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Application of Neutrosophic Correlation in the Identification of Deficiencies in Animal Protection

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Abstract. The purpose of this study was to assess the utility of neutrosophic logic in identifying gaps and areas for improvement in animal protection in Ecuador. The methodology employed was exploratory and relied on the experience and knowledge of experts in the field of animal protection. It was framed within a qualitative perspective, adopting a descriptive and exploratory design to comprehend and analyze deficiencies in animal protection in Ecuador. The results of this research allowed for the identification of the most significant areas for improvement in animal protection in Ecuador through the definition of the gaps with the greatest impact on the study subject. Deficiencies related to the lack of protocols for animal rescue and inadequate enforcement of sanctions stood out as the most severe and impactful on animal welfare. The use of neutrosophic logic enabled a precise evaluation and quantification of deficiencies in animal protection. Its application is recommended in future research in the field to obtain a more accurate understanding of the situation.

Keywords: neutrosophic logic, evaluation, animal welfare, correlation coefficient.

1. Introduction

In the early 21st century, animal welfare preservation emerged as a topic of recent relevance on the international stage. The lack of a comprehensive regulatory framework regarding the protection of animal welfare appeared to create a gap in international law. In recent years, animal rights advocacy movements in Ecuador, primarily led by civil society, have experienced a significant increase. These movements have emerged mainly in response to the shortcomings of the legal and administrative framework in not only protecting but also regulating the relationship between the human species and animals.

Currently, animal protection mechanisms in Ecuador are characterized by a complex interaction of legislative, implementation, and socioeconomic factors. Despite having a solid regulatory framework in the form of the Organic Law on Animal Welfare and specific regulations, the effectiveness of these mechanisms is limited due to deficiencies in implementation and the lack of adequate resources. Government agencies responsible for enforcing animal protection laws often face budgetary and logistical constraints that hinder their ability to monitor and sanction non-compliance with regulations. This results in a lack of effective prevention against animal abuse and the illegal exploitation of wildlife.

The situation of animal shelters in Ecuador is a cause for concern, as inadequate conditions are observed in many of these places, including overcrowding and insufficient veterinary care. These inadequate conditions not only jeopardize the welfare of animals but also perpetuate the cycle of abandonment and mistreatment. Furthermore, Ecuadorian society largely lacks awareness of animal welfare. Public education in this regard is scarce, contributing to the persistence of harmful practices towards animals and irresponsible pet ownership.

The situation in Ecuador demands a scientific and systematic assessment of animal protection mechanisms, taking into account the availability of resources, the efficiency of law enforcement, and the promotion of public education. Such an evaluation is essential for developing more effective animal protection strategies that ensure a safer and more humane environment for animals in the country. However, in this context, it is imperative to identify the elements with the greatest potential to exponentially impact the current situation to achieve effective changes.

In this regard, multiple criteria decision-making methods hold significant consideration in the discipline of decision sciences [1]. In recent years, the need to simultaneously consider criteria and alternatives in decision problems has become more crucial, especially in the presence of uncertain datasets. Therefore, decision-makers employ subjective evaluation methods to address this challenge.[2]

Neutrosophic set theory is presented as a solid formal framework with a generalizability that covers the spectrum of concepts that includes the classical set, fuzzy set, interval-valued fuzzy set, intuitionistic fuzzy set, and interval-valued intuitionistic fuzzy set, among others [3, 4]. Neutrosophy, a philosophical branch with its roots in the work of [5], focuses on the investigation of the origin, nature, and scope of neutralities, and how they interact with various ideational conceptions.

The introduction of neutrosophy has given rise to an innovative concept called "<NeutA>" that addresses the indeterminacy related to <A>. The author maintains that this element is capable of solving certain problems that escape resolution through fuzzy logic [6]. Everyday problems, such as weather forecasting, stock price estimation, and electoral processes, often involve conditions of indeterminacy that are not effectively handled by fuzzy set theory. Therefore, neutrosophic set theory focuses on addressing imprecise and ambiguous situations, in which precise analysis becomes difficult or even unattainable [7]. In the context of animal protection in Ecuador, this theoretical approach could provide a valuable tool to address the complexity of decision-making, especially when faced with uncertain or vague situations where conventional precision is limited.

As a result of Smarandache's contributions, various notions aimed at neutrosophic sets have been introduced, which provide a more solid mathematical framework to address information characterized by its indeterminacy and inconsistency [8], [9]. Within this framework, concepts such as the interval neutrosophic set (INS) [10] and the single-valued neutrosophic set (SVNS) [11] have emerged. These elements represent subcategories of neutrosophic sets and have established set-theoretic operators as well as various properties inherent to SVNS and INS. Consequently, SVNS and INS can find concrete applications in the fields of science and engineering.[12],[13]

Subsequently, the use of SVNS correlation coefficients has been proposed, which are based on the extension of the correlation coefficient of intuitionistic fuzzy sets. This approach has shown that the SVNS cosine similarity measure is a particular case of the SVNS correlation coefficient, and has consequently been applied in the context of single-valued neutrosophic numbers in the field of decision-making.[14], [15], [19], [20-23]

The purpose of this study is to demonstrate the usefulness of neutrosophic logic in identifying deficiencies and areas for improvement in animal protection in Ecuador. In this context, correlation coefficients are revealed as a highly relevant tool to evaluate the relationship between two objects, being widely applied in data analysis and classification, decision-making, and other related areas [16]. The article initially addresses the foundations of neutrosophic logic and SVNS, as well as the formulas intended for the analysis of correlation coefficients in the field of single-valued neutrosophic sets. Subsequently, the foundations to carry out the analysis are set, the results obtained are presented and, finally, the conclusions of the study are derived.

2 Methodology

2.1 Preliminary information on neutrosophy

Definition 1: Let X be a space of elements (objects), where a generic element in X is represented as x. A neutrosophic set A in X is defined by three distinct functions: the membership function in terms of truth, $T_A(x)$, the membership function in terms of indeterminacy, $I_A(x)$, and the membership function in terms of falsity, $F_A(x)$. These functions, $T_A(x), I_A(x)$, and $F_A(x)$, represent subsets that are standard or non-standard real numbers and are constrained to the open interval $]0^-, 1^+[$, which means $T_A\ (x): X \to]0^-, 1^+[, I_A\ (x): X \to]0^-, 1^+[\ and\ F_A\ (x): X \to]0^-, 1^+[$. It is worth noting that there is no limitation on the sum of the functions $T_A(x), I_A(x)$, and $F_A(x)$, which implies that $0^- \leq supT_A(x) +\ supI_A(x) + supF_A(x) \leq 3^+$. [17-22]

Since the application of neutrosophic sets in practical situations is often challenging, the notion of a single-valued neutrosophic set (SVNS) has been proposed, which is configured as a specific instance of a neutrosophic set. This approach is intended to be used in real applications in scientific and engineering fields. The definition of SVNS is presented below.[12-21]

Definition 2. [12] Let X be a space of points (objects) with generic elements in X denoted by x. An SVNS A in X is characterized by a truth-membership function $T_A(x)$, an indeterminacy-membership function $I_A(x)$, and a falsity-membership function $F_A(x)$ for each point x in X, where $T_A(x), I_A(x), F_A(x) \in [0,1]$. Therefore, a SVNS A can be expressed as $A = \{x, T_A(x), I_A(x), F_A(x)\ | x \in X\}$. This means that the sum of $T_A(x), I_A(x)$, and $F_A(x)$ satisfies the condition $0 \leq T_A(x) +\ I_A(x) + F_A(x) \leq 3$.

Definition 3. An SVNS A is included in another SVNS B, denoted as $A \subseteq B$, when it holds that $T_A(x) \leq T_B(x), I_A(x) \geq\ I_B(x), y\ F_A(x) \geq\ F_B(x)$ for all elements x in the set X.

Definition 4. In accordance with [12], the complement of an SVNS A can be denoted by Ac and can be defined as: $Ac = \{x, F_A(x), 1 - I_A(x), T_A(x)\ | x \in X\}$

Definition 5. Two single-valued neutrosophic sets A and B are considered identical, denoted as A = B, if and only if $A \subseteq B$ and $B \subseteq A$.

Definition 6. The correlation coefficient between two single-valued neutrosophic sets A and B in the universe of discourse $X = \{x_1, x_2, \dots, x_n\}$ is defined as follows:

$$M(A,B) = \frac{1}{3n}\sum_{i=1}^{n}[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (1)$$

where

$$\phi_i = \frac{3-\Delta T_i - \Delta T_{max}}{3-\Delta T_{min} - \Delta T_{max}},$$

$$\varphi_i = \frac{3-\Delta I_i - \Delta I_{max}}{3-\Delta I_{min} - \Delta I_{max}},$$

$$\psi_i = \frac{3-\Delta F_i - \Delta F_{max}}{3-\Delta F_{min} - \Delta F_{max}},$$

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta I_i = |I_A(x_i) - I_B(x_i)|$,

$\Delta T_i = |T_A(x_i) - T_B(x_i)|$,

$\Delta T_{min} = min_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{min} = min_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{min} = min_i|F_A(x_i) - F_B(x_i)|$,

$\Delta T_{max} = max_i|T_A(x_i) - T_B(x_i)|$,

$\Delta I_{max} = max_i|I_A(x_i) - I_B(x_i)|$,

$\Delta F_{max} = max_i|F_A(x_i) - F_B(x_i)|$,

For all $xi \in X$ and i = 1, 2, . . ., n

However, the differences in the importance of the elements in the universe must be taken into account. Consequently, it is necessary to consider the weight of the element $x_i (i = 1, 2, \dots, n)$. Below, a weighted correlation coefficient between the SVNS is presented.

Definition 7. Given that w_i is the weight of each element $x_i\ (i = 1, 2, \dots, n), w_i \in [0, 1]$, and $\sum_{i=1}^{n} w_i = 1$, it is possible to obtain the weighted correlation coefficient between the SVNS A and B as shown in equation (2):

$$M_w(A,B) = \frac{1}{3}\sum_{i=1}^{n} w_i[\phi_i(1-\Delta T_i) + \varphi_i(1-\Delta I_i) + \psi_i(1-\Delta F_i)] \quad (2)$$

2.2 Correlation coefficient of SVNSs for decision-making.

In the context of a multi-attribute decision-making problem, considering single-valued neutrosophic information, the representation of the characteristic of an alternative $A_i\ (i = 1, 2, \dots, m)$ with respect to an attribute $C_j\ (j = 1, 2, \dots, n)$ is represented by the following Single-Valued Neutrosophic Set (SVNS): $A_i = \{C_j, T_{Ai}(C_j), I_{Ai}(C_j), F_{Ai}(C_j) | Cj \in C, j = 1, 2, \dots, n\}$, $T_{Ai}(C_j),\ I_{Ai}(C_j), F_{Ai}(C_j)) \in [0, 1]$, and $0 \leq T_{Ai}(C_j)$, $I_{Ai}(C_j), F_{Ai}(C_j) \leq 3$ for $Cj \in C, j = 1, 2, \dots, n,$ and $i = 1, 2, \dots, m.$. For the sake of simplicity and convenience in the analysis, the values of the three functions $T_{Ai(C_j)}, I_{Ai(C_j)}$, and $F_{Ai(C_j)}$ are represented using a Single-Valued Neutrosophic Value (SVNV) $d_{ij} = < t_{ij}, i_{ij}, f_{ij} >$ (where i = 1, 2, ..., m; j = 1, 2, ..., n). These values are often derived from the evaluation of an alternative A_i with respect to a criterion C_j by an expert or decision-maker. Consequently, a Single-Valued Neutrosophic Decision Matrix, $D = (d_{ij})_{mxn}$, is constructed.

In accordance with [18], in multi-attribute decision-making problems, the ideal point concept is used to help identify the best alternative within the decision set. Although the ideal alternative does not exist in reality, it provides a useful theoretical reference for evaluating the other alternatives.

In the decision-making method, an ideal Single-Valued Neutrosophic Value (SVNV) is defined as $d_j^* =< t_j^*, i_j^*, f_j^* >=< 1, 0, 0 > (j = 1, 2, \dots, n)$ for the ideal alternative A^*. Therefore, by applying Equation (2), the weighted correlation coefficient between an alternative A_i (where i = 1, 2, ..., m) and the ideal alternative A^* is calculated as follows:

$$M_w(A_i, A^*) = \frac{1}{3}\sum_{j=1}^{n} w_j\left[\phi_{ij}\left(1-\Delta t_{ij}\right) + \varphi_{ij}\left(1-\Delta i_{ij}\right) + \psi_{ij}\left(1-\Delta f_{ij}\right)\right] \quad (3)$$

where

$$\phi_{ij} = \frac{3 - \Delta t_{ij} - \Delta t_{i\,max}}{3 - \Delta t_{i\,min} - \Delta t_{i\,max}},$$

$$\varphi_i = \frac{3 - \Delta i_{ij} - \Delta i_{i\,max}}{3 - \Delta i_{i\,min} - \Delta i_{i\,max}},$$

$$\psi_i = \frac{3 - \Delta f_{ij} - \Delta f_{i\,max}}{3 - \Delta f_{i\,min} - \Delta f_{i\,max}},$$

$$\Delta t_{ij} = \left|t_{ij} - t_j^*)\right|,$$

$$\Delta i_{ij} = \left|i_{ij} - i_j^*)\right|,$$

$$\Delta f_{ij} = \left|f_{ij} - f_j^*)\right|,$$

$$\Delta t_{i\,min} = min_j\left|t_{ij} - t_j^*\right|,$$

$$\Delta i_{i\,min} = min_j\left|i_{ij} - i_j^*\right|,$$

$$\Delta f_{i\,min} = min_j\left|f_{ij} - f_j^*\right|,$$

$$\Delta t_{i\,max} = max_j\left|t_{ij} - t_j^*\right|,$$

$$\Delta i_{i\,max} = max_j\left|i_{ij} - i_j^*\right|,$$

$$\Delta f_{i\,max} = max_j\left|f_{ij} - f_j^*\right|,$$

For $i = 1,2,\ldots,m$ and $j = 1,2,\ldots,n$. By calculating the correlation coefficient $M_w\,(A_i, A^*)\,(i = 1,2,\ldots,m)$, it is possible to subsequently obtain the ranking order of all the alternatives and the best one(s).

2.3 Methodological framework

The research was based on an approach focused on evaluating the gaps and deficiencies inherent in the field of animal protection in Ecuador, using neutrosophic logic as its primary analytical tool. The methodology employed in this study was characterized by its exploratory approach, supported by the expertise and knowledge of experts in the field of animal protection. This study was framed within a qualitative perspective, adopting a descriptive and exploratory design to precisely understand and analyze the existing deficiencies in the field of animal protection in Ecuador. It is worth noting that the inherent indeterminacies in the decision-making process were considered.

To identify the gaps and deficiencies related to animal protection in Ecuador, an exhaustive documentary review of the legislation and regulations related to animal protection in the country was conducted. This analysis allowed for the detection of potential legal gaps and weaknesses in the implementation of existing regulations. In parallel, structured interviews were conducted with a panel of five experts in the field of animal protection in Ecuador. These experts significantly contributed by providing detailed information about the deficiencies they identified in both the legislation and the practice of animal protection in the country.

Additionally, three evaluation criteria were defined to assess the impact of the deficiencies on animal protection rights. These criteria were based on considerations regarding the severity of the identified deficiencies (Criterion 1), the magnitude of their influence on animal welfare (Criterion 2), and the effectiveness of existing measures (Criterion 3).

Once the identification of gaps and deficiencies through documentary review and expert interviews was achieved, neutrosophic correlation coefficients were applied. These coefficients allowed for a rigorous quantification and analysis of the relationship between the identified gaps and the previously established criteria, providing a precise measure of the magnitude of these gaps and their impact on animal rights.

The results obtained from the evaluation of the deficiencies under the proposed criteria will enable the identification of the most significant areas for improvement in animal protection in Ecuador. These areas of improvement will form a solid basis for the formulation of strategies that have a significant impact on the promotion and guarantee of animal rights in the country. The main goal of this research lies in its contribution to strengthening policies and legislation in favor of animal protection in Ecuador, as well as promoting positive changes in public awareness regarding this issue. These improvements are made possible through the implementation of neutrosophy as a tool to address aspects involving indeterminacies in the decision-making process.

3 Results

The exhaustive literature review and consultations with experts in the field of animal protection in Ecuador allowed to identify seven fundamental categories of gaps and deficiencies in the country's animal protection. Each of these categories represents critical areas that require substantial improvements:

1. Need to promote research: Scientific research in the field of animal welfare proved to be limited in Ecuador. The scarcity of studies and research in this area hindered informed and evidence-based decision-making, which is crucial for driving significant improvements.
2. Inadequate application of sanctions: Despite having animal protection laws, there was inconsistent application of sanctions in cases of animal abuse or mistreatment. The existing sanctions did not always reflect the severity of the crimes committed, resulting in inadequate punishments.
3. Limited public education: The lack of educational programs and public awareness campaigns on animal welfare contributed to widespread indifference towards animal protection in society. The lack of adequate information on the rights and needs of animals was evident.
4. Deficient supervision and control: Authorities responsible for supervising compliance with animal protection laws faced significant limitations in terms of resources and personnel. This lack of capacity resulted in inadequate supervision, allowing harmful practices to persist.
5. Lack of protocols for rescue and rehabilitation: The absence of standardized protocols for the rescue and rehabilitation of abused or endangered animals limited the effectiveness of rescue efforts and the care provided to animal abuse victims.
6. Limited international cooperation: Ecuador lacked agreements and collaboration with other countries in the field of animal protection. International cooperation, essential for combating the illegal wildlife trade and promoting global animal welfare standards, was identified as an area of deficiency.
7. Legal gaps and regulatory ambiguities: Animal protection legislation in Ecuador showed deficiencies in terms of the clarity and consistency of its provisions. The lack of precise definitions and specific provisions created ambiguities that complicated the effective application of regulations.

Each of these gaps and deficiencies was thoroughly evaluated based on three key criteria: severity, impact on animal welfare, and the effectiveness of existing measures. The application of neutrosophic logic allowed for assigning values of truth, indeterminacy, and falsehood to each gap in relation to these criteria. The assessment of these gaps was based on the previously defined criteria, and neutrosophic logic was used to accurately quantify their impact on animal rights in Ecuador.

The analysis conducted was based on obtaining the arithmetic mean of the evaluations provided by the experts in the study. This methodology was applied to combine and synthesize the individual perspectives of the experts, enabling the creation of a resulting decision matrix. The decision matrix, denoted as "D," was generated from the assessments of the identified gaps and deficiencies concerning the three previously defined criteria: severity, impact on animal welfare, and effectiveness of existing measures. The decision matrix D is presented below:

$$D=\begin{vmatrix} (0.4; 0.2; 0.2) & (0.4; 0.2; 0.3) & (0.5; 0.2; 0.3) \\ (0.5; 0.2; 0.3) & (0.7; 0.1; 0.2) & (0.6; 0.2; 0.3) \\ (0.4; 0.3; 0.2) & (0.5; 0.2; 0.3) & (0.6; 0.1; 0.2) \\ (0.5; 0.2; 0.3) & (0.4; 0.2; 0.2) & (0.4; 0.2; 0.2) \\ (0.4; 0.2; 0.2) & (0.6; 0.1; 0.2) & (0.3; 0.2; 0.3) \\ (0.6; 0.1; 0.2) & (0.5; 0.2; 0.3) & (0.6; 0.1; 0.2) \\ (0.7; 0.1; 0.2) & (0.6; 0.1; 0.2) & (0.6; 0.1; 0.2) \end{vmatrix}$$

According to the previously established methodology and the obtained results, the next step involved determining the minimum and maximum values in the membership functions for truth, falsehood, and indeterminacy.

These values are crucial for understanding the uncertainty in the data and assessments because they provide specific values for each gap in relation to the evaluation criteria. The inherent uncertainty in the assessments is reflected in these minimum and maximum values, contributing to a more precise and evidence-based assessment of deficiencies in animal protection in the country. The values obtained after conducting this analysis are presented in Table 1.

Table 1: Minimum and maximum values in the membership functions of truth, falsehood, and indeterminacy. Source: own elaboration.

	ΔTmin	**ΔImin**	**ΔFmin**	**ΔTmax**	**ΔImax**	**ΔFmax**
Need to promote research	0.5	0.2	0.2	0.6	0.3	0.2
Inadequate application of sanctions	0.3	0.2	0.1	0.5	0.3	0.2
Limited public education	0.4	0.2	0.1	0.6	0.3	0.3
Deficient supervision and control	0.5	0.2	0.2	0.6	0.3	0.2
Lack of protocols for rescue and rehabilitation	0.4	0.2	0.1	0.7	0.3	0.2
Limited international cooperation	0.4	0.2	0.1	0.5	0.3	0.2
Legal gaps and regulatory ambiguities	0.3	0.2	0.1	0.4	0.2	0.1

On the other hand, the values of φ, μ, and ψ for each selection alternative are essential to determine the relationship between the identified gaps and the evaluation criteria. These values reflect the uncertainty and ambiguity in the evaluations of each alternative based on the established criteria. These values are crucial for the calculation of neutrosophic correlation coefficients. The results obtained in this regard are shown in Table 2.

Table 2: Values of φ, μ, and ψ for each selection alternative. Source: own elaboration.

	ϕ			**μ**			**ψ**		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Need to promote research	0.95	0.95	1	1	0.96	0.96	1	1	1
Inadequate application of sanctions	0.91	1	0.95	0.96	1	0.96	0.96	1	1
Limited public education	0.9	0.95	1	1	0.96	1	0.92	0.96	1
Deficient supervision and control	1	0.95	0.95	0.96	1	1	1	1	1
Lack of protocols for rescue and rehabilitation	0.89	1	0.84	1	1	0.96	0.96	1	1
Limited international cooperation	1	0.95	1	1	0.96	1	1	0.96	1
Legal gaps and regulatory ambiguities	1	0.96	0.96	1	1	1	1	1	1

The use of equation (3) allows calculating the values of the M_w correlation coefficients (A_i, A^*). These coefficients reflect the relationship between each alternative A_i and the ideal alternative A^*, based on the previously established evaluation criteria. Table 3 shows the calculated values of the M_w correlation coefficients (A_i, A^*) and their corresponding ranking. These values are crucial for identifying the most significant areas for improvement in animal protection in Ecuador, serving as a basis for the formulation of effective strategies and the promotion of animal rights in the country.

Table 3: Weighted correlation coefficients. Source: own elaboration.

Detected deficiencies	**M**
Need to promote research	0.6447
Inadequate application of sanctions	0.7046
Limited public education	0.6732
Deficient supervision and control	0.6589
Lack of protocols for rescue and rehabilitation	0.6614
Limited international cooperation	0.7283
Legal gaps and regulatory ambiguities	0.7758

In the presented table, the deficiencies are ranked according to the values of "M." The gap with the highest "M" value is related to "Legal gaps and regulatory ambiguities," with a weighted correlation coefficient of 0.7758. This highlights the importance of addressing the lack of precise definitions and specific provisions in animal protection legislation in Ecuador. Legal ambiguity can hinder the effective implementation of regulations and should, therefore, be considered a priority.

In second place, the deficiencies related to "Limited international cooperation" and "Inadequate application of sanctions," with "M" values of 0.7283 and 0.7046, respectively. These deficiencies indicate that improving international cooperation on animal protection issues and ensuring consistency in the application of sanctions are crucial aspects for strengthening animal protection in the country.

The deficiencies of "Limited public education," "Lack of protocols for rescue and rehabilitation," and "Deficient supervision and control" are also considered critical areas for improvement, with "M" values ranging between 0.6614 and 0.6732. This suggests the need to implement public education programs, establish protocols for the rescue and rehabilitation of abused animals, and strengthen the supervision and control of animal protection laws.

Finally, the "Need to promote research" has an "M" value of 0.6447. Although slightly less significant than other deficiencies, it remains a priority for strengthening the knowledge base in the field of animal welfare.

Conclusions

The present study demonstrated the utility of neutrosophic logic in identifying deficiencies and areas for improvement in animal protection in Ecuador. The use of neutrosophic logic as an analytical tool allowed for the assessment of the magnitude of these deficiencies based on three key criteria: severity, impact on animal welfare, and the effectiveness of existing measures. The results revealed seven main categories of gaps and deficiencies in animal protection in Ecuador. The most significant deficiency was related to "Legal gaps and regulatory ambiguities," followed closely by "Limited international cooperation" and "Inadequate application of sanctions." These gaps emphasized the need to address the lack of clear definitions in legislation, strengthen international cooperation, and ensure consistent sanctions for animal abuse.

Neutrosophic logic played a crucial role in evaluating these deficiencies by addressing the inherent uncertainty in this type of analysis. Neutrosophic correlation coefficients provided a precise measure of the magnitude of the deficiencies and their impact on animal rights. The use of neutrosophic logic as an analytical tool allowed for a precise and quantifiable assessment of the extent of gaps and deficiencies in animal protection. It is recommended that future research in the field of animal protection consider the use of neutrosophic logic as an effective tool for evaluating gaps and deficiencies, as it can offer a more comprehensive and accurate understanding of the situation.

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