgebraic Structures and AntiAlgebraic Structures (revisited).," *Neutrosophic Sets Syst.*, vol. 31, pp. 1–17, 2020.

[12] J. C. de J. Arrias Añez, F. C. Bandera, L. R. Ayala Ayala, J. C. Nevárez Moncayo, and M. D. L. C. Salabarría Roig, "Neutrosophic analysis of the origin of domestic violence," *Neutrosophic sets Syst.*, vol. 44, pp. 26–34, 2021.

[13] C. G. R. Martínez, I. J. D. Basurto, F. A. G. Almache, and J. P. R. Carpio, "Neutrosophic Assessment of Corporate Responsibility in Ecuador's Environmental Context.," *Neutrosophic Sets Syst.*, vol. 62, pp. 51–59, 2023.

[14] N. El-Hefenawy, M. A. Metwally, Z. M. Ahmed, and I. M. El-Henawy, "A review on the applications of neutrosophic sets," *J. Comput. Theor. Nanosci.*, vol. 13, no. 1, pp. 936–944, 2016.

[15] I. Deli, "Operators on single valued trapezoidal neutrosophic numbers and SVTN-group decision making," *Neutrosophic Sets Syst.*, vol. 22, pp. 131–150, 2018.

[16] J. Chen, S. Zeng, and C. Zhang, "An OWA distance-based, single-valued neutrosophic linguistic topsis approach for green supplier evaluation and selection in low-carbon supply chains," *Int. J. Environ. Res. Public Health*, vol. 15, no. 7, p. 1439, 2018.

[17] M. LEYVA, J. HECHAVARRIA, N. BATISTA, J. A. ALARCON, and O. GOMEZ, "A framework for PEST analysis based on fuzzy decision maps.," *Rev. Espac.*, vol. 39, no. 16, 2018,

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