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Economic valuation of forests: advances in research and future challenges

Valoración económica de bosques: avances en la investigación y desafíos futuros

Valorização econômica das florestas: avanços nas pesquisas e desafios futuros

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ABSTRACT

The protection of forests has become a center of attention for scientists and academics given their potential to combat climate change and for housing the rich biodiversity that lives in them. Governments and environmental organizations are relying on economic valuation to integrate the use of natural resources with environmental protection to establish sanctions for those responsible for the damage caused to the environment. The objective of this work was to analyze the progress of research on the economic valuation of forests. A bibliometric analysis was carried out with articles from the Scopus database and the Vosviewer program in order to know the advances in research and future challenges. The results revealed a co-occurrence mapping of keywords by author that resulted in the formation of three clusters, namely: the first cluster identified with the color red is related to economic valuation, the second cluster identified with the color green is related to management of environmental ecosystems and the third cluster identified with the color blue is related to environmental sustainability. For its part, the overlay analysis revealed that currently the research trend is focused on Willingness to pay, Investment model, Forest ecosystem services and Forest management. It is concluded that research on the economic valuation of forests has evolved significantly. Studies have focused their attention on the ecosystem services that forests provide, which include provision, regulation and cultural services. Also, the use of various economic valuation methods has been evidenced, such as revealed, declared and integrated valuation methods, with contingent valuation being the most used due to the ease of obtaining the information and the effectiveness of the analysis.

Keywords: Economic valuation, forests, environmental ecosystem management, environmental sustainability.

RESUMEN

La protección de los bosques se ha convertido en centro de atención para los científicos y académicos dado su potencial para combatir el cambio climático y por albergar la rica biodiversidad que viven en ellos. Gobiernos y organismos ambientales se están apoyando

en la valoración económica para integrar el aprovechamiento de los recursos naturales con la protección ambiental para establecer sanciones a los responsables de los daños causados al ambiente. Este trabajo tuvo por objetivo analizar los avances de la investigación sobre la valoración económica de bosques. Se realizó un análisis bibliométrico con artículos de la base de datos Scopus y el programa Vosviewer a fin de conocer los avances en la investigación y desafíos futuros. Los resultados revelaron un mapeo de coocurrencia de palabras clave por autor que arrojó la formación de tres clústeres a saber: el primer clúster identificado con el color rojo está relacionado con la valoración económica, el segundo clúster identificado con el color verde está relacionado con la gestión de ecosistemas ambientales y el tercer clúster identificado con el color azul está relacionado con la sustentabilidad ambiental. Por su parte, el análisis de superposición reveló que en la actualidad la tendencia de la investigación está centrada en Disposición a pagar, Modelo de inversión, Servicios de los ecosistemas forestales y Gestión forestal. Se concluye que la investigación sobre la valoración económica de los bosques ha evolucionado significativamente. Los estudios han puesto su atención en los servicios ecosistémicos que los bosques proporcionan, los cuales comprenden los servicios de provisión, regulación y culturales. También, se ha evidenciado el uso de métodos de valoración económica diversos como son los métodos de valoración revelada, declarada e integrada, siendo el más utilizado el de valoración contingente debido a la facilidad de obtener la información y la efectividad del análisis.

Palabras clave: Valoración económica, bosques, gestión de ecosistemas ambientales, sustentabilidad ambiental.

RESUMEN

La protección de los bosques se ha convertido en centro de atención para los científicos y académicos dado su potencial para combatir el cambio climático y por albergar la rica biodiversidad que viven en ellos. Gobiernos y organismos ambientales se están apoyando en la valoración económica para integrar el aprovechamiento de los recursos naturales con la protección ambiental para establecer sanciones a los responsables de los daños causados

al ambiente. Este trabajo tuvo por objetivo analizar los avances de la investigación sobre la valoración económica de bosques. Se realizó un análisis bibliométrico con artículos de la base de datos Scopus y el programa Vosviewer a fin de conocer los avances en la investigación y desafíos futuros. Los resultados revelaron un mapeo de coocurrencia de palabras clave por autor que arrojó la formación de tres clústeres a saber: el primer clúster identificado con el color rojo está relacionado con la valoración económica, el segundo clúster identificado con el color verde está relacionado con la gestión de ecosistemas ambientales y el tercer clúster identificado con el color azul está relacionado con la sustentabilidad ambiental. Por su parte, el análisis de superposición reveló que en la actualidad la tendencia de la investigación está centrada en Disposición a pagar, Modelo de inversión, Servicios de los ecosistemas forestales y Gestión forestal. Se concluye que la investigación sobre la valoración económica de los bosques ha evolucionado significativamente. Los estudios han puesto su atención en los servicios ecosistémicos que los bosques proporcionan, los cuales comprenden los servicios de provisión, regulación y culturales. También, se ha evidenciado el uso de métodos de valoración económica diversos como son los métodos de valoración revelada, declarada e integrada, siendo el más utilizado el de valoración contingente debido a la facilidad de obtener la información y la efectividad del análisis.

Palabras clave: Valoración económica, bosques, gestión de ecosistemas ambientales, sustentabilidad ambiental.

INTRODUCTION

The protection of forests has become a center of attention for scientists and academics given their potential to combat climate change and for housing the rich biodiversity that lives in them (Gómez-Parada *et al.*, 2020). Forests have a lot to do with the air we breathe, the regulation of the water cycle, the absorption of carbon dioxide, the control of soil erosion, among other aspects, which justify their protection (Murgas Téllez *et al.*, 2023). The accelerated process of deforestation that is taking place on the planet is worrying, which

endangers plants, animals and, in general, extensive terrestrial biodiversity (Benavides-Pupiales *et al.*, 2024).

At this time, profound changes based on collective consciousness are needed to reduce greenhouse gas emissions by 2030. The global economy based on the exploitation of natural resources has led to the loss of natural forests and a negative chain reaction. People are ignoring the essence of trees as oxygen generators and microclimate regulators that help produce precipitation that drives rain (Villamizar-Loaiza *et al.*, 2020). Burning trees is part of the problem of climate change since it involves the release of CO_2 that warms the planet even more. Deforestation is rampant worldwide and some countries show high rates of logging or burning, as is the case with Brazil and Indonesia (Sanabria-Martínez, 2022).

From the economic point of view, governments and environmental organizations are relying on economic valuation techniques to integrate the use of natural resources with environmental protection, in order to establish sanctions for those responsible for the damage caused to the environment (Maldonado-Palacios y Caraballo, 2022). Economic valuation allows establishing monetary values for goods and services of natural resources even when they do not have market prices (Ochoa-Paredes *et al.*, 2023).

The economic valuation methods are collected in four groups, namely: market valuation methods (market price); revealed preference methods (productivity change, travel cost, hedonic prices, and avoided costs); stated preference methods (contingent valuation and choice experiment) and; transfer of benefits (Eslava-Zapata, 2021). In this sense, economic valuation methods allow governments to design public policies that guarantee the protection of the environment and benefit the use of ecosystem services (Ochoa-Paredes *et al.*, 2023). Therefore, this study aimed to analyze the progress of research on the economic valuation of forests.

MATERIALS AND METHODS

We worked with articles published in the Scopus database in the period 2003-2024 and in English. In this regard, books, book chapters, presentations, among others, were omitted (Eslava-Zapata *et al.*, 2024).

The search filter was (TITLE -ABS-KEY ("economic valuation") AND TITLE-ABS-KEY (forests)) AND PUBYEAR > 2002 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, " ar ")) AND (LIMIT-TO (PUBSTAGE, "end")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")).

The documents were analyzed by year, source, author, affiliation, country, and area of knowledge. Likewise, co-authorship and co-occurrence of keywords were analyzed.

RESULTS AND DISCUSSION

Table 1 shows the scientific production by year. Scientific production has been increasing, reaching 8 articles by 2024. Even though scientific production is not very high, it is relevant to the research area. In this sense, for the years 2023, 2022 and 2021 the scientific production was 27, 28 and 24 (Table 1).

Table 1. *- Documents by years*

Year	Documents
2024	8
2023	27
2022	28
2021	24
2020	21
2019	31
2018	19
2017	18

2016	20
2015	17
2014	16
2013	19
2012	17
2011	7
2010	11
2009	5
2008	4
2007	7
2006	2
2005	3
2004	2
2003	2

In Table 2, it can be seen that the main journals that have published articles on the economic valuation of forests are Ecosystem Services (19), Ecological Economics (17), Forests (13) (Table 2).

Table 2. *- Documents by source*

No.	Fountain	Documents
1	Ecosystem Services	19
2	Ecological Economics	17
3	Forests	13
4	Forest Policy And Economics	10
5	Journal Of Environmental Management	9
6	Land Use Policy	9
7	Environmental Science And Policy	8
8	Sustainability Switzerland	6
9	Malaysian Forester	5
10	Science Of The Total Environment	5

From Table 3, it is derived that the authors who have published the most are Soliño, M. (8), Paletto, A. (5) and Varela, E. (5) (Table 3).

Table 3. *- Documents by author*

No.	Author	Documents
1	Soliño, M.	8
2	Paletto, A.	5
3	Varela, E.	5
4	Awang Noor, AG	4
5	Badola, R.	4
6	Hussain, S.A.	4
7	Acharya, R.P.	3
8	Balmford, A.	3
9	Bateman, I.J.	3
10	Burgess, N.D.	3

Table 4 shows that Universiti Putra Malaysia (10) is the main institution to which the articles are linked, followed by Københavns Universitet (9) and CSIC-INIA-CIFOR - Forestry Research Center (9) (Table 4).

Table 4. *- Documents by affiliation*

No.	Membership	Documents
1	University Putra Malaysia	10
2	Københavns Universitet	9
3	CSIC-INIA-CIFOR - Forestry Research Center	9
4	CSIC-INIA - National Institute of Agricultural and Food Research and Technology	8
5	University of Valladolid	7
6	INRAE	7
7	University of East Anglia	6
8	Wageningen University y Research	6
9	Norwegian University of the Environment and Life Sciences	6
10	Vrije Universiteit Amsterdam	6

The United States leads scientific production, followed by Spain (35) and Indonesia (26). There is evidence of global interest in research on the economic valuation of forests, considering the concern of the United Nations (UN) with the 2030 agenda, in which the protection of forests points to several objectives such as objective 13 related to the fight against climatic changes (Table 5).

Table 5. *- Documents by country*

No.	Country	Documents
1	United States	43
2	Spain	35
3	Indonesia	26
4	Germany	21
5	United Kingdom	20
6	Malaysia	19
7	India	18
8	Brazil	17
9	Italy	17
10	Australia	16

Table 6 shows the documents by knowledge area. Environmental Science leads scientific production with 215 documents, followed by Agricultural and Biological Sciences (172) and Social Sciences (97) (Table 6).

Table 6. *- Documents by area*

No.	Area	Documents
1	Environmental Science	215
2	Agricultural and Biological Sciences	172
3	Social Sciences	97
4	Economics, Econometrics and Finance	50
5	Energy	13
6	Biochemistry, Genetics and Molecular Biology	12
7	Business, Management and Accounting	10

8	Earth and Planetary Sciences	10
9	Computer Science	7
10	Engineering	7

For co-authorship per author, one document per author and seventy-six citations were considered. The results showed that out of 306 documents only 20 documents met the criteria. The results revealed that there is no collaboration between the authors (Table 7).

Table 7. *- Co-authorship by author*

No.	Author	Year	Citations
1	Feng Z. et al.	2019	230
2	Badola R. et al.	2005	225
3	Grêt-Regamey A. et al.	2008	159
4	Nielsen AB et al.	2007	153
5	Bernués A. et al.	2014	152
6	Häyhä T. et al.	2015	133
7	Uddin MS et al.	2013	122
8	Hougner C. et al.	2006	118
9	Bravo-Oviedo A. et al.	2014	117
10	Van Beukering PJH et al.	2003	111

Regarding the analysis of co-authorship by country, seven documents and one hundred and forty-one citations were considered. The results reveal that of 79 countries, 20 meet the criterion. In Table 8, it is observed that the first three places are occupied by the United States (44), Spain (35) and Indonesia (26).

The collaboration between the countries formed three clusters. The first identified with the color red are made up of Czech Republic, France, Germany, Italy, Mexico, Netherlands, Norway, Poland, Spain and Sweden. The second cluster identified with the color green is made up of Australia, China, Denmark, India, Indonesia, Japan and Malaysia. The third

cluster identified with the color blue is made up of Brazil, United Kingdom and United States (Figure 1).

Table 8. - *Co-authorship by country*

No.	País	Documentos
1	United States	44
2	Spain	35
3	Indonesia	26
4	Germany	21
5	United Kingdom	20
6	Malaysia	19
7	India	18
8	Brazil	17
9	Italy	17
10	Australia	16

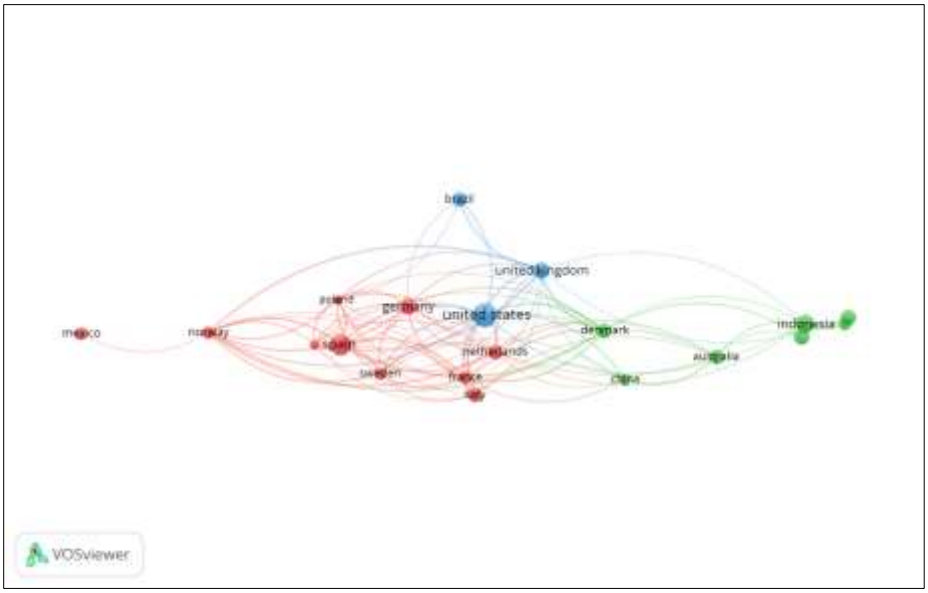

Figure 1. *- Co-authorship map by country*

Regarding the analysis of the occurrence of all keywords, considering a minimum occurrence of twenty-five, out of 2189 keywords, only 18 words met the criterion. Two common words were matched to the thesaurus file and one word not related to the research was removed. In Table 9, it is observed that the words that are most repeated are Economic Valuation (140), Ecosystem Service (129) and Valuation (72).

The co-occurrence map of all keywords reveals the formation of three clusters. The first cluster identified with the color red is made up of the words Biodiversity, Carbon Sequestration, Economics, Ecosystem, Environmental Protection, Forest and Land Use. The second cluster identified with the color green is made up of the words Contingent Valuation, Decision Making, Economic Valuation, Ecosystem Service, Environmental Economics and Willingness to Pay. The third cluster identified with the color blue is made up of the words Economic Analysis, Forest Ecosystem, Forest Management, Forestry and Valuation (Table 9).

Table 9. *- Co-occurrence of all keywords*

No.	Keyword	Idea
1	Economic Valuation	140
2	Ecosystem Service	129
3	Valuation	72
4	Ecosystem	57
5	Forestry	57
6	Willingness To Pay	51
7	Forest Management	49
8	Economic Analysis	41
9	Environmental Economics	39
10	Contingent Valuation	36

On the other hand, for the co-occurrence analysis of keywords by author, considering a minimum of six keywords, the results reveal that of 946 keywords only 20 met the criterion.

Two common words were joined with the thesaurus file. The co-occurrence map showed the formation of three clusters (Figure 2).

The first cluster identified with the color red is related to economic valuation. This cluster is integrated for the words Choice Experiment, Conservation, Contingent Valuation, Contingent Valuation Method, Economic Value, Forest Recreation, Mangrove Valuation and Willingness to Pay.

Environmental economic valuation allows assigning a monetary value to the benefits provided by ecosystems, which allows making correct decisions that favor the conservation of natural resources. Environmental economic valuation allows obtaining crucial information to compare the benefits obtained from conserving ecosystems with those activities that can degrade them. Likewise, it allows the establishment of public policies and development of projects that promote the sustainability of resources. It should be noted that economic valuation allows establishing payment systems for ecosystem services and raising people's awareness about the importance of environmental responsibility (Mada et al., 2023).

There are several methods of environmental economic valuation, among them is contingent valuation which measures the willingness to pay to conserve an ecosystem; the hedonic price method which measures how environmental characteristics affect market prices, the travel cost method which measures the cost people incur to visit a natural site; the avoided cost method which measures the cost that is avoided if the natural resources were not present; the benefit transfer method which consists of using estimates made in other studies due to scarce resources to carry out new studies and; Production valuation measures the value of ecosystem services based on their contribution to the production of goods and services (Pardo-Rozo *et al.*, 2022).

The second cluster identified with the color green is related to the management of environmental ecosystems. This cluster is made up of the words Benefit Transfer, Carbon Sequestration, Ecosystem Service, Forest Ecosystem Services, Forest Management and Invest Model.

The management of environmental ecosystems is essential to preserve biodiversity and achieve the sustainability of environmental resources in order to ensure a healthy future of the planet in the face of human activities. Conserving biodiversity means achieving the stability of ecosystems and not compromising their ability to regenerate. To ensure that ecosystems recover from human and environmental disturbances, it is necessary to establish strategies for monitoring ecosystems that involve governments and society, which ensure the implementation of sustainable measures to confront climate change and pollution (Okumu y Muchapondwa, 2022).

Ecosystem services emerge as an alternative to provide natural resources to human beings by regulating ecological processes that serve as a basis for providing natural resources to the economy and sustaining the life of both humans and biodiversity. Therefore, it is necessary to reduce greenhouse gas emissions to mitigate climate change and develop legal frameworks that promote the sustainable use of ecosystems (Costa-Pinto *et al.,* 2022).

The third cluster identified with the color blue is related to environmental sustainability. This cluster is related to the words Biodiversity, Climate Change, Economic Valuation, Forests and Land Use Change.

The environmental sustainability approach focuses on the protection of natural resources to ensure their responsible use without compromising the satisfaction of the needs of future generations. In this sense, under this approach the preservation of biodiversity is promoted to ensure its resilience; the recycling of solid waste and the implementation of measures to reduce greenhouse gases (Suzuki y Kohsaka, 2022).

It should be noted that climate change is one of the biggest challenges facing today's society. Aspects such as the burning of fossil fuels, the deforestation of forests, the methane produced by organic waste, the nitrogen oxide produced by agricultural activities, the intensive use of land due to urban expansions, among others, are altering climate patterns and the intense increase in temperatures (Zegeye *et al.,* 2023).

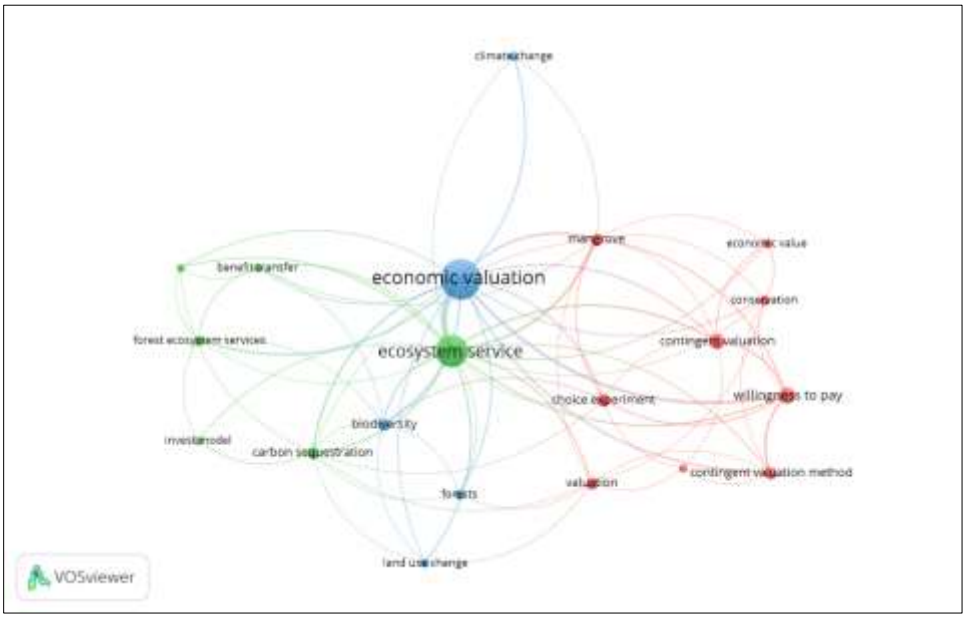

Figure 2. *- Keyword co-occurrence map by author*

The overlay reveals that currently the research trend is focused on Willingness to Pay, Invest Model, Forest Ecosystem Services and Forest Management (Figure 3).

Research on Willingness to Pay is providing valuable information to establish environmental management policies and promote environmental protection. This tool allows us to understand how people value goods and services. Among the most common methods are the contingent valuation method (survey to determine willingness to pay), choice experiments (presenting people with products or services with different attributes to analyze the choice), travel cost method (costs incurred by people to visit a recreational site) and the hedonic pricing method (variation of the prices of goods due to environmental attributes). It should be noted that there are some biases that may arise due to respondents' preferences and the complexity of the surveys (Rexhepi *et al.,* 2024).

Regarding the Invest Model, researchers have proposed strategies for the allocation of resources in order to promote sustainability and social well-being. The proposed models go through different stages, from diagnosis, through the definition of objectives and opportunities, to the feasibility analysis. The idea is to follow a comprehensive approach in order to promote green investments (Sulistyawan *et al.,* 2022).

In relation to Forest Ecosystem Services, research is emphasizing the different categories of services that benefit the environment, humans and the economy. Among the categories, provision services (wood and food) stand out; regulation services (climate, air and soil); cultural services (tourism, education and cultural heritage) and; support services (habitats for biodiversity) (Rahmadwiati *et al.,* 2022). Therefore, the studies have been supported by environmental economic valuation and sustainable management models that ensure the sustainability of forest services for future generations (Rahmadwiati *et al.,* 2022).

Regarding Forest Management, research is explaining current and future challenges for the sustainability of forests and the well-being of society. Practices are being proposed to take advantage of resources without compromising forest resources. Aspects such as forest inventories and environmental impact are being reviewed to explain the problem of deforestation and the scarce resources that favor efficient and effective forest management (Tolera, 2022).

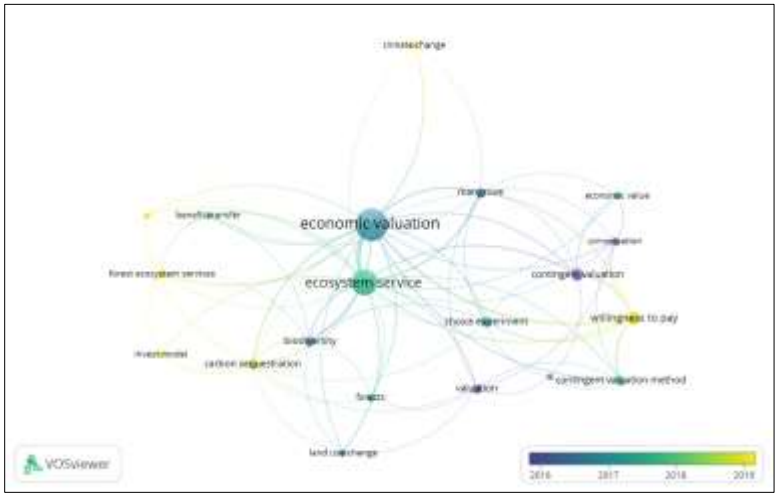

Figure 3. - *Overlay keywords by author*

CONCLUSIONS

Research on the economic valuation of forests has evolved significantly. Studies have focused their attention on the ecosystem services that forests provide, which include provision, regulation and support services. Also, the use of various economic valuation methods has been evidenced, such as revealed, declared and integrated valuation methods.

There is still some way to go to fully develop the economic valuation of forests. Without a doubt, the economic valuation of forests does not help to eliminate the problems that affect forests, but it does help to understand the value of forests and to make decisions that promote conservation, optimization of resources and evaluation of the impact of the activities of the society.

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The authors declare not to have any interest conflicts.

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The authors have participated in the writing of the work and analysis of the documents.