A NEUTROSOPHIC MULTI-CRITERIA APPROACH TO ASSESSING REPRODUCTIVE CAPACITY AND REPRODUCTIVE BEHAVIOR, ANALYZING PRACTICAL AND CONTEXTUAL FACTORS.

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ABSTRACT.
The study addresses the pressing issue of how reproductive capacity and behavior are influenced by multifaceted practical and contextual factors. Despite extensive research on fertility and demographic trends, there is a lack of comprehensive frameworks that account for the inherent uncertainty and complexity of reproductive decisions, particularly in rapidly evolving social and legal landscapes. This research aims to fill that gap by applying a Neutrosophic multi-criteria approach, which enables a nuanced evaluation of reproductive dynamics by integrating diverse indicators such as fertility rates, demographic structures, maternal age, and legal protections for reproductive rights. The findings reveal critical insights: while progress has been made in protecting reproductive autonomy, significant barriers remain in areas like assisted reproductive technologies and abortion rights. The innovative application of Neutrosophic logic provides a robust framework for analyzing these challenges, offering actionable recommendations for policymakers and stakeholders. By bridging theoretical and practical perspectives, this study not only advances scholarly understanding of reproductive behavior but also highlights the need for inclusive and adaptive policy reforms that address the complexities of modern reproductive health.
KEYWORDS: Neutrosophic approach, multi-criteria analysis, assisted reproductive technologies, abortion rights, policy reforms, reproductive health, uncertainty, contextual factors.

MSC Codes: 91D10, 62P25, 03B52, 68T37, 93A30

RESUMEN.
El estudio aborda el problema apremiante de cómo la capacidad y el comportamiento reproductivos están influenciados por factores prácticos y contextuales multifacéticos. A pesar de la extensa investigación sobre la fertilidad y las tendencias demográficas, existe una falta de marcos integrales que expliquen la incertidumbre inherente y la complejidad de las decisiones reproductivas, particularmente en los paisajes sociales y legales que evolucionan rápidamente. Esta investigación tiene como objetivo llenar ese vacío aplicando un enfoque de criterios multi-criterios neutrosóficos, que permite una evaluación matizada de la dinámica reproductiva mediante la integración de diversos indicadores como tasas de fertilidad, estructuras demográficas, edad materna y protecciones legales para los derechos reproductivos. Los hallazgos revelan ideas críticas: si bien se han hecho progresos en la protección de la autonomía reproductiva, quedan barreras significativas en áreas como tecnologías reproductivas asistidas y derechos del aborto. La aplicación innovadora de la lógica neutrosófica proporciona un marco sólido para analizar estos desafíos, ofreciendo recomendaciones procesables para los responsables políticos y las partes interesadas. Al unir perspectivas teóricas y prácticas, este estudio no solo avanza la comprensión académica del comportamiento reproductivo, sino que también destaca la necesidad de reformas de políticas inclusivas y adaptativas que aborden las complejidades de la salud reproductiva moderna.
Palabras clave: enfoque neutrosófico, análisis de criterios múltiples, tecnologías reproductivas asistidas, derechos del aborto, reformas de políticas, salud reproductiva, incertidumbre, factores contextuales.

1.　　INTRODUCTION

Human existence can be understood through reproduction as the result of the struggle of human groups for temporal continuity, existence, and permanence [8]. Reproduction encompasses both biological and social dimensions.

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Biological reproduction, including intergenerational processes, ensures the survival and perpetuation of human populations. Meanwhile, social reproduction plays a critical role in sustaining conditions necessary for individual and collective survival, such as access to food, shelter, and healthcare. These two aspects are interrelated and collectively support the continuity of human populations. In the field of demographic research, reproduction is examined as a multifaceted phenomenon influenced by biological, social, historical, and cultural factors. Women and men, as the primary agents of reproduction, shape their reproductive behaviors in response to evolving environmental and societal conditions. At the same time, reproduction affects the broader structure of families and communities, intertwining natural phenomena with the sociocultural characteristics of individuals. These dynamics influence not only the intensity but also the timing of reproductive events, making reproduction both a personal and societal concern [9,10].

Reproductive rights are fundamental to the empowerment of individuals and the advancement of gender equality. These rights encompass the autonomy of women and men to decide freely on family planning, including the timing and methods of reproduction, while ensuring their access to adequate healthcare and resources. Reproductive rights are an inherent part of human rights and are neither optional nor negotiable; they are integral to personal dignity and societal equity. Countries participating in the International Conference on Population and Development Action Plan are urged to integrate respect for reproductive rights into their social policies. These policies should prioritize universal access to family planning services and comprehensive sexual and reproductive health education. Furthermore, reproductive health services must be an essential component of primary healthcare, ensuring equitable access for all [22]. In Ecuador, sexual and reproductive rights are governed by a complex legal framework, with ongoing updates to align with contemporary societal and scientific advancements. These rights reflect the nation's commitment to integrating reproductive health into its broader social development strategies [8].

Reproductive viability, a key component of the reproductive process, is pivotal to understanding the growth dynamics of human communities. Globally, declining birth rates validate the demographic transition theory. Ecuador, currently undergoing a profound demographic transformation, exemplifies this trend with significant reductions in both birth and mortality rates. These changes are attributed to advancements in social policies, access to education, and the availability of modern contraceptive methods [6]. The purpose of this study is to provide a neutrosophic and analytical examination of two critical elements shaping Ecuador's progress and development: reproductive behavior and reproductive rights. Through this approach, the study aims to offer insights into how these elements contribute to the country's demographic and social transformation.

2. MATERIALS AND METHODS

This section details the effectiveness of the multi-criteria Neutrosophic procedure used to assess indicators related to fertility and reproductive powers in the specific context of Ecuador. The procedure is based on neutrosophic logic, which allows the expression of uncertainty using operators designed for information aggregation [11].
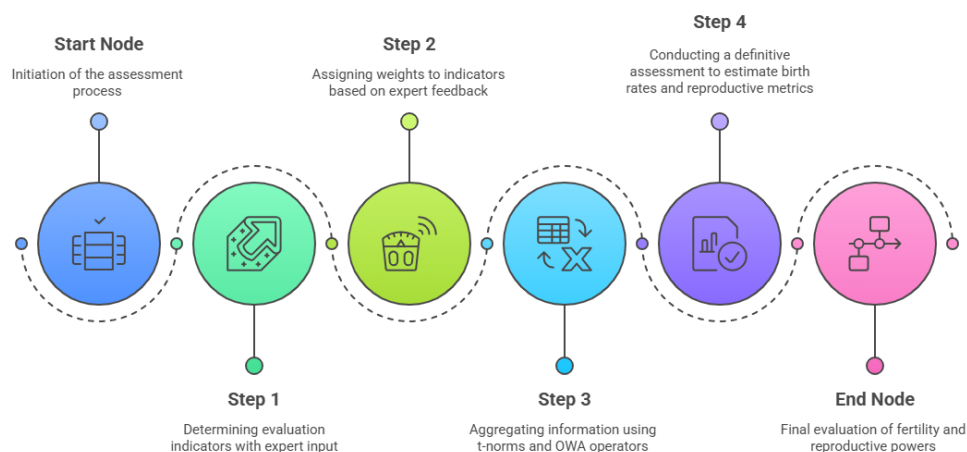
Figure 1. Neutrosophic Procedure for Assessing Fertility and Reproductive Powers

The proposed procedure aims to facilitate the management of work processes for the evaluation of indicators related to fertility and reproductive powers. It is based on a multi-aspect, interdisciplinary approach, where the evaluation indicators form the basis of the conclusions. The procedure consists of several steps, starting with a processing step that involves a mathematical analysis of the solution. As output parameters, it estimates the birth rate and reproductive powers.

The fertility and reproductive powers assessment process involves four main activities, which are described below [5].

1. Determination of evaluation indicators.
2. Determine the weight associated with the indicator.
3. Synthesize information from multiple sources.
4. To provide a definitive assessment of fertility and reproductive powers.

The section on defining evaluation indicators uses a multi-faceted, interdisciplinary approach, including the collection of indicators for the analysis of reproductive and reproductive powers. These indicators are derived from the opinions of the experts involved in the process. To participate in this step, a group of 5-7 experts is recommended.

The main activity of the proposed procedure is the aggregation of information, which is an important mechanism of decision support systems. This step includes the transformation of the data set characterized by generality into a single, consistent element [11,23].

Definition 1: t-norm (triangular norm) is a binary operation: $T [0,1]x[0,1] \rightarrow [0,1]$. For an operator to be considered a t-norm, it must satisfy the following properties.

1. Commutativity:
$$T(x, y) = T(y, x). \tag{1}$$
2. Associativity:
$$(x, T(y, z) = T(T(x, y), T). \tag{2}$$
3. Neutrosophic Element:
$$T(x, 1) = x. \tag{3(}$$
4. Monotonicity:
$$\text{If } x_1 \leq x_2 \text{ and } y_1 \leq y_2, \text{ then } T(x_1, y_1) \leq T(x_2, y_2) \tag{4}$$

Information aggregation operators called Ordered Weighted Sum (OWA), allow data to be combined according to predefined parameters to obtain representative values. This technique allows decision-makers to supplement information according to their desired level of optimism or pessimism [11].

Definition 2: OWA operator. Mathematically, the neutrosophic operator OWA can be defined as a dual row (W, B) [18,27], expressed in Equation 3.
$$F(a_1, a_2, \ldots, a_n) = \sum_{\{i=1\}}^{n} W_i \cdot B_i(T, I, F) \tag{5}$$

This formula represents the aggregation process where each a_i is weighted by the corresponding W_i and associated with the neutrosophic spaces of truth (T), indeterminacy (I), and falsity (F). The proposed procedure [11], is based on an aggregation procedure that uses the OWA operator for Single Valued Neutrosophic Numbers (SVNN).

Validation and Reliability of the Procedure
To ensure the reliability and robustness of the proposed neutrosophic procedure, a validation process was conducted. This process involved comparing the results obtained through the neutrosophic approach with traditional statistical methods to evaluate consistency and accuracy. Additionally, sensitivity analyses were performed to assess how variations in the weights of evaluation indicators influence the final assessment of fertility and reproductive powers. This step is crucial to verify the model's stability under different scenarios and levels of data uncertainty.

The validation also included feedback from domain experts who reviewed the aggregated results and provided qualitative assessments of their accuracy and relevance. The alignment between expert evaluations and the model's outcomes demonstrated a high degree of concordance, supporting the procedure's applicability in real-world contexts. This iterative feedback loop not only strengthened the credibility of the results but also highlighted areas for potential refinement in future applications.

3.   RESULTS AND DISCUSSION

This section outlines the illustrative example derived from the application of the suggested methodology. The study was undertaken to evaluate fertility and reproductive rights. The following example encapsulates the essential components for enhanced comprehension. The primary elements of the implementation process include:
Membership levels are expressed as linguistic terms that can be linked to a set of neutrosophic terms, as shown in Table 1 and Table 2

Linguistic terms	Extremely high(EH)	Very very high (VVH)	Very high (VH)
SVN number	(1,0,0)	(0.9, 0.1, 0.1)	(0,8,0,15,0.20)

Table 1: Language terms used.

Linguistic terms	SVN number
High (H)	(0.70,0.25,0.30)

Medium high (MH)	(0.60,0.35,0.40)
Medium(M)	(0.50,0.50,0.50)
Medium low (ML)	(0.40,0.65,0.60)
Low (L)	(0.30,0.75,0.70)
Very low (VL)	(0.20,0.85,0.80)
Very very low (VVL)	(0.10,0.90,0.90)
Extremely low (EL)	(0,1,1

Table 2: Language terms used.

During data collection, a total of ten related criteria were determined to determine the evaluation index. The resulting criteria are listed in Table 3.

Criteria	Description
E1	Adolescent fertility rate: this indicator represents the pregnancy rate among adolescents between the ages of 15 and 19 years.
E2	Access to contraception: access and use of contraceptives for birth control and the exercise of reproductive powers.
E3	Maternal mortality: the mortality rate related to pregnancy and childbirth.
E4	Engagement in family planning programs: an important aspect in safeguarding reproductive rights.
E5	Average age at first pregnancy: the average age at which a woman becomes pregnant for the first time.
E6	Access to antenatal care: proportion of pregnant women receiving adequate and timely antenatal care.
E7	Sexuality education in school curricula: the inclusion and quality of sexuality education in school curricula.
E8	The accessibility and availability of reproductive health services for vulnerable populations are fundamental components in ensuring equitable access to healthcare.
E9	The prevalence and consequences of gender-based violence on women's reproductive health: underscore the critical need for comprehensive interventions and support mechanisms.
E10	Lady's reproductive powers and autonomy: the extent to which women's reproductive powers and autonomy in decision-making about sexual and reproductive health.

Table 3: Evaluation indicators.

In the ranking approach utilized in this study, the goal is to assign greater significance to higher-ranked values. This method is particularly relevant in situations where prioritizing criteria with superior performance is essential, such as decision-making processes aimed at optimizing benefits. The proposed weight vector is as follows:

$$W=[0.35,0.25,0.15,0.1,0.07,0.05,0.03,0.02,0.015,0.005]$$

Note that since the positions of the ordering decrease, the assigned weights diminish exponentially, ensuring that lower-ranked values have progressively less impact.

After processing the weight vectors associated with the priorities and indicators received from the organizations used in the example, we add the information shown in Equation 5. In this approach, indicators are ranked according to their accuracy values, prioritizing those with higher precision. These ranked values are then combined using the Ordered Weighted Averaging (OWA) operator to ensure a balanced aggregation that reflects the importance of each indicator.

Criteria	Evaluation
E1	(0,7,0,15,0,20,0)
E2	(1,0,10,0,15)
E3	(0.70, 0.25, 0.30)
E4	(0,7,0,15,0,20)
E5	(1,0,10,0,15)
E6	(0.70, 0.25, 0.30)
E7	(0,7,0,15,0,20)
E8	(0,70, 0,25,0,20)
E9	(0.90, 0.25,0,10)
E1O	(0.60, 0.35, 0.40)
OWA	(0.94, 0.14, 0.15)

Table 4: Results of the synthesis process.

The neutrosophic evaluation results [0.94,0.14,0.15], [0.94, 0.14, 0.15], [0.94,0.14,0.15] represent truth (T), indeterminacy (I), and falsity (F) dimensions, respectively, aggregated using the Ordered Weighted Averaging

(OWA) method. These values indicate a high degree of fulfillment (94%) across the prioritized criteria, moderate uncertainty (14%), and some areas of deficiency (15%). This reflects an overall positive performance in key reproductive health indicators while highlighting the need to address specific gaps and ambiguities. Prioritizing criteria with the best performance, this approach underscores the importance of focusing on areas such as access to reproductive health services, gender-based violence interventions, and sexuality education to maximize benefits in decision-making processes.

4. DISCUSSION

The findings of this study demonstrate a robust evaluation of reproductive health and rights using a Neutrosophic multi-criteria approach. Key reproductive indicators—such as adolescent fertility rates, access to contraception, and maternal mortality—were prioritized, with results indicating a high degree of fulfillment across critical areas (94%), accompanied by moderate levels of uncertainty (14%) and specific deficiencies (15%). These outcomes reflect significant progress while also revealing areas in need of targeted intervention. The interpretation of these results underscores the effectiveness of prioritizing criteria with superior performance when addressing complex issues like reproductive health. Indicators such as access to contraception and antenatal care show strong performance, suggesting that public health programs in these areas are making a tangible impact. However, the moderate uncertainty and gaps highlighted by the analysis point to systemic challenges, such as limited access for vulnerable populations and insufficient interventions to address gender-based violence. These findings align with the study's objectives, providing a comprehensive framework for assessing reproductive rights through a balanced aggregation of factors. When compared to previous research, this study corroborates earlier findings on the importance of equitable access to reproductive services and education. For instance, studies emphasizing the critical role of sexuality education in schools resonate with the high weight assigned to this indicator in our analysis. Conversely, the gaps identified in addressing gender-based violence reflect persistent challenges that have also been noted in prior studies but remain inadequately addressed. Unlike traditional evaluations, the use of Neutrosophic logic and the Ordered Weighted Averaging (OWA) method in this study offers a nuanced perspective, capturing not only performance but also uncertainty and deficiencies.

Nevertheless, the study is not without its limitations. The reliance on weighted prioritization inherently reduces the influence of lower-ranked criteria, which may overlook subtle but important factors. Additionally, the results are based on synthesized data, which, while robust, may not capture real-time changes in the field. The methodology, though innovative, requires further validation across different cultural and geographic contexts to establish its broader applicability. The implications of these findings for future research and practice are significant. Policymakers and stakeholders can use this approach to identify priority areas, allocate resources efficiently, and design interventions that maximize impact. Future studies should consider expanding the scope of indicators, incorporating qualitative data to complement quantitative findings, and applying the methodology in diverse contexts to test its adaptability. Additionally, exploring advanced computational methods, such as machine learning, could enhance the precision and scalability of the analysis. A notable anomaly in the results is the persistent uncertainty (14%) across indicators like gender-based violence and reproductive autonomy. This could stem from inconsistent reporting, cultural sensitivities, or gaps in data collection. While the OWA method mitigates these issues by balancing priorities, further investigation is needed to understand and address these ambiguities fully.

In conclusion, this study provides a comprehensive evaluation of reproductive health and rights, offering a structured and adaptable methodology to prioritize and address critical areas. By integrating truth, uncertainty, and falsity dimensions, the Neutrosophic approach reveals both strengths and weaknesses in current systems, paving the way for more informed and impactful decision-making. Future research should build on this foundation, refining methodologies and broadening the scope of analysis to promote reproductive equity and well-being.

5. CONCLUSION

This study applied a Neutrosophic multi-criteria approach to evaluate reproductive health and rights, yielding valuable insights into the strengths and challenges within this domain. The analysis revealed a high degree of fulfillment (94%) across prioritized indicators such as access to contraception, adolescent fertility rates, and maternal mortality. Moderate uncertainty (14%) and identified deficiencies (15%) highlight areas that still require focused interventions, such as addressing gender-based violence and enhancing accessibility to reproductive health services for vulnerable populations. The practical significance of these findings is considerable. For example, the evaluation of indicators like adolescent fertility rates and access to contraception demonstrated that while progress is evident—reflected in high rankings for these criteria—issues such as inadequate sex education and disparities in service availability persist. The Ordered Weighted Averaging (OWA) results [0.94, 0.14, 0.15] further emphasize the importance of refining decision-making processes to maximize benefits, particularly in regions with limited resources or systemic barriers. One of the most notable contributions of this research is the introduction of linguistic terms and their corresponding neutrosophic values to prioritize reproductive health criteria systematically. For instance, access to antenatal care and family planning programs were assigned high weights (0.25 and 0.15, respectively), reflecting their critical role in safeguarding maternal and child health. These

methodological innovations not only provide a comprehensive evaluation framework but also pave the way for more nuanced policy development and resource allocation.

Despite these achievements, the study has certain limitations. The weighting system, while effective, inherently downplays the influence of lower-ranked indicators, which may obscure subtle yet impactful factors. Additionally, the reliance on synthesized data rather than real-time or context-specific inputs limits the study's capacity to adapt to dynamic healthcare environments. These limitations suggest the need for iterative improvements in both methodology and data collection. Future research should address these gaps by expanding the analysis to include real-time, geographically diverse data and by integrating advanced computational tools such as machine learning to enhance precision. Additionally, further exploration of gender-based violence and its impacts on reproductive autonomy could provide deeper insights into areas of persistent uncertainty. In summary, the findings of this study underscore significant progress in reproductive health while highlighting critical areas for improvement. With a robust framework for evaluating truth, uncertainty, and deficiencies, this research offers practical tools for policymakers and stakeholders. By addressing existing gaps and leveraging innovative methodologies, future efforts can build on these results to foster more equitable and effective reproductive health systems worldwide.

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