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Bibliometric Study of Neutrosophy as an Emerging Discipline

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Abstract: Neutrosophy constitutes an emerging field of scientific knowledge; therefore, the study of its structure and dynamics represents a topic of current and global interest. Using bibliometric methods combined with artificial intelligence techniques, this research explores a corpus of N = 6846 metadata records retrieved from Scopus and related to neutrosophy. A remarkable growth during the last decade is observed, together with the identification of six consolidated research domains, a set of core conceptual topics, and the existence of a scientific community with clearly defined leadership. The results are applicable to the formulation of science policies, including the definition of research lines and the identification of fundamental topics and problems. The application of the L-index identifies a reasonable number of scientific leaders within the macro-academic community under study and proves to be potentially applicable to similar bibliometric analyses.

Keywords: Neutrosophy; Emerging Sciences; Bibliometric Analysis; Thematic Mapping; Scientific Communities; Collaboration Networks; Scientific Leadership; L-index; Artificial Intelligence.

1. Introduction

Neutrosophy is a recent branch of philosophy introduced by the mathematician Florentin Smarandache, whose purpose is to analyze the origin, nature, and scope of neutralities in knowledge and reality. This theory arises in response to the limitations of traditional logical systems, acknowledging that any proposition may simultaneously contain degrees of truth, falsity, and indeterminacy [1]. It may be interpreted as emerging niches or areas in the process of consolidation, fuzzy logic proposed by Zadeh [2], intuitionistic fuzzy logic developed by Atanassov [3], Pythagorean fuzzy sets introduced by Yager [4] within extensible algebraic structures [5] and, strikingly, the Cloud Model proposed by Li and collaborators [6]. Applications of neutrosophy span multiple domains, notably machine learning, image segmentation, decision-making under uncertainty, and scientific information analysis.

At present, numerous fields are finding points of convergence, broadening and diversifying theoretical scope as well as applications in both science and technology, thereby constructing an increasingly transdisciplinary and interdisciplinary corpus [7]. For instance, data science and machine learning contend with the processing of incomplete or contradictory datasets [8]; cognitive neuroscience examines perception and decision-making processes [9]; while systems theory introduces biological concepts such as homeostasis and autopoiesis, which prove applicable even in social research. Neutrosophy is situated within this transdisciplinary and interdisciplinary framework, providing a mathematical formalization of uncertainty and neutrality, while also offering a philosophical foundation that supports the construction and application of knowledge. From this

standpoint, it becomes reasonable to inquire into the current status of this emerging field of knowledge in order to outline new prospective pathways for future scientific and technological research.

Over the past decades, the rapid expansion of information has unfolded in parallel with the convergent development of powerful technologies. As one illustration, the management of large-scale databases has been closely tied to engineering advances, while in the scientific domain disciplines such as statistics and data mining have merged to shape what is now referred to as data science. Within this setting, specialized bibliographic platforms have emerged—among them Google Scholar, Scopus, PubMed, and the Science Citation Index (in Web of Science)—providing structured access to scholarly records. These resources have enabled researchers to map the current state of science and to outline prospective directions, thereby anticipating the future evolution of knowledge [10]. In this way, a modern and transversal perspective on bibliometrics and scientometrics has taken shape, allowing deeper engagement with the established scientific corpus while also delineating emerging and relatively autonomous disciplines.

The history of science itself shows that universal recognition does not emerge spontaneously in its early stages; rather, it requires time, the consolidation of a scientific community, the possibility of verification, and above all, applications that contribute to improving the quality of human life. Such was the case of psychophysics, which employed mathematical methods to secure legitimacy and credibility, much like chemistry and physics in the nineteenth and early twentieth centuries. This trajectory eventually opened the way to the broader domain of psychology, gradually displacing the initial positivist framework. In the twenty-first century, however, the dynamics of knowledge unfold at a faster pace, leading to the swift establishment of emerging disciplines. For instance, within the educational sciences, the adoption of learning technologies first created new bridges across existing branches [11], yet in a relatively short period research began to acknowledge E-learning as an emergent corpus in its own right [12]. Similarly, bibliometric studies have identified fields in formation that do not originate from a single discipline, such as technostress [13] and altmetrics [14].

Although neutrosophy represents a very recent domain of scientific knowledge, bibliometric investigations have pointed to a kind of abrupt "takeoff" beginning in 2015 [15]. Likewise, other related studies describe a diversification in the applications of neutrosophic sets, largely originating from countries with developing economies [16]. Systematic investigations have identified leading countries, journals, and authors in specific areas such as the fusion of neutrosophic theory with rough set theory, a subdomain applied to uncertain information management [17]. Regional studies have also revealed distinctive sociological patterns, including the influence of the Latin American Association for Neutrosophic Sciences (LANS) and a pronounced emphasis on addressing social problems [18]. Overall, bibliometric studies in neutrosophy remain relatively scarce. Existing works primarily rely on high-impact databases [15, 16, 18] or focus on the evolutionary behavior of the field within influential journals [19, 20]. Even less frequent are studies that explicitly implement neutrosophic methods within bibliometric analysis itself [21]. The present research aims to analyze a sufficiently large sample of high-quality publications in order to reveal not only classical bibliometric patterns, but also the structure of the emerging scientific community and its patterns of scientific leadership.

From a bibliometric perspective, scientific leadership should not be reduced exclusively to individual productivity. Indicators such as the h-index and citation counts provide useful complementary information; however, they do not necessarily capture other dimensions of scientific performance [22]. Leadership within a scientific community may be reasonably identified based on the principle that *a leader is both highly productive in a given field and plays a fundamental role in the development of each published study* [23]. Previous research has confirmed that corresponding authors typically appear either at the beginning or at the end of the authorship list [24]. Accordingly, this study employs an index referred to as the L-index, which simultaneously captures high productivity within a scientific field and a central role in the execution of research.

2. Materials and Methods

Given the relatively recent status and the specificity of the corpus in neutrosophy, a census-type search was carried out in Scopus database. The aim was to satisfy two simultaneous requirements: (1) a representative volume of information and (2) a context with high scientific visibility and impact. The search logic targeted terms of the form "neutrosophi" within titles, abstracts, and keywords of scientific documents indexed as metadata. The use of the truncation operator with an asterisk (*) captured related variants such as *neutrosophic*, *neutrosophics*, *neutrosophie*, and *neutrosophical*. The query restricted the results exclusively to citable documents, which mainly included book chapters, conference papers, and journal articles. The search query implemented is as follows:

TITLE-ABS-KEY (neutrosophi*) AND (LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar"))

The metadata were downloaded in BibTeX format and subjected to a normalization process to achieve greater uniformity. Particular attention was given to standardizing author names—including the consolidation of duplicate identifiers—and keywords, as both are central to the present study. A systematic cleaning procedure revealed inconsistencies such as anomalous characters, repeated identifiers, variations in letter case, and the absence of extended keywords. Automated routines in R were also applied to help standardize and correct the retrieved records. With the support of the convert2df function from the *bibliometrix* package in R, a data frame was constructed whose structure is more organized and facilitates statistical analysis. To examine the structure of the macro-scientific community, the Louvain algorithm [25] was employed, which is based on modularity optimization. In this way, it becomes possible to segment the network into coherent clusters, maximizing the density of internal connectivity while minimizing external links.

Based on the systematized information, potential fundamental themes related to scientific publications in neutrosophy are identified. In this case, the analysis focuses exclusively on author keywords, which more faithfully describe the topics with which the research content is directly or indirectly connected. The processing of these keywords, grouped by the main clusters, is carried out with the support of Microsoft Copilot AI. Specifically, the AI is provided with the 500 most frequent keywords per cluster, so that it can determine the most reasonable thematic area to which they might be aligned. Alluvial diagrams are also generated using the geom_alluvium function from the *ggalluvial* package in R. In this way, significant flows among authors, journals, and the themes previously identified with AI are determined with greater rigor. The visualization facilitates the identification of publication and collaboration patterns and reveals how certain authors concentrate their output in specific journals, filtered through particular thematic perspectives.

Subsequently, thematic maps are constructed with the support of the thematicMap function from *bibliometrix*. The algorithm implemented by this function combines measures of centrality and density, which makes it possible to graphically represent the relevance and degree of development of the identified clusters. Centrality constitutes one dimension (the x-axis) and indicates the level of connection of a theme with others, while density provides a second dimension that reflects internal cohesion (the y-axis). To introduce a Cartesian coordinate system, the median values of each dimension are taken. In this way, four qualitatively interpretable quadrants are delimited: Motor (Q-I), Niche (Q-II), Emerging/Declining (Q-III), and Basic (Q-IV) [26].

Finally, the number L of individual leaders is determined according to the principle stated at the end of the introduction. If M denotes the number of communities identified by the Louvain algorithm, then the set of L leaders consists of those authors who: (1) belong to the group of the first M most productive, and (2) belong to the first M with the highest frequency of appearances as either first or last author [23]. The value of L does not necessarily imply scientific impact, but rather productivity and scientific responsibility, reflecting a social role with local leadership.

3. Results

3.1 Quality of the Neutrosophic Research Database

The data were retrieved on January 16, 2026, yielding a total of N = 6846 documents. The primary records exhibit encoding problems due to the presence of 105 characters originating from Unicode extensions. Instead of the alphanumeric characters and conventional punctuation typical of ASCII code, the metadata contain mathematical, typographic, and diacritical symbols, generating noise and excessive heterogeneity, mainly in abstracts and in the names of authors and institutions. After cleaning and normalization, these issues are significantly reduced, ensuring greater uniformity and reliability during the execution of automated algorithms. In particular, the DE field (author keywords) contains 411 empty cells (6.00%), while the SO field (Source = journal name, conference proceedings, or similar) contains another 393 (5.74%). All missing data were filled with the code NA. Overall, the remaining fields required for this study present less than 2.70% missing values.

Although automated processing globally standardizes the text in terms of uppercase and lowercase, in the field of author keywords (DE field) normalization problems are observed, concentrated in the most frequent terms (Mean = 2.31, SD = 0.86, Median = 2). A typical problem arises in those terms with absence/presence of juxtapositions, with the use of acronyms and lexical variations. For example: *Multi Criteria Decision Making*, *MCDM*, *Multi Criteria Decision Making (MCDM)*, *Multi-Criteria Decision-Making*, *Multicriteria Decision Making*, *Multiple Criteria Decision Making*, among other variants. Semantic fragmentation is also evident, as well as the existence of several conceptual subtypes with respect to the same root term. For example, regarding *Neutrosophic Open Set*, the following specificities appear: *Cubic Spherical Linguistic Neutrosophic Open Set*, *Linguistic Neutrosophic Open Set*, *R-Single-Valued Neutrosophic Open Set*, *Two-Fold Neutrosophic Open Set*, *N-Cylindrical Fuzzy Neutrosophic Open Sets*, among others. In addition, a total of 5106 authors present multiple and even excessive IDs (Mean = 6.69, SD = 10.36, Median = 5). For instance, the most productive author appears with 581 different IDs.

The use of Copilot AI substantially mitigated these issues. For example, the term *multicriteria decision-making* appeared in multiple equivalent forms: *multicriteria decision-making* (226 occurrences), *multi criteria decision-making* (189), *multicriterion decision makings* (177), *multi-criteria decision making* (269), *MCDM* (358), *multicriteria decision analysis* (13), and *MCDA* (5), which dispersed frequency counts and fragmented the concept. Through Copilot-assisted normalization, all variants were consolidated into a single coherent entry under the standardized form *multicriteria decision-making (MCDM)*, providing greater uniformity and consistency to the analyzed corpus. A similar procedure was applied to all terms with frequency ≥ 10.

3.2 Bibliometric Status of the Neutrosophic Knowledge Field

In the document stratification, journal articles dominate with 5979 records (87.34%), followed by conference papers with 527 (7.70%) and book chapters with 340 (4.97%). The number of journals publishing at least one article is 750, of which 511 (68.13%) publish at most two articles. Source distribution analysis shows that most publications are concentrated in *Neutrosophic Sets and Systems* (1719 documents; 26.64%, excluding missing records), followed by *International Journal of Neutrosophic Science* (797; 12.35%), *Symmetry* (209; 3.24%), *Journal of Intelligent and Fuzzy Systems* (200; 3.10%), and *AIP Conference Proceedings* (102; 1.58%). All remaining sources individually account for less than 1.5%, with 717 sources publishing fewer than ten documents (89.70%). In total, 35 sources concentrate 4292 documents (66.51%).

All journal articles include complete journal references. However, among conference papers, 165 metadata records (31.31%) lack the title of the scientific event, and 227 book chapters (66.76%) omit the book title. In both cases, this information is generally recoverable via DOIs, which exist for 149 conference papers (90.30%) and 187 book chapters (82.38%). The total number of distinct proceedings featuring neutrosophic research is 46, while 12 books (10 of which include a neutrosophy-related term in the title) and six edited volumes were identified. The proceeding with the highest number of

documents is *AIP Conference Proceedings* (102), and the most frequent book series is *Studies in Fuzziness and Soft Computing* (61).

When the document set is subdivided according to sources ranked in non-increasing order, three zones with approximately equal numbers of documents emerge. These correspond to Bradford zones [27], where the first zone (Core) includes only *Neutrosophic Sets and Systems*, the intermediate zone comprises 34 sources, and the third zone consists of 764 sources, representing the vast majority. Assuming that the 411 missing records belong to the third zone (764 + 411 = 1,175), the document distribution ratio across zones is 1:34:1175. These observed values satisfy Bradford's Law in a reasonable way [28], following the ratio $1:n:n^2$ (note that $34^2 = 1156 \approx 1175$).

Throughout the entire period under study, scientific collaboration is evident, with an average co-authorship of 3.16 (SD = 1.56, Median = 3). A high impact is also observed in terms of citations, with an average of 13.81 (SD = 33.1, Median = 4). As is typical in bibliometrics, productivity as a function of publication count follows a decreasing trend. Indeed, most authors are signatories of a single publication, while a well-restricted group concentrates the highest productivity. Comparative model analysis confirms that a power-law distribution $f(x) \sim x^{-\alpha}$ with $\alpha = 2.311$ provides the best fit (log-likelihood = −156.11, AIC = 314.21, BIC = 316.27), outperforming the log-normal ($\mu = 3.36$, $\sigma = 1.008$; AIC = 538.82, BIC = 542.94) and exponential alternatives ($\lambda = 0.021$; AIC = 568.34, BIC = 570.40).

The observed evidence supports the fulfillment of Lotka's Law [29] in bibliometrics, where the exponent α is estimated at values close to 2 (equilateral hyperbola model), indicating a typical concentration of productive volumes. Similarly, when exploring citation frequency as a function of the ordered rank of documents, it also exhibits a steep decline, with few works showing high citation levels among many others with very scarce citations. The power-law model also provides the best fit ($\alpha = 3.417$; log-likelihood = -565.10, AIC = 1132.20, BIC = 1138.75) compared to the log-normal ($\mu = 2.358$, $\sigma = 1.234$; AIC = 23730.54, BIC = 23743.64) and the exponential ($\lambda = 0.014$; AIC = 2174.51, BIC = 2181.06). These observations also confirm compliance with the bibliometric Zipf's Law [30], as a distinctive reflection of the behavior of scientific citations.

Figure 1 synthesizes compliance with three important bibliometric laws. In the case of Bradford's Law, all sources corresponding to the first two zones are included (35 = 30 journals + 5 proceedings series). For Lotka's and Zipf's laws, log–log scales are employed on both coordinate axes, with the objective of adequately visualizing the behavior of productive volumes and their respective impact.

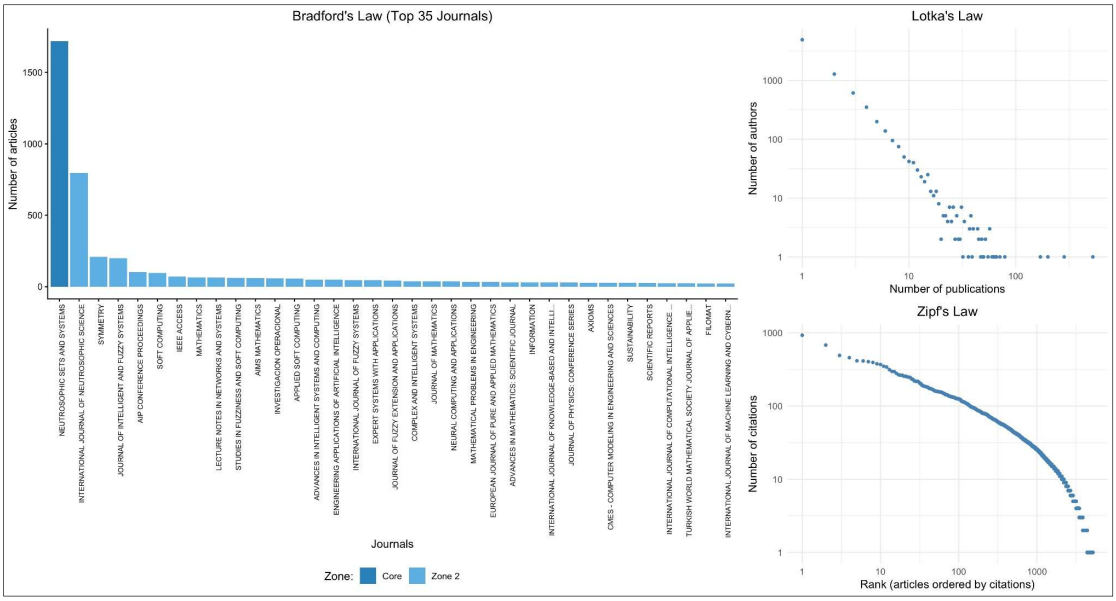

Figure 1. Bibliometric Laws in Neutrosophic Research

3.3 Productivity Dynamics and Thematic Consolidation in Neutrosophic Research

Since the pioneering work in information science by the British physicist Derek J. de Solla Price, it has been well established that scientific production tends to expand very rapidly [31]. Recent studies have confirmed an exponential nature in this growth dynamic [32, 33]. In the case of the neutrosophic literature explored here, the evidence is consistent, as exponential regression adequately describes the global trend ($R^2 = 0.95$, AAGR = 39%). Nevertheless, the implementation of segmented regression [34] yields a more precise model, with a very pronounced slope change in the year 2015. This finding aligns with a previous study, which identified that year as a markedly accelerated takeoff point in neutrosophic scientific production [15]. It is worth noting that this growth is strongly influenced by *Neutrosophic Sets and Systems* and *International Journal of Neutrosophic Science*, which were indexed in Scopus in 2018 and 2020, respectively.

From the breakpoint onward, two phases can be distinguished: an initial phase (2001–2015), characterized by low absolute growth (+2.5 documents/year) but relatively high relative growth (22%) over a small base, and a subsequent phase (2016–2025), marked by much higher absolute growth (+125 documents/year) and excellent model fit (adjusted $R^2 = 0.95$). Figure 2 shows the diachronic evolution of neutrosophic research output indexed in Scopus.

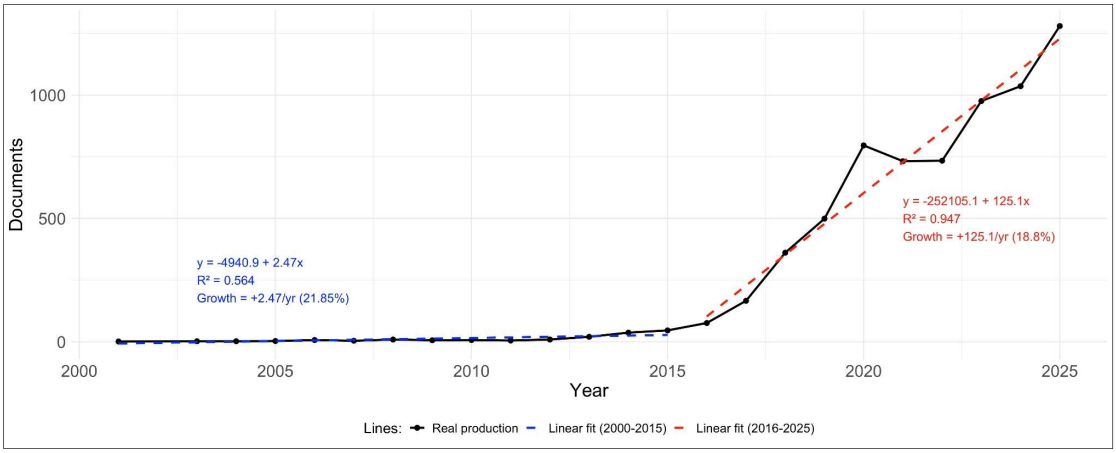

Figure 2. Diachronic Evolution of Scientific Productivity in Neutrosophy

Tokenization of documents, noise filtering, normalization of lexical variants using equivalence dictionaries, and frequency counting yielded 2,302 words with at least 50 occurrences across titles, abstracts, and keywords. A strong concentration near the minimum threshold is observed: 75% of words do not exceed 251 occurrences, and only 5% surpass one thousand. The 500 most frequent terms (top 22% of relevant vocabulary) were processed using Copilot AI to identify latent regularities. Table 1 summarizes the main results, revealing six general thematic blocks that condense the most consolidated research areas in neutrosophic studies.

Table 1. Fundamental Themes in Neutrosophic Research Based on Word Frequency Analysis

Thematic Block	Representative Keywords (Frequencies)[†]	Description
Theoretical Foundations	neutrosophic (50,679), fuzzy (12,070), logic (2,406), intuitionistic (1,554), indeterminacy (2,179), valued (8,560)	Core conceptual and mathematical basis of neutrosophy, linked to fuzzy logic and multivalued extensions.

Decision-Making Methods	decision (14,090), criteria (4,408), evaluation (2,908), selection (2,021), MCDM (1,567), TOPSIS (1,492), MADM (968), AHP (836)	Dominant application in complex choice and evaluation problems using multicriteria decision-making approaches.
Mathematical Formalization	interval (4,249), operator (2,698), function (2,493), entropy (1,248), algebra (1,005), matrix (1,276), topology (835)	Development of operators, membership functions, and rigorous mathematical structures.
Algorithmic Modeling & AI	model (4,482), algorithm (2,189), optimization (1,632), learning (1,626), clustering (1,240), segmentation (1,196), neural (597), machine (780)	Integration with artificial intelligence, machine learning, and optimization techniques.
Interdisciplinary Applications	data (4,466), image (2,158), medical (1,164), diagnosis (979), environment (1,800), energy (1,360), sustainability (700), transportation (1,093)	Practical use in medicine, image processing, sustainability, energy, and complex systems.
Methodology & Scientific Dissemination	proposed (5,434), analysis (5,116), framework (1,634), research (2,261), evaluation (2,908), assessment (1,294), article (992), publishing (1,039)	Typical academic language and evidence of consolidation in scientific journals and publishing houses.

[†]Consolidates lexical variants (singular/plural, acronyms, abbreviations) for consistency in frequency counts. The term *neutrosophic* simultaneously encompasses the variants neutrosophic, neutrosophical, neutrosophy, and neutrosophie.

Complementarily, the coordinate map in Figure 3 provides a structural view of the organization of the fundamental concepts, positioning them according to their degree of relevance (centrality) and development (density). The representation distinguishes four interpretable quadrants (Q):

- Q-I. The motor conceptual topics, where neutrosophic logic, uncertainty, and neutrosophy stand out as elements that articulate the core of neutrosophic research;
- Q-II. The niche conceptual topics, such as neutrosophic number and neutrosophic graph, developed intensively within specific communities but with less connection to the global set;
- Q-III. The emerging/declining conceptual topics, where single-valued neutrosophic set, multi-attribute decision-making, and aggregation operator show positive slopes in their annual frequencies (3.00, 0.357, and 0.639, respectively), thus classified as emerging and, far from declining, represent research lines that show signs of growth and possible future consolidation within the field; and
- Q-IV. The basic conceptual topics, such as neutrosophic set and decision-making, which constitute conceptual foundations widely used in related studies.

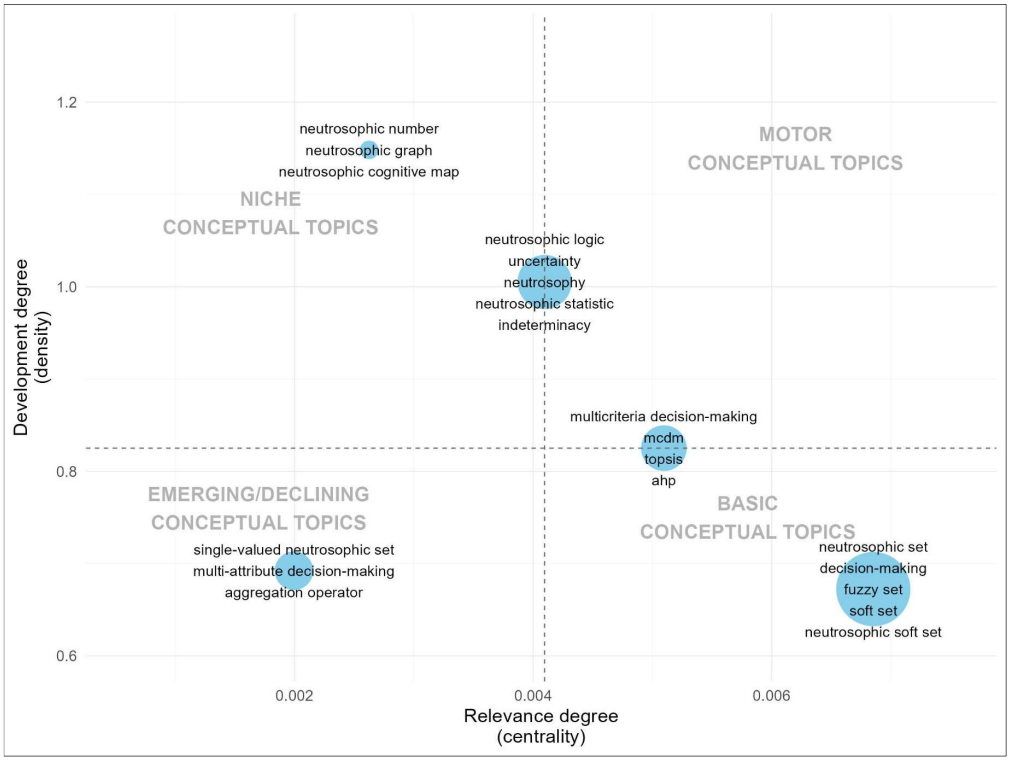

Figure 3. Neutrosophic Conceptual Topics in Terms of Relevance and Development

3.4 Structural and Functional Mapping of an Emerging Neutrosophic Research Community

In only 28 documents (0.41%) it is not possible to determine the nationality of all their authors. Productivity by continent is led by Asia (5759 documents; average citations = 13.36, SD = 30.23, Median = 4), followed by America (1316 documents; average citations = 12.32, SD = 29.63, Median = 3), Africa (865 documents; average citations = 15.32, SD = 33.35, Median = 4), Europe (489 documents; average citations = 22.06, SD = 37.27, Median = 8), and Oceania (115 documents; average citations = 19.58, SD = 30.85, Median = 8). Countries such as India and China lead the production volume with more than one thousand documents, a finding consistent with previous studies [16].

Table 2. Research Output and Bibliometric Indicators in Countries with ≥20 Publications

Country	Authors	Documents†	h-index	i10	Cites	Mean	SD	Median
India	1908	2410	93	888	41304	9.33	21.42	2
China	992	1183	71	1075	42128	21.56	43.81	8
Saudi Arabia	570	703	71	497	8684	9.57	15.95	3
United States	552	698	67	380	18583	25.04	44.61	10
Turkey	530	641	58	269	24071	23.17	56.15	9
Pakistan	473	518	52	341	11657	14.74	22.14	7
Ecuador	468	473	42	257	4402	4.97	10.03	1
Egypt	410	448	41	78	14187	17.56	39.37	4
Morocco	272	298	39	130	5587	14.11	24.04	5
Iraq	262	292	39	138	4013	7.60	11.77	3
Malaysia	200	228	35	128	4261	12.68	18.21	5

Iran	190	225	31	122	4803	15.15	20.89	7
Jordan	155	178	31	146	1879	6.76	9.63	3
Syrian Arab Republic	101	139	31	52	2254	13.10	18.18	7.5
Australia	92	112	30	50	2622	19.71	31.21	8
Peru	89	90	27	75	359	1.80	2.46	1
Serbia	81	81	26	59	3858	29.01	35.19	13
United Kingdom	61	63	23	67	2496	34.67	37.73	23
Cuba	49	49	17	25	618	9.81	18.32	2
Lithuania	45	47	16	25	2765	36.87	39.22	19
Romania	41	47	15	19	2023	25.94	74.64	3
Colombia	41	45	14	16	312	5.67	9.35	1
Canada	38	43	14	16	660	14.35	20.39	6.5
Denmark	36	43	14	22	497	11.30	17.12	4.5
Spain	36	43	13	16	1253	23.20	35.71	8
Nigeria	33	41	12	15	555	9.41	14.27	3
Greece	31	35	10	10	343	7.98	15.79	2
Poland	29	31	9	9	776	18.93	23.41	11
Russian Federation	29	31	8	3	182	2.84	4.21	2
Italy	24	29	7	6	631	21.76	32.62	11
Mexico	21	21	7	3	147	6.13	7.52	2.5
Ethiopia	19	20	6	2	110	4.40	6.43	3

[†]Values correspond only to the data retrieved in the present study. Each country may have higher overall publication volumes in Scopus, which are likely unrelated to neutrosophy.

Application of the Louvain algorithm to the co-authorship network identifies 63 clusters. Of these, 25 are single-author communities, while the remaining 36 comprise at least two researchers, yielding $M = 36$ stable collaborative communities. Figure 4 displays the collaboration network, highlighting 14 clusters with at least five stable co-authors (A–N).

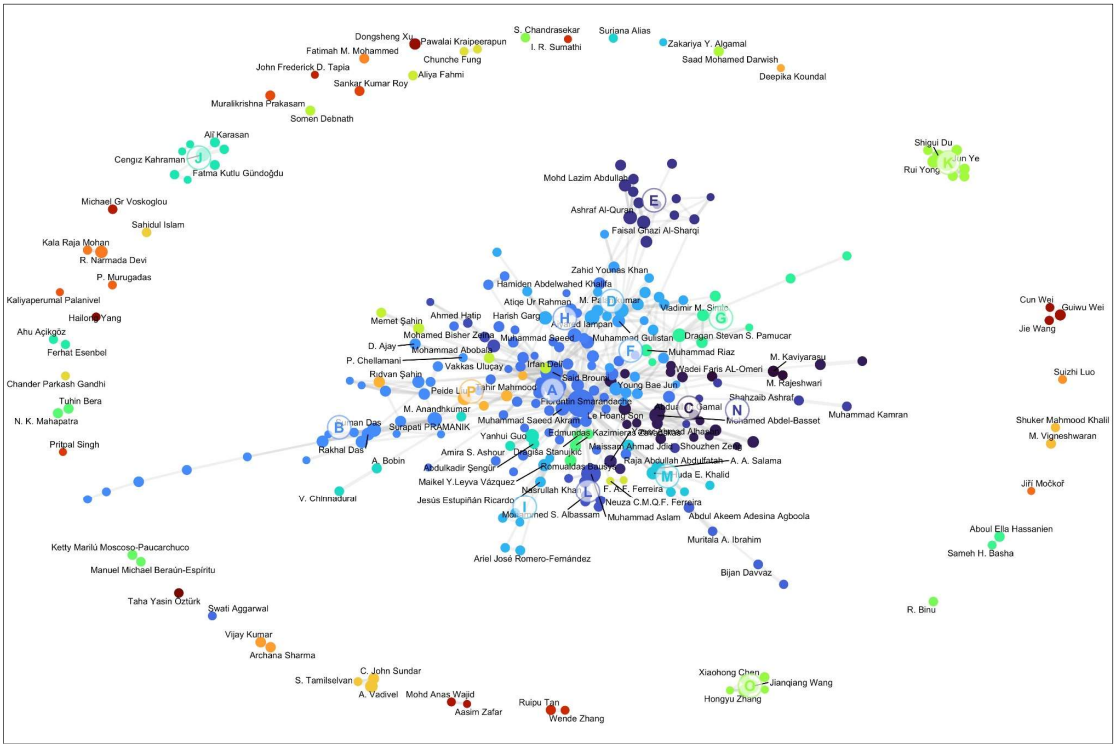

Figure 4. Scientific Collaboration Communities in Neutrosophy

Community A (54 authors, 1190 documents, 19138 citations, h-index 62) occupies the central position, with dense interconnection and a focus on theoretical foundations (neutrosophic, fuzzy, logic). In contrast, smaller communities such as E (18 authors, 222 documents, 2971 citations, h-index 34, decision methods) or N (5 authors, 93 documents, 3792 citations, h-index 35, mathematical formalization) appear on the periphery, with more limited links and thematic specialization. Other medium-sized communities, such as B (24 authors, 380 documents, 6003 citations, h-index 42, decision methods) and C (22 authors, 262 documents, 3948 citations, h-index 34, decision methods), offer compelling testimony that the main practical applications of neutrosophy are focused on evaluation and selection problems. The coexistence of highly cohesive central cores (for example, A and D) together with fragmented peripheral communities reveals a diverse ecosystem, where poles of high productivity coexist with emerging networks that contribute thematic variety and new connections.

3.5 Scientific Leadership in Neutrosophy

The five most productive authors in the field of neutrosophy are F. Smarandache (527 documents), S. Broumi (284), M. Aslam (200), J. Ye (170), and M. Abdel-Basset (79). A total of 19 authors have published 50 or more documents, while the top 50 authors each have at least 30 publications. The alluvial diagram in Figure 5 illustrates the connections among the 50 most productive authors, the thematic cores, and the collaborating countries. Specifically, the alluvial diagram depicts the relationships between leading authors, the research themes identified in Table 1, and the corresponding publication sources (journals, book series, and conference proceedings). These links do not directly represent the number of articles published, but rather the frequency with which an author is associated with a given thematic block within the analyzed corpus. Consequently, a single document may generate multiple links if it is classified into more than one thematic block or

involves multiple co-authors. Each connection count therefore reflects the breadth and diversity of an author's participation in the neutrosophic literature.

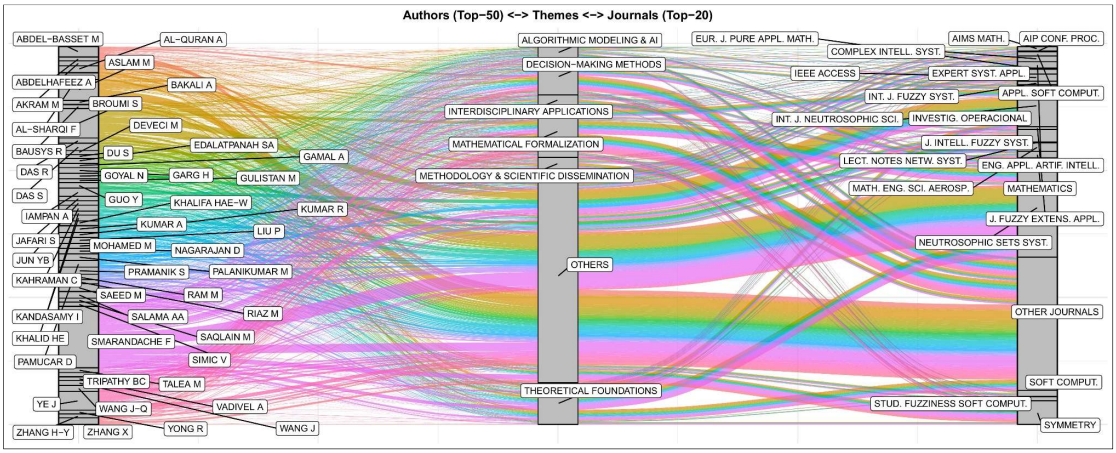

Figure 5. Alluvial Diagram of Leading Authors, Thematic Blocks, and Main Journals

After identifying the M = 36 most productive authors, all authors were re-ranked based on their occurrence as first or last author. Of these, L = 24 exhibit strong scientific leadership. Table 3 lists these authors along with key bibliometric indicators.

Table 3. Top-L Leading Authors by Productivity and Impact

Author	Country	Documents†	Cites	h-index	i10	First/Last‡
F. Smarandache	United States	527	7029	50	89	377
S. Broumi	Morocco	284	2288	29	47	190
M. Aslam	Saudi Arabia	200	1674	26	41	206
J. Ye	China	170	6251	39	66	175
M. Abdel-Basset	Egypt	79	5294	39	52	60
A. Iampan	Thailand	71	167	8	6	48
M. Palanikumar	India	66	357	10	10	52
S. Pramanik	India	65	1521	21	28	46
Y. Guo	China	63	1972	25	36	43
S. Das	India	61	527	13	15	43
M. Akram	Pakistan	60	717	16	22	56
P. Liu	China	57	2509	27	37	51
J-Q. Wang	China	57	4026	31	42	24
X. Zhang	China	56	597	15	19	39
A. Al-Quran	Jordan	52	601	14	17	29
D. Pamucar	Serbia	52	1425	21	26	29
A. A. Salama	Egypt	50	330	9	9	30
C. Kahraman	Turkey	49	3255	20	31	46
H. Garg	India	48	1594	24	31	33
Y.B. Jun	South Korea	45	566	13	15	37

S. A. Edalatpanah	Iran	44	912	17	22	33
N. Martin	India	38	251	10	10	28
R. Kumar	India	38	745	14	14	24
A. Vadivel	India	38	194	8	7	24

†Values correspond only to the data retrieved in the present study. Each author may have additional articles indexed in Scopus, which are likely unrelated to neutrosophy.

‡Counts the occurrences in which the author is listed either first or last among the co-authors.

It is important to note that the L/M fraction provides a measure of leadership density. In this case, 24/36 = 2/3 indicates that the macro-community is fairly cohesive, with a relatively broad and distributed leadership structure. On average, one third of the communities still do not have clearly recognized leaders, which can be interpreted as emerging niches or areas in the process of consolidation and is consistent with the peripheral zone of Figure 4.

4. Applications

The results obtained are applicable in two fundamental directions. First, the evidence indicates that neutrosophic research constitutes an emerging field within contemporary science, characterized by well-defined thematic areas alongside others that are still undergoing consolidation. Table 1 identifies six thematic domains that provide the structural (Theoretical Foundations and Mathematical Formalization), methodological (Decision-Making Methods and Methodology & Scientific Dissemination), and applied (Algorithmic Modeling & AI and Interdisciplinary Applications) bases of the field. An interpretation of the central column in Figure 5 suggests that these domains represent only a partial snapshot of current scientific activity, and that future growth is likely to give rise to new areas or to reconfigure the existing ones.

With respect to conceptual elements in neutrosophy, Figure 3 shows that theoretical foundations are consolidated as a transversal basis, while neutrosophic logic and multicriteria decision-making function as genuine motor themes, exhibiting high density and centrality that sustain the institutionalization of the field. Single-valued neutrosophic sets, together with multi-attribute decision-making and aggregation operators, rather than declining, display positive trends in their annual frequencies, indicating that they constitute expanding and emerging research lines with the potential to become future motor themes. In contrast, neutrosophic numbers and their applications in graphs and cognitive maps emerge as specialized niches, characterized by high internal density but still limited external connectivity. These findings are directly applicable to the definition of research lines and projects, the design of scientific events, and the selection of keywords for specialized thesauri.

Second, the evidence confirms the existence of a macro-scientific community in the field of neutrosophy, composed of robust and highly active collaborative niches alongside others that are still in development. The application of the L-index reveals that within these communities there are researchers with local scientific leadership, characterized by showing a balance between their academic productivity and their predominant responsibility in the execution or conduct of research. In this sense, the L-index makes it possible to distinguish not only publication volume, but also scientific leadership and direction, and may therefore be transferable to bibliometric studies of other scientific fields.

5. Conclusions (authors also should add some future directions points related to her/his research)

This study implements implements bibliometric methods in a census-type sample, which seeks to encompass as many high-impact and highly visible investigations in neutrosophy as possible. The sample size and the compliance with bibliometric laws provide a high level of reliability to the

findings described in the results section. The evidence reveals that neutrosophy is an emerging field of intense academic activity, with a significant growth in publications during the last decade, which is associated with the indexing of two specialized journals in Scopus that concentrate most of the results. Consolidated topics that delineate specific research areas are also observed. There is an active scientific community with well-defined leadership. The procedure employed in this study for determining the principal scientific leaders (L-index) is extendable to the analysis of other scientific communities. In particular, future studies may establish comparisons with other emerging disciplines, where the M/L ratio could serve as an additional indicator to analyze a scientific macro-community in both structural and functional terms.

As a matter for future attention, it is prudent to suggest work directed toward the normalization of fundamental concepts and terms, which are systematically employed as keywords. It is also advisable to implement policies that encourage the diversification of journals and other dissemination channels, since publications on neutrosophy are largely concentrated in a limited set of documentary sources.

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