Neutrosophic Likert Scale for Evaluating Environmental Sanctions

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Abstract

One of the fundamental tools to guarantee compliance with environmental laws is the sanctions, which act as deterrent mechanisms against possible violations. The present study focused on evaluating public perceptions towards environmental policies and sanctions, applying a methodology that integrates neutrosophy and indeterminate Likert scales to capture the complexity of human opinions on environmental legislation. By distributing a structured questionnaire to a representative sample, data was collected and subsequently analyzed using neutrosophic logic and cluster analysis techniques. The results underlined the importance of considering indeterminacy and uncertainty in the study of public perceptions towards environmental sanctions, providing valuable data for the improvement of environmental policies and communication in this area. This study demonstrates the relevance of addressing human attitudes and behaviors toward environmental challenges inclusively and effectively.

Keywords: environmental sanctions; neutrosophy; public perceptions; environmental legislation; discretionary application

1. Introduction

The protection and preservation of the environment is an unavoidable imperative in the 21st century, given the growing concern about the negative impacts that human activity has generated on nature. Environmental degradation, climate change, and biodiversity loss are global challenges that threaten the sustainability of our planet and, therefore, the quality of life of present and future generations.[1]

In response to the urgent need to care for the natural environment, governments and societies have established increasingly stringent environmental legislation. These regulations aim to regulate and control human activities that can cause harm to the environment and, in turn, promote more sustainable and responsible practices.

One of the fundamental tools to ensure compliance with these laws is environmental sanctions, which act as deterrent mechanisms against potential infringements. These sanctions, whether economic, administrative, or criminal, intend to discourage harmful behaviors and ensure respect for established environmental regulations [2]. However, as the application of environmental laws becomes more effective, questions arise regarding the suitability and equity of the imposed sanctions. It is necessary

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

to examine in detail whether the penalties are proportional to the degree of damage caused, whether they match the severity of the infringements, and whether they truly fulfill their goal of prevention and correction. [3]

The debate on the effectiveness and fairness of environmental sanctions also focuses on how these affect different social actors. It is crucial to consider how these sanctions can impact small businesses, local communities, or individuals with limited resources, to prevent inequalities or injustices in their application. [4]

In the Ecuadorian context, the protection and preservation of the environment have become a matter of utmost priority in recent years. The country, known for its biological diversity and natural wealth, faces significant environmental challenges that require decisive action to ensure sustainability and well-being for future generations. In response to this need, the Ecuadorian State has enacted increasingly stringent environmental laws and regulations, seeking to establish a solid legal framework that regulates and controls the use of natural resources, as well as economic activities that may impact the natural environment. [5]

The main objective of these laws and regulations is to safeguard the environment and promote sustainable development in the country. The aim is to balance economic growth with the protection of the natural environment so that productive activities are sustainable and do not negatively affect ecosystems and biodiversity.

The adoption of stricter environmental legislation seeks not only to protect the environment but also to fulfill international commitments regarding conservation and climate change. Ecuador, as a signatory to various international agreements, has taken on the responsibility to contribute to the fight against climate change and the preservation of biodiversity. [6]

Such is the case of the Unified Text of Secondary Legislation of the Ministry of the Environment (TULSMA) which is an essential regulation in Ecuador for comprehensively regulating environmental issues. It compiles various laws and regulations into a single document, facilitating access to up-to-date information. TULSMA covers fundamental aspects such as pollution prevention and the sustainable management of natural resources, in addition to establishing sanctions for those who violate environmental norms. However, a critical evaluation of its application is required to ensure that sanctions are fair and proportional, thus guaranteeing the effective protection of the environment. It is crucial to assess whether environmental sanctions are being applied consistently and equitably, avoiding any hint of discretion or arbitrariness. A fair application of sanctions is fundamental to maintaining public trust in the environmental justice system and ensuring that the regulations are effectively respected by all sectors of society.

In this sense, addressing the evaluation methodologies that allow measuring public perception of these measures is crucial. The Likert scale emerges as a valuable tool for investigating attitudes and opinions regarding environmental policies and sanctions. The application of the Likert scale in studies on environmental legislation offers a structured and quantifiable way of collecting data, providing insights into the acceptance, effectiveness, and perception of fairness in imposed sanctions. [7]

A traditional Likert scale consists of a series of statements that respondents assess based on a range of agreement or disagreement, usually in five or seven points. However, the implementation of a Likert scale with indeterminate options adds a dimension to the analysis, more faithfully reflecting the complexity of human opinions in the context of environmental policies. [8]

The inclusion of indeterminacies in the Likert scale is justified by the reality that perceptions and attitudes toward environmental sanctions are not always absolute. This approach allows respondents to express uncertainty or neutrality, avoiding the false dichotomy of forced positive or negative responses that can distort the results and interpretations [9]. In the realm of environmental legislation, where opinions can be influenced by a wide range of factors—such as specific knowledge on the topic, personal experiences, and the perceived impact of sanctions on various sectors—capturing this ambiguity is essential to obtain a more accurate picture of public opinion.

In this regard, it is pertinent to explore the use of neutrosophy as a theoretical and methodological framework to enrich the interpretation of these data. Neutrosophy, conceived by Florentin Smarandache in the last years of the 20th century, focuses on the study of the neutral, or the intermediate state between two opposite poles, such as true and false, or agreement and disagreement

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

[10], [11]. This approach is especially relevant for the analysis of data collected through Likert scales with indeterminate options, as it provides conceptual and analytical tools to handle the uncertainty and indeterminacy present in the responses.

The application of neutrosophy in the analysis of data obtained through indeterminate Likert scales allows for an effective approach to the ambiguity inherent in perceptions and opinions on complex issues like environmental legislation. Neutrosophy introduces the concept of neutrosophic triads, composed of true, false, and indeterminate, enabling a more granular and representative analysis of the data [12]. This theoretical framework recognizes that respondents' answers often reflect a mixture of these three elements, thereby overcoming the limitation of binary or simplistic approaches.

In this context, the purpose of this research focuses on the use of indeterminate Likert scales for the assessment of current legislation in the environmental field, particularly regarding the regulation of sanctions for infringements related to the management and supervision of the environment. The aim is to explore, evaluate, and verify the relevance or capacity of indeterminate Likert scales, through the prism of neutrosophy, for the improvement of policies and practices in conservation and environmental protection.

In the following sections, different perspectives and arguments will be presented to allow for a comprehensive and enriching analysis, seeking to contribute to the academic and legal debate surrounding the effectiveness and fairness of environmental sanctions in today's Ecuadorian society.

2. Neutrosophy and refined neutrosophic set

Neutrosophy, familiarized by Smarandache (2000), studies a perception or event or entity, “A” in relation to its opposite, “Anti- *A*” and not *A*, “Non- *A*”, and as neither “*A*” nor “Anti*A*”, denoted by “Neut-*A*”.

Let us denote X as a metric space, where individual entities within X are symbolized by x. In this context, a single-valued neutrosophic set (SVNS) A within the space X is defined by the following membership functions: the truth function $T_{A(x)}$, the indeterminacy function $I_{A(x)}$, and the falsity function $F_{A(x)}$. For an arbitrary point x in X, the values of $T_{A(x)}$, $I_{A(x)}$, and $F_{A(x)}$ are confined to the closed interval $[0,1]$, fulfilling the condition $0 \leq T_{A(x)} + I_{A(x)} + F_{A(x)} \leq 3$). The SVNS A is thus represented as $A = \{ x, T_{A(x)}, I_{A(x)}, F_{A(x)} | x \in X \}$.[13]

According to the refined neutrosophic logic as formulated by Smarandache, we have the following:[14]

Definition 1: The concept of truth T is fractionated into distinct subclasses $T_1, T_2, \dots, T_p$; similarly, indeterminacy I is categorized into $I_1, I_2, \dots, I_r$, and falsity F into $F_1, F_2, \dots, F_s$. Here, p, r, and s are all positive integers such that $p + r + s = n$.

Triple refined indeterminate neutrosophic sets (TRINS) further refine the notion of indeterminacy into three distinct memberships, enhancing both precision and applicability to contexts like the Likert scale. TRINS have been applied in areas such as personality classification. In contrast, a double-valued neutrosophic set (DVNS) bifurcates the concept of indeterminacy into two components.

Definition 2: A TRINS A in X, as previously outlined, is identified by five membership functions, namely positive $P_{A(x)}$, indeterminate $I_{A(x)}$, negative $N_{A(x)}$, positively indeterminate $IP_{A(x)}$, and negatively indeterminate $IN_{A(x)}$, each accompanied by a respective weight $w_m \in [0,5]$. For every $x \in X$, we stipulate:

$P_A(x), IP_A(x), I_A(x), IN_A(x), N_A(x) \in [0,1]$

and their weighted equivalents:

$w_m P(P_A(x)) , w_m IP(IP_A(x)) , w_m I(I_A(x)) , w_m IN(IN_A(x)) , w_m N(N_A(x)) \in [0,5]$

subject to the constraint:

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

$0 \leq P_A(x) + IP_A(x) + I_A(x) + IN_A(x) + N_A(x) \leq 5$

The TRINS A is thus notated as:

$A = \{ x, P_A(x), IP_A(x), I_A(x), IN_A(x), N_A(x) | x \in X \}$

Consider two sets of Triple Refined Indeterminate Neutrosophic Sets (TRINS), designated A and B, defined in the metric space X. The intersection of A and B produces a third TRINS C, expressed as $C = A \cap B$. The membership formulation of C in terms of truth, indetermination towards truth, indetermination, indetermination towards falsehood, and falsehood is determined by the following functional relationships based on the corresponding membership values of A and B:

$T_{C(x)} = \min(T_{A(x)}, T_{B(x)})$

$IT_{C(x)} = \min(IT_{A(x)}, IT_{B(x)})$

$I_{C(x)} = \min(I_{A(x)}, I_{B(x)})$

$IF_{C(x)} = min(IF_{A(x)}, IF_{B(x)})$

$F_{C(x)} = \max(F_{A(x)}, F_{B(x)})$

In the context of refined neutrosophy, the fourth definition is introduced for the calculation of the generalized weight, which synthesizes the influence of all the membership functions within the framework of the TRINS. This definition is crucial for evaluating the relevance and contribution of each membership function to the overall value of a neutrosophic set. The generalized weighting for a TRINS A, symbolized by w_A, is mathematically defined as:

$$w_A = (\sum_{i=1}^{n} w^T T_{A(x_i)} + w^I IT_{A(x_i)} + w\, I_{A(x_i)} + w^F IF_{A(x_i)} + w^N F_{A(x_i)}) \quad (1)$$

Here, w^T, w^I, w, w^F, and w^N represent the weights associated with the membership functions for truth, indetermination towards truth, indetermination, indetermination towards falsehood, and falsehood, respectively. These weights play a crucial role in evaluating the relevance of the various membership functions within the neutrosophic set and in determining their contribution to the broader theoretical construct of neutrosophic analysis.

3. Materials and Methods

An analytical and critical scientific investigation was carried out. The analytical approach allowed for the examination of legal and regulatory provisions in environmental matters, as well as the analysis of sanctions imposed in specific cases. A thorough analysis of existing laws and regulations was conducted to understand their scope and applicability in real situations.

The study was structured under a descriptive research design, using a quantitative methodology for the analysis of data collected through a structured questionnaire. The research is categorized as applied, as it seeks to generate practical knowledge to evaluate and potentially improve the practices and policies of environmental sanctions in Ecuador. It focused on the collection of empirical data through surveys directed at a sample of 25 legal professionals, thus providing valuable information for the critical and legal analysis of environmental sanctions.

A cross-sectional design was chosen, where data collection was carried out at a single point in time, allowing for a snapshot of the respondents' opinions and attitudes regarding the subject of study. This approach facilitated the efficient administration of the questionnaire and the rapid obtaining of results for subsequent analysis.

Data collection was carried out through the distribution of a structured online questionnaire, ensuring an effective and accessible method to reach practicing legal professionals. The questionnaire included sections dedicated to personal information, knowledge of environmental legislation, familiarity with specific environmental sanctions, opinions on the fairness and adequacy of these sanctions, and the importance of critical social and legal analysis. To ensure informed and reflective responses, respondents were asked to provide arguments supporting their opinions. The applied structured questionnaire was composed as follows:

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

Section 1: Personal Information

- Name
- Email
- Years of experience practicing law

Section 2: Knowledge of Environmental Legislation

4. On a scale of 1 to 5, how familiar are you with the Unified Text of Secondary Legislation of the Ministry of the Environment (TULSMA)?

- 1: Not familiar at all
- 2: Slightly familiar
- 3: Indeterminate/Neutral
- 4: Quite familiar
- 5: Very familiar

Section 3: Knowledge of Environmental Sanctions

5. To what extent are you aware of the fines established for not regulating economic activities that impact the environment according to TULSMA?

- 1: Not aware at all
- 2: Slightly aware
- 3: Indeterminate/Neutral
- 4: Quite aware
- 5: Very aware

6. Did you know about the range of environmental fines contemplated in the TULSMA, between 20 and 200 unified basic remunerations?

- 1: I was not aware
- 2: I was somewhat aware
- 3: Indeterminate/Neutral
- 4: I had partial knowledge
- 5: I was fully informed

Section 4: Opinion on Environmental Sanctions

7. Do you consider that the fines established in Art. 279 and 283 of the TULSMA are proportional and adjust to the socioeconomic reality of the subject of control?

- 1: Completely disproportionate
- 2: Somewhat disproportionate
- 3: Indeterminate/Neutral
- 4: Somewhat proportional
- 5: Completely proportional

8 Do you believe that the fines set comply with the principles of proportionality and legal certainty?

- 1: They do not comply at all
- 2: They comply little
- 3: Indeterminate/Neutral
- 4: They largely comply
- 5: They fully comply

Section 5: Importance of Critical Social and Legal Analysis

9. How important do you consider the development of a critical social and legal analysis on the consequences of imposing environmental sanctions discretionally?

- 1: Not important at all
- 2: Slightly important
- 3: Indeterminate/Neutral
- 4: Quite important
- 5: Very important

Section 6: Additional Comments

10. If you wish to add any comments or additional information on the subject, please do so in the space below.

The design of the implemented questionnaire allowed participants, in each item, to indicate their level of agreement, covering, in different ways, from the most negative aspect or completely disagreeing to the most positive aspect or completely agreeing with the proposal presented, assigning to each statement a valuation within a scale of 0 to 1.

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Once the results were obtained, the TRINS matrix was constructed for each respondent, taking each rating per statement as an indeterminate Likert scale with (1) negative membership, (2) indetermination inclined towards negative membership, (3) indeterminate membership, (4) indetermination inclined towards positive membership, and (5) positive membership. Thus, for each respondent, it was possible to obtain their degree of acceptance of the statements, and the responses to each question in the form of TRINS, denoted as G_x.

Then, the partial rate for each section that makes up the questionnaire was calculated, and from this, the total Approval Rate GT of the respondent was calculated through this expression:

$$GT = G_1 \cap G_2 \cap G_3 \cap G_x \quad (2)$$

To obtain a single and defined value, the generalized Triple Refined Indeterminate Neutrosophic weight was calculated with:

$$wGT = w_T\,(TA(GT)) + w_{I_T}\,(I_{T_A}(GT)) + w_I(I_A(GT)) + w_{I_F}\,(I_{F_A}(GT)) + w_F(F_A(GT)) \quad (3)$$

Where, $w_T, w_{I_T}, w_I, w_{I_F}, w_F$ denote the weights of each membership.

To organize the total approval ratings in terms of highest and lowest acceptance, the assumed weights for each membership were:

$w_T = 5, w_{I_T} = 4, w_I = 3, w_{I_F} = 2, w_F = 1$

Thus, those with the highest values will be the ones with the highest acceptance index. For a better understanding, the Acceptance Index (AI) was calculated by: $AI = \frac{w}{5}$

4. Results

A survey was administered to a group of 25 legal professionals from the Province of Cotopaxi. The distribution of professional experience among the participants spanned from 1 to 10 years, yielding an average of 5.7 years of professional practice. This diversity in the respondents' years of experience was considered significant, facilitating the consolidation of a more comprehensive and representative overview of the evolution in the implementation of environmental sanctions over time, as well as their impact on different social strata. The findings corresponding to each segment of the questionnaire are presented in Table 1.

Table 1: Approval rate in each section of the questionnaire

No	Knowledge of Environmental Legislation	Knowledge of Environmental Sanctions	Opinion on Environmental Sanctions	Importance of Critical and Legal Social Analysis
1	(0.9;0.25;0.25;0.2;0)	(0.8;0.5;0.25;0;0.1)	(0.5;0.5;0.5;0.5;0.5)	(0.75;0;0.25;0.2;0.15)
2	(0.75;0.25;0.25;0.2;0.25)	(0.5;0.5;0.5;0.5;0.5)	(1;0.15;0.25;0.25;0.1)	(0.5;0.5;0.75;0.5;0.5)
3	(0.75;0;0.25;0.2;0.15)	(1;0;0.25;0;0.1)	(0.5;0.5;0.5;0;0.5)	(0.75;0.35;0.25;0.1;0.25)
4	(0.5;0.5;0.5;0.5;0.5)	(0.5;0.5;0.5;0.1;0.5)	(0.7;0.35;0.25;0;0.25)	(0.5;0;0.25;0.2;0.1)
5	(0.96;0.5;0.25;0.2;0.1)	(0.75;0.35;0.25;0;0.25)	(0.8;0.2;0.25;0.2;0.1)	(0.9;0.5;0.25;0.01;0.1)
6	(0.75;0.35;0.25;0.1;0.25)	(0.8;0.2;0.25;0.2;0.1)	(1;0.15;0.25;0.2;0.1)	(0.75;0.35;0.25;0.2;0.25)
7	(1;0;0.25;0.2;0.1)	(0.9;0.15;0.25;0.2;0.1)	(0.25;0.2;0.75;0.4;0.75)	(0.85;0.5;0.25;0.2;0.1)
8	(0.9;0.5;0.25;0.01;0.1)	(1;0.2;0.75;0.4;0.75)	(0.85;0.5;0.25;0;0)	(0.5;0.5;0;0.2;0.5)
9	(0.75;0.35;0.25;0.2;0.25)	(0.75;0.25;0.25;0.2;0.25)	(1;0.26;0.2;0.2;0.1)	(1;0;0.25;0.2;0.1)
10	(0.85;0.5;0.25;0.2;0.1)	(0.75;0;0.25;0.2;0.15)	(0.75;0.35;0.15;0.2;0)	(0.9;0.5;0.25;0.01;0.5)
11	(0.5;0.5;0;0.2;0.5)	(0.5;0.5;0.75;0.5;0.5)	(0.75;0.3;0;0.2;0.15)	(0.75;0.35;0.25;0.2;0.1)
12	(1;0.5;0.25;0.2;0.1)	(0.75;0.35;0.25;0.1;0.25)	(0.9;0.15;0.25;0.2;0.1)	(0.85;0.5;0.25;0.2;0.1)

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

13	(0.5;0.5;0;0.5;0.5)	(0.5;0;0.25;0.2;0.1)	(1;0.2;0.75;0.4;0.75)	(0.5;0.5;0;0.2;0.1)
14	(0.9;0.5;0.25;0.2;0.1)	(0.9;0.5;0.25;0.01;0.1)	(0.75;0.25;0.25;0.2;0.25)	(0.8;0.5;0.25;0;0.1)
15	(0.5;0.5;0.5;0.5;0.5)	(0.75;0.35;0.25;0.2;0.25)	(0.75;0;0.25;0.2;0.15)	(0.5;0.5;0.5;0.5;0.5)
16	(1;0;0.25;0;0.1)	(0.85;0.5;0.25;0.2;0.1)	(0.5;0.5;0.75;0.5;0.5)	(1;0;0.25;0;0.1)
17	(0.5;0.5;0.5;0;0.5)	(0.5;0.5;0;0.2;0.5)	(0.75;0.35;0.25;0.1;0.25)	(0.5;0.5;0.5;0.1;0.5)
18	(0.75;0.35;0.25;0;0.25)	(0.9;0.5;0.25;0.2;0.1)	(0.75;0;0.5;0.5;0.5)	(0.75;0.35;0.25;0;0.25)
19	(0.99;0.2;0.25;0.2;0.1)	(0.5;0.5;0;0.5;0.5)	(0.96;0.5;0.25;0.2;0.1)	(0.8;0.2;0.25;0.2;0.1)
20	(1;0.15;0.25;0.2;0.1)	(0.9;0.5;0.25;0.2;0.1)	(0.75;0.35;0.45;0.1;0.25)	(0.9;0.15;0.25;0.2;0.1)
21	(0.25;0.2;0.75;0.4;0.75)	(0.5;0.5;0.5;0.5;0.5)	(1;0;0.25;0.2;0.1)	(1;0.2;0.75;0.4;0.75)
22	(0.85;0.5;0.25;0;0)	(1;0;0.25;0;0.1)	(0.9;0.5;0.25;0.01;0.1)	(0.75;0.25;0.25;0.2;0.25)
23	(1;0.26;0.2;0.2;0.1)	(0.5;0.5;0.5;0;0.5)	(0.75;0.35;0.25;0.2;0.25)	(0.75;0;0.25;0.2;0.15)
24	(0.75;0.35;0.15;0.2;0)	(0.75;0.35;0.25;0;0.25)	(0.5;0.5;0.5;0;0.5)	(0.5;0.5;0.75;0.5;0.5)
25	(0.75;0.3;0;0.2;0.25)	(0.99;0.2;0.25;0.2;0.1)	(0.7;0.35;0.25;0;0.25)	(0.75;0.35;0.25;0.1;0.25)

Based on these data, it was possible to calculate the total degree of acceptance and the General Acceptance Index for each respondent regarding the topics addressed in the questionnaire, as shown in Table 2.

Table 2: General Acceptance Index calculated for each respondent

No	GT	W(Gt)	AI
1	(0.5;0;0.25;0;0.5)	3.75	0.8
2	(0.5;0.15;0.25;0.2;0.5)	4.75	1
3	(0.5;0;0.25;0;0.5)	3.75	0.8
4	(0.5;0;0.25;0;0.5)	3.75	0.8
5	(0.75;0.2;0.25;0;0.25)	5.55	1.1
6	(0.75;0.15;0.25;0.1;0.25)	5.55	1.1
7	(0.25;0;0.25;0.2;0.75)	3.15	0.6
8	(0.5;0.2;0;0;0.75)	4.05	0.8
9	(0.75;0;0.2;0.2;0.25)	5.00	1
10	(0.75;0;0.15;0.01;0.5)	4.72	0.9
11	(0.5;0.3;0;0.2;0.5)	4.60	0.9
12	(0.75;0.15;0.25;0.1;0.25)	5.55	1.1
13	(0.5;0;0;0.2;0.75)	3.65	0.7
14	(0.75;0.25;0.25;0;0.25)	5.75	1.2
15	(0.5;0;0.25;0.2;0.5)	4.15	0.8
16	(0.5;0;0.25;0;0.5)	3.75	0.8
17	(0.5;0.35;0;0;0.5)	4.40	0.9
18	(0.75;0;0.25;0;0.5)	5.00	1
19	(0.5;0.2;0;0.2;0.5)	4.20	0.8

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

20	(0.75;0.15;0.25;0.1;0.25)	5.55	1.1
21	(0.25;0;0.25;0.2;0.75)	3.15	0.6
22	(0.75;0;0.25;0;0.25)	4.75	1
23	(0.5;0;0.2;0;0.5)	3.60	0.7
24	(0.5;0.35;0.15;0;0.5)	4.85	1
25	(0.7;0.2;0;0;0.25)	4.55	0.9

The results obtained show a marked inclination towards positive membership in familiarity with environmental legislation. The scores assigned to the first category, corresponding to positive membership, were predominantly high for most participants in the study. This finding suggests that there is a significant level of knowledge and understanding of current environmental regulations among legal professionals who were the subject of this survey.

Similarly, considerable awareness was identified regarding the existence and specifications of environmental sanctions. This trend is consistent with the high level of familiarity observed in relation to environmental legislation. However, variability in participants' responses revealed diversity in perceptions about the clarity and effective application of such sanctions. This suggests that, while there is widespread knowledge about environmental sanctions, a detailed understanding of their structure, application criteria, and effectiveness may significantly differ among professionals. Based on the obtained results, it is inferred that although the surveyed legal professionals are aware of environmental sanctions, there is room for improvement in clarity and consistency in their application.

On the other hand, a certain equity in the distribution of responses was observed regarding opinions on environmental sanctions, as well as a notable presence of indetermination. This balance suggests that while a segment of professionals recognizes the necessity and potential effectiveness of sanctions as compliance tools, there is simultaneously a significant proportion expressing uncertainty or ambivalence towards these. The heterogeneity in responses is interpreted as a reflection of diversity in personal experiences, specific knowledge, and subjective assessments of the tangible outcomes of environmental sanctions in practice. This variety in perceptions underscores the importance of clear and transparent communication by environmental authorities, as well as the need for empirical evidence supporting the efficacy of sanctions as effective deterrents against environmental infractions.

Furthermore, the assessment of the importance of critical social and legal analysis revealed a positive inclination, indicating widespread recognition of the relevance of these analyses for a deep understanding of socio-environmental and legal dynamics. Nonetheless, the significant presence of indeterminate responses indicates a possible demand for more information or deeper debates around this topic.

To deepen the understanding of perceptions about environmental sanctions and the valuation of the importance of critical social and legal analysis, the implementation of a cluster analysis technique is proposed. This methodology allows grouping respondents into different categories based on their responses, thereby facilitating the identification of common patterns and significant differences in opinions and perceptions. [15]

The clustering chart shown in Figure 1 displays the distribution of the analyzed workers into three distinct groups based on the Total Evaluation, Evaluation Index, and Years of Experience. The clusters have been created from the standardization of the variables and the application of a K-Means algorithm assuming an arbitrary number of four clusters.

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

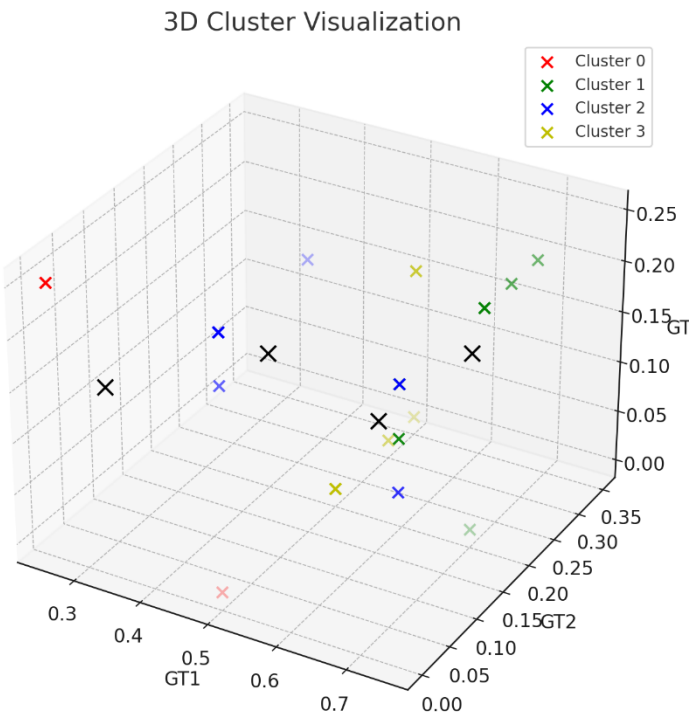

Figure 1: 3D visualization of your clustered data

During the analysis conducted, distinct groupings of workers were identified based on their total evaluation, evaluation index, and years of experience. On one hand, a small group of individuals whose scores in total evaluation and evaluation index are lower compared to individuals from other identified clusters was observed. This characterization suggests that the members of this group possess a level of performance or experience that is less outstanding compared to their peers.

On the other hand, an even smaller group of individuals was observed, characterized by including workers who not only present high scores in the total evaluation and evaluation index but are also distinguished by having a greater number of years of work experience. This pattern suggests that the members of this group are highly experienced, indicating that this grouping could represent a segment of workers who combine extensive knowledge and skill in their areas of specialization with a remarkable commitment and effectiveness in their assigned tasks.

Finally, clusters 3 and 1 gather workers who exhibit a total evaluation with a varied but generally high amplitude and a relatively high evaluation index, even though the years of experience among them differ significantly. This group appears to be made up of employees who demonstrate outstanding performance in their evaluations, regardless of the duration of their service in the organization. The distinction between these clusters highlights the diversity within the workforce in terms of experience and assessed performance, offering valuable insights for human resource management focused on environmental management.

5. Discussion

The results of the study have validated that the implementation of neutrosophy in the analysis of environmental policies offers significant methodological benefits that enrich the evaluative process. On one hand, this methodological approach enables the precise distinction and quantification of uncertainty present in public perceptions. Such capability is essential for differentiating between the absence of information, indifference, or genuine neutrality expressed by the participants in the research.

From an applied perspective, adopting neutrosophy in data processing and analysis is of great value in addressing the inherent complexity of attitudes toward environmental sanctions. The neutrosophic

Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024

logic, integrated with Likert scales, offers a framework for the development of models capable of incorporating contradictory and neutral statements, more authentically reflecting the complexity of human stances. This framework not only acknowledges the complexity and diversity of human perceptions but also enhances the ability of researchers and policymakers to identify, understand, and manage uncertainty and ambiguity in public opinions. Adopting this approach facilitates the creation of legislative and environmental governance frameworks that are more inclusive, effective, and coherent with the complex reality of human reactions and behaviors in the face of environmental challenges.

The application of the indeterminate Likert scale has captured a broad range of perceptions among legal professionals, highlighting both the degree of knowledge and acceptance of the legislation and environmental sanctions, as well as areas of ambiguity or debate. The notable presence of indetermination in various responses underscores the complexity of these issues and the need for more nuanced approaches in the analysis of environmental policies and practices.

6. Conclusion

Throughout the study, public perceptions of environmental policies and sanctions were evaluated using an innovative methodological approach that integrates neutrosophy and indeterminate Likert scales. This methodology addressed the complexity of human perceptions, facilitating the distinction between various degrees of agreement, disagreement, and indeterminate neutrality. Participants were selected to obtain a representative sample of individuals knowledgeable in environmental legislation. Data collection was carried out through a structured questionnaire, designed to capture respondents' perceptions of a series of statements related to environmental legislation and sanctions. The responses obtained allowed for the construction of models that explicitly address the indeterminacy inherent in the opinions gathered, as well as the application of statistical analysis, such as cluster analysis, to obtain information relevant to the study.

It was observed that there is a notable awareness and familiarity with environmental legislation among participants, as well as diversified opinions regarding the suitability and effectiveness of environmental sanctions. A balanced distribution of perceptions was identified, reflecting a variety of opinions ranging from positive assessment to neutrality and critique. This variability in responses underscores the complexity of public perceptions in relation to environmental policies. Additionally, the analysis highlighted the importance of considering indeterminacy and uncertainty as crucial aspects in the study of attitudes toward environmental sanctions. Integrating neutrosophy into data analysis provided a valuable tool for better understanding the multifaceted nature of public opinions, thereby identifying key areas for improving communication and formulating more effective environmental policies.

The study demonstrated the usefulness of applying a neutrosophic approach combined with indeterminate Likert scales for evaluating perceptions of environmental legislation and sanctions. Furthermore, the findings emphasize the utility of addressing indeterminacy and uncertainty in public perceptions, to facilitate the development of legislative and environmental governance strategies that are inclusive, effective, and aligned with the complex reality of human attitudes and behaviors toward environmental challenges.

Funding: “This research received no external funding”

Conflicts of Interest: “The authors declare no conflict of interest.”

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Doi: https://doi.org/10.54216/IJNS.240103
Received: January 19, 2024 Revised: March 17, 2024 Accepted: April 15, 2024