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LAURA ANDREINA MATOS MÁRQUEZ

TURISMO EM UNIDADES DE CONSERVAÇÃO: CAPACIDADE DE CARGA TURÍSTICA, VALORAÇÃO E SERVIÇOS AMBIENTAIS CULTURAIS

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Tese apresentada ao Programa de Pós-Graduação em Recursos Naturais do Cerrado da Universidade Estadual de Goiás - UEG, como requisito para obtenção do título de Doutora em Ciências Ambientais.

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Orientador: Prof. Dr. João Carlos Nabout
Coorientadora: Dra. Joana D arc Bardella Castro.

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Aos 28 de março de 2025, a partir das 13 horas em formato híbrido, foi realizada a sessão de Banca de Defesa de Doutorado da discente **LAURA ANDREINA MATOS MARQUEZ**, que apresentou o trabalho **intitulado “TURISMO EM UNIDADES DE CONSERVAÇÃO: CAPACIDADE DE CARGA TURÍSTICA, VALORAÇÃO E SERVIÇOS AMBIENTAIS CULTURAIS ”.** A Banca Examinadora foi composta pelos seguintes Professores: Prof. Dr. João Carlos Nabout (Orientador - presidente da banca), Dra. Hélida Ferreira da Cunha (Avaliadora Interna- UEG), Dr. Rodrigo Assis de Carvalho (Avaliador interno - UEG), Dra. Josana de Castro Peixoto (Avaliadora Externa - UNIEVANGÉLICA), Dra. Márcia Teixeira Falcão (Avaliadora Externa - UERR). Após a apresentação da discente, os examinadores a arguiram, tendo a discente respondido às perguntas formuladas. Terminada a arguição, a Banca Examinadora reuniu-se emitindo os seguintes pareceres:

Membros da Banca	Parecer (Aprovado/Reprovado)
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SUMÁRIO

RESUMO

Os Serviços Ecossistêmicos Culturais (SEC) têm se consolidado como um campo de pesquisa em expansão, com diferentes abordagens para sua valoração. No primeiro capítulo, realizamos uma revisão sistemática da literatura para identificar tendências e métodos empregados na valoração dos SEC. Os resultados evidenciaram um crescimento nas publicações sobre o tema, com destaque para ambientes terrestres e o valor recreativo, além da predominância de métodos não monetários. No segundo capítulo, analisamos a relação entre biodiversidade e turismo em Unidades de Conservação Federais no Brasil. Os achados indicaram que a riqueza de espécies registrada por cientistas cidadãos e a densidade populacional das cidades vizinhas influenciam significativamente o número de visitantes. No terceiro capítulo, avaliamos a capacidade de carga turística da Floresta Nacional de Silvânia, utilizando o método de Cifuentes. Os resultados sugerem que a área comporta um maior número de visitantes, desde que haja um monitoramento contínuo da biodiversidade para mitigar impactos negativos. Por fim, no quarto capítulo, investigamos a percepção dos visitantes sobre os SEC na Floresta Nacional de Silvânia, considerando fatores socioeconômicos. A variável mais relevante para a percepção dos SEC foi a educação, ressaltando o potencial da área como recurso cultural, recreativo e ecológico.

Palavras-chave: revisão sistemática; capacidade de carga turística; bioma Cerrado; percepção; serviços ecossistêmicos culturais; biodiversidade; abundância, riqueza, cientista-cidadão, cientistas.

# ABSTRACT

Cultural Ecosystem Services (CES) have been consolidating as a growing field of research, with different approaches to their valuation. In the first chapter, we conducted a systematic literature review to identify trends and methods used in the valuation of CES. The results showed an increase in publications on the topic, with an emphasis on terrestrial environments and recreational value, as well as the predominance of non-monetary methods. In the second chapter, we analyzed the relationship between biodiversity and tourism in Federal Conservation Units in Brazil. The findings indicated that species richness recorded by citizen scientists and the population density of nearby cities significantly influence the number of visitors. In the third chapter, we assessed the tourism carrying capacity of the Silvânia National Forest using the Cifuentes method. The results suggest that the area can accommodate a greater number of visitors, provided that continuous biodiversity monitoring is conducted to mitigate negative impacts. Finally, in the fourth chapter, we investigated visitors' perceptions of CES in the Silvânia National Forest, considering socioeconomic factors. The most relevant variable for the perception of CES was education, highlighting the area's potential as a cultural, recreational, and ecological resource.

Keywords: systematic review; tourism carrying capacity; Cerrado biome; perception; cultural ecosystem services; biodiversity; abundance, richness, citizen-scientist, scientists.

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1. Introdução Geral

O turismo se apresenta como uma alternativa para a apreciação do espaço, refletindo os novos valores da sociedade contemporânea, que demonstra uma clara preferência por lugares serenos e isolados, onde é possível desfrutar de atividades em ambientes abertos e livres. Um novo perfil turístico está surgindo, caracterizado por uma crescente sensibilidade em relação ao meio ambiente, à herança tradicional, histórica e cultural (Colmenares, 2018). Os benefícios imateriais proporcionados pelos ecossistemas, conhecidos como serviços culturais associados ao lazer (turismo), inspiração espiritual e bem-estar mental, desempenham um papel crucial na ligação entre o turismo e as áreas de conservação, reconhecendo que a capacidade dos ecossistemas de fornecer serviços essenciais é vital para a vida humana no planeta (Simonetti e do Nascimento, 2012).

O turismo, sendo um fenômeno complexo e multifacetado, varia de acordo com diversos fatores, como localização geográfica, clima, aspectos sociais e ambientais, além da cultura, entre outros. Portanto, o planejamento e a gestão do turismo devem ser adaptados às particularidades de cada destino (Oliveira, 2019). O aumento do uso dos ecossistemas para recreação e turismo é impulsionado pelo crescimento populacional, maior disponibilidade de tempo para lazer nas camadas mais afluentes da sociedade e melhorias na infraestrutura (Mendonça e Neiman, 2003; Andrade, 2010; Alho, 2012). Os turistas buscam vivências únicas, alinhadas às suas novas necessidades e preferências, muitas vezes voltadas para o ambiente natural (Gil, 2003; Torres, 2004). Assim, as tradições, a cultura, o patrimônio natural e arquitetônico, bem como as características de áreas rurais, estão se tornando destinos de crescente interesse entre os turistas (Cintra, 2004; Saxena et al., 2007).

A sustentabilidade e a competitividade turística estão profundamente interligadas, sendo que a competitividade depende, inevitavelmente, do respeito, da conservação e da valorização do patrimônio, especialmente quando se trata de áreas naturais protegidas (Márquez e Colmenares, 2018). Paisagens que evocam sensações de prazer, com relevo diversificado, água limpa, vegetação exuberante e rica biodiversidade, são altamente valorizadas (Gómez, 2008). A paisagem é um recurso fundamental para o turismo, servindo como base e apoio para essa atividade. Como qualquer recurso, está sujeita a condições de utilidade e escassez, sendo a conservação essencial para manter a atratividade dos espaços naturais (Hunter, 2012; Cruz, 2006). É imperativo repensar as abordagens e metodologias turísticas tradicionais, que embora lucrativas, podem ameaçar a sustentabilidade da própria atividade, das comunidades e do equilíbrio ambiental do planeta (Colmenares, 2017).

Nesse contexto, o turismo depende profundamente da conservação dos recursos naturais, que constituem os principais atrativos turísticos (Tolón et al., 2008). Com o crescente interesse nos serviços ecossistêmicos e sua relação com o bem-estar humano, a preservação desses serviços ganhou destaque tanto nos debates acadêmicos quanto na formulação de políticas. A valoração ecossistêmica tornou-se central, fornecendo diretrizes para estratégias de gestão sustentável do capital natural. Ao lidar com destinos turísticos, o conceito de capacidade de carga é fundamental, estabelecendo limites para o número de visitantes e a intensidade de uso sem causar danos irreversíveis (Cifuentes, 1992; Bonilla; Bonilla, 2008).

No Brasil, muitos dos principais atrativos turísticos estão em Unidades de Conservação (UCs), onde ambientes naturais, como praias fluviais, lagoas e cachoeiras, adquirem valor turístico à medida que são preservados (Lira; Pelicice, 2020). Além de conservar os recursos naturais, as UCs desempenham um papel significativo no turismo tanto no Brasil quanto internacionalmente. O aumento no fluxo de visitantes em busca de lazer em áreas protegidas reflete uma resposta à insatisfação com o turismo de massa, que frequentemente resulta em impactos negativos, especialmente ambientais (Oliveira, 2019).

Este trabalho tem como foco principal a análise do turismo em Unidades de Conservação (UCs) no Brasil, abordando tanto uma escala macro quanto micro. Em uma escala macro, investiga-se a relação entre o número de visitas e a biodiversidade das UCs Federais em todo o país, visando compreender os padrões e impactos do turismo nessas áreas protegidas. Além disso, foi realizada uma revisão da literatura a nível global sobre métodos de valoração dos Serviços Ecossistêmicos Culturais (CES). Em uma escala micro, o estudo concentra-se na percepção e na capacidade de carga turística da Floresta Nacional de Silvânia (FLONA Silvânia), localizada no município de Silvânia, Estado de Goiás. Apesar de ser uma das menores Unidades de Conservação de Uso Sustentável no Brasil, a FLONA Silvânia desempenha um papel crucial na preservação da biodiversidade do Cerrado (Fernandes e Da Silva, 2010; ICMBio).

Com base nessas considerações, os objetivos deste trabalho são: (1) Realizar uma revisão sistemática da literatura científica sobre métodos de avaliação de serviços ecossistêmicos culturais, utilizando as bases de dados Web of Science e Scopus; (2) Investigar se Unidades de Conservação com maior fluxo turístico apresentam mais registros de espécies, tanto por cientistas quanto por visitantes comuns; (3) Estimar a capacidade de carga turística em uma área protegida no Cerrado brasileiro (FLONA Silvânia), promovendo o desenvolvimento socioeconômico, turismo sustentável e conservação da biodiversidade; (4) Examinar como os visitantes interpretam os Serviços Ecossistêmicos Culturais (CES) na FLONA Silvânia e determinar o impacto de fatores como idade, gênero, distância e renda nessa percepção.

Objetivos da pesquisa:

Objetivo Geral:

Avaliar os determinantes ambientais, econômicos e de serviços ecossistêmicos culturais sobre as atividades turísticas em unidades de conservação.

Objetivos Específicos:

1. Realizar uma revisão sistemática da literatura explicitamente focada na valoração dos serviços ecossistêmicos culturais (SEC).
2. Investigar a relação entre a visita de turistas às Áreas Protegidas (AP) do Brasil e o número de espécies registradas por cientistas cidadãos e pesquisadores.
3. Avaliar a capacidade de carga turística da Floresta Nacional Silvânia (Estado de Goiás), através do método de Cifuentes (1992).
4. Examinar cómo los visitantes interpretan los Servicios Ecosistémicos (CES) de la Floresta Nacional Silvânia y determinar el impacto de factores como la edad, el género, la distancia y los ingresos en dicha percepción.

3. Estrutura da tese

Além do resumo e da introdução geral, esta tese está dividida em quatro capítulos, dois já foram publicados e dois estão em revisão

Capítulo 1. Márquez, L. A. M., Rezende, E. C. N., Machado, K. B., do Nascimento, E. L. M., Castro, J. D. A. B., & Nabout, J. C. (2023). Trends in valuation approaches for cultural ecosystem services: A systematic literature review. *Ecosystem Services*, *64*, 101572**.** https://doi.org/10.1016/j.ecoser.2023.101572

Capítulo 2. Nature-based tourism and biodiversity: Assessing the relationship between visitation and citizen science records in brazilian protected areas.

Capítulo 3. Matos, L. A., Velásquez, J. R., Miranda, R. C. de, & Nabout, J. C. (2023). Assessing Tourism Carrying Capacity in one Sustainable Protected Area of Cerrado: Balancing Ecological and Socio-Economic Dimensions. *Fronteira: Journal of Social, Technological and Environmental Science*, 12(3), 194–212. https://doi.org/10.21664/2238-8869.2023v12i3.p194-212

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CAPÍTULO 1:

Trends in valuation approaches for cultural ecosystem services: A systematic literature review.

Abstract

Cultural ecosystem services constitute a field of research characterised by a growing number of publications from various academic disciplines. We carried out a systematic review of the literature that explicitly assessed with the valuation of cultural ecosystem services (CES). We used the review to identify, evaluate and interpret globally available research on the valuation of CES through the Web of Science and Scopus databases from 2005 to 2022. Thus, 349 articles were included in the analysis. The first article on valuation CES was published in 2010. We observed a temporal trend towards an increase in the number of articles between 2010 and 2022. The terrestrial environment and recreational value being the most emphasised among all the analysed articles. The countries in North America and Europe presented the highest numbers of studies on the theme. We observed associations between valuation methods and typologies of CES. The most studies focused on recreational and ecotourism typology with most of them associated with non-monetary methods for valuing cultural services. However, we did not observe an association between the valuation methods and the types of ecosystems investigated in the studies. We also found a temporal trend in the keywords, with clear differentiation in the theme of the studies from 2015 onwards. The most recent themes in the research area are associated with landscape, protected areas, perception, urban green space and social media studies. In conclusion, future research should focus on considering all CES categories for unequivocal descriptions of each category, proposing the development of typologies that may be applicable in various ecosystems.

Keywords: cultural services; scientific productivity; systematic review

1. Introduction

Ecosystem services are the conditions and processes through which natural ecosystems and the species that compose them sustain and fulfil human life (Daily, 1997). According to the Millennium Ecosystem Assessment (2005), four service categories are recognised: support services, regulation services, provision services and cultural services. Many papers synthesise the scientific literature about ecosystem services (see for example Almenar et al., 2021; Ayompe et al., 2021; Eddy et al., 2021; Wang et al., 2021; Nabout et al., 2023). The amount of scientific literature on cultural ecosystem services (CES) has increased over the years (see Kosanic and Petzold, 2020), and CES are addressed in different areas, such as cultural landscapes (Schaich et al., 2010), environment and religion (Jenkins and Chapple, 2011), ecotourism (Hulme, 2011) and environmental arts and humanities (Weaver, 2001). According to the Millennium Ecosystem Assessment (MMA, 2005), CES are generally described as the "non-material benefits that people derive from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences". As an example, CES have motivated local conservation decisions in western countries. Local communities often rise up in citizen-driven campaigns to counter commercial development or privatization of green spaces used for leisure activities, such as walking, swimming or wildlife viewing (Kenter et al., 2015). Research has also shown that CES are essential for cultural identity, ecotourism (Hasan et al., 2020) and even the survival of many traditional communities, where relatively little research is focused (Voora and Barg, 2008).

CES can involve the use of natural resources directly (e.g., enjoying walking or viewing the scenery) or indirectly (e.g., the cultural heritage and spiritual value of green spaces) (Sen and Guchhait, 2021). Unlike other ecosystem services, such as carbon sequestration and water or air purification that require scientific knowledge to be recorded, CES are directly experienced and intuitively understood by people from all walks of life who come into contact with nature and the close connection between citizens, and nature offers a valuable opportunity for increasing awareness of the multi-functionality and interconnectedness of different ecosystem services and their significance for quality of life (IUCN, 2015). The services derived from ecosystems, however, cannot be defined without incorporating social constructs (Daniel et al., 2012).

The CES concept itself has been the subject of a great deal of debate and controversy in the literature. Some authors suggest revising and expanding the standard frameworks of the concept or discarding the term “cultural” (Chan et al., 2012a; Chan et al., 2012b; Fish et al., 2016; Small et al., 2017; Winthrop, 2014), while others indicate the need to abandon the concept (Kirchhoff, 2019), given the multiple approaches to categorizing what can or cannot be included as a cultural service. However, some patterns for the classification of ecosystem services typologies have been observed in the literature (Gould and Lincoln, 2017, see also see Figure S1 in Supplementary Material 1). This consensus is almost certainly not the result of the convergent evolution of thought, but of researchers building on and modifying earlier theories. For example, recreation and spirituality typologies are included in most available classifications (e.g., the proposals by Bieling, 2014; Boyd and Banzhaf, 2006; Chan, et al., 2012b; CICES, 2018; Costanza et al., 1997; de Groot et al., 2002; de Groot et al., 2010; Milcu et al., 2013; Millenium Ecosystem

Assessment, 2005; Raymond, 2009; U. K. National Ecosystem Assessment, 2011). However, for artistic, aesthetic cultural heritage, education, social/capital relations, sense of place, existence, knowledge systems, cultural diversity, identity and bequest typologies, the inclusion in the different classifications in literature of CES is quite variable (Gould and Lincoln, 2017). Furthermore, recently new typologies have been created and incorporated into the literature on CES, such as cognitive, experiential and symbolic (Daniel et al., 2012); ingenuity and life teaching perspective (Gould and Lincoln, 2017); myths (Onofri and Boatto, 2020); and music (Axelsson and Grady, 2022).

Valuation of CES is a way to understand and demonstrate the importance of non-material benefits from nature that matter to humans, and can therefore be used to inform the planning of green infrastructure (Chan et al. 2012a). Because people allocate very different meanings to nature, various methods and approaches have been used for the valuation of CES in various areas. Currently, four groups of methodologies for valuing CES are defined (Harrison and Dunford, 2015; Kelemen et al., 2015; Hirons et al., 2016), enabling the integration of various dimensions. They can be based on quantitative or qualitative data, or a combination of them, examine people's stated preferences or revealed preferences or they can yield monetary or non-monetary valuations.

In the first group of methods, there are monetary valuation techniques, such as Hedonic Pricing (HPM), Contingent Valuation (CVM), Deliberative Valuation, Choice Experiment, Avoided Cost Method, Benefits/Value Transfer, Market Price, Total Economic Value (TEV), Travel Cost Method (TCM) and Willingness to Pay (WTP) (Carson and Hanemann, 2005; Costanza et al., 1989; Farber et al., 2002). The second group contains non-monetary methods based on a socio-cultural valuation (De Souza et al., 2017; Malinauskaite et al., 2021), Observational studies, Likert scales, Delphi Method, Expert-Based, Focus Group, Interview, Observation, Participatory GIS (PGIS), Participatory Mapping, Public Participation GIS (PPGIS), Q-Method, Questionnaire, Scenario Simulation and Social Media-Based (Cheng et al., 2019; Kopperoinen et al., 2014). The third group is represented by Social Learning methods as participatory model fits (Document, Narrative), with the different actors involved in resource management and integrating different areas of reference and temporal scales with a variety of tools and coordination workshops (Étienne, 2013). Finally, in the fourth group, Integrated Methods as Bayesian Belief Networks, Multi-Criteria Decision Analysis (MCDA), Social Values for Ecosystem Services (SolVES) are available that allows users to understand a given service from different angles (Kopperoinen et al., 2014). Additionally, this categorization allows for the involvement of stakeholders in the assessment process, facilitating deliberations and social learning among them, and incorporating a spatial analysis component. Despite so many CES valuation methods, there is no global methodological consistency. Each valuation is based on a specific problem and therefore needs specific classifications, definitions and methods (Hernández et al., 2013).

We can therefore use changes in the networks of publications through time to document and visualize the development of a field (Van Eck and Waltman, 2014). The importance of this systematic review on the valuation of CES lies in the understanding, through the available articles, of the perceptions (direct and subjective) of the benefits provided by natural assets, and the value assigned through the material and symbolic practices that people establish about the places they visit (Fish et al., 2016). A review of the evaluation methods of CES contributes to the scientific advancement of this field by helping identify knowledge gaps, areas for improvement, and emerging trends (Himes-Cornell et al., 2018). This review not only aids in synthesizing existing research but also in identifying research needs, guiding future studies and methodologies and facilitating the refinement and development of valuation approaches for CES. CES valuation studies, which often involve public participation and engagement with local communities, cultural professionals and indigenous groups (Martin et al., 2012), ensure that diverse perspectives and values are considered in the valuation process. Moreover, a comprehensive review of CES valuation methods plays a crucial role in identifying existing approaches by assessing their strengths, limitations and applicability in various contexts and ultimately assisting policymakers in formulating effective policies that take into account the significance of CES (Chan et al., 2016; Schaefer et al., 2015).

In this article, we conducted a systematic review of the scientific literature on valuation approaches for CES, offering a general overview of the valuation methods used in the studies, highlighting its association with different typologies of cultural ecosystem services and their temporal trends. Thus, this study introduces a sequential and multifaceted methodology that acknowledges the complexities and nuances of CES. This study addresses the challenges associated with certain categories of CES and emphasizes the need for diverse methods to comprehensively capture the richness of cultural services. We used two global databases that index articles from different journals in the most diverse areas of knowledge, the Web of Science and Scopus. The search was carried out between 2005 and 2022. Specifically, we evaluated the following information obtained from the literature: i) the temporal trend of the scientific literature on CES over the years; ii) which ecosystems were studied; iii) in which regions (countries or groups of countries) the studies were carried out; iv) the typologies of cultural ecosystem services (according to the classification of Millennium Ecosystem Assessment, 2005); v) which valuation methods and techniques of valuation were used; vi) what strategies (e.g., qualitative, quantitative, primary data, secondary data) were used to access the information of people who use the cultural service; vii) relationship of CES typology with valuation method and their respective techniques of valuation; vii) relationship between ecosystem type and valuation method; and ix) temporal trends in the keywords used in articles on valuation of CES. Our findings in this systematic mapping contribute to understanding the main trends and gaps associated with CES valuation studies.

2. Material and Methods

2.1. Search and evaluation of the literature

We performed a systematic literature review to identify, evaluate and interpret globally available research relevant to our research questions. The review followed PRISMA guidelines for literature selections (Liberati et al., 2009), including identification, screening, eligibility and inclusion phases. The bibliography used in this study was obtained from the Web of Science (WoS – Clarivate) and Scopus databases on 10 August 2023. These databases are among the most utilized general databases for academic literature and allow for complex Boolean search terms and access to thousands of journals across all disciplines (Franceschini et al., 2016; Wang and Waltman, 2016). We used the following terms and Boolean structure: TOPIC: ("cultural ecosystem service*") and TOPIC: (Valuation* OR Evaluation*). We refined the documents and kept only articles and reviews. Studies were selected if they contained the words “cultural ecosystem service” along with other terms related to valuation present in their title, abstract or keywords. The asterisk indicates that word variations were accepted. The searches were carried out for the period from 2005 to 2022, from the publication of the Millennium Ecosystem Assessment (2005) in the previous year to the preparation of the study.

A total of 427 papers were found in the WoS database and 271 were found on the Scopus platform, totalling 698 articles. Among these, 234 were duplicated between the two search platforms and were excluded. After reading the abstracts of the remaining 464 articles, 115 papers were removed because they consisted of a literature review and did not contemplate the practical application of methods for valuing CES in a study area. As a result, 349 articles were included in the analysis.

The following information was extracted from each article: i) year of publication; ii) geographic location (country or geographic region); iii) type of ecosystem (aquatic, coastal, terrestrial, marine); iv) typology of CES, according to the Millennium Ecosystem Assessment (2005) classification (cultural diversity, spiritual services, knowledge systems (traditional and formal), educational values, inspiration, aesthetic values, social relations, sense of place and identity, values of the cultural heritage, recreation and ecotourism, including other categories proposed by recurrent authors, such as (scientific value, therapeutic services and sports services); v) valuation method used (monetary, non-monetary, integrated, social learning); vi) valuation technique used within each valuation method according to Hirons et al. (2016) and Cheng et al. (2019); vii) assigned value (qualitative, quantitative, both); viii) instrument, that is, the type of data used in the study (primary data [questionnaires, focus groups/workshops, interviews, participatory mapping] and secondary data [literature reviews]; and ix) authors keywords. The items presented above may be classified simultaneously in more than one category. The complete scheme of the methodology is shown in Figure 1.

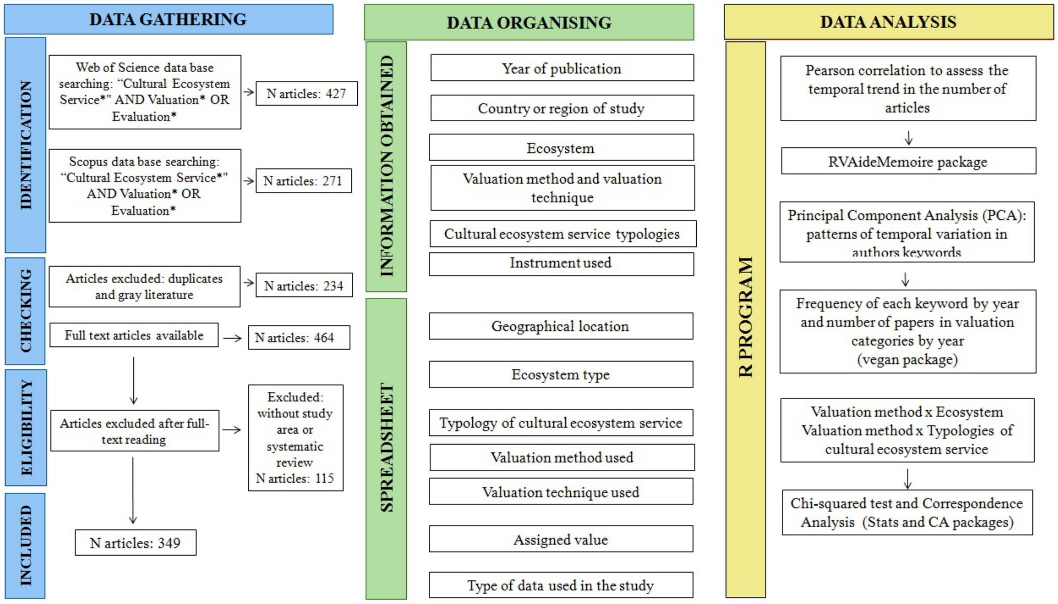

Fig. 1. Methodology workflow applied in this study, highlighting each phase in the stages of gathering, organising and analysis of data.

2.2. Data Analysis

All statistical analyses were performed in the R program (R Core Team, 2022). We used the Pearson correlation to assess the temporal trend in the number of articles over the years. This analysis was performed using the "RVAideMemoire" package (Hervé, 2021) and the significance was tested using the Monte Carlo test with 999 randomizations.

We used the chi-squared test to investigate relationships between the valuation methods with the typology of CES and the types of ecosystems analysed in the studies. A correspondence analysis (CA) was used to visualize possible patterns in these relationships. Both analyses were performed considering the number of studies obtained for each category. The chi-squared test was performed using the "stats" package (R Core Team, 2022), while the CA used the "ca" package (Nenadic and Greenacre, 2007). The CA plots were created using the "factoextra" package (Kassambara and Mundt, 2020).

A principal component analysis (PCA) was used to assess patterns of temporal variation in the authors' keywords used in the studies over the years. We found a total of 1,040 keywords from the 349 articles on the topic. Initially, we estimated the frequency with which each keyword was mentioned in the articles over the years. Then, we summed the frequency of synonymous words (e.g., biodiversity loss and biodiversity losses). In this step, we excluded the keywords "cultural ecosystem service", "cultural service", "evaluation" and "valuation", since these terms were used in the article search in the WoS and Scopus databases or are terms synonymous with them.

For the keyword PCA analysis, we considered only words with a frequency equal to or greater than two, totalling 227 keywords. Then, we divided the frequency of each keyword by the total number of keywords observed in each year. This standardised frequency was logarithmised (Log x +1) and used in the construction of the PCA. For the PCA plot, we considered the five most important keywords both negatively and positively for the first and second axis (see the complete list of keywords in Table S1 of Supplementary Material 1). PCA test was conducted using the *prcomp* function in the "vegan" package (Oksanen et al., 2020). All figures of this study and the PCA plot were created using the "ggplot2" package (Wickham, 2016).

3. Results

3.1. Temporal trends in publication number

Although our search included publications from 2005 onwards, the first article on valuation methods of CES was published in 2010. We observed a temporal trend of increasing numbers of articles between 2010 and 2022 ($r = 0.96$; $P = 0.002$), although a small reduction in the number of articles was observed in 2020. The greater number of publications was found in 2021 (Figure 2).

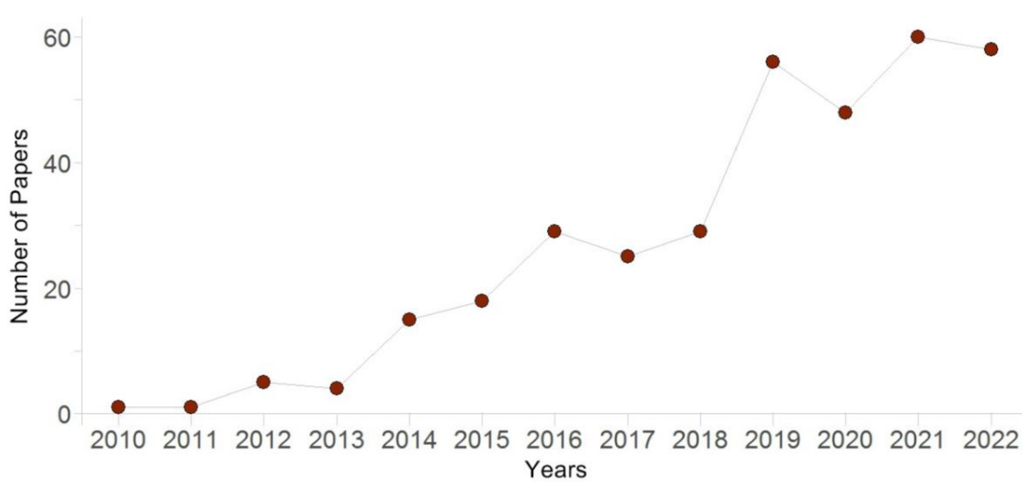

Fig. 2. Temporal trend in the number of articles published on valuation for cultural ecosystem services between the years of 2010 to 2022 available on the web of science and Scopus databases.

3.2. Characterization of ecosystems, geographic distribution and typologies of cultural ecosystem services used in the papers

Most of the studies were carried out in terrestrial ecosystems (249 articles, Figure 3A). The articles were developed in 74 different countries or regions. China (41 articles), Spain (30 articles), the United States (24 articles) and Germany (20 articles) were the countries with the greatest numbers of studies (Figure 4). Furthermore, 26 studies were developed globally, while 11 were performed considering the Europe continent and 29 in the United Kingdom region. Regarding the typologies of CES, most of the studies were directed towards recreation and ecotourism (236 articles), followed by aesthetic values (178 articles) and cultural heritage values (109 articles) (Figure 5). A smaller number of studies were dedicated to knowledge systems (44 articles), cultural diversity (40 articles) and sports (16 articles) (Figure 5).

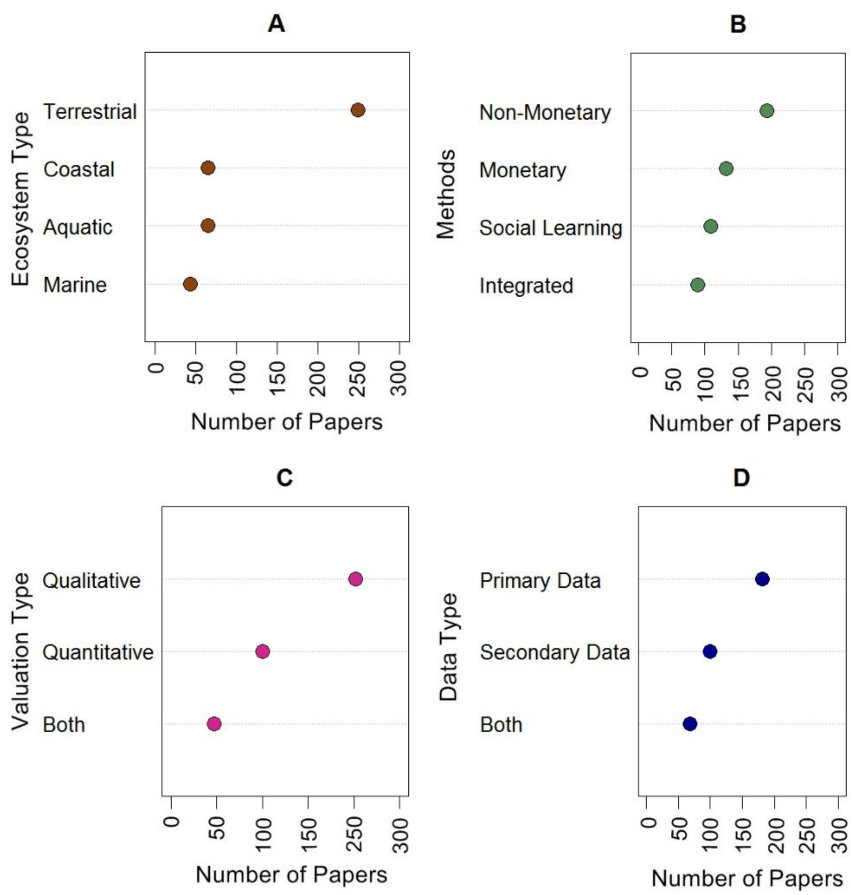

Fig. 3. Number of articles published on valuation for cultural ecosystem services considering (A) the type of ecosystem, (B) the method adopted, (C) the type of valuation and (D) the data used in the study.

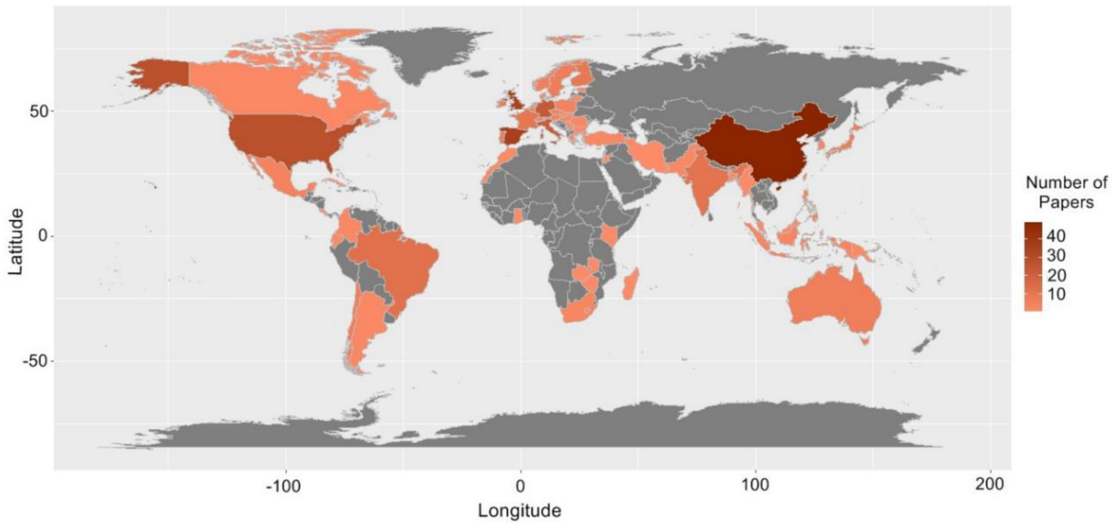

Fig. 4. Number of articles published on valuation for cultural ecosystem services considering the countries or regions of study.

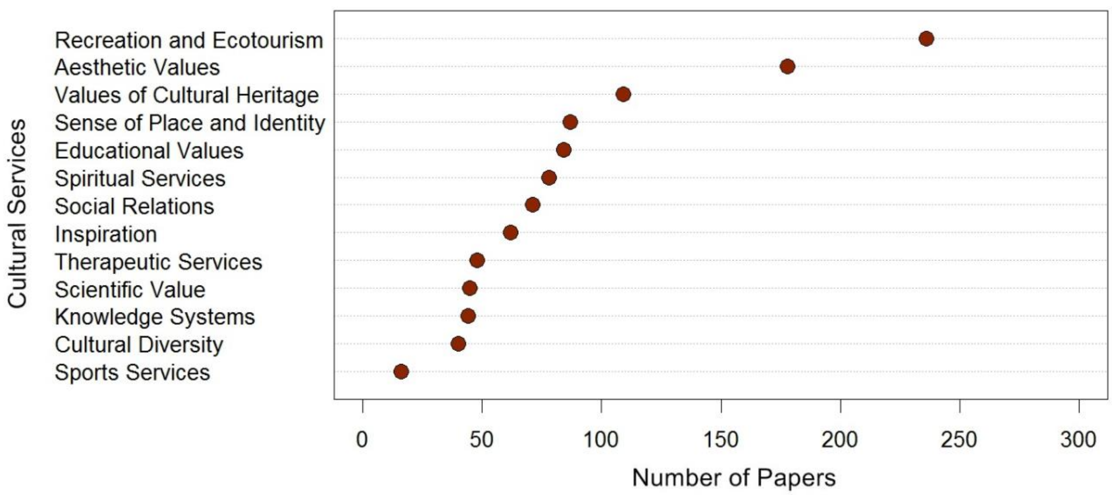

Fig. 5. Number of articles published on valuation for cultural ecosystem services considering the typology of service.

3.3. Characterization of the methods valuation

The most studies used non-monetary (194 articles) and monetary (132 articles) valuation methods, followed by social learning and integrated methods (Figure 3B). We found a total of 28 different valuation techniques considering the four categories of valuation methods (Table 1). Most of the studies focused on qualitative evaluations (202 articles, Figure 3C), and more than 50% of the studies obtained their information from primary sources through direct observations, fieldwork and interviews with stakeholders (181 articles) (Figure 3D).

Table 1 – Number of papers according to the type of valuation method used in valuation of cultural ecosystem services studies.

Method	**Number of papers**
Monetary methods	
Benefits/Value Transfer	63
Travel Cost	58
Willingness to Pay	58
Choice Experiment	38
Deliberative Valuation	21
Hedonic Pricing	14
Contingent Valuation	13
Total Economic Value	12
Avoided Cost Method	3
Market Price	3
Non-monetary methods	
Questionnaire	253
Participatory Mapping	134
Social Media-Based	68
Observation	54
Focus Group	45
Participatory GIS	31
Expert-Based	27
Scenario Simulation	22
Public Participation GIS	18
Interview	16
Delphi Method	8
Q-Method	7
Social learning	
Narrative	72
Document	56
Integrated	
Own Design	45
Social Values for Ecosystems Services	36
Multi-Criteria Decision Analysis	21
Bayesian Belief Networks	1

We found that all methods were engaged in the evaluation of recreation and ecotourism services (Figure 6). Aesthetic values emerged as the primary focus for most methods, closely followed by spiritual and religious values, as well as educational values. Notably, the monetary method exhibited a narrower scope, assessing fewer services compared to the broader coverage of non-monetary and social learning methods. Among the monetary techniques, Choice Experiment, Deliberative Valuation, Travel Cost, Willingness to Pay, and Benefits/Value Transfer demonstrated a higher capability for evaluating multiple services, outperforming other monetary approaches. In contrast, the non-monetary method showcased versatility, successfully encompassing a wide array of services. Interviews, Questionnaires, Expert-based analyses, and Participatory Mapping (GIS) methods demonstrated their effectiveness by being capable of evaluating all services. However, services that received less attention, such as Knowledge systems (traditional and formal), predominantly relied on non-monetary methodologies, particularly through observation. The social learning method, conveyed through document analysis and narrative experiences, emerged as a consistent presence across all CES categories. Turning to integrated approaches, Own Design and Social Values for Ecosystem Services (SolVES) emerged as the most commonly utilized methods for CES assessments, with Bayesian Belief Networks being comparatively less employed.

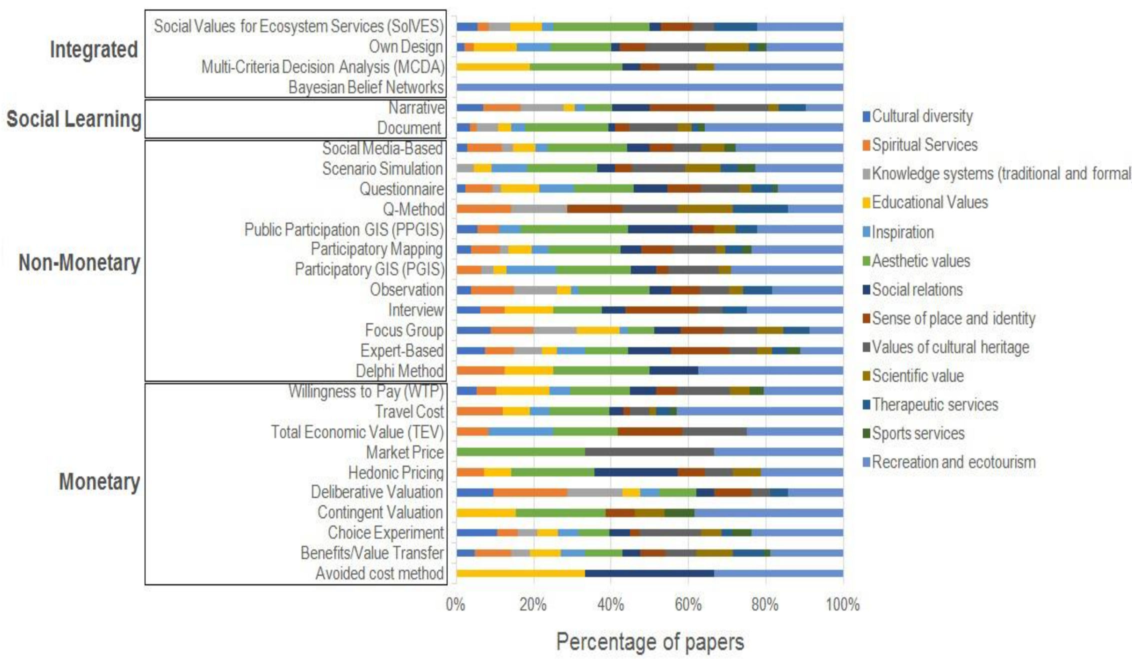

Fig. 6. Percentage of studies according the type of valuation method and typology of cultural ecosystem services (CES) investigated. The bars corresponding to 28 valuation techniques found in studies evaluated. Here, we considered the relative distribution of CES assessments by each method, rather than the absolute numerical values.

We found an association between the valuation methods and the typologies of the CES investigated in the studies ($X^2_{(36)} = 52.04$; P = 0.04). Most ecosystem service typologies were evaluated in studies using non-monetary methods (Figure 7A). These included cultural diversity, knowledge systems, inspiration, sports services, cultural heritage values and therapeutic values. The typologies of social relations, spiritual services and educational values were associated with studies with social learning and integrated methods. The typologies of sense of place and identity, recreation and ecotourism and scientific values were associated with studies that used the monetary method. However, we did not find a relationship between the types of ecosystems investigated and the valuation method used in the studies ($X^2_{(9)} = 3.71$; P = 0.92; Figure 7B).

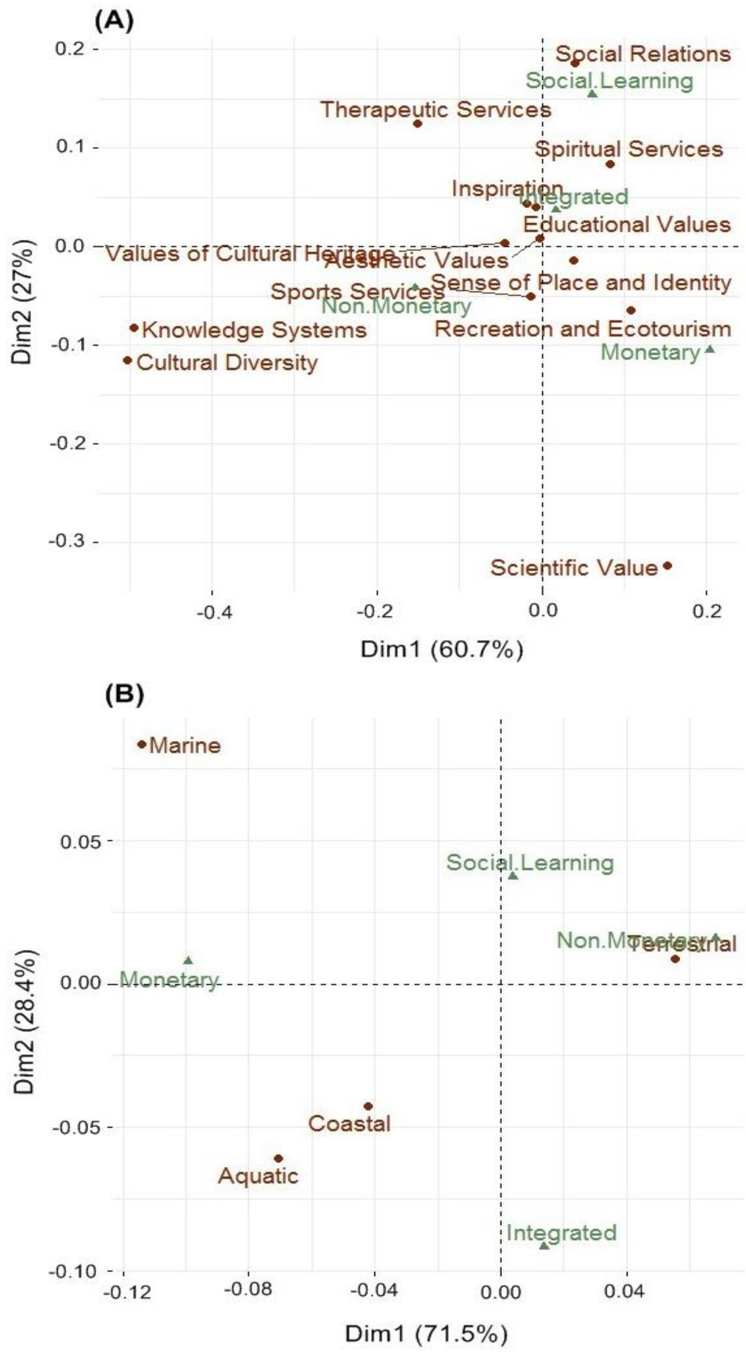

Fig. 7. Correspondence Analysis for the association between valuation methods with the typology of cultural service (A) and ecosystems (B) evaluated in the studies.

3.4. Temporal trends in research themes – Keyword Analysis

The first two axes for the PCA used to synthesise the keywords used in each year explained 26% of the variation in the data (14% for the first axis and 12% for the second axis). We verified a temporal shift in the keywords used in articles on valuation methods of CES. The first axis of the PCA provided a separation into two groups. In general, articles published between 2010 and 2014 were more associated with words such as *marine spatial planning, marine biodiversity, intangible benefits* and *cultural landscape and geographic information system*, while articles published between 2015 and 2022 were more associated with the words *landscape, protected areas, perception, urban green space* and *social media* (Figure 8). The second axis of the PCA promoted a separation mainly between the years 2012, 2017 and the other periods investigated. Thus, the articles published in this two years were mainly associated with the words *scenic beauty, ecosystem based management, natural capital, cultural landscape and geographic information system* while articles published in other years were mainly associated with the words *cost benefit analysis, southern Chile, mapping ecosystem service, marine biodiversity* and *rural landscapes* (Figure 8).

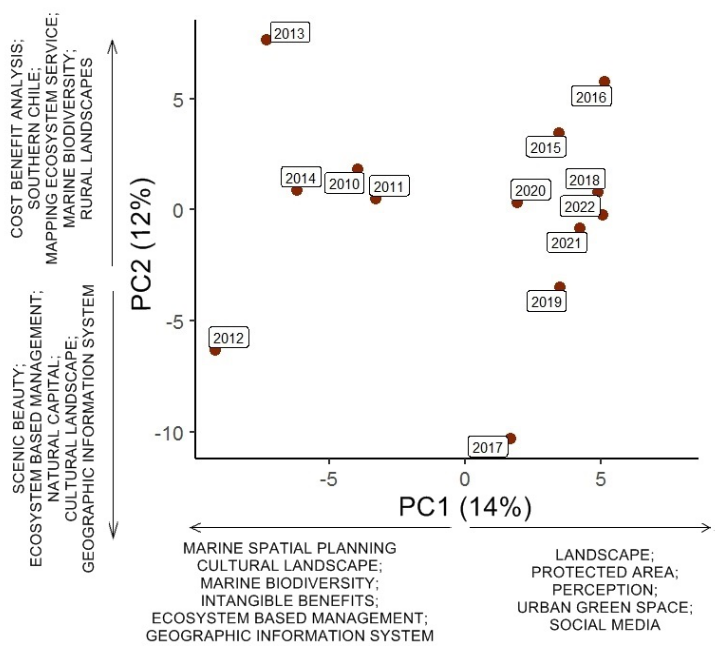

Fig. 8. Principal component analysis (PCA) scores using the keyword frequencies from articles on valuation for cultural ecosystem services. Only the most important keywords for the formation of axes 1 and 2 are presented; the list of all keywords and their relationships to the PCA axes can be found in Supplementary Material (Table 1 – SM1).

4. Discussion

In this study, we evaluated the trends in scientific publications on the valuation of CES. We found that there was an increase in the number of articles associated with this theme over the years. This increase may be linked to the impact of global initiatives, such as the Millennium Ecosystem Assessment (MEA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB, 2010), together with the Common International Classification of Ecosystem Services (CICES, 2018) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). The foundation of these intergovernmental platforms on political issues involving biodiversity involves various actors regarding the importance of environmental impacts, biodiversity and climate concerns, thus attracting more and more researchers (MEA, 2005). The publications on the theme were also due to the geographical and economic expansions of the CICES investigations (2018) since CES involve several disciplines of scientific knowledge with technical advances in their applications in those fields and dissemination through journals on the topic (Acharya et al., 2019; Chaudhary et al., 2015). However, numerous other factors can influence variations in this growth pattern. For the small reduction observed since 2020, researchers might have encountered methodological difficulties or limitations, leading to a decrease in published articles until new approaches or methods are developed (Fish et al., 2016). Furthermore, the pandemic has disrupted fieldwork, limited access to research sites and affected funding priorities. These factors may have contributed to a decline in published articles in the field of CES, partially being displaced by research in research fields related to COVID-19 (Bryan et al., 2020). Another possible cause of the recent decline could be the variation in terminology used in the cultural ecosystem services. The need for inclusivity, both in terms of incorporated threads of knowledge and the representation of worldviews, interests, and values, required the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to replace the term 'ecosystem services' with 'nature's contributions to people'. This new approach has the potential to firmly incorporate and welcome a broader array of viewpoints and stakeholders, ranging from natural, social, humanistic, and engineering sciences to indigenous peoples and local communities in whose territories much of the world's biodiversity is situated (Pascual et al., 2017; Díaz et al., 2018). However, an increasing number of researchers are using both concepts. The choice to use one or both terms is linked to the perception of differences between them and specific professional traits (Pires et al., 2020).

Our results corroborate previous findings, and we found that studies first focused on the analysis and valuation of ecosystem services in terrestrial environments (183 articles), with a lack of studies on coastal and aquatic CES and marine environments (Ahtiainen et al., 2019; Blythe et al., 2020; Kobryn et al., 2018; Martín et al., 2016). In fact, marine systems have diffused boundaries, large spatial scales and fine temporal scales that make their study difficult and may contribute to fewer investigations in these areas compared to terrestrial ecosystems (Liquete et al., 2013). Few studies synthesised data or studied all four environments (e.g., Lankia et al., 2020).

Likewise, most of the studies that address the effects of CES on human well-being mainly cover the Northern Hemisphere of the planet, with emphasis on countries in North America and Europe. Currently, scientific activity is highly concentrated in a few industrialised countries (Jappe, 2007). The predominance of publications by authors from higher-income countries is a pattern that is also found in other fields, such as medicine, biology and geography (UNESCO, 2001). It is obvious that the richest countries can invest more resources in science and, therefore, represent the largest number of publications in various academic areas (Holmgren and Schnitzer, 2004). Knowledge gaps are evident, especially regarding Africa, Central and East Asia and Latin America (Friedman et al., 2018). Few valuations of ecosystem services have been carried out in countries with less developed economies (Christie et al., 2008; Fazey et al., 2005), even though these countries host most of the world's biodiversity, and people from those countries are dependent on those services for their survival and livelihood (Christie et al., 2008). While it is difficult to specify the reasons behind the paucity of research in these countries, it may be due to the late adoption of the concept, limited funding, limited human resources and the lack of adoption and implementation of the CES assessment in all economies (Christie and Rayment, 2012).

This study shows how the categories recreation and ecotourism and aesthetic value were the most frequently investigated. This was probably due to the ease of measurement, as these typologies of cultural services can be assessed using landscape indicators or social media data (Arslan and Örücü, 2021). Another possible reason is that recreation and ecotourism or cultural heritage has rather clear and demarcated definitions, which is less true for more ambiguous CES categories like inspiration or sense of place. This coincides with the observation that the existing primary international definitions (e.g., MEA, CICES and TEEB) are still controversial (Costanza et al. 2017; Czúcz et al. 2018; Wallace, 2007). However, for some other services, it is difficult to find corresponding categories in the different international classification systems. Due to these difficulties, some researchers have focused on a single clear category, such as recreation, to represent Cultural Ecosystem Services (CES), while ignoring all other categories (Cheng et al., 2019).

Our findings highlight that half of the studies adopted a multimethod approach, primarily characterized by three distinct combinations. The prevailing trend involved a blend of monetary and non-monetary methods, illustrated by techniques like Willingness to Pay (WTP) and Participatory GIS (PGIS) (Nahuelhual et al., 2014; Zhang and Oki, 2021). Additionally, sixteen studies exclusively employed combinations of monetary methods. For instance, Garcia et al. (2016) estimated Benefits/Value Transfer and Hedonic Pricing, while Zunino et al. (2020) utilized Willingness to Pay (WTP), Choice Experiment, and other methodologies. Moreover, a subset of studies embraced a comprehensive approach, integrating monetary, non-monetary, integrated, and social learning methods (Vollmer et al., 2015; Saarikoski et al., 2022). Among these, interviews, questionnaires, document analysis, GIS, and own design were the most prevalent and effective combination.

Our research reinforces the notion that researchers frequently employ a combination of diverse methods throughout the trajectory of an evaluation process (Milcu et al., 2013; Hirons et al., 2016). Firstly, non-monetary methods predominantly take the lead during the initial stages of the study, serving as effective tools for information gathering, CES identification, and categorization. These encompass diverse approaches, such as observation, expert-based methodologies, the Q method, questionnaires, interviews, and participatory mapping, among others. Subsequently, Social Learning methods, particularly those grounded in document analysis and narrative exploration, come into play. These methods delve into understanding human preferences concerning CES, utilizing visual aids like photos and images and analyzing narratives shared by individuals to ascertain their sense of connection to the environment. The sequence then advances to encompass monetary methods, which involve techniques like market pricing or benefit/value transfer. These strategies are harnessed to quantify the economic worth of CES. This sequential arrangement holds immense promise for a meticulous evaluation of CES and offers a coherent roadmap for researchers to navigate. Lastly, integrated methods enter the scene, aiming to foster interdisciplinary and transdisciplinary collaboration in CES assessment. However, these integrated methods stand as the least utilized approach, perhaps owing to their complexity and the evolving nature of their application. This multifaceted approach not only underscores the intricate nature of CES assessment but also underscores the potential for synergistic outcomes that arise from combining diverse perspectives and techniques. The novel approach presented in our research, which involves a sequential and multifaceted methodology for evaluating CES stands out as a significant contribution to the field of environmental assessment. This approach is grounded in the understanding that CES are multifaceted and complex, requiring a holistic and nuanced evaluation process. Our research reinforces the notion that effective evaluation often necessitates the integration of diverse methods throughout the trajectory of the assessment.

The Benefits/Value Transfer method gains significant relevance in assessing the educational worth of ecosystem services. This is due to its frequent application in scenarios where resource constraints impede the execution of new primary studies (Johnston et al., 2015). Aesthetic values are intimately linked with individuals' visual and sensory encounters in natural landscapes. Among the notable methodologies in this category, the Hedonic Price method stands out, as it quantifies the valuation individuals attribute to aesthetic qualities that exert influence over economic decisions (Banarsyadhimi et al., 2022). Social relationships have been assessed through non-monetary techniques, encompassing focus groups, interviews, and participatory mapping. These non-monetary approaches possess the capacity to capture intricate social facets intrinsic to CES due to its abstract character, which heavily relies on the perceptions of the public (Riechers et al., 2018). The notion of sense of place and identity is intertwined with emotional and psychological bonds to specific locales. Among the tools employed to evaluate this category, narrative analysis (the examination of personal stories to discern one's sense of place) as part of the social learning methodology, along with participatory mapping and interviews as constituents of the non-monetary methodology, have emerged as the most frequently utilized. This enables individuals to articulate their emotional connections to places and elucidate how these connections contribute to their sense of identity (Ryfield et al., 2019).

The cultural heritage aspect exhibited a closer alignment with expert-driven methodologies, document analysis (an exploration of written materials, visuals, or other content to gather insights into human preferences within CES), and narratives. This inclination arises from the propensity to adopt a values-oriented approach, entailing a methodical assessment of the values and significance attributed to cultural assets, often accompanied by substantial emphasis on engaging stakeholders in the process (Tengberg et al., 2012). Certain categories, such as inspiration, scientific value, and therapeutic services, yielded diminished scores across various methodologies. This might stem from the challenges associated with precisely delineating and appraising these forms of services, contributing to a lack of methodological precision (Hernández et al., 2013). Aesthetic value extensively drew upon the SolVES methodology, driven by its capability to capture the subjective, social, and cultural values linked to the visual and sensory appreciation of ecosystem services. SolVES offers a fitting framework for evaluating these non-monetary dimensions and for accommodating the diverse range of community perspectives and viewpoints (Bagstad et al., 2017).

Ultimately, the adoption and application of social networks, observation and mapping as evaluation methodologies across various categories of cultural ecosystem services stem from their capacity to capture contextual information, offer a broader panorama of perceptions and viewpoints, and facilitate active community involvement. These methodologies possess the capability to complement more established techniques and furnish a more comprehensive and dynamic outlook on how individuals perceive and engage with cultural services in their everyday lives. The utilization of tailor-made methodologies to assess nearly all CES categories can be attributed to the necessity of addressing specific and intricate facets of cultural ecosystem services that don't seamlessly align with conventional methods, as elucidated in the studies of (Hérnandez et al., 2013; Hirons et al., 2016). This empowers researchers to adapt valuation strategies to the distinct attributes of cultural services and the localized contexts within which their evaluation takes place.

The analysis of keywords also demonstrated significant interest in the study of CES. The occurrence of keywords has frequently been used in systematic mappings, bibliometric studies, and/or scientometric analyses (e.g., Nabout et al., 2012). In this review, we found a clear temporal trend in the variation of keywords. Overall, all the years were associated with terms such as cost benefit analysis, mapping ecosystem service, marine biodiversity and rural landscapes. These are recurring themes in studies on the valuation of CES and have been used in publications from the earliest to the most recent ones. In the research process, the cost benefit analysis (also named as benefits/value transfer) and mapping ecosystem (also named mapping participative) are important means to measure the value monetary and non-monetary of cultural services, respectively (Hirons et al., 2016; Cheng et al., 2019). The ‘benefits/value transfer method’ evaluates economic values by transferring existing benefit estimates from studies that have already been completed for another case (D'Amato et al., 2016); while in the participatory mapping, information is obtained by asking the participants to identify the attributes of the perceived place and to mark their locations on a map (Canedoli et al., 2017). This pattern observed in the study of keywords reinforces the perspective that different valuation strategies have been used in studies of cultural ecosystem services over the years.

However, we also observe the separation of studies into two distinct periods based on their keywords. During this initial period (2010 to 2014), keywords such as "cultural landscapes," "intangible benefits," and valuation of cultural services in marine ecosystems" prevailed. This marked the beginning of Cultural Ecosystem Services (CES) studies. The primary focus was to establish fundamental concepts and meanings associated with cultural landscapes. Researchers attempted to define and understand the intricate relationships between ecosystems and human cultures. This phase aimed to provide a conceptual framework for future CES research (e.g., Bennett et al., 2005; Palmer et al., 2005).

On the other hand, publications from 2015 to 2022 were associated with a new set of keywords, including "protected areas", "landscape", "perception", "urban green space" and "social networks". It is worth noting that the year 2017 was characterized by terms such as "geographic information system", "cultural landscapes", "scenic beauty" and "ecosystem-based management". This period marked a phase of rapid development in CES research, with a substantial increase in the number of papers published each year. The evolution of keywords is consistent with key areas of concern in various CES periods, as highlighted below. Ecosystems had experienced significant degradation, intensifying concerns about the conservation and protection of areas that provide CES (Tallis et al., 2008). Technological advances and the rise of digital media opened new avenues for CES research. Geographic Information Systems (GIS) allowed researchers to evaluate the spatial patterns of cultural services and their demand. This technology provided valuable information for cultural service management, decision-making, and landscape protection and development (e.g., Foltête et al., 2020; Langemeyer et al., 2018). Social media platforms offered new channels to interact with stakeholders and the public, facilitating the dissemination of research results and raising awareness about CES (e.g., Richards and Tunçer, 2018; Ghermandi et al., 2020; Zhang et al., 2022). A growing number of studies in this period aimed to understand people's perceptions of changes in ecosystems. This shift in focus reflects a greater interest in the human dimension of CES research. Researchers sought to capture how individuals perceive and interact with changing ecosystems, recognizing the importance of considering human values, experiences, and attitudes in the evaluation of cultural services (e.g., Gai et al., 2022; Hegetschweiler et al., 2022; Nie et al., 2022). The persistence of “scenic beauty” as a keyword in this period reflects the ongoing importance of aesthetics in CES research. Researchers increasingly examined how scenic beauty influenced tourism, outdoor recreation, and property values (Do, 2019; Codoceo et al., 2021). Finally, “urban green space” remained an important keyword, but its relevance evolved with rapid urbanization and growing recognition of the need for green infrastructure in cities. Researchers from this period explored how urban green spaces not only provided cultural benefits but also contributed to urban biodiversity, climate resilience, and public health (e.g., Enssle and Kabisch, 2020; Tian et al., 2020).

5. Conclusions

Throughout the course of this review, we have extensively examined a literature of valuation for CES encompassing monetary, non-monetary, social learning, and integrated approaches. We have taken great care to assess their individual strengths, limitations, and suitability within diverse contexts. Fundamentally, our research illuminates a dynamic and continually evolving process that mirrors the ever-changing character of ecosystems and human interactions with them. By amalgamating various methodologies, our multifaceted approach enhances the comprehensiveness and precision of CES assessments. This approach not only underscores the intricate and interconnected nature of CES evaluation but also accentuates the potential for synergistic outcomes that result from the amalgamation of diverse perspectives and techniques. In an era where conservation and sustainable ecosystem management take precedence, our research provides an invaluable guide for researchers and professionals to adeptly navigate the intricacies of CES assessment. We encourage all stakeholders to utilize this review as a valuable resource, selecting and tailoring the most suitable assessment methods to align with their specific needs and circumstances. By doing so, we can collectively progress towards a more all-encompassing and holistic approach to the management of cultural ecosystem services, thereby safeguarding the rich blend of culture and nature that defines our communities and our planet. It is important to underscore that there is no one-size-fits-all approach to CES assessment, given that the cultural significance and relevance of these services vary across regions and communities. Instead, this diversity offers an opportunity for adaptability, ensuring that the chosen method resonates with the distinctive attributes of the services being evaluated.

Lastly, the temporal analysis of keywords in CES research underscores the field's evolution over time. The shift from establishing fundamental concepts to rapid development, driven by environmental concerns and technological innovations, underscores the dynamic nature of cultural ecosystem services research. This evolution underscores the increasing recognition of CES's significance in contemporary society and the necessity for comprehensive approaches that encompass both ecological and human aspects.

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Trends in valuation approaches for cultural ecosystem services: A systematic literature review.

Supplementary Material 1

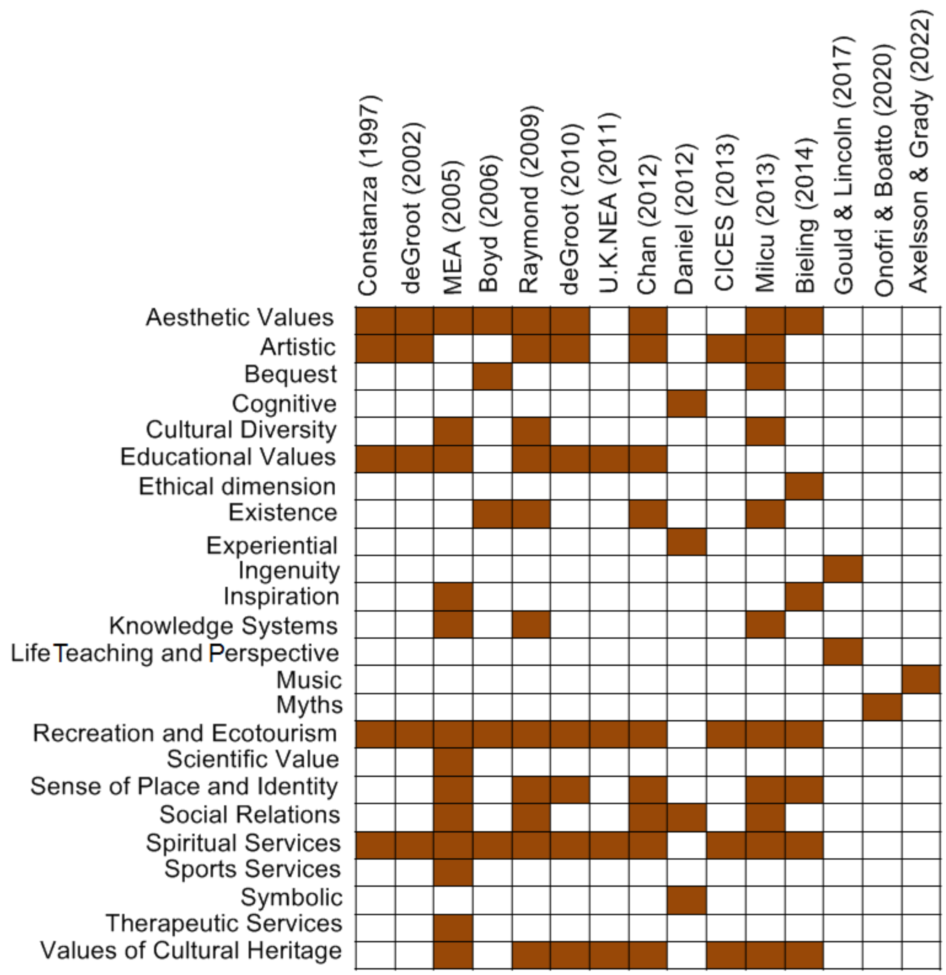


Figure S1 - Typologies of ecosystem cultural services available in the literature.

Table 1 – Scores for Principal Component Analysis (PCA) considering the keywords variation along the years in articles on valuation methods of cultural ecosystem services

Keywords	PC1	PC2
Aesthetic Value	0.028482	-0.09915
Agricultural Landscape	0.068621	0.013271
Agriculture	0.042514	0.038072
Agrienvironmental Policy	0.042229	0.030097
Agroecosystem	0.047298	0.03931
Agroecosystem Services	0.023335	-0.00234
Barcelona	0.05934	0.048613
Behaviour	0.043503	0.001689

Benefit Transfer	-0.00256	0.047994
Bequest Value	0.044748	0.031656
Big Data	0.067162	-0.01957
Biodiversity	0.072431	-0.02288
Biodiversity Conservation	0.05934	0.048613
Bivalve	0.013496	0.002608
Black Sea	-0.02084	0.044148
Bundles	0.041545	-0.02712
Carbon Sequestration	0.013496	0.002608
China	0.031017	-0.10689
Choice Experiment	0.0663	-0.06361
City	0.05679	0.040959
Climate	0.043503	0.001689
Coastal	0.047995	0.004412
Coastal Management	0.018266	-0.01155
Coastal Wetland	0.018266	-0.01155
College Students	0.026392	-0.01683
Colombia	0.035377	0.006965
Conservation	0.138584	-0.09783
Conservation Economics	0.028673	-0.00694
Content Analysis	0.04924	0.03438
Contingent Valuation Method	0.023198	-0.00975
Cost Benefit Analysis	-0.02453	0.189522
Cultural Landscape	-0.16898	-0.20034
Culture	-0.02208	0.014181
Decision Support	-0.02208	0.014181
Deliberative Democracy	0.042229	0.030097
Deliberative Monetary Valuation	0.056452	0.077106
Deliberative Valuation	0.027827	0.000386
Deliberative Value Formation Model	0.05934	0.048613
Demand	0.013652	0.012265
Demography	0.051108	0.003158
Developing Country	0.026392	-0.01683
Discrete Choice Experiment	0.078467	0.03318
Ecological Restoration	0.041679	-0.11991
Ecological Status	0.042229	0.030097
Economic Valuation	-0.06379	-0.10111
Economic Value	0.046615	-0.01791
Ecosystem Based Management	-0.14248	-0.20216
Ecosystem Service Demand	-0.03413	0.004878
Ecotourism	0.098696	0.020241

Environmental Ethics	0.030884	-0.0141
Environmental Policy	-0.05752	-0.09783
Environmental Valuation	0.059148	-0.11028
Environmental Value	-0.03919	-0.00433
Environmental Values And Valuation	-0.09587	-0.09846
Ethnography	0.030884	-0.0141
Europe	0.021323	-0.02604
Fair Price	0.047268	0.064562
Fisheries	0.038488	-0.01263
Flickr	0.070286	0.043567
Focusing	0.030884	-0.0141
Forest Park	0.026392	-0.01683
Forests	0.046039	-0.00605
Freshwater	0.044278	-0.15056
Geographic Information System	-0.13246	-0.17841
Geotagged Photographs	0.046615	-0.01791
Germany	0.035377	0.006965
Global Change	0.032974	-0.09643
Green Infrastructure	0.110286	0.004605
Greenspace Management	0.023335	-0.00234
Grounded Theory	-0.02963	0.007601
Hedonic Pricing	-0.11603	-0.10249
Human Wellbeing	0.026392	-0.01683
Image Recognition	0.028673	-0.00694
Importance Performance Analysis	0.035953	-0.00489
India	0.023335	-0.00234
Indicators	0.027827	0.000386
Indonesia	0.027827	0.000386
Intangible Benefits	-0.14794	0.0639
Integrated Valuation	0.076283	0.051887
Land Use	0.059126	0.009462
Land Use Change	0.080987	0.066086
Landscape	0.183843	0.083101
Landscape Aesthetic	0.045659	-0.12824
Landscape Aesthetic Quality	0.035953	-0.00489
Landscape Architecture	0.026392	-0.01683
Landscape Features	-0.04225	0.010154
Landscape Management	0.056576	0.001809
Landscape Perception	0.042229	0.030097
Landscape Planning	0.057276	-0.03093
Landscape Planning And Management	0.035953	-0.00489

Landscape Services	0.032974	-0.09643
Landscape Value	-0.02302	-0.02095
Literature Review	0.023413	-0.10836
Local Scale	0.038488	-0.01263
Machine Learning	0.028673	-0.00694
Mangrove	0.055265	-0.05727
Mapping	-0.10994	0.130219
Mapping Ecosystem Service	-0.11284	0.146842
Marine	0.035377	0.006965
Marine Biodiversity	-0.15634	0.145154
Marine Ecosystem Services	0.080948	0.030548
Marine Protected Area	0.09632	0.076665
Marine Spatial Planning	-0.23012	0.032514
Marine Strategy Framework Directive	0.039679	0.022444
Maxent	0.030884	-0.0141
Maximum Entropy Models	0.030884	-0.0141
Meta Analysis	-0.00256	0.047994
Millennium Ecosystem Assessment	0.04924	0.03438
Mixed Methods	0.056844	0.035849
Mixed Methods Research	0.023335	-0.00234
Monetary Valuation	0.031017	-0.10689
Mountain Landscape	0.035735	-0.00192
Multifunctionality	0.045064	0.045725
Multiple Values	0.027827	0.000386
National Forest	-0.04534	-0.09639
National Park	0.134462	0.036281
Natural Capital	-0.06144	-0.20158
Natural Language Processing	0.023335	-0.00234
Natural Resource Management	0.047298	0.03931
Natural Resources	0.047995	0.004412
Nature Based Recreation	0.054001	-0.01347
Nature Based Solutions	0.102898	0.045191
Nature Contributions To People	0.072789	-0.03176
Nature Perception	0.039679	0.022444
Nature Valuation	0.047298	0.03931
Neuroscience	0.027827	0.000386
Non Monetary Valuation	0.070711	-0.06905
Non Use Values	-0.10791	-0.10776
Nonmarket Valuation	0.06497	0.030572
Nonmaterial Benefits	0.042229	0.030097
Norway	0.05498	-0.06524

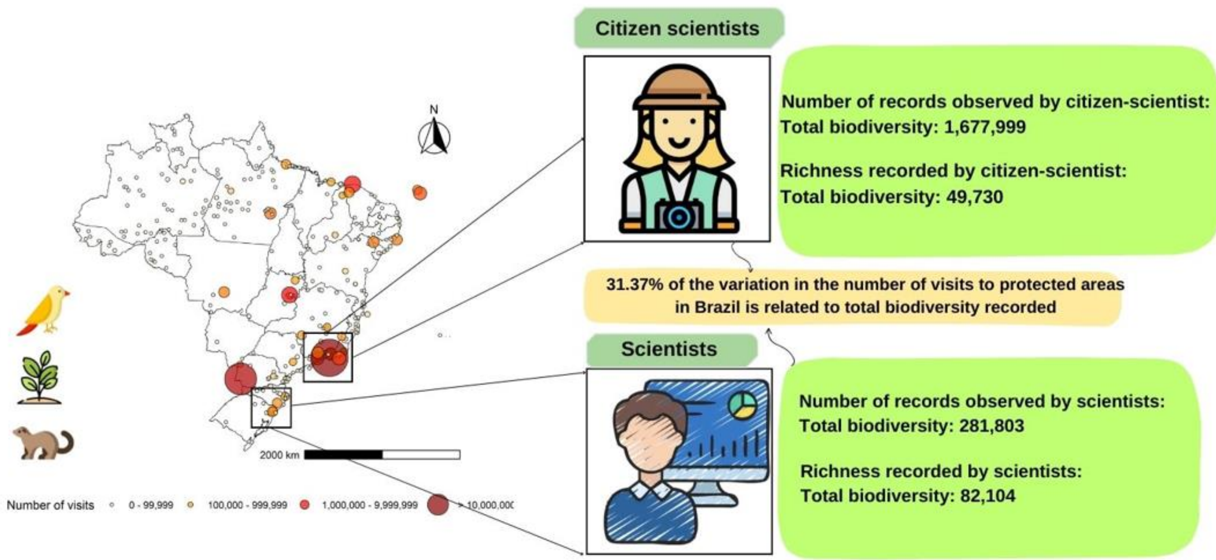
Nutrient Removal	0.013496	0.002608
Outdoor Recreation	0.065286	0.044641
Participation	-0.01829	0.051802
Participatory Mapping	0.071178	0.021023
Participatory Methods	0.044319	-0.05223
Passive Crowdsourcing	0.030884	-0.0141
Peatlands	0.026392	-0.01683
Perception	0.16301	-0.11047
Photoseries Analysis	0.070001	0.035593
Place Attachment	0.082463	0.03091
Place Identity	0.041769	-0.05988
Policy	0.056041	-0.1328
Pragmatism	0.028482	-0.09915
Protected Area	0.174468	-0.08394
Public Participation	-0.11298	-0.11697
Public Participation Gis .Ppgis.	0.130948	-0.09013
Public Perception	0.038488	-0.01263
Public Space	0.035953	-0.00489
Q Methodology	0.044748	0.031656
Questionnaire	0.053445	-0.00455
Random Utility Model	0.018266	-0.01155
Recreation	0.023145	0.09792
Recreation Opportunity	0.060241	0.036177
Recreation Potential	-0.09075	0.132662
Recreational Activities	0.043503	0.001689
Recreational Benefit	0.044748	0.031656
Recreational Ecosystem Services	0.038434	-0.00752
Recreational Value	0.047995	0.004412
Regulating Services	-0.09888	0.137939
Relational Values	0.125556	-0.04155
Remote Sensing	0.038488	-0.01263
River	0.056255	-0.09365
River Rehabilitation	0.060584	0.07858
Rural Development	-0.04225	0.010154
Rural Landscapes	-0.07277	0.137993
Scenarios	0.021323	-0.02604
Scenic Beauty	-0.09815	-0.23622
Scotland	0.075071	0.044805
Sense Of Place	-0.02652	0.006347
Shared Values	0.084011	0.043452
Shenzhen	0.032974	-0.09643

Smart Approach	0.035377	0.006965
Social Differentiation	0.026392	-0.01683
Social Ecological Systems	0.087723	0.040693
Social Media	0.158717	-0.10838
Social Network Data	0.021323	-0.02604
Social Perception	0.096508	0.098941
Social Valuation	0.086603	0.044603
Social Values	0.083814	-0.12731
Social Values For Ecosystem Services .Solves.	0.074387	-0.01241
Socio Cultural Valuation	0.104037	-0.12839
Socio Cultural Values	0.05179	0.042033
Soil Ecosystem Services	0.042229	0.030097
Southern Chile	-0.07492	0.179586
Spain	0.060584	0.07858
Spatial Analysis	0.103186	0.026025
Spatial Planning	0.030884	-0.0141
Spatially Explicit Indicator	-0.02084	0.044148
Stakeholders	0.084617	0.041345
Stated Preferences	0.035377	0.006965
Stewardship	-0.06875	0.011976
Sundarbans	0.018266	-0.01155
Supply	-0.01412	0.006769
Surveys	0.043503	0.001689
Sustainability	-0.0139	0.003794
Sustainable Development	0.067302	0.041201
Synergies	0.035735	-0.00192
Systematic Review	0.047298	0.03931
Text Mining	0.036245	-0.00877
Tourism	-0.07449	-0.12961
Trade Offs	0.088165	-0.07481
Traditional Ecological Knowledge	0.023413	-0.10836
Transcendental Values	0.047268	0.064562
Travel Cost Method	0.112248	-0.01679
Turkey	-0.02084	0.044148
Urban Adaptation	0.035377	0.006965
Urban Agriculture	0.047298	0.03931
Urban Biodiversity	0.05679	0.040959
Urban Ecosystem Services	0.059828	0.04732
Urban Ecosystems	0.080125	0.038622
Urban Green Space	0.159813	0.062947
Urban Parks	0.0978	-0.12078

Urban Planning	0.023413	-0.10836
Urban Protected Area	0.030884	-0.0141
Urban Sustainability	0.018266	-0.01155
Urbanization	0.05179	0.042033
Value Transfer	0.046039	-0.00605
Visitor Employed Photography	0.023335	-0.00234
Vulture Restaurant	0.028673	-0.00694
Vultures	0.028673	-0.00694
Well Being	0.096624	-0.13016
West Bengal	0.023335	-0.00234
Wetland Management	0.013496	0.002608
Wetlands	0.041545	-0.02712
Willingness To Pay	0.040243	-0.05662
Willingness To Pay Highly Urbanized City	0.026392	-0.01683

CAPITULO 2

Nature-based tourism and biodiversity: Assessing the relationship between visitation and citizen science records in brazilian protected areas.



Abstract

The connection between biodiversity and cultural ecosystem services extends beyond an environmental relationship; it acts as a bridge to sustainability, conservation, and human well-being. This study examines whether tourist visitation to Brazil's Federal Protected Areas is influenced by species biodiversity considering the number of species (i.e. richness) and number of records by species of birds, plants, and mammals. Acknowledging that other factors may also affect ecotourism in these areas, the models also assessed area size, protected area age, distance from urban centers, and population density of surrounding cities. Data were collected from 334 protected areas, including biodiversity records by scientists and citizen-scientists, visitation statistics, and relevant geographic and demographic variables. A multiple regression analysis was conducted to identify the factors affecting visitation rates. The results revealed that citizen-scientist recorded 33 times more biodiversity quantity and three times more biodiversity richness than scientists. Birds were the group with the highest number of records, while plants recorded the greatest richness. Mammals had the lowest records in both profiles. The number of visits to protected areas was significantly influenced by the increase in species richness recorded by citizen-scientists and by the higher population density in the cities where the protected areas are located. The findings suggest that biodiversity and population density, rather than the size or age of protected areas, is the true draw for tourism. Ultimately, the data collected from visitors not only complement scientific records but also promote greater public engagement and awareness of the importance of biodiversity.

Keywords: Abundance, richness, citizen-scientist, scientists, cultural ecosystem services.

1. Introduction

Biodiversity is one of the fundamental pillars of the planet's sustainability, as it supports essential ecosystem services for life, such as the provision of food, clean water, climate regulation, and crop pollination (Cardinale et al., 2012). Its role in conservation lies in ensuring the stability and resilience of ecosystems in the face of disturbances, such as climate change and human activities (Chapin et al., 2000). Moreover, biodiversity is not only a preservation goal but also an indispensable tool for maintaining environmental, social, and economic balance (Díaz et al., 2019). Therefore, protecting it not only ensures the functioning of ecosystems but also the sustainability of present and future generations (Sala et al., 2000).

Biodiversity encompasses more than the variety of species present in the world; it also includes genetic diversity within species and ecosystem diversity. Genetic diversity refers to the variation in genes within a species, which allows it to adapt to changing environmental conditions and plays a critical role in conservation (Bellard et al., 2012). Meanwhile, ecosystem diversity involves the variety of habitats, ecological communities, and processes that sustain life on Earth (MEA, 2005). These dimensions of biodiversity are deeply interconnected and are essential for maintaining ecosystem stability and resilience (Loreau et al., 2001). The loss of biodiversity in any of these forms—species, genetic, or ecosystems—can destabilize ecosystems and compromise the vital services they provide, such as food production, climate regulation, and water purification, thereby threatening human well-being and planetary sustainability (IPBES, 2019).

The short- and long-term benefits that biodiversity provides to humans can be classified as "ecosystem services" (Jennings et al., 2016). Ecosystem services are defined as the ecological processes and functions that directly or indirectly contribute to human well-being, encompassing the benefits people derive from ecosystem functioning (Costanza et al., 2017). Thus, biodiversity contributes to ecosystem services, regulating processes, and providing intrinsic value (Mace et al., 2012). Well-conserved ecosystem services and biodiversity have been shown to significantly enhance human well-being (Guo et al., 2010). Among these, cultural ecosystem services stand out for their role in shaping human experiences and interactions with nature. They encompass intangible benefits such as spiritual enrichment, cognitive development, recreation, and aesthetic appreciation, which are deeply rooted in the dynamic relationship between human cultures and natural environments (MEA, 2005; Daniel et al., 2012). These benefits vary among individuals and communities, influenced by socioeconomic contexts, personal values, and cultural traditions, making their evaluation inherently complex (Plieninger et al., 2015; Viera et al., 2021). Moreover, the intuitive and subjective nature of these services often fosters emotional connections with ecosystems, potentially mobilizing public support for conservation initiatives (Daily et al., 2009). However, the challenge lies in quantifying these services, as traditional evaluation methods, such as structured interviews and participatory mapping, are resource-intensive and geographically limited, underscoring the need for more efficient and standardized approaches to assess their value (Richards and Friess, 2015; Bragagnolo et al., 2021; Ives et al., 2017).

Biodiversity encompasses various interconnected values: instrumental values (benefits derived from nature), relational values (living in harmony with nature), and intrinsic values (moral considerations for non-human life) (Díaz et al., 2015; Martin, 2022). These values are reflected in a complex framework that highlights the different ways individuals perceive and value non-human nature (Himes and Muraca, 2018). A key aspect in this context is the impact of green spaces on human health and well-being, facilitated by these essential cultural ecosystem services (Oosterbroek et al., 2016). Numerous studies have shown that natural landscapes contribute to psychological benefits, such as stress reduction (Ulrich et al., 1991; Parsons et al., 1998; Ulrich, 1999), and cross-cultural appreciation for nature-related behaviors is widely observed (Grinde and Patil, 2009). In this regard, studies by Norton et al. (2012) and van Berkel and Verburg (2014) emphasize that the attribution of CES is closely linked to specific ecosystems and spatial characteristics. Their findings reveal correlations between cultural services and physical landscape elements, such as forests, water bodies, geographical relief, and coastal areas (in England), as well as cultural buildings, tree lines, lakes, rivers, and semi-natural landscapes (in the Netherlands). Furthermore, settlements and pastures near villages foster a sense of belonging and social cohesion, despite higher noise levels. Water bodies are pivotal for recreation, education, aesthetic enjoyment, and cultural heritage, while forests significantly contribute to educational and spiritual aspects. In contrast, agricultural lands and quarries are seldom associated with cultural services, highlighting distinct gaps in ecosystem service provision.

Brazil, with its vast array of ecosystems, is home to unique and abundant biodiversity (Lewinsohn et al., 2005; Rylands and Brandon, 2005). This biological wealth is essential for maintaining natural ecosystems and attracts millions of tourists each year (Almeida et al., 2022; Pinheiro et al., 2021). The country boasts the highest insect biodiversity in the world (Rafael et al., 2009) and is composed of six biomes that vary in size, geomorphology, climate patterns, species richness, and endemism (IBGE, 2004). Protected areas (PAs) are not isolated from the rest of the world (Chung et al., 2018). Nature enjoyment, particularly in protected areas, is recognized as one of the most prominent cultural ecosystem services (MEA, 2005). Several factors influence tourist visitation to these areas (Neuvonen et al., 2010; Nabout et al., 2022). Most visitors to protected areas travel from distant locations to experience them (Liu et al., 2013). As the proximity between urban areas and protected areas increases, so does the potential for both positive and negative interactions (McDonald et al., 2009). Biodiversity has a positive relationship with the number of annual visitors to protected areas. Each 1% increase in species richness is associated with a 0.87% rise in visitor numbers, highlighting biodiversity as one of the strongest influences on tourism (Siikamäki et al., 2015; Chung et al., 2018). Visitors may be interested in interacting with many species (high species richness), diverse species (high phylogenetic diversity), or abundant individuals (high abundance) (Winterbach et al., 2015; Arbieu et al., 2018).

In this study, we investigate the relationship between tourist visitation in Brazilian Protected Areas (PAs) and the number of species recorded by citizen scientists and scientists. Additionally, we consider other geographic and socio-economic factors that may influence the number of tourists visiting these areas, including the size of the protected area, population density in surrounding regions, and the year of creation of the protected area. We hypothesize that there is a positive association between biodiversity (as recorded by citizen scientists and scientists) and the number of visits to protected areas (e.g., Chung et al. 2018). This is expected because biodiversity provides a cultural ecosystem service through its aesthetic and contemplative value, attracting visitors to areas with greater biodiversity. Additionally, more frequently visited areas are likely to have higher species records due to increased sampling effort by citizen scientists.

2. Material and methods

For each Brazilian protected area, we obtained: 1) tourist visitation as a response variable; 2) species number of mammals, birds and plants found by citizen-scientist and scientists (hereinafter referred to as richness); 3) number of records by species of mammals, birds and plants observed by citizen-scientist and scientists; 4) size of the protected area; 5) year of creation of the protected area; 6) distance from the protected area to the nearest city; 7) population density; 8) geographic coordinates. Below, we present how each of these data was analyzed.

2.1. – Biodiversity in Brazilian protected areas

Data on species records (plants, birds, mammals) were consulted on Global Biodiversity Information Facility (GBIF, https://www.gbif.org/) a citizen science platform where species found by both citizens-scientists and researchers are recorded. Data on species richness (i.e. number of species) number of registers by specie were collected to identify patterns of diversity in relation to tourist visitation. Both observations made by scientists and citizen-scientist were considered in analysis. This analysis allows the assessment the relationship between biological diversity and tourist interest in PAs.

Using data from the GBIF database (https://www.gbif.org/), we extracted geographic coordinates of species records for birds, mammals, and plants documented by scientists and citizen scientists between 2000 and 2023 within Brazilian national parks. To do this, we utilized geospatial data on federal conservation units from the National Cartography Reference and thematic datasets produced by ICMBio (https://www.gov.br/icmbio/pt-br/assuntos/dados_geoespaciais/mapa-tematico-e-dados-geoestatisticos-das-unidades-de-conservacao-federais). The shapefiles provided by the Chico Mendes Institute for Biodiversity Conservation (ICMBio) served as a geographic reference for federal conservation units. By overlaying these with species records, we extracted only those occurring within park boundaries. The extracted geographic coordinates underwent a rigorous cleaning process. First, records with NA coordinates were removed. Next, we identified and excluded unreliable entries, such as fossil records, transposed coordinates, or points unlikely to represent actual occurrences—those situated in large urban centers, at sea, or in locations like zoos and research facilities. To further refine the dataset, we standardized species nomenclature using reliable taxonomic sources, ensuring that synonymous records were not mistakenly treated as distinct species.

The records from the GBIF dataset were classified, identifying the sources of data collection (scientists and citizen scientists). Based on collection information (from the "collection code" and "institution code" tabs), each coordinate was categorized as belonging to a citizen scientist or a scientist. At the end of this process, we organized all data according to each federal conservation unit, obtaining data of species richness and number of registers from citizen science, species richness and number of registers from scientists, total species richness and total number of registers where we simultaneously consider the records of citizen science and scientists. All analyses were performed using the bdc package (Ribeiro et al., 2022), dplyr (Wickham, 2017), and sf (Pebesma, 2018) with the assistance of R software version 4.3.2 (R Core Team, 2023).

2.2 Visits in Brazilian protected areas

In Brazil, protected areas (PA) were established by law No. 9,985/2000. The Integral Protection Units aim to fully preserve ecosystems, allowing only indirect use of natural resources. They include: Ecological Station, Biological Reserve, National Park, Natural Monument, Wildlife Refuge, RPPNs (Private Natural Heritage Reserves). The Sustainable Use PA reconcile conservation with the sustainable use of natural resources, ensuring permanence and biodiversity. Categories include: Environmental Protection Area, Area of Relevant Ecological Interest, National Forest, Extractive Reserve, Wildlife Reserve, Sustainable Development Reserve. Both categories of conservation units were considered in this study.

The number and location of Brazilian Protected Areas were obtained from the Chico Mendes Institute for Biodiversity Conservation (ICMBio, https://www.icmbio.gov.br/). According to this database, Brazil has a total of 334 Protected Areas administered by the Brazilian Federal Government. The number of tourists who visit conservation units was obtained from the website of the National Registry of Conservation Units (CNUC, https://cnuc.mma.gov.br/) which is the official data platform for Conservation Units that are part of the National System of Nature Conservation Units (SNUC). We considered the number of tourists to be the sum of visits between 2000 and 2020.

2.3 Geographic and socio-economics variables

Following the methodology proposed by Nabout et al. (2022) and Chung et al. (2018), we also considered the variables of protected area size (ha), age of the conservation unit, distance to urban areas, and population density of the municipality where the conservation unit is located (measured in inhabitants/km²). The location, age, and size of the protected areas were obtained from the ICMBio website (https://www.gov.br/icmbio/pt-br/assuntos/dados_geoespaciais/mapa-tematico-e-dados-geoestatisticos-das-unidades-de-conservacao-federais). The coordinates of the centroid of each municipality were obtained from the IBGE (Brazilian Institute of Geography and Statistics) city map (https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html).

The size of a protected area refers to its area in ha. The age of the protected area corresponds to the number of years since its creation. The distance from the protected area to the nearest urban area was calculated as the straight-line distance from the centroid of the protected area to the centroid of the nearest city. To estimate population density, we considered the proportion of inhabitants per area in the municipality where the protected area is located, using data on inhabitants per municipality from the IBGE database https://www.ibge.gov.br/estatisticas/sociais/populacao/22827-censo-demografico-2022.html?edicao=35938&t=resultados). If a protected area spans more than one municipality, the population density is calculated as the weighted average of the population densities in all cities. For example, the PARNA das Araucárias covers 45% of the municipality of Passos Maia and 54% of the municipality of Ponte Serrada. Considering that the population densities of Passos Maia and Ponte Serra da are 6.52 inhabitants/km² and 18.57 inhabitants/km², respectively, the average population density of the PARNA das Araucárias is 13.11 inhabitants/km². In cases where the protected area does not cover any municipality, such as the APA of the Trindade and Martim Vaz Archipelago located in the Exclusive Economic Zone (EEZ), the population density is zero.

2.4. Data Analysis

All statistical analyses were performed using the program (R Core Team, 2024). To assess the spatial distribution in the visitors number to Brazilian protected areas, we tested the spatial correlation through Moran's I correlogram, using the “correlog” function of the ncf package (Bjornstad, 2022). We considered Sturges' rule to determine the number of classes in the correlogram. All variables used were transformed into log (x + 1). Collinearity between the biodiversity predictor variables (richness and number of records by citizen-scientist and scientists), distance to the nearest city, size of the PAs, population density of the nearest city and year of creation of the PA, was tested using the Variance Inflation Factor (VIF) with the “vif” function of the faraway package (Faraway, 2016). Predictor variables with a VIF equal to or greater than 2 were considered to have high collinearity and were removed from the next steps of the analyses (see Johnston et al., 2018). Therefore, the variables number of biodiversity records observed by citizen-scientist, number of biodiversity records observed by scientists, distance to the nearest city and size of the PAs were considered collinear and removed from the final model (Table S1).

Multiple regression was performed using the “lm” function of the stats package (R Core Team, 2024) to verify which factors influence the number of visitors to Brazilian PAs. Here, only the predictors selected by VIF were used. Are they, biodiversity richness recorded by citizens, biodiversity richness recorded by citizen-scientist, size of PA, age of PA and population density of the municipality where the protected area is located. We assessed model assumptions, such as data linearity, normality, and spatial independence, using the residuals of the multiple regression model. Residual normality was assessed using the Shapiro-Wilk test with the “shapiro.test” function of the stats package (R Core Team, 2024). Spatial independence was assessed by analyzing the spatial correlogram of residuals with the “correlog” function of the ncf package (see Hawkins et al., 2007; Fig. S1). We also tested for overdispersion of the data using the “testDispersion” function of the DHARMa package (Harting, 2022). We used the standardized regression coefficients (std-b) in the linear model using the “lm.beta” function of the lm.beta package (Behrendt et al., 2023). The significance of the model predictors was assessed by comparing them with a null model, using 999 Monte Carlo simulations (Manly, 2018). All our analyses were also performed separately by groups (mammals, birds and plants).

3. Results

The number of tourists (2000-2020) in Brazilian protected areas varied, with PARNA Tijuca having the highest number of visits (n = 36,732,885), followed by PARNA Iguaçu (n = 26,035,613), PARNA Jericoacoara (n = 5,572,208) and PARNA Brasília (n = 5,070,163) (see Fig. S1). In 159 protected areas there were no visits at all, of which 31.06% were in Extractive Reserves (RESEX), 21.12% in National Forests (FLONA) and 15.53% in Environmental Protection Areas (APA). Thus, when considering the spatial distribution of the number of tourists in Brazilian protected areas, we observed a strong spatial pattern at closer distances, for example up to 35 decimal degrees (Fig. 1). Citizen scientists recorded almost six times more number of records by species and almost half the species richness (i.e. number of species) compared to scientists (Table 1). Among the groups, mammals had the lowest number of records and richness by both audiences (Table 1). Birds stood out with the highest number of records observed by citizen scientists in terms of and richness (Table 1). Plants had a greater number of richness and records and wealth by scientists (Table 1).

Table 1. Number of records and richness of total biodiversity, birds, mammals and plants recorded by citizen-scientist and scientists.

	Total biodiversity	**Birds**	**Mammals**	**Plants**
Number of records observed by citizen-scientist	1,677,999	1,658,317	5,159	14,523
Number of records observed by scientists	281,803	4,880	2,667	274,256
Richness recorded by citizen-scientist	49,730	46,732	952	2,046
Richness recorded by scientists	82,104	2,151	552	79,401

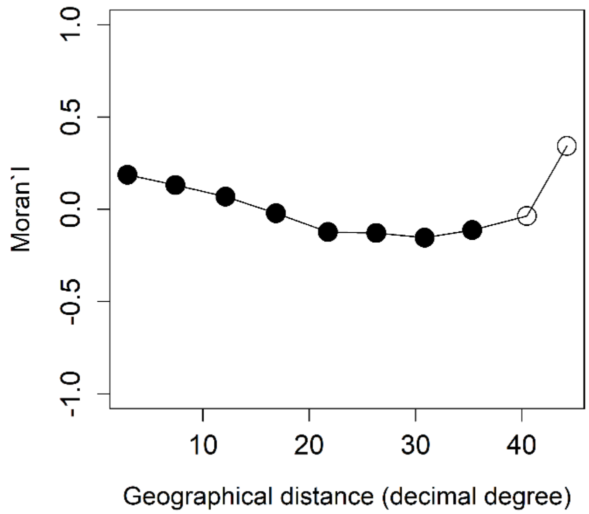


Figure 1. Spatial correlogram (Moran'I) of the number of tourists registered in Brazilian Protected Areas

Considering all biodiversity (plants, birds and mammals), the number of biodiversity records per protected area by citizen-scientist were higher than those recorded by scientists (Fig. 2a and 2c). In contrast, the biodiversity richness records per protected area by scientists were higher than those recorded by citizen-scientist (Fig. 2b and 2d). Mammals had low number of records per protected area by citizen-scientist and scientists (Fig. 3a and 3c), except for the protected area PARNA Montanhas do Tumucumaque, located between the states of Amapá and Pará, where citizen-scientist recorded 2,200 individuals of mammals. Regarding mammal richness, there were higher records per protected area by citizen-scientist than by traditional science (Fig. 3b and 3d).

The number of records and richness of birds observed by the citizen-scientist per protected area were much higher than those reported by the scientists (Fig. 4a-d). In general, the bird richness recorded by the citizen-scientist was similar in almost all protected areas, while number of records was more concentrated in the southeast region. The greatest number of records and richness of plants per protected area were observed by the scientists (Fig. 5a-d). The APA Planalto Central stood out in terms of number of records and richness in relation to the other protected areas.

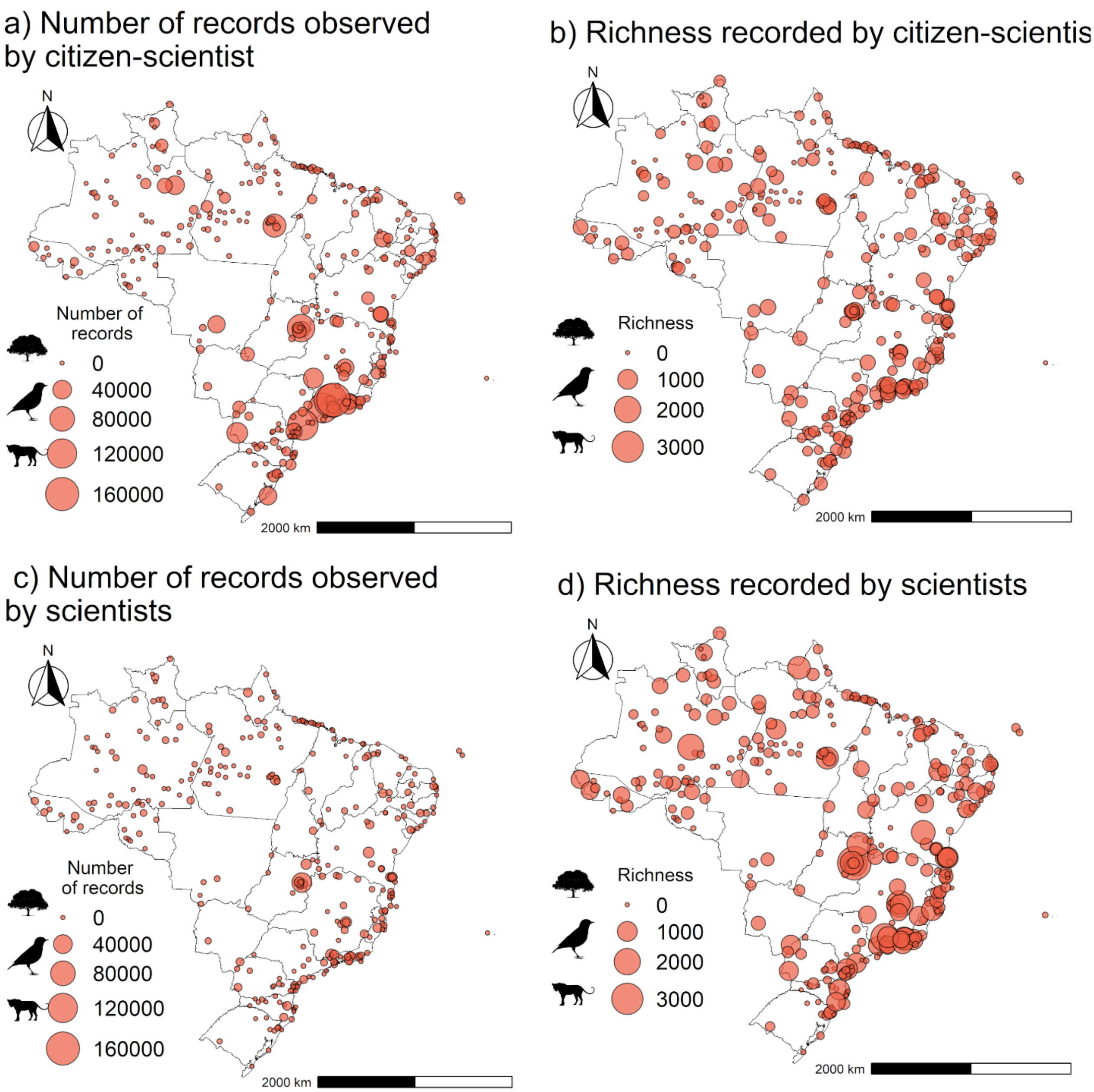


Figure 2. Record of biodiversity (plants, birds and mammals) by protected area. In (a) number of records and (b) richness of biodiversity observed by citizen-scientist. In (c) the number of records and (d) richness of biodiversity observed by scientists. The size of the circles is proportional to the value of number of records or richness.

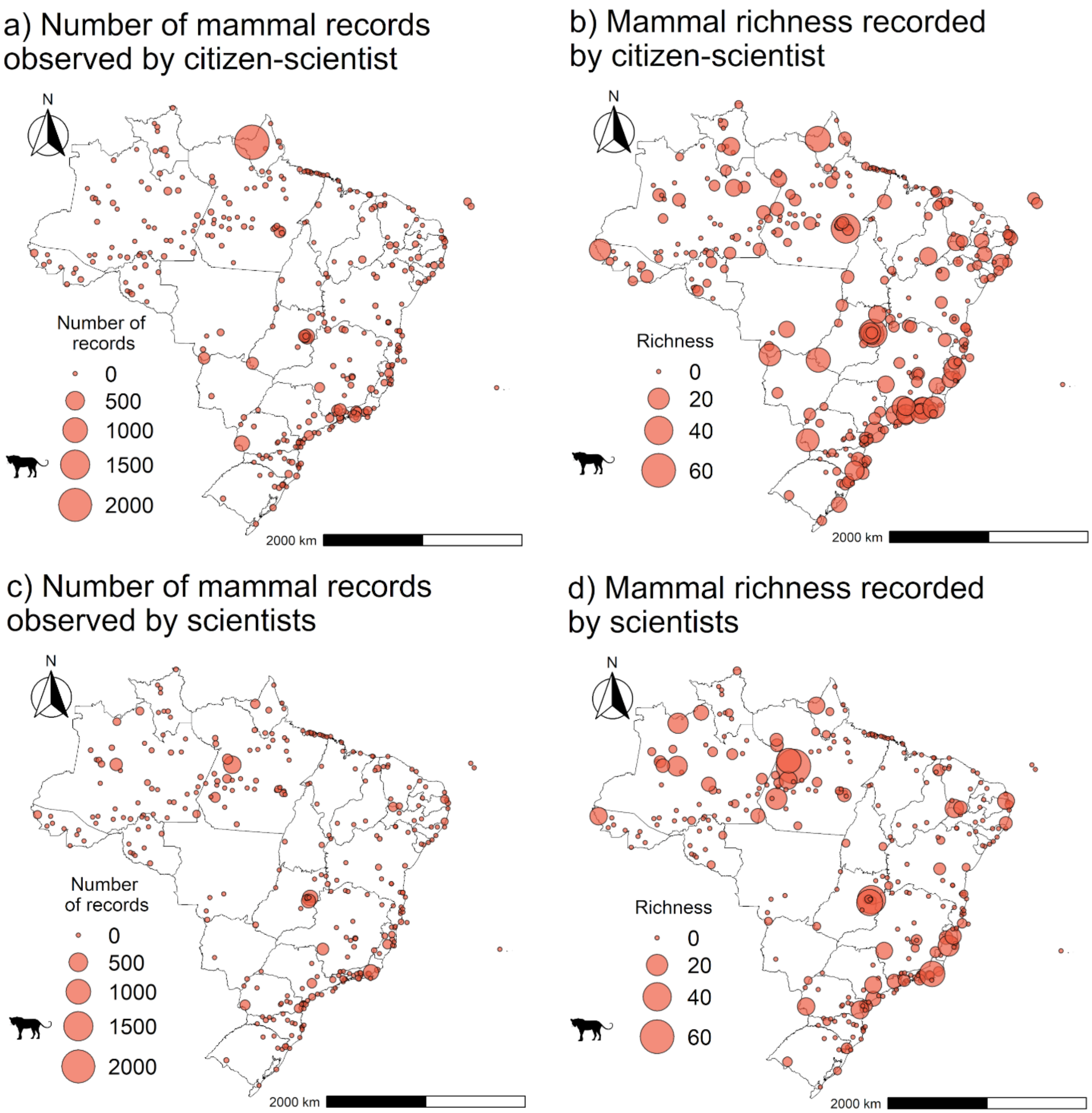


Figure 3. Record of mammals by protected area. In (a) number of records and (b) richness of mammals observed by citizen-scientist. In (c) the number of records and (d) richness of mammals observed by scientists. The size of the circles is proportional to the value of number of records or richness.

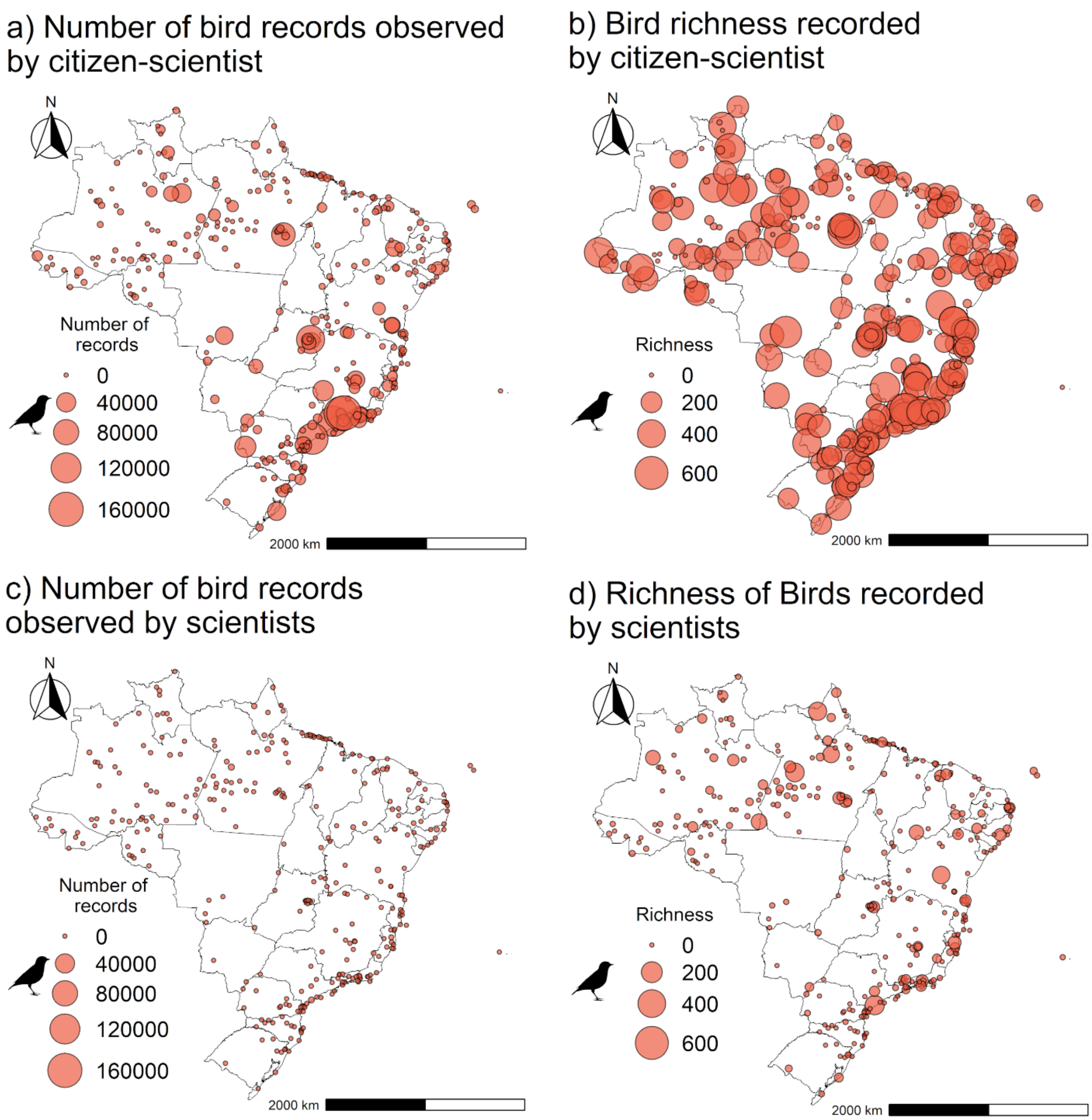


Figure 4. Record by protected area of birds. In (a) the number of records and (b) richness of birds observed by citizen-scientist. In (c) the number of records and (d) richness of birds observed by scientists. The size of the circles is proportional to the value of number of records or richness.

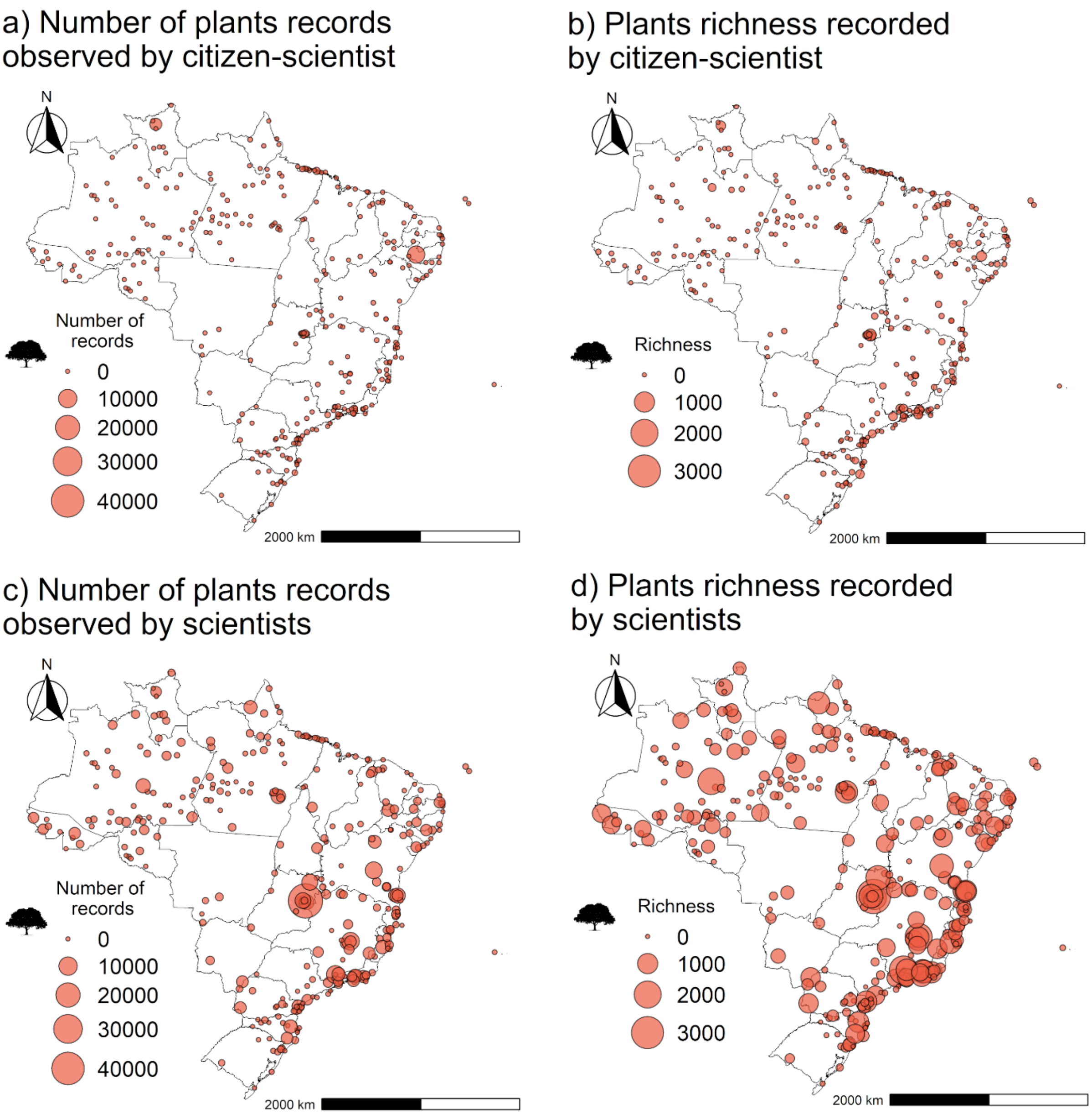


Figure 5. Record of plants by protected area. In (a) the number of records and (b) richness of plants observed by citizen-scientist. In (c) the number of records and (d) richness of plants observed by scientists. The size of the circles is proportional to the value of number of records or richness.

The multiple regression model for all biodiversity explained 31.37% of the variation in the number of visits to Brazilian protected areas (adjusted $R^2 = 0.3137$; $p < 0.001$). We observed that the number of visits is positively associated with the total biodiversity richness recorded by citizen-scientist and population density of the municipality where the protected area is located (Table 2). Multiple regression residuals were not autocorrelated (Fig S2).

The multiple regression models evaluating the groups separately (mammals, birds and plants) also gave similar results to the total biodiversity model. When evaluating the mammal group separately, the number of visits was significantly explained ($R^2 = 0.2844$, p = <0.001) by the mammal richness recorded by the citizen-scientist and by the population density (Table 3). Similarly, the number of visits to protected areas was also significantly explained by bird richness recorded by citizen scientists and population density (R^2 = 0.3184, p = <0.001; Table 4). For the plant group, the number of visits was negatively associated with plant richness recorded by scientists and positively associated with population density (R^2 = 0.2752, p = <0.001; Table 5). Multiple regression residuals for biodiversity groups (mammals, birds, and plants) were also not spatial autocorrelated (Fig S3).

Table 2. Results of multiple regression for all biodiversity evaluating the relationships between the number of visits and different explanatory variables. The regression coefficients were standardized (mean = 0, standard deviation = 1) and the significance of each predictor was tested using Monte Carlo simulation.

	Estimate	**p-value**
Biodiversity richness recorded by citizen-scientist	0.27898902	**0.001**
Biodiversity richness recorded by scientists	0.06174452	0.212
Size	-0.21871012	1.00
Population density	0.13071562	**0.016**
Year of creation	-0.25036497	1.00

Table 3. Results of multiple regression for mammals evaluating the relationships between the number of visits and different explanatory variables. The regression coefficients were standardized (mean = 0, standard deviation = 1) and the significance of each predictor was tested using Monte Carlo simulation.

	Estimate	**p-value**
Mammal richness recorded by citizen-scientist	0.25879621	**0.001**
Number of mammal records observed by scientists	-0.0673585	0.85
Size	-0.2240382	1.00
Population density	0.16293748	**0.003**
Year of creation	-0.2653877	1.00

Table 4. Results of multiple regression for birds evaluating the relationships between the number of visits and different explanatory variables. The regression coefficients were standardized (mean = 0, standard deviation = 1) and the significance of each predictor was tested using Monte Carlo simulation.

	Estimate	p-value
Bird richness recorded by citizen-scientist	0.31340491	**0.001**
Bird richness recorded by scientists	-0.0732362	0.89
Size	-0.1782146	1.00
Population density	0.15228862	**0.004**
Year of creation	-0.2838418	1.00

Table 5. Results of multiple regression for plants evaluating the relationships between the number of visits and different explanatory variables. The regression coefficients were standardized (mean = 0, standard deviation = 1) and the significance of each predictor was tested using Monte Carlo simulation.

	Estimate	p-value
Plants richness observed by citizen-scientist	0.31340491	0.1
Plants richness recorded by scientists	-0.0732362	**0.015**
Size	-0.1782146	1.00
Population density	0.15228862	**0.001**
Year of creation	-0.2838418	1.00

4. Discussion

This study examined the importance of geographic, demographic, and biodiversity variables (number of records and richness of birds, mammals, and plants) on tourist numbers in protected areas (PAs) in Brazil. The results show that biodiversity in PAs, in terms of species richness recorded by citizen-scientist and population density, positively influences the number of visitors. In contrast, plant richness recorded by scientists negatively influenced the number of visitors. This negative relationship could be explained by the fact that areas with higher plant species richness, such as those found in regions like the Amazon, are often less accessible to tourists due to their remote location and the logistical challenges involved in reaching them (Cardoso et al., 2017). Furthermore, the size of PAs and the year of creation were not significant. These findings highlight that species richness recorded by citizen-scientist plays a key role in attracting tourists to PAs, likely reflecting biodiversity elements that are more easily observed and appreciated by visitors. In fact, most Essential Biodiversity Variables are monitored by citizens or communities (Chandler et al., 2017). Furthermore, the lack of significance of species richness recorded by scientists may reflect the specialized nature of these records, which do not necessarily correspond to aspects of biodiversity that are most appreciated by the general public (Loureiro et al., 2012), as seen in studies of specific groups (e.g., microorganisms, Joosten et al., 2011) or cryptic species that require specialized knowledge for identification (Fišer et al., 2018).

Our study corroborates others that also found that the number of visitors is higher when the population density in which the AP is located is higher (Balmford et al., 2015; Ghermandi & Nunes, 2013; Chung et al., 2018). Higher population density in cities hosting PAs may indicate better-developed infrastructure to support and attract tourists. Some studies have shown that the age and size of PAs positively affect visitor numbers (Chung et al., 2018; Karanth & DeFries, 2011; Neuvonen et al., 2010; Balmford et al., 2015; Baum et al., 2017). Older PAs have had more time to gain recognition and may cover more spectacular areas and therefore may have been preserved in a more pristine state (Chung et al., 2018). However, the age of a protected area does not necessarily guarantee its current popularity (Butler, 2022). The size of the area does not always determine the tourist experience (Govers et al., 2008). There is extensive discussion about the role of PA size in maximizing species richness and prolonging extinction times, with arguments supporting both larger and smaller Pas (Cho et al., 2019; Caughley, 1994; Parks and Harcourt 2002; Robert, 2009; Ovaskainen 2002; Maiorano et al., 2008). In regions of high biodiversity such as Brazil, the size of a protected area does not appear to influence visitor numbers, as both small and large areas often harbor high biodiversity.

We observed distinct differences in how citizen-scientist and scientists perceive biodiversity in protected areas. Overall, both the number of records and richness were more frequently recorded by citizen-scientist. Birds were the biological group that attracted the most attention from both citizen-scientist and scientists in terms of number of records, while plants received the highest richness records in both groups. In general, citizen science is making a substantial contribution to global biodiversity data (Chandler et al., 2017).

Birds, with their diverse species and attributes such as size, coloration, and vocalization, are charismatic to the general public, which may explain the preference of citizen-scientist for recording them. Randler et al. (2023) observed that colorful, striking, and easily detectable birds attract more casual observers compared to advanced ones, who possess more specialized knowledge. Ganzevoort et al. (2017) also found that biodiversity data on birds is more frequently collected than data on mammals or plants. This trend is further supported by the high diversity of birds in Brazil, with 1,971 species recorded to date by the Brazilian Committee for Ornithological Records (CBRO). Additionally, there are more and better apps available for bird identification, such as Merlin Bird ID, Picture Bird, Audubon Bird Guide, iNaturalist, and BirdNET, which are more accurate compared to those for other taxonomic groups. For instance, Campbell et al. (2022) found that many smartphone apps for plant identification are inaccurate, with only 4% of them able to correctly recognize herbs from photos after testing six of the most common plant identification apps.

Plants, despite their wide variety, are generally less popular in tourism (Cohen and Fennell, 2019) and are less frequently considered by citizen-scientist. This could be attributed to the tendency of people to overlook more discreet organisms in their immediate environment, leading to the underappreciation of their beauty, attractiveness, or uniqueness, a phenomenon known as " biological blindness" (Wandersee and Schussler, 1999). However, plants play crucial ecological roles in the functioning of ecosystems, and their biodiversity components, such as richness and number of records, are strong predictors of the diversity of other taxa (Pereira and Cooper, 2006). This ecological significance may explain why plants receive more attention from scientists. Furthermore, the environmental context of Protected Areas (PAs), including the region or biome, can influence visitors' preferences for different biological groups and their willingness to contribute to conservation efforts, as noted by Cerda et al. (2018a) and Cerda et al. (2018b).

In our study, mammals were the least recorded group in terms of both richness and number of records, according to both citizen-scientist and scientists. However, we observed regional variations in mammal richness (see Figures 4b and d), suggesting that geographic location influences perception. For example, in areas with large predatory mammals, the number of visitors tends to be higher due to the presence of these species (Grünewald et al., 2016). One such case is the PARNA Montanhas do Tumucumaque protected area, located between the states of Amapá and Pará, where citizen-scientist recorded 2,200 mammal sightings (Ávila et al., 2010). While the practice of observing mammals is well-established in some countries, it remains relatively uncommon in Brazil, despite the country's vast mammal diversity (Tortato et al., 2022). This is primarily because Brazilian mammal species are generally not as large as those found in Africa (Grünewald et al., 2016), and their populations tend to be sparser (except for capybaras), making them more elusive (except for monkeys). Another contributing factor to the low number of records is the nocturnal behavior of many mammal species (Arbieu et al., 2018), which makes their observation challenging for both citizen-scientist and scientists. Thus, the combination of these ecological and behavioral factors likely explains the lower number of mammal sightings in Brazil's protected areas.

Species richness is a crucial factor in nature-based tourism in protected areas (PAs) (Arbieu et al., 2018), but the relationship between other aspects of biodiversity, such as abundance and equity, and tourism in PAs requires further attention (Graves et al., 2017; Siikamäki et al., 2015). In line with this approach, our findings demonstrate that biodiversity richness has a significant influence on visits to PAs, providing evidence of the direct link between biodiversity protection and the provision of ecosystem services in these areas. Biodiversity not only offers a variety of benefits, often underestimated due to challenges in quantifying non-utilitarian values, but also plays a fundamental role in human well-being. Natural landscapes and green spaces contribute significantly to human well-being, promoting sustainable lifestyles and improving various aspects of health (Carrus et al., 2015; Aerts et al., 2018). Neotropical birds exemplify these benefits by offering cultural services such as pets, recreational activities like birdwatching and hunting, and inspiring art, photography, and religious practices (Michel et al., 2020). The restorative power of nature and wildlife on human well-being is well-documented, provoking joy and happiness when discovering the wonders of the animal kingdom (Curtin, 2009). Furthermore, protected areas with high biodiversity values, such as the Pantanal, home to one of the most intact mammal faunas in the world, can attract more tourists due to the presence of charismatic fauna like caimans, capybaras, otters, jaguars, and anacondas (Arts et al., 2018; Bogoni et al., 2020). This appeal can, in turn, generate socioeconomic benefits for local communities through nature-based tourism, providing an economic justification for biodiversity conservation in PAs (Naidoo et al., 2011; Naidoo & Adamowicz, 2005).

5. Conclusion

Biodiversity, rather than the size or age of protected areas, proves to be the true driving force behind tourism. Citizen-generated data, being more spontaneous and often closer to the tourist experience, offers a more accurate reflection of what truly attracts visitors. Despite their significant ecological value, remote and less accessible areas remain largely overlooked by tourism, highlighting a gap between ecological potential and actual visitor access. This gap limits the development of ecotourism, particularly in less urbanized areas. In this context, citizen science plays a crucial role by offering valuable insights for the management of protected areas. Not only does the data gathered from visitors complement scientific records, but it also fosters increased public engagement and awareness regarding the importance of biodiversity. However, to effectively balance tourism and conservation, it is essential to implement management strategies that minimize negative impacts, such as regulating carrying capacity and promoting environmental education. To meet global conservation and biodiversity monitoring obligations, it is critical for governments, NGOs, and the research community to leverage all possible sources of data, including emerging ones like citizen science, where volunteers actively participate in various aspects of environmental assessments.

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Supplementary Material

Table S1. Assessment of multicollinearity before and after variable selection for the model with all biodiversity. The variables number of records observed by scientists, number of records observed by citizen-scientist, and distance were removed because they presented high VIF (>2). After selection, all variables were below the VIF <2 limit.

Predictor variable	**VIF (Initial)**	**VIF (round 1)**	**VIF (round 2)**	**VIF (Final)**
Number of records observed by citizen-scientist	14.30	14.25	Removed	Removed
Richness recorded by citizen-scientist	12.66	12.65	1.55	1.54
Number of records observed by scientists	82.40	Removed	Removed	Removed
Richness recorded by scientists	81.86	1.80	1.74	1.71
Distance to urban areas	2.19	2.19	2.17	Removed
Size	2.16	2.15	2.14	1.30
Population density	1.45	1.45	1.39	1.17
Year of creation	1.18	1.18	1.14	1.14

Table S2. Assessment of multicollinearity before and after variable selection for the model with mammals. The variables mammal richness recorded by scientists, number of mammal records observed by citizen-scientist, and distance were removed because they presented high VIF (>2). After selection, all variables were below the VIF <2 limit.

Predictor variable	**VIF (Initial)**	**VIF (round 1)**	**VIF (round 2)**	**VIF (Final)**
Number of mammal records observed by citizen-scientist	15.76	15.22	Removed	Removed
Mammal richness recorded by citizen-scientist	15.40	14.84	1.59	1.59
Number of mammal records observed by scientists	22.54	1.29	1.29	1.28
Mammal richness recorded by scientists	22.65	Removed	Removed	Removed
Distance to urban areas	2.13	2.13	2.13	Removed
Size	1.94	1.91	1.91	1.16
Population density	1.43	1.43	1.41	1.17
Year of creation	1.24	1.24	1.22	1.22

Table S3. Assessment of multicollinearity before and after variable selection for the model with birds. The variables number of bird records observed by scientists, number of bird records observed by citizen-scientist, and distance were removed because they presented high VIF (>2). After selection, all variables were below the VIF <2 limit.

Predictor variable	**VIF (Initial)**	**VIF (round 1)**	**VIF (round 2)**	**VIF (Final)**
Number of bird records observed by citizen-scientist	14.03	13.98	Removed	Removed
Bird richness recorded by citizen-scientist	12.34	12.33	1.31	1.29
Number of bird records observed by scientists	41.32	Removed	Removed	Removed
Bird richness recorded by scientists	40.9	1.35	1.29	1.29
Distance to urban areas	2.18	2.17	2.14	Removed
Size	1.92	1.91	1.89	1.16
Population density	1.45	1.45	1.39	1.15
Year of creation	1.19	1.19	1.14	1.14

Table S4. Assessment of multicollinearity before and after variable selection for the model with plants. The variables number of plants records observed by scientists, plants richness recorded by citizen-scientist, and distance were removed because they presented high VIF (>2). After selection, all variables were below the VIF <2 limit.

Predictor variable	**VIF (Initial)**	**VIF (round 1)**	**VIF (round 2)**	**VIF (Final)**
Number of plants records observed by citizen-scientist	12.57	12.57	1.45	1.45
Plants richness recorded by citizen-scientist	14.18	14.12	Removed	Removed
Number of plants records observed by scientists	94.36	Removed	Removed	Removed
Plants richness recorded by scientists	93.02	1.61	1.54	1.52
Distance to urban areas	2.21	2.21	2.18	Removed
Size	2.12	2.12	2.11	1.25
Population density	1.46	1.45	1.43	1.22
Year of creation	1.19	1.19	1.14	1.14

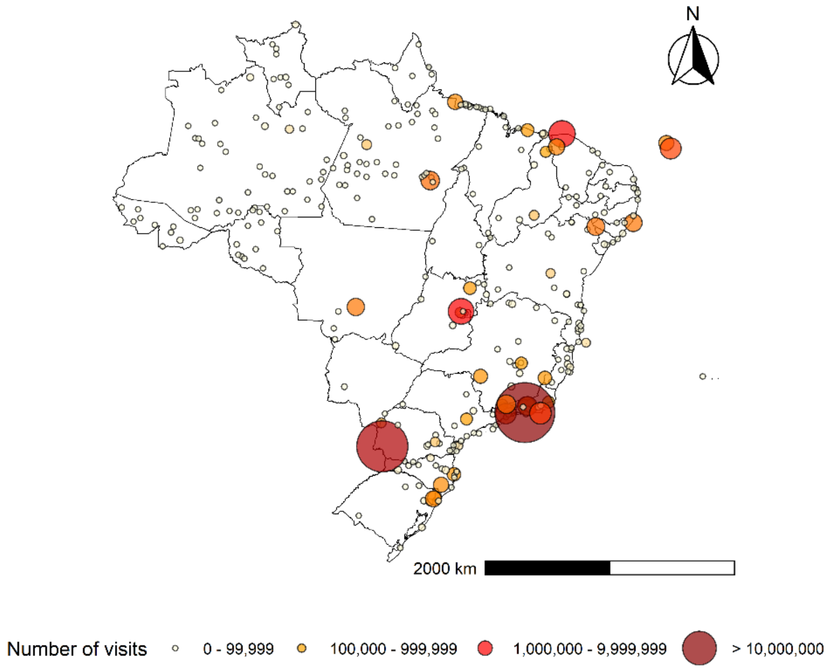

Fig. S1. Number of visitors per protected area in 2000-2020. The size of the circles and the color gradient is proportional to the number of visits, higher values have larger circles and darker colors.

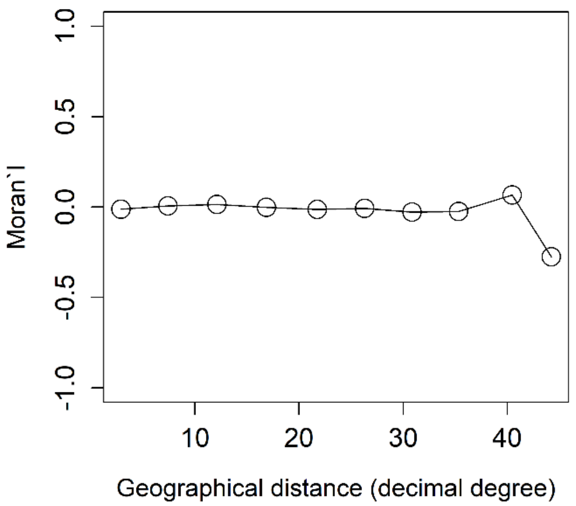

Fig. S2. Spatial correlogram of regression residual of linear models of total biodiversity presented in manuscript (Table 2).

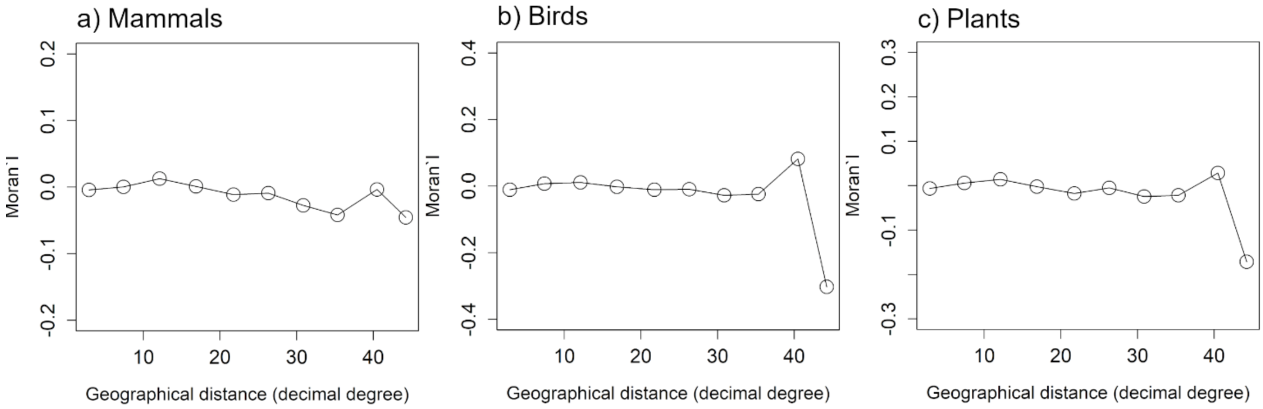

Fig. S3. Spatial correlograms of the residuals from the regressions of the linear models presented in the manuscript, a) for mammals (Table 3), b) for birds (Table 4) and c) for plants (Table 5).

CAPÍTULO 3

Assessing Tourism Carrying Capacity in a Sustainable Protected Area of the Cerrado: Balancing Ecological and Socio-Economic Dimensions

Summary
Each destination can sustain a specific level of acceptance for tourism development and use. Beyond this level, further development may result in socio-cultural deterioration or a decrease in the quality of the visitor experience. This study aims to assess the tourist carrying capacity of the National Forest Silvânia, situated approximately 7 km from the urban center of Silvânia in the Goiás State. To achieve this, we used the highly adaptable Cifuentes method to establish field variables based on ecosystem criteria. Our findings indicate that the study area has the capacity to accommodate more visitors than it currently does, and the social correction factor received the most attention due to the diversity of distances between groups and visiting times. It is important to increase the tourist offerings in a way that is appropriate to the characteristics of the territory and fulfills the management objectives without damaging the natural space in order to reach the expected limit of visits. Nevertheless, it is crucial to continuously monitor the local biodiversity because the predicted increase in tourist visits shouldn't have an impact on its preservation.

Keywords: Tourism acceptance level; Tourism carrying capacity; National Forest Silvânia; Cifuentes approach.

Resumo
Cada destino pode sustentar um nível específico de aceitação para o desenvolvimento e uso do turismo. Além desse nível, um maior desenvolvimento pode resultar em deterioração sociocultural ou diminuição da qualidade da experiência do visitante. Neste estudo, avaliamos a capacidade de carga turística da Floresta Nacional de Silvânia, que está localizada aproximadamente a 7 km do centro urbano de Silvânia (estado de Goiás). Para isso, utilizamos o método altamente adaptável de Cifuentes para estabelecer variáveis de campo com base em critérios ecossistêmicos. Nossas descobertas indicam que a área de estudo tem capacidade para receber mais visitantes do que atualmente recebe, sendo que o fator de correção social recebeu a maior atenção devido à diversidade de distâncias entre grupos e horários de visita. É importante aumentar a oferta turística de maneira adequada às características do território e cumprindo os objetivos de gestão, sem danificar o espaço natural, a fim de atingir o limite esperado de visitação. Entretanto, é importante monitorar constantemente a biodiversidade local, uma vez que o aumento indicado de visitas turísticas não deve impactar na conservação da biodiversidade.

Palavras-chave: Nível de aceitação do turismo; Capacidade de carga turística; Floresta Nacional de Silvânia; Metodologia Cifuentes.

1. Introduction

The carrying capacity of a tourist (TCC) area refers to the point where the minimum infrastructure and natural resources that attract visitors become inadequate to meet the needs of both the resident population and tourists, resulting in environmental risks (Đorđević *et al.*, 2016; Marsiglio, 2017; Zekan *et al.*, 2022). This concept has been applied in various areas, such as geological sites (Santos and Brilha, 2023), coastal areas (Leka *et al.*, 2022), beaches (Rajan *et al.*, 2013; De Sousa *et al.*, 2014; Cisneros *et al.*, 2016), mountains (Chen *et al.*, 2021; Fidelus *et al.*, 2021), and trails (Queiroz *et al.*, 2014; Huang *et al.*, 2021). The concept of carrying capacity is not just about limiting the number of visitors to a particular destination. It also considers the intensity of use that an area can tolerate without causing irreversible damage (Butler, 1980; Rodríguez *et al.*, 2008).

The idea of carrying capacity is multifaceted and can be assessed using different dimensions, including physical, environmental, economic, social, perceptual, and infrastructure dimensions (Saveriades, 2000; López-Bonilla and López-Bonilla, 2008). The physical dimension specifically focuses on physical carrying capacity, which is determined by the relationship between the available space and the normal space requirement per visitor. However, actual carrying capacity is determined by applying correction factors specific to each site, while effective carrying capacity takes into consideration the acceptable limit of use by considering the management capacity of the area administration (Cifuentes, 1992). Meanwhile, the tourist reception capacity of a particular location is influenced by various factors such as the type of destination, tourism, and market segment it caters to, as well as the management and cultural characteristics of the host community (Morales, 2014). Although the naming and classification of these dimensions vary depending on the author and spatial area studied (Pasková, 2003; Saarinen, 2006; Pásková, 2008; Zelenka and Pásková, 2012; Salerno *et al.,* 2013), they are fundamentally related to the four factors affecting the tourism subsystem: physical factors (natural or cultural environment and tourism- related infrastructure), economic factors (tourism costs and benefits), social factors (visitor and resident perceptions of tourism), and political factors (policies and management measures) (Saveriades, 2000). To manage the impacts of tourism and ensure they remain within acceptable limits, it is necessary to establish critical values or thresholds for each dimension, from which appropriate management strategies or responses can be developed (Zelenka and Kacetl, 2014). It should be noted that the magnitude of tourist carrying capacity is directly linked to the dimension under consideration, such as resident visitors, area, and activity intensity for social, ecological, and physical dimensions, respectively (Saveriades, 2000). Therefore, measuring tourist reception capacity should not be based solely on visitor volume, but should consider different perspectives or dimensions. Recent research has emphasized the need for a multidimensional perspective that combines quantitative and qualitative aspects to study tourist carrying capacity (Segrado *et al*., 2017).

For these reasons, there is no standard methodology for calculating carrying capacity, as it depends on the objectives of the survey, the supports on which the indicator is based – be it the visitor, host or destination – and the use you want to grant to the area; but it stands out for being an early warning instrument that can be adapted and applied in different destinations, consolidated or emerging, at any stage of the life cycle and any dimension of sustainable development (Butler, 1980). In this sense, it can be affirmed that it is a theoretical, methodological, and pragmatic instrument that is part of the philosophy of sustainability, and as such is based on any of its dimensions: ecological-environmental, physical, social, economic, and institutional (Echamendi, 2001; Matos and Pérez, 2019).

Brazil is known for its extensive biological diversity and is often referred to as a country of megadiversity (Medeiros, 2006). Protected areas have become the primary strategy for safeguarding this natural wealth, and they are the most common form of protection established to ensure the representation of various biomes, environments, and biodiversity throughout the country (Dudley, 2008). In recent years, the media has provided a wealth of information about natural areas, which has increased interest in recreational activities in these areas (Wilkins *et al.*,2021). However, since most of the natural attractions are located within protected areas, their managers must determine the optimal number of visitors that each unit can handle without degrading the environment (Butler, 1980). Public tours are frequently conducted on interpretive trails, which not only enhance visitor satisfaction, but also provide greater insight and appreciation of the protected resources, potential impacts on them, and a stronger connection with the location (MacLeod, 2017). With the increase in tourist arrivals, the activities conducted in protected areas require careful planning and management to ensure that visitors do not cause harm to the environment. Therefore, it is essential to analyze the possible positive and negative impacts of public use and propose measures that mitigate any negative effects, ensuring the long-term conservation of these valuable sites (Saveriades, 2000).

The concept of tourist carrying capacity (TCC) serves as an essential methodological tool for assessing the potential impacts of new recreational activities and land use, acting as an early warning system (Zelenka and Kacetl, 2014). Given the growing concern of overtourism, destination managers are increasingly seeking effective tools to guide their decisions on visitor management and attraction (Capocchi *et al.*, 2019). TCC is the most widely employed method for determining the sustainable number of visitors that a conservation unit can accommodate (Cifuentes, 1992). Its adaptability and simplicity have contributed to its widespread application, making it suitable for diverse natural and urban environments. TCC has been successfully implemented in protected areas worldwide, including Natural Parks in Ukraine (Poletaeva and Safranov, 2021), Huascarán National Park in Peru (Espinoza *et al.*, 2020), and Caravaca de La Cruz Trails in Spain (Serrano and Alarte, 2009). In Brazil, research on carrying capacity is relatively recent, as highlighted by studies conducted by (Lobo and Moretti, 2009; De Souza *et al.*, 2014; Cipolat and Bidarte, 2022). Although the utilization of these methodologies has not been extensive, efforts have been made to adapt them to suit the specific conditions of protected areas (PA) in the country.

Based on the above considerations, this work aims to estimate the physical dimension of the tourist carrying capacity, integrated by the variables (physical, real, and effective) in a sustainable protected area situated in the Brazilian Cerrado (National Forest Silvânia). The estimation of tourism carrying capacity is important for the management of the protected area, promoting the socio-economic development of the region, tourism, but primarily maintaining biodiversity conservation.

2. Materials and methods

2.1 Area of study

The National Forest Silvânia is a sustainable use Unit that seeks to reconcile the conservation of nature with the sustainable use of its natural resources, according to the National System of Nature Conservation Units, Law No. 9,985, OF JULY 18, 2000. This is a protected area (Figure 1) covering an area of 486.67 hectares. It is located approximately at 16º39'S and 48º36'W, with an average altitude of 900 meters. The National Forest is characterized by a forest cover predominantly composed of native species and has the objective of sustainable multiple use of forest resources and scientific research, with an emphasis on methods for the sustainable exploitation of native forests.

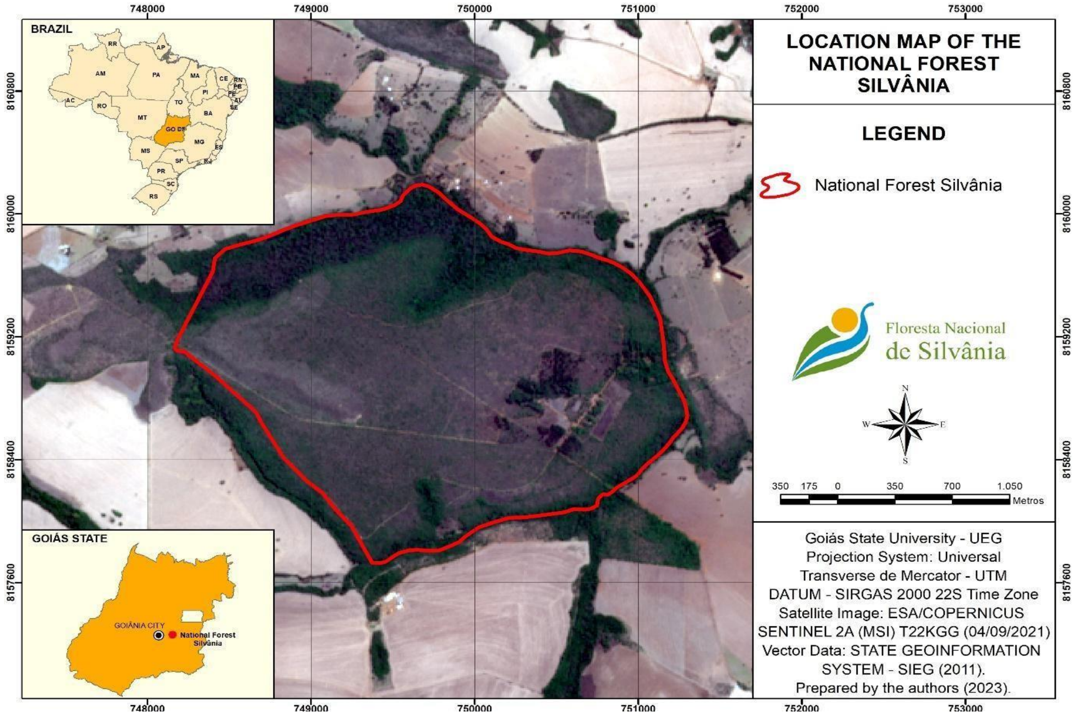

Figure 1: Location map of the National Forest Silvânia, Goiás. Sentinel-2 satellite images provided by Land View (https://eos.com/find-satellite/) were used to define the study area.

According to Köppen (1943), the climate in the region is classified as Aw (tropical rainy), characterized by a hot and rainy summer from October to March, and a dry and cold winter from April to September. The geological composition of the National Forest Silvânia consists of a single unit of supracrustal rocks, and only a few areas have a slope greater than 12% (Figure 2). The relief of the area is characterized by the presence of old erosion surfaces that have been partially dismantled by river processes, resulting in long convex slopes. Additionally, there are isolated erosive remnants in the form of hills, capped by outcrops of laterites (Chico Mendes Institute for Biodiversity Conservation [ICMBIO], 2015).

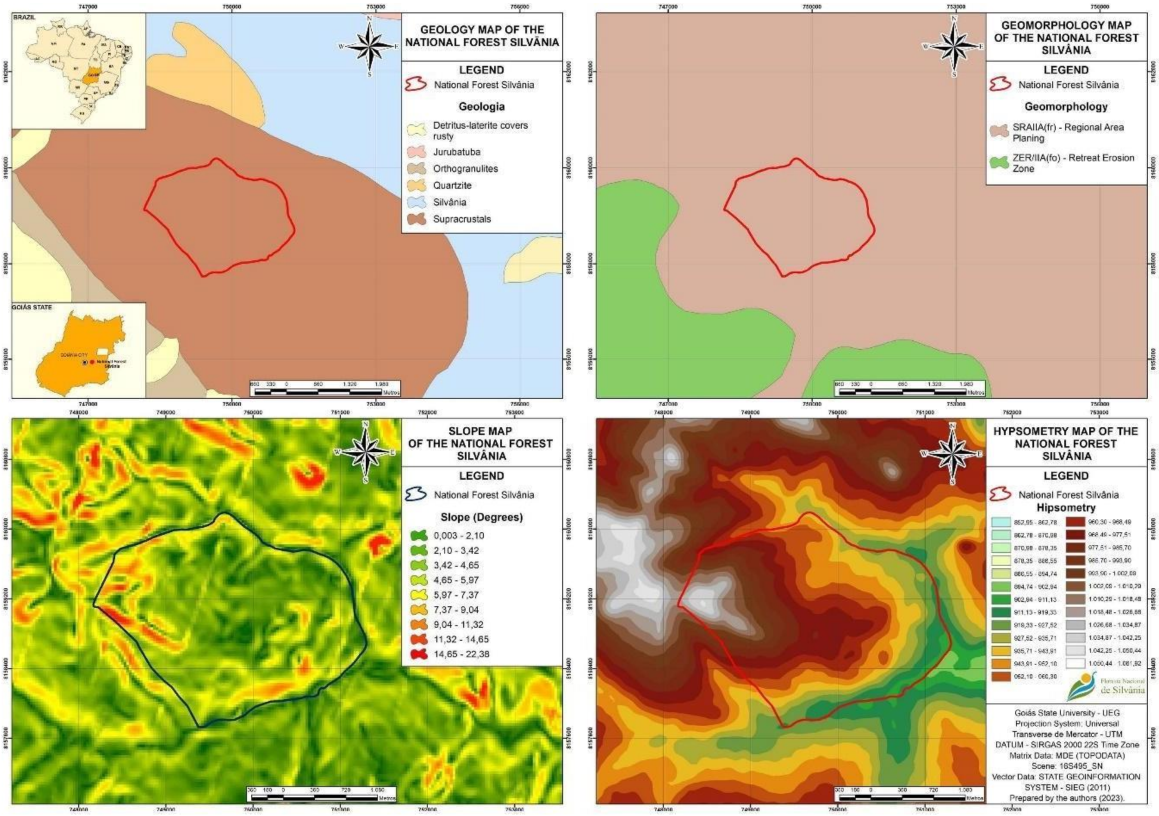

Figure 2: Mosaic view (a) showcasing various physical variables, including geology, geomorphology, slope, and hypsometry, within the National Forest Silvânia, Goiás. The maps were created using data compiled from multiple databases, incorporating information from the following sources: thematic maps for the state of Goiás were obtained from the Portal SIEG - State Geoinformation System (http://www.sieg.go.gov.br/siegdownloads/); additional environmental information was extracted from the IBGE website - BrazilianInstitute of Geography and Statistics (https://www.ibge.gov.br/geociencias/cartas-e-mapas/bases-cartograficas-continuas/15759-brasil.html?=&t=downloads

Latosols predominate in the area, occupying almost the entire length of the National Forest Silvânia (Figure 3). The forest exhibits a wide variety of phytophysiognomies, including rural types (dirty field), savanna (cerrado sensu stricto and vereda), and forest (cerradão, semideciduous forest, and gallery forest). The vermelho river is the main watercourse in the vicinity and within the National Forest Silvânia. Currently, the Cerrado biogeographic system is experiencing the fastest process of agricultural expansion in the country, attracting a significant portion of the national agroindustry, forestry, and grazing).

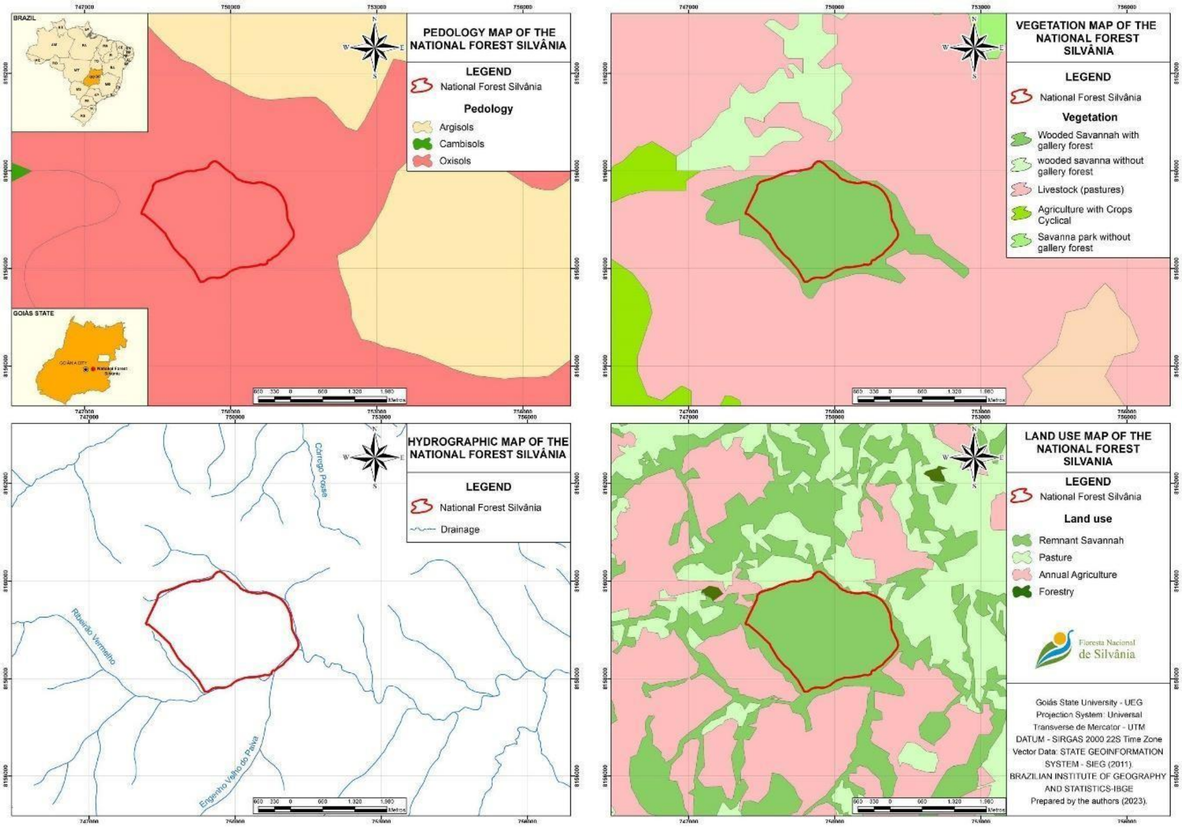

Figure 3: Mosaic view (b) showcasing various physical variables, including pedology, vegetation, drainage, and soil use within the National Forest Silvânia, Goiás. The maps were created using data compiled from multiple databases, incorporating information from the following sources: i) Thematic maps for the state of Goiás were obtained from the Portal SIEG - State Geoinformation System (http://www.sieg.go.gov.br/siegdownloads/); ii) Soil maps of Brazil were acquired from GeoInfo- Embrapa (http://geoinfo.cnps.embrapa.br/); iii) Additional environmental information was obtained from the IBGE website - Brazilian Institute of Geography and Statistics (https://www.ibge.gov.br/geociencias/cartas-e-mapas/bases-cartograficas-continuas/15759-brasil.html?=&t=downloads

2.1.1 Description of trails

The National Forest Silvânia is currently managed by ICMBio and is open to visitors. The site showcases several examples of the Cerrado's flora and fauna, with a predominant native forest cover. Therefore, it is possible to find species such as *Caryocar Brasiliense* (Pequi), *Handroanthus spp* (Ipê), *Dipteryx alata Vog* (Baru), and *Jacaranda mimosifolia* (Jacarandá-mimoso) (ICMBio, 2015). Endemic species can also be found, including the *Leptodactylus mystaceus* (Amphibian) (De Morais *et al.*, 2014), *Rhipidomys macrurus* (Arboreal rodent) (Benvindo *et al.*, 2021), and *Agaricomycetes*, *Basidiomycota* (Poroid fungi) (Santos, 2020).

The main attraction for visitors at the National Forest Silvânia is its trail system, which is used by hikers, cyclists, and for educational activities. One of the trails, named as Mirante trail, has approximately 7.5 kilometer long, is ideal for families with children and the elderly, the Mata trail has 6 km dense forest with roots, ditches. Additionally, there is a 4.5-kilometer trail, named as Meio trail, that takes you through areas of denser vegetation and more enclosed forest. The recreation and visitor area of the National Forest Silvânia provides facilities such as picnic tables, benches, and restrooms. It also offers electricity points for tourist groups, community members, students, and researchers. Other features include a lookout point with a panoramic view of the entire region, a nursery with native seedlings, and a small artificial lake. Information regarding the trails, restrooms, and other amenities is clearly marked throughout the protected area.

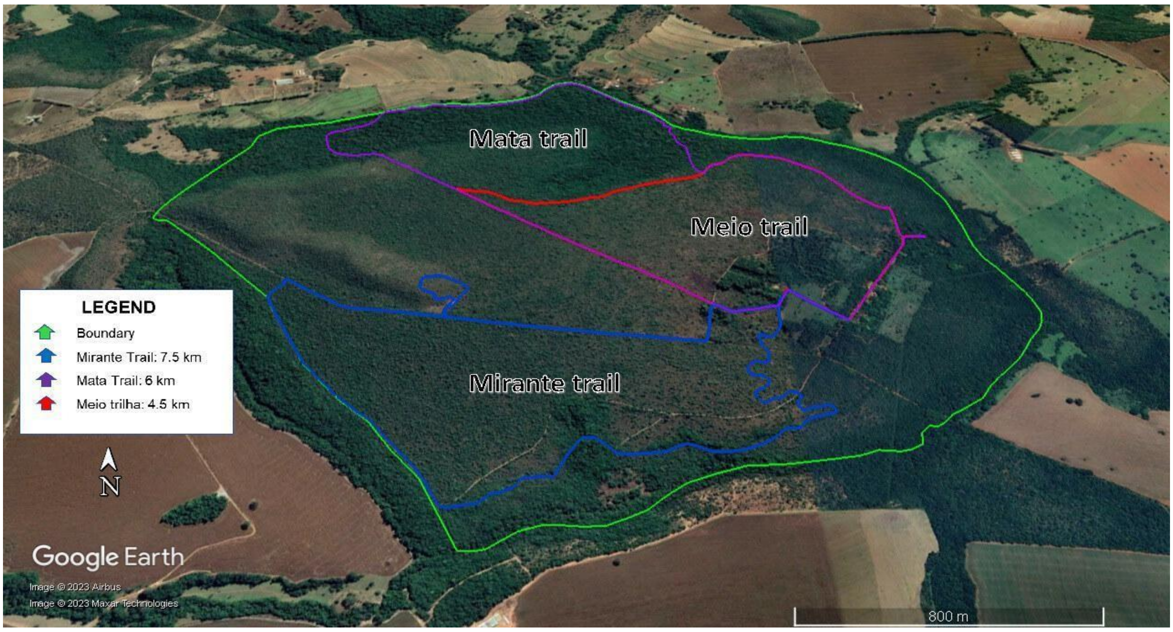

Figure 4 - Color-Coded Representation of the Network of National Forest Trails in Silvânia: ICMBio's Trail Marking Standard (ICMBio, 2015). Image obtained by Google Earth (Maio, 2023)

In this study, we assessed the tourism carrying capacity of the Public Use Zone in the National Forest Silvânia, which includes three trails: i) Mirante trail (7.5 km), ii) Mata trail (6 km), and iii) Meio trail (4.5 km) (Figure 4). The total combined length of these trails is 13.5 km. We evaluated the physical, real, and effective carrying capacity using Cifuentes' methodology (Cifuentes, 1992), which was adapted to account for the specific biophysical characteristics of the area (Figure 4) in line with recommendations from the International Union for Conservation of Nature (IUCN) (Ceballos-Lascuráin, 1996). This methodology considers site-specific factors that can limit the level and quality of visitation, taking into account the restricting factors of the areas.

2.2 Tourist Carrying Capacity (TCC)

This methodology is based on the concept of physical carrying capacity (PCC) of the site, which determines the relationship between the available space and time for visitation, thus indicating how many visits can occur within a specific place (Morales, 2014). It involves a mathematical calculation that takes into account various factors that restrict availability or access, resulting in the calculation of the real carrying capacity (RCC). Factors such as accessibility, erosion, flooding, precipitation, space required per person, opening hours, and visitor management are considered in the determination of RCC. Finally, the effective carrying capacity (ECC) represents the maximum limit of visitors that can be allowed in an area, considering the operational capacity to manage and provide adequate services to visitors (Zumbardo, 2017).

The procedure for determining the carrying capacity for tourist activities in protected areas, as outlined by Cifuentes (1992), consists of the following main phases: i) Analysis of tourism policies and area management: This phase involves an examination of the existing policies and management strategies related to tourism in the protected area; ii) Analysis of the objectives of the management plan: in this phase, the objectives outlined in the management plan are reviewed to understand the intended outcomes and priorities for the protected area; iii) Analysis of the situation of the sites of public use and their zoning: this phase focuses on evaluating the current state of the areas designated for public use within the protected area and their zoning arrangements; iv) Identification and measurement of factors/characteristics influencing each site of public use: here, the factors and characteristics that influence each location designated for public use are identified and measured.

These factors may include ecological, social, and economic considerations; v) Determination of the carrying capacity for each location: In this final phase, the carrying capacity for each specific location within the protected area is determined based on the information gathered in the previous steps. It is important to note that the first three steps, which involve the analysis of tourism policies, area management, and the objectives of the management plan, were conducted as part of the management plan review. These steps provide important background information and context for the subsequent phases of determining the carrying capacity for tourist activities in the protected area.

To determine the tourism carrying capacity, it is crucial to have a comprehensive understanding of the general context of the study site. This involves identifying the environmental units present in the area. The process includes describing the key elements of the territorial system, such as the physiography and geology of the region. Additionally, factors like geomorphological characteristics, soils, hydrography, and climate are examined to further enhance the understanding of the study area (as described in the study area section). Once this information is gathered, a careful selection of variables is made to be included in the actual carrying capacity assessment. These chosen variables play a significant role in determining the area's capacity to effectively sustain tourism activities.

2.2.1 Assumptions in determining tourist carrying capacity (TCC)

The calculations for tourism carrying capacity were made based on several assumptions. The first assumption is that each person typically requires 10 m^2 of space to move around freely, as suggested by previous research (Zacarias *et al*., 2011; Bera *et al*., 2015; Rodella *et al.*, 2017; Maji, 2018). This indicates that the area required by tourists (U/a) falls within the range of 5 to 10 m^2. Another assumption is that it takes approximately 2 hours to complete a trail, as found in studies (Cifuentes *et al*., 1992). Visiting hours were considered to be from 8:00 a.m. to 6:00 p.m., which amounts to 10 hours per day. This time frame aligns with the presence of the ICMBio team at the site. To calculate the RCC, we needed to analyze several correction factors.

Although the solar brightness correction factor could be a limitation for visitation, particularly between 10 am and 4 pm in this region, we did not consider it in this work because the trail is covered by vegetation, making it enjoyable throughout the day. Similarly, the flood correction factor will not be considered as visitors can effortlessly bypass flooding points due to the wide variety of phytophysiognomies of rural types (dirty field), savanna, and forest on the trails. The degree of difficulty for visitors to move around the area is also not a concern since slopes below 10% are overconsidered. In the study area of National Forest Silvânia, 85% of the relief is flat or almost flat, and although the access road is unpaved and extends 7 km to the main gate of the National Forest Silvânia, it will be disregarded due to its absence of erosion and slope. As the trail does not present any degradation sectors, we do not need to calculate the erodibility correction factor. Cifuentes (1992) considers only points that show evidence of erosion as limiting factors. These factors are closely tied to the unique conditions and characteristics of each site or activity. Lastly, the effective carrying capacity (ECC) was derived from information obtained from the management plan and through discussions with the forest manager.

2.2.2 Physical Carrying Capacity (PCC)

PCC is defined as the maximum number of users that can physically fit into, or onto, a specific area. Is the maximum limit of visits that a place can receive per day, considering the time, and space of each trail for the visit.

$$PCC \geq RCC \geq ECC$$

The formula for determining physical carring capacity is:

$$PCC = A * \frac{U}{a} * Rf$$

Where: A = available area for public use (trail distance)
U/ a = Area required per user to walk comfortably; Rf = Rotation factor (number of visits/day)

2.2.3 Real Carrying Capacity (RCC)

RCC is the maximum allowable number of users to the hiking trails, once the correction factors (Cf) derived from the characteristics of the site have been applied to the PCC. The general formula for calculating correction factors is as follows:

$$Cf = 1 - \left[\frac{Ml}{Mt} \right]$$

Where: $M1$ = limiting magnitude of variable
Mt = total magnitude of variable

$$RCC = PCC * (Cf1 * Cf2 * \ldots \ldots * Cfn)$$

Where: Cf = correction factor

These factors are calculated after fieldwork and are selected based on tourism activities and local conditions of the study area. The factors used to calculate RCC are:

Cf Social:

It refers to the quality of visitation, and the distance required between groups to avoid crowding. This factor we consider groups of 10 people and a distance of 200 m between groups. Regarding the group size, we calculated the carrying capacity for the hiking trails, with a maximum of 10 members per group, according to the directions proposed for ecotourism by The International Ecotourism Society (TIES, 2006) and WWF-Brazil (2003). The distance required per group was calculated through the sum of the distances between groups and the space occupied by each group. Also, the number of groups (NG) that can be simultaneously in the path is generated by the expression:

$$NG = (Site\ total(trail) \div distance\ required\ by\ each\ group)$$

To calculate the *Cf soc*, we first obtain the number of people (P):

$$P = NG \times Number\ of\ people\ per\ group$$

Moreover, the limiting magnitude (Ml) presented by the site was calculated:

$$Ml = Mt - P$$

Cf Temporary site closures:

In view of the need to perform the maintenance of the trails for the management of boar, it was proposed that the trail be closed to visitation, incentioding the limitation of one day per month, according to Cifuentes (1992) the calculation was performed of the following formula:

$$Cfcitemp = 1 - \frac{Ml}{Mt}$$

Ml: N° of hours per year in which the attraction is closed Mt: N° of total ours per year

Cf Precipitation:

It is a factor that prevents normal visitation, as most people are not willing to visit natural environments in rain. The average hours of daily rainfall should be considered in the months in which precipitation is significant:

$$Cfpre = 1 - \frac{Ml}{Mt}$$

Ml: Limiting rain months
Mt: N of months open to public

2.2.4 *Effective Carrying Capacity (ECC)*

ECC is the maximum number of visitors that a trail can sustain, given the management capacity (MC) available, and adjusting the RCC to the correction factors. Thus, it takes into consideration the infrastructures related to the trails, facilities and equipment, staff (number and qualifications), funding, among others, providing the number of visitants.

$$MC = \frac{Equioment + infrastructure + personnel}{3} * 100$$

3. Results

The conservation unit aims to ensure the area's sustainability and minimize potential impacts from tourist visits. These trails have a gentle slope and do not require physical preparation, allowing anyone to take part in the tour. With sustainability in mind, Table 1 displays the effective daily load capacities based on the number of times people can embark on each journey: Mirante (16.42), Mata (13.15), and Meio (10.07). In the other words, for the Mirante trail, the carry capacity is approximately 16 people per day, staying all day on the trail. These numbers provide an indication of the tourist capacity on the trails of the National Forest Silvânia, and may fluctuate, considering changes in the duration of stay of the visitor, or even changes in the physical structure of the conservation unit.

	Hiking trails		
Carring Capacity	**Mirante**	**Mata**	**Meio**
Physical (PCC) (visits/day)	3750	3000	2300
Correction Factor (Cf)			
Cfs (%)	95	95	95
Cfcitemp (%)	3.28	3.28	3.28
Cfpre (%)	18.53	18.53	18.53
Real (RCC) (visits/day)	147.58	118.19	90.52
Management capacity (MC)	55.64	55.64	55.64
Effective (ECC) (visits/day)	82.11	65.76	50.36
ECC/ (visits/day/times of visits)	16.42	13.15	10.07
ECC/ annuals	5796.26	4641.95	3554.71

Table 1 - Summary of Tourist Carrying Capacity. Physical Carrying Capacity (PCC) and rotation factors (number of visits/day); Real Carrying Capacity (RCC) and correction factors, calculated for the hiking trails; and Effective Carrying Capacity (ECC) including equipment, infrastructure, and personnel.

The National Forest Silvânia presented a social factor as a correction factor, which showed high variation due to the heterogeneity of distances between groups and the length of their visits. The study considered a distance of 100 meters between two groups, assuming a maximum of 10 individuals per group, which occupied $10m^2$ each (10*10+100). Therefore, the total space occupied by each group on the trail was 200 meters. Additionally, a temporary closure correction factor was calculated due to the need to perform maintenance on the trails for the management of boar. The study proposed closing the trail to visitation for one day per month to allow for maintenance.

According to National Institute of Meteorology (INMET), the average annual rainfall for the forest region of Silvânia is 1503.49 mm, with December being the month in which the highest precipitated volume occurs (259.28 mm) and July the month with the lowest precipitated volume (2.27 mm). In relation to the time of highest rainfall incidence, it coincides with the opening period of the area (from 8:00 am to 6:00 pm). The rainy season begins in October and ends in March, with a precipitated volume of 1299.41 mm, corresponding to almost 87% of the annual rainfall. Being (October- November- December) 2h of daily rain, for 92 days; in (January-February- March) 3h daily incidence of rain for 90 days. The least rainy period is from April to September.

The precipitation factor yields identical results for all trails since it uses the average number of days with precipitation per year. However, the correction factors with the least impact are precipitation, as rain does not restrict visitation, and temporary closures (due to maintenance for wild boars, occurring once a month) do not occur frequently. The most restrictive correction factor of all is the social factor, although it is not the most influential. The trails all produce the same outcome because of the presence of fixed variables such as the maximum number of people per group (10) and the minimum distance required between each group (200 meters).

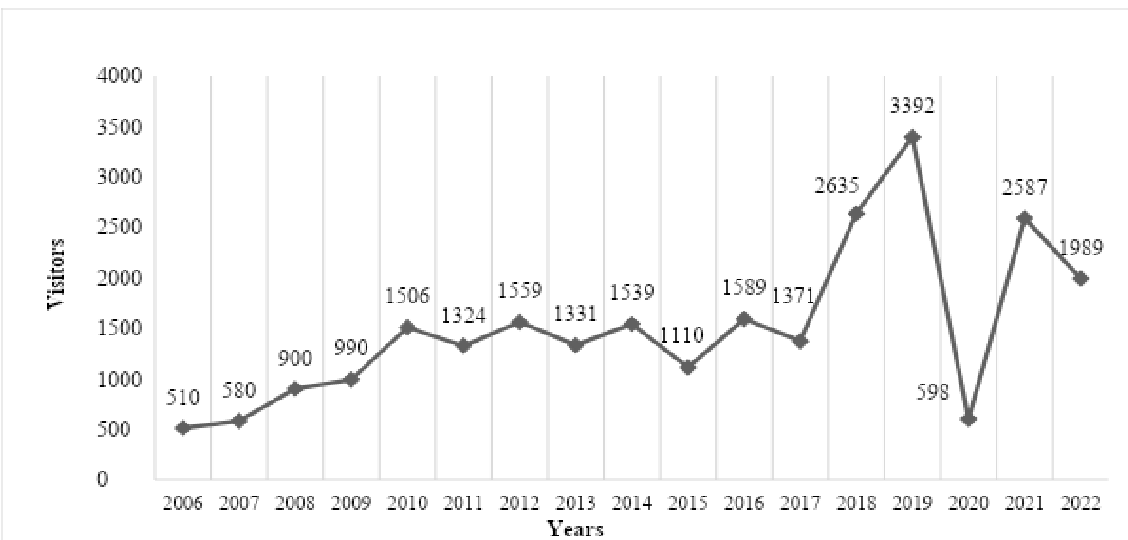

Figure 5 - Tourist Visitations Over Time in National Forest Silvânia.

Regarding the ECC, the trails present a moderate level of management capacity for recreational activities (see supplementary material). The infrastructure is in good condition, indicating that the area is suitable for receiving visitors. The trails are accessible, the signage is in good condition and there is transportation for internal displacement and monitoring of the trails by officials and brigade members. In addition, the area has recreational areas such as plant nurseries, viewpoints and picnic areas, as well as points for accommodation and overnight stays for researchers.

The evaluation of the physical carrying capacity (Table 1) indicates that the study area may accommodate more visitors than it has in the past. In 2019, the highest number of visits was recorded at 3,392, followed by a sharp decline in 2020 (only 598 visits) due to the COVID-19 pandemic and subsequent lockdown measures (Figure 5). Analysis of the period from 2006 to 2022 shows that the trails have not yet reached their maximum visitation capacity (Table 1). One potential method for increasing visits is through promotion via social media, newspapers, radio, and television. With this information, it can be concluded that the current number of visits is well below the carrying capacity of the trails as determined by their physical, real, and effective variables (Table 1). The scenic beauty and biological diversity of the area make it a promising destination for sustainable ecotourism activities that align with the objectives of the conservation area.

4. Discussion

The effective carrying capacity (ECC) was determined to be 5796.26 annual visitors for the Mirante trail, 4641.95 for the Mata trail, and 3554.71 for the Meio trail. These findings suggest that there is potential to increase visitation if the management capacity (MC) is improved. Therefore, improvements in management capacity are necessary to support the anticipated increase in visitation. It is worth noting that the social correction factor, which considers the space used by visitors and the distance between groups, had the greatest impact on the calculated carrying capacity in this study.

The primary mission of a protected area is to conserve biodiversity and ecological services, which is crucial for the preservation of the Cerrado biome. However, these areas can also contribute to sustainable use through research, public awareness campaigns, and tourism.

Recent studies have shown that natural features and biodiversity found in protected areas are attractive to tourists (Nabout *et al.* 2022; Chung *et al*. 2018). Thus, the suggestions proposed in this study, such as the potential increase in visitor numbers to National Forest Silvânia, should be taken into consideration while ensuring the preservation of biodiversity. Similar studies offer valuable insights and guidance for managing tourism in protected areas while ensuring the preservation of biodiversity. Manning *et al.* (2017) present case studies from various national parks, exploring the management of outdoor recreation with the preservation of biodiversity in mind. Eagles *et al*. (2002) provide guidelines for planning and managing sustainable tourism in protected areas, with a focus on balancing visitor numbers and biodiversity conservation. Buckley (2012) discusses the concept of sustainable tourism and highlights the importance of considering the preservation of biodiversity, while Bushell and Eagles (2006) explore the benefits and challenges of tourism in protected areas, emphasizing the need to balance visitor numbers with biodiversity conservation. Balmford *et al.* (2002) discuss the economic justifications for conserving wilderness, including the value of biodiversity preservation in the context of tourism.

Our study found that the annual tourist carrying capacity of the National Forest Silvânia has not reached its visitation limit, which aligns with similar findings in the following studies: Schlüter and Drummond (2012) conducted a study of Itiquira Municipal Park and discovered that the park's physical carrying capacity restricted the number of annual visitors to approximately 40,000, a figure close to the maximum limit calculated in our study (39,785). Da Soller and Borghetti (2013) investigated the Rural Paths of Porto Alegre, emphasizing the significance of carrying capacity in conservation efforts. Binelli et al. (1997) examined trails in Brotas, São Paulo, highlighting the importance of considering carrying capacity in conservation practices. De Sousa et al. (2020) determined that the Caída do Morro Trail in Ilha Grande, Piauí, Brazil, can sustainably accommodate up to 39 visits per day, which represents only 6.2% of its actual capacity. These findings suggest that with appropriate management, such as the construction of additional support points and the acquisition of extra equipment, the number of visits could potentially be increased.

In this article, we emphasize the importance of utilizing tourism carrying capacity early warning tools to preserve ecosystems within conservation units, ensure the sustainability of tourism activities in Brazil, and recognize their crucial role as protectors of biodiversity. Regrettably, Brazil has witnessed the implementation of detrimental environmental policies in recent years, which pose a significant threat to the country's rich biodiversity (Bernard et al., 2014; Soares-Filho et al., 2014; Pereira et al., 2019; Begotti and Peres, 2020). Therefore, it is imperative to understand the role of protected areas and their intrinsic connection to human utilization, as this knowledge forms the foundation for developing future conservation strategies.

5. Conclusions

From this study, it becomes evident that distinct spatial and social constraints should be formulated for each emerging or established tourist destination. The danger of an unregulated influx of tourists can result in surpassing a specific threshold and, consequently, disturb the equilibrium of the territory, which, in turn, could have adverse effects on the quality of life for local residents and the level of visitor satisfaction. Regarding the National Forest of Silvânia, the findings indicate that the maximum limit of visitations has not been exceeded, allowing the area to potentially accommodate a greater number of annual tourist visits than it has received until 2022. To achieve this, it is crucial to enhance the tourism offerings in a manner that corresponds to the characteristics of the area and fulfills the management objectives, without compromising the natural surroundings. Enhancing the managerial capabilities of an area translates into an increase in its capacity to receive visitors. In order to foster greater sustainability, land managers need to elevate their development goals while simultaneously reducing thresholds. This shift in approach acknowledges that sustainability is attained through development and that sustainability itself becomes the impetus for future progress. However, the real challenge lies in utilizing this methodology to establish a more comprehensive analysis of destinations within a limited timeframe.

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Supplementary Material

1. Turistic Carring Capacity (TCC)

Table 1. Shows the Physical Carrying Capacity *(PCC)* of the trails in the National Forest Silvânia.

Hiking trails	Nv	S (meters)	Occupied area (meters)	Hv	Tv (hours)	PCC
Mirante	5	7500	$10m^2$	10 hrs	2	3750
Mata	5	6000	$10m^2$	10 hrs	2	3000
Meio	5	4600	$10m^2$	10 hrs	2	2300

2. Real Carring Capacity (RCC)
2.1 Cf Social:
a) Mirante trail

$$\text{Ngroups} = \frac{\text{surface. trails 7500 m}}{\text{distance. groups 200m}} = \text{37.5 groups}$$

NP = 37.5 x 10 = 375 people
NP = number of people
ML = 7500 - 375 = 7125
ML = limiting magnitude

$$CFs = \frac{\text{ML}}{\text{MT}} \times 100 \rightarrow \frac{7125}{7500} \times 100 \rightarrow 0.95\ x\ 100\ =\ 95\ \%$$

b) Mata trail

$$\text{Ngroups} = \frac{\text{surface. trails 6.000 m}}{\text{distance. groups 200m}} = \text{30 groups}$$

NP = 30 x 10 = 300 people
NP = number of people
ML = 6000 - 300 = 5700
ML = limiting magnitude

$$CFs = \frac{\text{ML}}{\text{MT}} \times 100 \rightarrow \frac{5700}{6000} \times 100 \rightarrow 0.95\ x\ 100\ =\ 95\ \%$$

c) Meio trail

$$\text{Ngroups} = \frac{\text{surface. trails 4.600 m}}{\text{distance. groups 200m}} = \text{23 groups}$$

NP = 23 x 10 = 230 people
NP = number of people
ML = 4600 - 230 = 4370
ML = limiting magnitude

$$Cfs = \frac{\text{ML}}{\text{MT}} \times 100 \rightarrow \frac{4370}{4600} \times 100 \rightarrow 0.95\ x\ 100 = 95\ \%$$

Table 2. Shows the Correction Factors Social *(CFs)* of the trails in the National Forest Silvânia.

Hiking trails	S (meters)	Group distance (meters)	NP	ML	CFs
Mirante	7500	200	375	7125	95 %
Mata	6000	200	300	5700	95 %
Meio	4600	200	230	4370	95 %

2.2 Cf Temporary site closures

Hc = Hours per year when the trail will be closed
Hc = 10 hours/day x 1 day/month x 12 months/year = 120 hours/year
Ht = Hours per year when the trail will be open
Ht = (365 days/year) x 10 hours/day = 3650

$$Cfcitemp = \frac{120}{3650} * 100 \rightarrow 0.032 = 3.28\ \%$$

2.3 Cf Precipitation

HL = Limiting hours of rain per year
HL = (92 x 2) + (90 x 3) = 454h/year
HT = Hours of year when the trail is open
HT = 365 days-120 Hours *Cfpre* x 10 hours/day = 2450 h/year

$$Cfpre = \frac{\text{HL}}{\text{HT}} \times 100 \rightarrow \frac{454}{2450} \times 100 \rightarrow 0.185 = 18.53\%$$

Table 3. Displays the Precipitation Factor *(Cfpre)* of the trails in the National Forest Silvânia.

Hiking trails	**Months > precipitation (days)**	**Rainy Hours (day)**	**Attention to the public (time)**	**HL**	**HT**	***Cfpre***
Mirante Mata Meio	182	2-3	10hrs	454	2450	18.53%

Table 4. Real Carrying Capacity (*RCC*) and correction factors, calculated for the hiking trails

Correction factors (Cf)					
Hiking trails	***PCC***	***Cfs***	***Cfcitemp***	***Cfpre***	***RCC***
Mirante	3750	95 %	3.28%	18.53%	147.58 ∴ visits
Mata	3000	95 %	3.28%	18.53%	118.19 ∴ visits
Meio	2300	95 %	3.28%	18.53%	**90.52**∴ visits

Table 5. Provides a description of the structure required for Effective Capacity according to ICMBio (2022)

Category	Description	Minimum handling capacity/15 %	Optimal level management capacity/100 %	Current
Staff	Administrator/Manager	01	02	1=50%
	Financial Administrative Coordinator	01	01	0=00%
	Guides in Ecotourism	02	03	0=00%
	Forestry Agent	01	02	0=00%
	Environmental Analyst	01	02	1=50%
	Environmental Technicians	01	02	2=100%
	Temporary Environmental Agent	01	01	1=100%
	Trail Maintenance Employee	02	04	1=25%
	Brigadists	02	02	5=100%
	General Services Assistant	01	01	1=100%
	Cook/Butler	02	04	0=00%
	Nurses/Technicians	03	06	0=00%
	Safety Personnel	05	10	0=00%
Infrastructure	Restroom Attendants (Male and Female)	02	04	4=100%
	Information Boards	01	02	22=100%
	Informative Banners	01	01	2=100%
	Signs	03	06	12=100%
	Picnic Areas	01	01	1=100%
	Visitor Reception Center	01	01	0=00%
	Snack Bar/Restaurant	01	01	0=00%
	External Recycling Bins	02	06	6=100%
	Artesian Well	01	01	0=00%
	River Water Catchment System by Pumping	01	01	1=100%
Equipment	Utility Vehicle	01	02	3=100%
	Motorcycle for Surveillance	02	06	0=00%
	Computer with Printer and Scanner	01	02	2=100%
	Phone/Internet Communication System	01	02	1=50%
	Television	01	03	0=00%
Maintenance	Bridges for Trails	02	03	4=100%
	Trail Cleaning Equipment	01	02	1=50%
	Chainsaw	01	02	3=100%

3. **Effective Carrying Capacity (ECC)**

$$\mathrm{MC} = \frac{\mathrm{CC}}{\mathrm{OLC}}\ \mathrm{X}\ 100$$
$$\mathrm{MC} = \frac{\mathrm{IF\%}}{\mathrm{Variable}} \rightarrow \frac{1725}{31} = 55.64\%$$

MC = Management Capacity
CC = Current capacity
OLC = Optimal level capacity
IF = Infrastructure
Variable = Regarding the number of items analyzed in chart 5.

3.1 Management capacity (MC):

a) Mirante trail:

$$\mathrm{ECC} = \frac{\mathrm{RCC} \times \mathrm{MC}}{1OO} \rightarrow \frac{147.58 \times 55.64}{100} \rightarrow \frac{8211.35}{100} = 82.11 \text{ visits} \therefore \text{day}$$

b) Mata trail:

$$\mathrm{ECC} = \frac{\mathrm{RCC} \times \mathrm{MC}}{1OO} \rightarrow \frac{118.19\ \times 55.64}{100} \rightarrow \frac{6.576{,}09}{100} = 65.76 \text{ visits} \therefore \text{day}$$

c) Meio trail:

$$\mathrm{ECC} = \frac{\mathrm{RCC} \times \mathrm{MC}}{1OO} \rightarrow \frac{90.52\ \times 55.64}{100} \rightarrow \frac{5036.53}{100} = 50.36 \text{ visits} \therefore \text{day}$$

3.2 Calculating the number of visitors per day:

a) Mirante trail:

$$\mathrm{ECC} \therefore \mathrm{VD} = \frac{\frac{\text{visits}}{\text{day}}}{\frac{\frac{\text{visits}}{\text{day}}}{\text{visitor}}} = \frac{82.11 \text{ visitas}}{5} = 16.42 \text{ visits} \therefore \text{day/visitor}$$

b) Mata trail:

$$\mathrm{ECC} \therefore \mathrm{VD} = \frac{\frac{\text{visits}}{\text{day}}}{\frac{\frac{\text{visits}}{\text{day}}}{\text{visitor}}} = \frac{65.76}{5} = 13.15 \text{ visits} \therefore \text{day/visitor}$$

c) Meio trail:

$$\mathrm{ECC} \therefore \mathrm{VD} = \frac{\frac{\text{visits}}{\text{day}}}{\frac{\frac{\text{visits}}{\text{day}}}{\text{visitor}}} = \frac{50.36}{5} = 10.07 \text{ visits} \therefore \text{day/visitor}$$

3.3 The number of annual visitors to the trail is:

a) Mirante: 16.42 visitors/day x (365days-12=353) = 5796.26 visitors/year
b) Mata: 13.15 visitors/day x (365days -12=353) = 4641.95 visitors/year
c) Meio: 10.07 visitors/day x (365 days-12=353) = 3554.71 visitors/year

CAPITULO 4

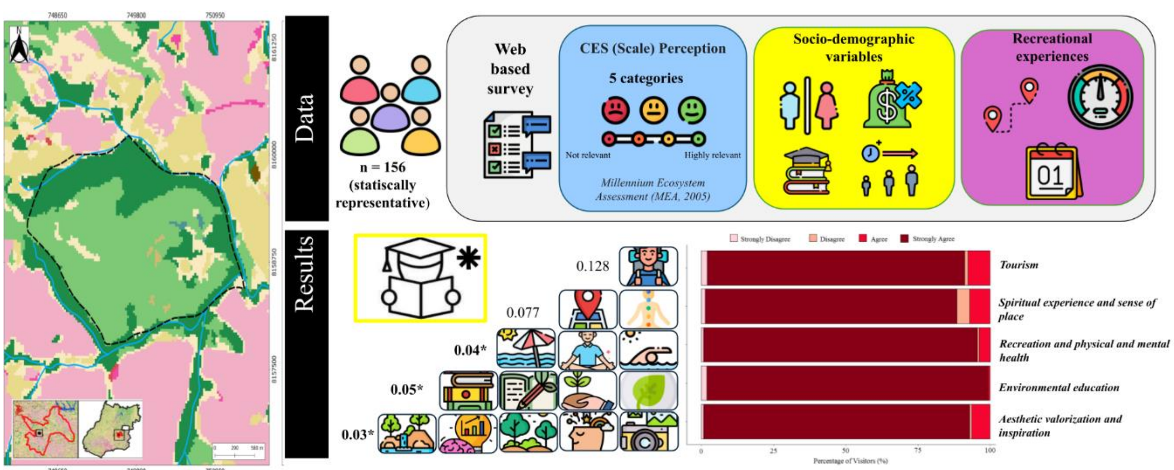
Tourist`s Perception of cultural ecosystem services in a Cerrado Protected Area

Abstract

The field of Cultural Ecosystem Services (CES) explores the non-material benefits that ecosystems provide to people. Human perceptions and valuations change for many reasons and in many ways. Our aim was to investigate whether factors such as age, gender, distance, income, and education influence the perceptions CES of visitors to the Silvânia National Forest (SNF), situated in a landscape dominated by agricultural activities, serving as an example of the loss of native Cerrado areas. In this study, we surveyed: (i) the socio-economic characteristics of the participants, (ii) visitation patterns and recreational experiences, and (iii) the perception of CES. Using Generalized Linear Models (GLM), we analyzed the relationship between CES perception and socio-economic variables, employing model selection based on the Akaike Information Criterion (AIC). A total of 156 visitors were interviewed, with the majority being women (63%) and young adults aged between 18 and 35 (59%). Most visitors had higher education (69%) and reported incomes ranging from 243 to 727 US dollars. Visitors mainly came from neighboring municipalities and traveled an average distance of 228 km to reach the forest. In our research, the variable that has shown a significant impact on human perception is education. We also found high scores for visitors perceptions in all CES categories. This suggests that respondents perceive the SNF as a multifaceted resource with significant cultural, recreational, and ecological value, enriching the lives of those who interact with it and contributing to overall social well-being. In line with the EU 2020 + Biodiversity strategy, the study may pave the way for the future implementation of payments for ecosystem services from this area that generates high provision of CES.

Keywords
Cerrado biome; Perception; Cultural ecosystem services; Biodiversity

Graphical abstract



1. Introduction

The concept of Cultural Ecosystem Services (CES) has sparked significant interest as our understanding of the intricate relationship between ecosystems and their myriad benefits to humanity has evolved (Costanza et al., 2017). While historically, the term "ecosystem services" primarily emphasized tangible gains like food production or climate regulation, it is now widely acknowledged that ecosystems provide invaluable cultural and social advantages (Milcu et al., 2013; Fish et al., 2016). This recognition that humans derive not only material but also cultural, emotional, and spiritual nourishment from ecosystems has led to the emergence of CES (Chan et al., 2012; Daniel et al., 2012). These services encompass a range of enriching experiences, including recreation (Kalinauskas et al., 2023), landscape aesthetics (Bachi et al., 2020), spiritual and cultural enrichment (Rall et al., 2017), preservation of cultural identity (Tengberg et al., 2012), and even artistic inspiration (Gould et al., 2017). The integration of CES into the broader framework of ecosystem services has been an evolutionary journey marked by extensive research and academic discourse. Pioneering initiatives such as the Millennium Ecosystem Assessment (MEA, 2005), the Economics of Ecosystems and Biodiversity (TEEB, 2010), the Common International Classification of Ecosystem Services (CICES, 2018), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) have collectively deepened our understanding of how ecosystems not only sustain material existence but also profoundly enrich human life in cultural and emotional dimensions (Kirchhoff et al., 2012). Nevertheless, CES present distinctive challenges due to their elusive and subjective nature, making precise definition and measurement elusive (MEA, 2005; Hernández et al., 2013; Hirons et al., 2016; Dickinson et al., 2017).

CES can be assessed through three main domains: ecological, sociocultural, and economic (de Groot et al., 2010). While economic and ecological benefits may be measured relatively directly (Howarth and Farber, 2002), sociocultural benefits are influenced by individual perceptions, preferences, demands, and human needs (Yahdjian et al., 2015). These benefits stem from the perceived qualities of natural ecosystems that contribute to human well-being (Summers et al., 2012). One approach to accessing this sociocultural domain is to understand stakeholders' perceptions of ecosystem services and their benefits (Scholte et al., 2015). For the purpose of this research, we adopt the definition of perception as "sensory experiences" (Wahlberg and Sjoberg, 2000; Krishna, 2012). It is shaped by individual traits, social norms, and local culture, thereby influencing how ecosystem services are perceived and valued within different contexts (Poortinga et al., 2004; Ertz et al., 2016; Costanza et al., 2017; Schweiker et al., 2020). This perception is acquired through direct interaction with the landscape, personal experiences, and oral transmission, illustrating the intricate interconnections among animals, plants, humans, and their environment (Campos et al., 2012). Integrating this understanding of perception into the assessment of CES can enhance our ability to accurately define, measure, and manage these valuable ecosystem benefits.

Different categories of cultural ecosystem services, such as recreation, tourism, aesthetics, spirituality, and education, are valued differently by individuals and communities based on their cultural backgrounds, personal beliefs, and experiences (Plieninger et al., 2013). For example, some individuals may perceive recreational activities like hiking or birdwatching as opportunities for physical exercise and relaxation, while others may view them as chances to connect with nature and escape the stress of urban life (Puhakka, 2021). Tourist attractions within ecosystems may be seen as opportunities for economic development by some communities, while others may prioritize the preservation of natural areas over tourism revenue (Novelli and Scarth, 2007). Beauty and cultural significance in landscapes and ecosystems can be subjectively interpreted, with different people finding value in different aspects of natural scenery based on their personal preferences and cultural backgrounds (Swanwick, 2009). The spiritual significance of ecosystems can vary greatly among different cultures and individuals (Cooper et al., 2016). Some may view nature as sacred and imbued with spiritual meaning, while others may not attribute spiritual significance to natural landscapes (Ashley, 2007). The value of educational opportunities provided by ecosystems may be appreciated differently depending on factors such as access to education, awareness of ecological issues, and cultural attitudes towards environmental stewardship (Mocior and Kruse, 2016). Overall, recognizing the diversity of perspectives on cultural ecosystem services is crucial for understanding their full range of benefits and ensuring inclusive and equitable management of natural resources (Márquez et al., 2023).

Our objective was to examine how visitors interpret CES and determine if factors such as age, gender, distance, and income influence that perception. To do this, we chose to study the Cerrado, a biome heavily impacted by human activity, particularly agricultural expansion, which has significantly altered nearly half of its original area (Machado et al., 2004), leading to ecological degradation (Klink and Machado, 2005). These changes have profoundly transformed natural habitats, displacing native populations and fragmenting ecosystems (Francoso et al., 2015). In particular, the Silvânia National Forest (SNF) stands as a sanctuary amidst the intense agricultural landscape of the Cerrado, spanning 486,37 hectares and preserving various facets of this biome (Lima and Bastos, 2019). It serves as a hub for tourism, environmental education, and scientific research (ICMBio, 2015). We proceeded with the belief that socioeconomic factors could shape visitors' perceptions, given their direct link to how people perceive their surroundings and understand environmental dynamics. Hence, we hypothesized that: i) younger visitors might prioritize ecosystem services associated with leisure and recreation, drawn to outdoor activities and seeking thrilling experiences in nature; ii) women, due to their stronger emotional connection with nature and sensitivity towards cultural and aesthetic aspects, are more inclined to recognize and value the benefits that ecosystems provide in terms of human well-being and quality of life; iii) visitors living closer to the SNF might possess a deeper understanding of ecosystem services, benefiting from their proximity and frequent interactions with nature; iv) individuals with lower incomes might gravitate towards accessible and low-cost ecosystem services, such as free hiking trails; v) those with higher education levels could have a more comprehensive understanding and appreciation of ecosystem services, recognizing a broader spectrum of environmental benefits.

2. Materials and Methods

2.1. Study Area

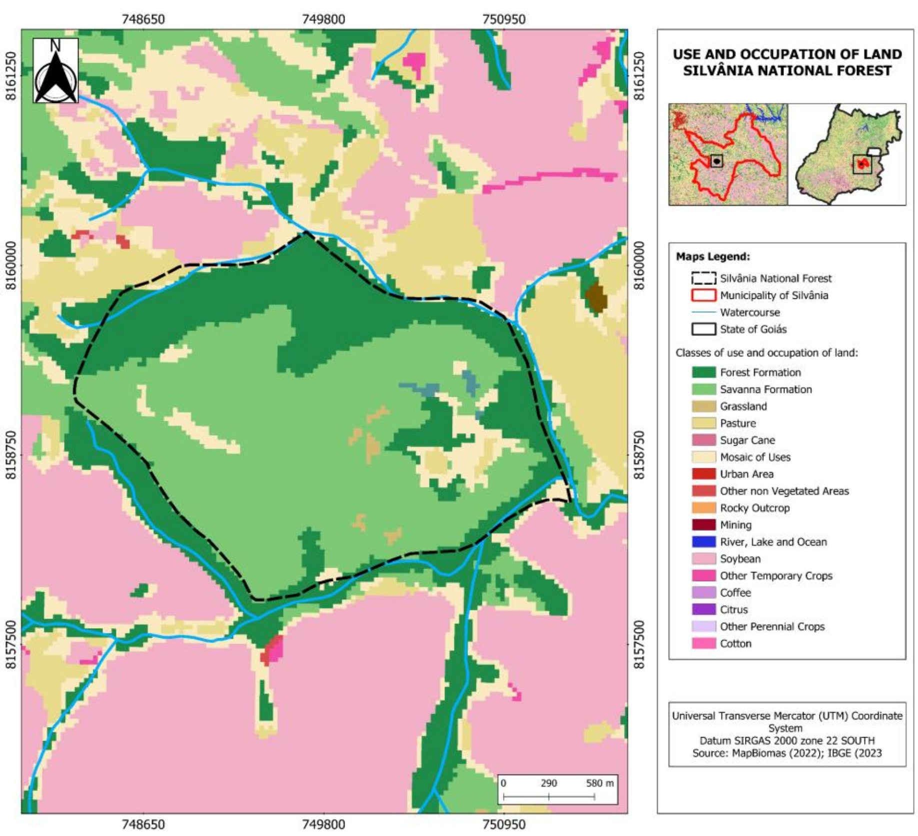


Figure 1. Land use and occupation locations within Silvânia National Forest. Sources: MapBiomas 2022; IBGE (2023).

The Silvânia National Forest (SNF) stands out as one of the most studied areas within the Cerrado biome, as demonstrated by various research efforts (e.g., Bastos et al., 2003; Bini et al., 2003; Morais et al., 2012). Located in the municipality of Silvânia, state of Goiás, in the heart of Brazil, the SNF covers a protected area of just 486.37 hectares, situated between the coordinates 16º 38' 30.0" S and 48º 39' 02.5" W. The average altitude is 900 meters, with an average temperature of 26°C. The original vegetation includes open savanna, typical cerrado, woodland cerrado, semi-deciduous seasonal forest, and gallery forests (MMA, 2015). The SNF is surrounded by a landscape dominated by agricultural activities (Figure 1). This region is an example of the loss of native Cerrado areas due to agricultural expansion. We chose to study visitors' perceptions of CES in the area primarily because of the importance of managing and maintaining ecosystem services in the region.

2.2 Classification of Cultural Ecosystem Services

In this study, we identified five categories of cultural services provided by the Silvânia National Forest (SNF) (Table 1). To categorize these services, we employed the framework established by the Millennium Ecosystem Assessment (MEA, 2005), which is widely recognized and applied globally. This framework allows for a comprehensive understanding of the diverse cultural benefits offered by the forest, providing a structured approach to assess and analyze its cultural ecosystem services.

Table 1. Selected Cultural Ecosystem Services and their definitions as used in this study.

Service	Definition
Recreation and physical and mental health	To activities and environments that promote physical and mental well-being through recreational and leisure activities, such as physical exercise, outdoor sports, relaxation time in nature, and participation in social and cultural activities that contribute to the balance and overall health of the individual.
Tourism	To the activity of traveling to places for pleasure, leisure, or business purposes. It involves visiting and exploring different destinations, experiencing their attractions, culture, heritage, and interacting with local people. Tourism plays a significant role in the economy of many countries and contributes to the development of infrastructure, services, and cultural exchange.
Aesthetic valorization and inspiration	To the process of appreciating, enhancing, and deriving inspiration from the visual and sensory qualities of natural or man-made environments. It involves recognizing and valuing the beauty, harmony, and artistic elements present in landscapes, architecture, art, and design. This appreciation can lead to creative

	inspiration, emotional well-being, and a deeper connection with one's surroundings.
Spiritual experience and sense of place	Refers to the profound feelings, connections, and insights individuals may have when they engage with specific locations or environments that hold spiritual or symbolic significance to them. It involves a sense of belonging, reverence, and personal meaning attributed to places that evoke spiritual or transcendent experiences, such as sacred sites, natural landscapes, or cultural heritage locations. This connection with place can foster a deeper understanding of oneself, spirituality, and the interconnectedness of humans with their surroundings.
Environmental education	Provide opportunities for the creation of scientific knowledge, research, experiences and education through the natural environment of the ecosystem.

2.3 Data Collection

Questionnaire data were collected from July 2022 to July 2023. A total of 70 in-person surveys and 86 virtual surveys were conducted using Google Forms. The questions were elaborated considering the five categories of ecosystem services previously mentioned and mainly divided into three sections: (i) socioeconomic characteristics of the participants. This included age, gender, income, education, characteristics of the living environment; (ii) characteristics of the visits and recreational experiences (e.g., frequency of visit, travel distance, travel time, satisfaction with the time spent); and (iii) perception of cultural ecosystem services provided by SNF, based in five questions. Are they: 1) Is SNF important for recreation and physical and mental health, serving as area for sporting activities, walks, picnics? 2) Is SNF important for tourism, and do its green areas and gardens attract international and local tourists? 3) Is SNF important for aesthetic appreciation and inspiration, and does its nature with its colors, sounds and smells enrich the human mind? 4) Is SNF important for spiritual experience and sense of place, does its landscape and specific locations creating a sense of place and stimulating spiritual experiences? 5) Is SNF important for environmental education, given that its natural environment forms a place for educating the population? The responses consisting of ten-point Likert scale. In this scale, values close to 1 indicate that the interviewee totally disagrees with the importance of the SNF in providing recreational, aesthetic, tourist, a sense of place, as well as spiritual and educational experiences; while values closer to 10 indicate that the interviewee completely agrees on the importance of the SNF in providing these experiences (See the questionnaire applied in the supplementary material). Then, we converted this Likert scale ranging from 1 to 10 according to the interviewees' answers. Thus, Likert scale 1-2: Strongly Disagree - Have no idea about the statement/Never participated in related activities; Likert scale 3-4: Disagree - Not sure about the statement/Might have participated in related activities; Likert scale 5-6: Agree - Agree with the statement/I have occasionally participated in related activities; Likert scale 7-10: Strongly Agree - Agree with the statement/I have frequently participated in related activities.

When conducting our survey, we made the decision not to inquire about the exact income levels since people generally are not willing to provide this kind of information, as highlighted in the works of Marrocu et al. (2015). This is why, in some databases, this variable is collected through ordinal categorical variables (i.e., income classes) (Brida and Raffaele, 2013). Therefore, in order to obtain a reliable response, at least within the relevant income range, our questionnaire asked respondents to indicate their relevant income bracket by choosing one of the following classes: up to 1 minimum wage (242.00US$); from 1 to 3 minimum wages (243.00 US$ to 727 US$); from 3 to 5 minimum wages (728 US$ to 1,212 US$); more than 5 minimum wages (1,212 US$). For age, we classify visitors into two categories, i) those between 18 and 35 years old and ii) those between 36 and 60 years old. For education, we classified the visitors in i) without education (i.e. those with no formal education level), ii) completed high school (i.e. those who have completed higher education) and iii) higher education (i.e. those who have graduation degree). This interval-based approach is consistent with the methodology used in the work of Zambrano et al. (2018).

Due to the low tourist influx, the questionnaire was administered over the course of one year. The representative sample consisted of 156 individuals, determined through stratified sampling. Eligible respondents for the questionnaire needed to be over 18 years of age, economically active, and from diverse professional backgrounds. Additionally, respondents were limited to those who had visited the park. In cases where visitors arrived in groups, the group leader was selected as the interviewee. These measures aimed to prevent data redundancy, ensuring the uniqueness of each respondent (Syamsul, 2010). Therefore, considering these particularities, the number of interviewees was representative for evaluating tourists' perceptions of the cultural ecosystem services provided by SNF. This data collection process received approval from the Ethics Committee of Goiás State University (UEG) with process number: 58464922.6.0000.8113.

2.4 Data analysis

We identified perceived CES through combined assessments of respondents' beliefs, perceptions, and reported activities. We used interview responses to determine if the respondent perceived each CES and to gather the value they assigned to their perceptions. We assessed the relationship between each of the perceptions of CES and socioeconomic variables (age, gender, distance, income, and education) using Generalized Linear Models (GLMs) (McCullagh and Nelder, 2019). We verified that the assumptions of a GLM with Gaussian distribution were not met. Considering the best fit of the model and according to Akaike's criteria, we selected models with Gamma distribution for the relationship between CES and socioeconomic variables, using the AICctab function from the AICcmodavg package (Mazerolle, 2020). The Gamma Regression model was employed to handle data that do not follow a typical Gaussian distribution, as is often the case with many human perceptions. In this model, the relationship between the perception of CES and socioeconomic variables was adjusted using the gamma distribution as the link function (Dunn and Smyth, 2018). This allows capturing nonlinear relationships between independent and dependent variables, which may be relevant in perception contexts. For each GLM model generated between each of the CES and the socioeconomic variables, we applied permutation tests, based on the likelihood ratio (999 permutations), obtaining significance values (with limits of $p<0.05$), using the predictmeans package (Luo et al., 2018). Furthermore, we evaluated pairwise differences (*pos hoc*) with bonferroni correction for models with significant categorical variables using the *emmens* package (Lenth et al., 2019). All analysis figures were created using the *ggplot2* package (Wickham and Wickham, 2016). All these analyses were conducted using R software version 4.3.2 (R Core Team, 2023).

3. Results

3.1 Respondent Characteristics

Table 2. Demographic information of the interviewees. The Education variable encompasses a wide range of educational backgrounds, ranging from individuals with no formal schooling to those with various levels of educational achievement, such as elementary education, incomplete high school, high school diploma, completed or incomplete bachelor's degrees, specialization degrees, master's degrees, and doctorates. The Age variable categorizes the interviewees into different age groups, including those aged 18 years or younger, individuals aged 19 to 35, those aged 36 to 59, and individuals aged 60 years or older.

Demographic Factors	Classification	Dimensions
Gender	Masculine	37%
	Feminine	63%
Age	18 and 35 years 36 and 60 years old	59% 41%
Education	Without education Completed high school Higher education	5.80% 25.20% 69%
Demographic Factors	**Classification**	**Dimensions**
Income	242.00US$ 243.00 US$ to 727 US$ 728 US$ to 1,212 US$ 1,212 US$	16.10% 43.90% 23.90% 16.10%
Round and trip distance	Anápolis	117 km
	Brasília	418 km
	Formosa	560 km
	Gameleira de Goiás	60 km
	Goiânia	146,2 km
	Jussara	600 km
	Leopoldo de Bulhões	24 km
	Morrinhos	376 km
	Orizona	142 km
	Silvânia	15,8 km
	Vianópolis	54,4 km

Considering the 156 visitors interviewed in the SNF, 98 were women (63%) and 58 were men (37%). We found that 92 visitors were young adults aged between 18 and 35 years (59%), while the other 64 visitors (41%) were aged between 36 and 60 years. The majority of visitors have higher education (69%) and income between 243 US$ to 727 US$. Visitors came mainly from municipalities neighboring the SNF. They traveled an average of 228 km from their place of origin to the conservation unit. The longest distance covered was traveled by visitors from Jussara (600 km), while the shortest distance was covered by visitors from Silvânia (15.8 km), both municipalities in the state of Goiás (Table 2).

3.2 Perceived importance of cultural ecosystem services

In general, visitors had a high perception of the cultural ecosystem services offered by the SNF, and the majority strongly agreed that the conservation unit provides services associated with tourism, spiritual and sense of place, recreation/physical and mental health, environmental education and aesthetic and inspiration (Figure 2). Furthermore, the lowest disagreement value was presented for the CES of recreation/physical and mental health and environmental education (Figure 2)

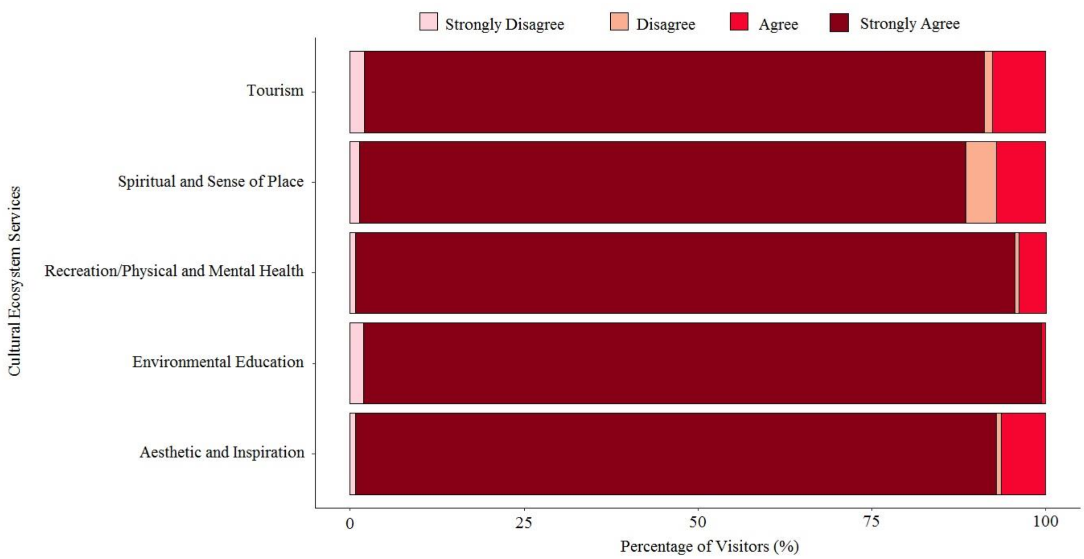


Figure 2 - Perceptions of visitors in relation to the importance of Cultural Ecosystem Services in the National Forest Silvânia, Goiás, Brazil. Strongly disagree: Likert Scale 1-2; Disagree: Likert Scale 3-4; Agree: Likert Scale 5-6; Strongly Agree: Likert Scale 7-10.

3.3 *Factors Determining CES Perception.*

We discovered that education emerged as the sole determining factor influencing the perception of cultural ecosystem services, as illustrated in Table 3. Specifically, education significantly impacted perceptions related to recreation and physical/mental health (Question 1), aesthetic valorization and inspiration (Question 3), and environmental education (Question 5). Conversely, none of the socioeconomic or demographic variables analyzed showed a significant association with cultural ecosystem services in tourism (Question 2) or with spiritual experience and sense of place (Question 4) (see Figure 3). Our findings underscore the broad-ranging effects of education on diverse perceptions of cultural ecosystem services (CES). Thus, lower education translates to a lower perception of the cultural service related to Recreation/Physical and Mental Health, inspiration, and environmental education. These results indicate that education is an important factor in the perception of cultural ecosystem services, highlighting its influence on these assessments.

Table 3. Influence of demographic factors on the perception of cultural ecosystem services: ANOVA analysis. * The p values were obtained from permutations based on the likelihood ratio (999 permutations)

CES Models	**Variables**	**Df**	**F**	**P-value***
Recreation and physical and mental health				
	Road trip distance	1	0.351	0.479
	Gender	1	1.705	0.217
	Age	3	0.504	0.311
	Education	2	8.473	**0.04***
	Income	3	1.343	0.242
Tourism				
	Road trip distance	1	0.130	0.675
	Gender	1	0.013	0.799
	Age	3	0.271	0.492
	Education	2	2.493	0.128
	Income	3	0.850	0.482
Aesthetic valorization and inspiration				
	Road trip distance	1	0.318	0.536
	Gender	1	2.097	0.078
	Age	3	0.166	0.988
	Education	2	9.182	**0.03***
	Income	3	1.705	0.095
Spiritual experience and sense of place				
	Road trip distance	1	0.001	0.974
	Gender	1	0.133	0.759
	Age	3	0.087	0.764
	Education	2	3.590	0.077
	Income	3	1.282	0.246
Environmental education				
	Road trip distance	1	0.004	0.960
	Gender	1	0.028	0.786
	Age	3	0.046	0.867
	Education	2	3.799	**0.05***
	Income	3	0.715	0.554

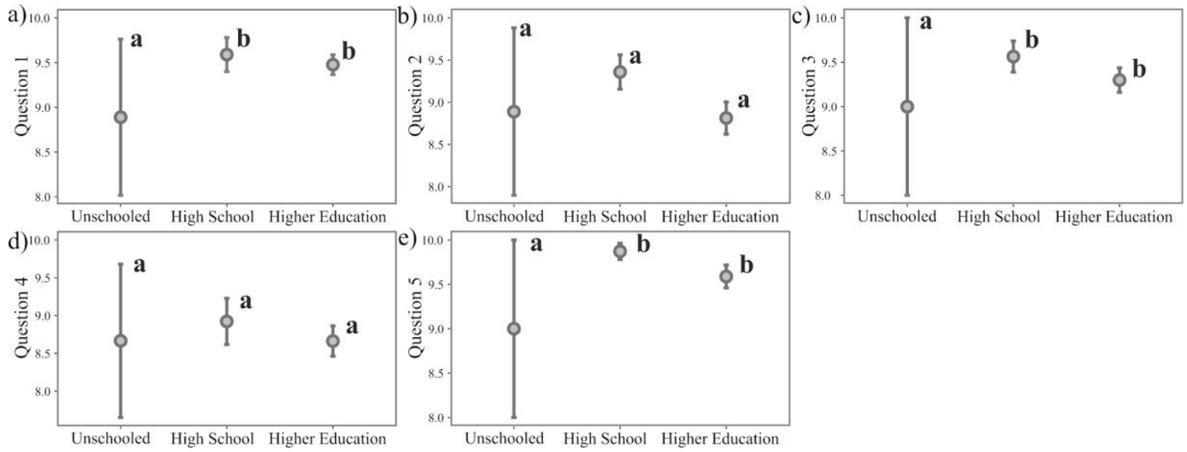


Figure 3. Relationship between education level and different perceptions of Cultural Ecosystem Services. Perception values are on a Likert scale, where participants rated their agreement with specific statements related to various cultural ecosystem services. On this scale, 1 represents 'completely disagree' and 10 indicates 'completely agree'. The graph in question demonstrates (The bars indicate the standard error and the points the mean) the relationship between education level and the following perceptions: a) Question 1: Recreation and physical and mental health; b) Question 2: Tourism; c) Question 3: Aesthetic appreciation and inspiration; d) Question 4: Spiritual experience and sense of place; e) Question 5: Environmental education. Categories with different letters represent significant differences, obtained from the Tukey Post Hoc test (p>0.05).

4. Discussion

Our research findings validate the hypotheses we formulated regarding visitor profiles within the SNF. The results showed that visitors exhibit variation related to their demographic and socioeconomic profiles. The majority of visitors to the SNF fall within the income bracket of 1 to 3 minimum wages, reflecting the socioeconomic reality of the Brazilian population. This finding aligns with the demographic profiles generated by the Brazilian Institute of Geography and Statistics (IBGE, 2022), which reports the average real income from formal employment among individuals aged 14 and over. In terms of gender representation, women dominate the visitor demographics, as they appreciate the landscape more than men due to their emphasis on intangible values, a trait explained through women's ethical inclination towards environmental care (Dietz et al., 2002; Plieninger et al., 2013). Regarding the relationship between age and tourist activity, the SNF primarily attracts a younger audience, aged between 18 and 35. Our research reveals that younger individuals prioritize their health and are more inclined to spend time exploring natural parks (Chen et al., 2022). The limited presence of individuals aged 60 and above in the area can be elucidated through studies by Zambrano et al. (2018), as age plays a crucial role in shaping preferences for recreational sites, and younger tourists prefer certain places and activities. Younger individuals prefer physical and other types of activities, while older age groups prefer heritage and cultural activities (Pinto et al., 2024). Our findings underscore a consistent trend: the farther tourists reside from the destination, the less likely they are to frequent the park, resulting in fewer visits. This phenomenon is attributed to the higher cost associated with traveling to the destination (Wu et al., 2013). Conversely, individuals living near the park tend to visit it more frequently, as the implicit cost of access, such as travel expenses, is lower (Nascimento et al., 2013). This aligns with reality, as most accesses to the recreation area come from the same municipality or adjacent areas where the conservation unit is located, with local attendance predominating.

In our study, we found that predictor variables such as income, age, gender, and distance did not influence the participants' perceptions regarding CES. It's possible that the surveyed group was quite homogeneous, suggesting that these variables didn't vary enough to impact perceptions of ecosystem services (Van Berkel and Verburg, 2014). Additionally, personal perceptions of connection with nature or direct experience with ecosystems may be more relevant factors (Russell et al., 2013). Another contributing factor could be the design and execution of the survey, which may have influenced the results (Wulff et al., 2023). However, this finding is consistent with Aguado et al.'s research (2018), which demonstrated that economic variables alone don't explain CES preferences among rural and urban populations in Ecuador. Similarly, Clucas et al. (2014) found that socioeconomic variables such as income and age were insignificant in models predicting the willingness of residents in Seattle, USA, to pay for the conservation of finches or corvids. Likewise, Lima and Bastos (2019) indicated that gender, age, and property size didn't affect owners' perceptions in areas adjacent to the Silvânia National Forest. Finally, a study conducted in urban green spaces in Korea showed no significant variability in perceptions of cultural services based on gender and origin (Ko and Son, 2018).

In our research, one factor that has shown to have a significant impact on human perception is education. Correlatively, other studies have found that CES are widely recognized by individuals with higher levels of education, especially in urban contexts in Spain (García et al., 2020). Research conducted in Poland has also clearly indicated the crucial role played by education and educational level in the perception of individual forest ecosystem services (Janeczko et al., 2023). Similarly, a study carried out in native areas of the Brazilian savanna has explained that education is a determining factor influencing the perception of Ecosystem Services, even more so than experience derived from land use activities (Lima and Bastos, 2019).

Our results indicate that respondents were more likely to recognize the ecosystem's capacity to provide services when they had a higher level of formal education. Previous studies have highlighted that formal education plays a crucial role in shaping various perceptions about ecosystem services (Sodhi et al., 2010; Campos et al., 2012; Martin et al., 2012; Lima and Bastos, 2019; Dou et al., 2021). It's likely that individuals with higher levels of education have encountered concepts of biodiversity and ecosystem services during their schooling, resulting in a more comprehensive understanding of the importance of these services (Baylan et al., 2023). As awareness of environmental conservation expands, appreciation for services provided by ecosystems is expected to grow (Aziz, 2023). Formal education also fosters cognitive and analytical skills that facilitate a deeper understanding and appreciation of these services (Phan et al., 2021). Consequently, formal education influences how individuals value and prioritize environmental education as an integral component of services provided by ecosystems (Ardoin et al., 2020).

Perception is heavily influenced by entirely subjective factors such as emotions, experiences, memories, sense of place, and identification with nature (Nowak et al., 2020). The high scores across all perceived CES categories in the research suggest that respondents perceive SNF as a multifaceted resource with significant cultural, recreational, and ecological value, enriching the lives of those who interact with it and contributing to overall social well-being, as also evidenced in the work of (Thiemann et al., 2022). Furthermore, the fact that respondents attribute high scores across all categories suggests an acknowledgment of the interconnectedness between the different types of cultural ecosystem services provided by the area. This is supported by research in Brazil, such as in the case of the Parque Estatal Pedra Branca, where scenic beauty, recreation, and social interaction were the cultural benefits most frequently mapped by respondents and were the most correlated (Ribeiro and Ribeiro, 2016). Similarly, in the RESEX Acaú-Goiana, located in the Northeast region of Brazil, aesthetic values, social relationships, religious values, and inspirational values were the CES most identified by users, reaffirming how users depend on and connect with nature in protected areas in various ways (Pinheiro et al., 2021). There is a general preference for landscapes managed traditionally in terms of aesthetic, recreational, and spiritual services (Howley et al., 2012). Overall, the high Likert scale scores assigned to individual CES made it more challenging to discern clear preferences among respondents, a finding also echoed in similar studies (Maestre et al., 2016). The numerous positive and significant correlations between the assigned ecosystem services show considerable overlap between individual services, indicating that people do not clearly separate one category of cultural services from another. This can be understood - and appreciated - as evidence of the interconnected and holistic nature of cultural ecosystem services (Daniel et al., 2012; Bieling and Plieninger, 2013). These results further confirm the existence of "aggregate" cultural services (Raudsepp-Hearne et al., 2010).

In a world of increasing complexity, uncertainty, and precariousness, we urgently need to reexamine and reimagine how knowledge and learning can contribute to the global common good (UNESCO, 2017). Research suggests that different types of knowledge may be necessary to capture the full range of services provided by ecosystems, namely experiential or local knowledge (informal) and technical or experimental knowledge (formal) (Martin et al., 2012). An expected outcome of environmental education programs is a deeper appreciation of the importance of ecosystem services (see Mocior and Kruse, 2016; Hutcheson et al., 2018), demonstrating that education has the strongest overall positive influence on the perceived importance of CES (Riechers et al., 2018).

5. Conclusion

This study serves as a catalyst for reevaluating how we assess and value cultural ecosystem services. By emphasizing the importance of visitor perceptions and incorporating qualitative assessments, we gain a deeper understanding of the complex interactions between people and their natural environment. This not only aids in policy formulation and decision-making but also fosters a heightened appreciation for the intrinsic value of ecosystems among stakeholders. Moving forward, it is essential to integrate the insights gained from formal and non-formal environmental education into broader conservation strategies. This includes recognizing the role of cultural ecosystem services in promoting biodiversity, supporting local livelihoods, and enhancing overall well-being. Such a holistic approach can lead to more effective and sustainable management of natural resources, ensuring their preservation for future generations.

In line with the EU 2020 + Biodiversity strategy, the study may pave the way for future implementation of payments for ecosystem services, particularly in areas with high provision. Furthermore, the findings of this study further support the development of future strategies by the tourism sector in collaboration with the agricultural sector, given that the Silvania National Forest is surrounded by plantations. Building on this idea, the traditional management of landscapes can be linked to new sources of income, such as agritourism, or increasing the production of high-quality products that appeal to tourists. Most importantly, future landscape management should be designed to make landscapes more accessible for multiple forms of experiencing and enjoying different CES.

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Supplementary Material

I. Introduction

Good morning/afternoon. My name is Laura Matos. I am a student at the State University of Goiás (UEG) and I am conducting a study on the use of leisure areas in the Silvânia National Forest. In this research, I will ask you some aspects related to the reason for your visit to the forest. The information you provide is strictly confidential and solely for academic purposes, the results of which will be used to conduct an economic assessment of the area.

Sociodemographic data

a) Gender:

□ Male
□ Female

b) Age group:

□ 18 years
□ 19 to 35 years
□ 36 to 59 years
□ 60 years or older

c) Level of education:

□ No formal education
□ Elementary school
□ Incomplete secondary education
□ Completed secondary education
□ Completed undergraduate degree
□ Incomplete undergraduate degree
□ Incomplete specialization
□ Completed specialization
□ Incomplete master's degree
□ Completed master's degree
□ Incomplete doctoral degree
□ Completed doctoral degree

d) Current activity or occupation: __________________________

e) Per capita income level:

□ Up to 1 minimum wage (R$ 1,212)
□ 1 to 3 minimum wages (R$ 1,213 to R$ 3,636)
□ 3 to 5 minimum wages (R$ 3,637 to R$ 6,060)
□ More than 5 minimum wages (R$ 6,061)

II. Travel cost data (Silvânia National Forest)

The Silvânia National Forest (Flona de Silvânia) is a Biodiversity Conservation Unit, hence it features diverse vegetation and abundant native fauna from the Brazilian Cerrado necessary for environmental balance, allowing visitors to enjoy a natural landscape, pleasant climate, and the benefits of breathing clean air. Additionally, the main attraction for visitors to Flona de Silvânia is its trails, used for hiking and by cyclists.

a) How many times have you visited the Silvânia National Forest for leisure and recreation in the last 12 months?

□ 1
□ 2
□ 3
□ 4
□ 5
□ 6
□ Other: ___________

b) Could you indicate the municipality from where you accessed the Silvânia National Forest?
Municipality: ______________________

c) How did you travel to the Silvânia National Forest?

□ Private vehicle ☐ Motorcycle:
Fuel used? ( ) Alcohol ( ) Gasoline ( ) Diesel
Distance traveled (round trip)? ___________ km
Fuel consumption in km/l ___________
□ Walking
□ Bicycle
□ Bus How much did you spend on round trip fare? _____
□ Carpool with shared costs

d) What was the travel time/distance (round trip) to the Silvânia National Forest?
Departure: ___________; Return: ___________

e) How long do you typically stay in the Silvânia National Forest?

□ Up to half an hour
□ More than half an hour to one hour
□ More than one hour to two hours
□ More than two hours
□ Other: ___________

f) How much money did you spend to reach the Silvânia National Forest? ________

g) Do you plan to visit another location in the Silvânia municipality later in the day?

□ Yes, which one? ___________________
□ No

h) Please consider your overall motivation for visiting Flona de Silvânia and mark an X among the following activities:			
Leisure and physical and mental health		Spiritual experience and sense of place	
Tourism		Environmental education	
Aesthetic appreciation and inspiration		Cultural activities (exhibitions, etc.)	
Research			

i) Please mark with an X the benefits provided by the Silvânia National Forest?

Cultural services	***Cultural services The Silvânia National Forest is important for***	1 = Strongly disagree 10 = Strongly agree				
Recreation and physical and mental health	serving as a leisure area for sports activities, hiking, picnics, etc.	1	2	3	4	5
		6	7	8	9	10
Tourism	its green areas and gardens attract both international and local tourists.	1	2	3	4	5
		6	7	8	9	10
Aesthetic appreciation and inspiration	its nature with its colors, sounds, and scents enriches the human mind.	1	2	3	4	5
		6	7	8	9	10
Spiritual experience and sense of place	its landscape and specific locations create a sense of place and stimulate spiritual experiences.	1	2	3	4	5
		6	7	8	9	10
Environmental education	its natural environment provides a place for educating the population.	1	2	3	4	5
		6	7	8	9	10

j) What tourist activity are you engaging in? ___________________________

Control Data
Time: ____________________ Date: _____ / ______ / ______

CONCLUSÃO GERAL

Os Serviços Ecossistêmicos Culturais (SEC) têm ganhado crescente destaque na pesquisa acadêmica, destacando-se pela diversidade de abordagens para sua valoração e avaliação. No **Capítulo 1**, realizamos uma revisão sistemática da literatura sobre os métodos utilizados na valoração dos SEC, abordando abordagens monetárias, não monetárias, de aprendizado social e integradas. A análise revelou que a área de pesquisa está em constante evolução, refletindo as mudanças nos ecossistemas e nas interações humanas. Os métodos de avaliação, ao combinar diferentes perspectivas, proporcionam uma abordagem mais abrangente e precisa, essenciais para o gerenciamento sustentável dos SEC e para a preservação da rica integração entre cultura e natureza.

No **Capítulo 2**, investigamos a relação entre biodiversidade e turismo em Unidades de Conservação Federais no Brasil. Os resultados demonstraram que a riqueza de espécies, registrada por cientistas cidadãos, tem uma influência significativa no número de visitantes. A pesquisa também destacou o papel crucial da ciência cidadã, oferecendo dados mais próximos da experiência do turista e complementando os registros científicos. A gestão eficaz do turismo, aliada à conservação da biodiversidade, exige estratégias que minimizem os impactos negativos e promovam a educação ambiental, garantindo que o ecoturismo seja sustentável e beneficie tanto as comunidades locais quanto os ecossistemas.

No **Capítulo 3**, avaliamos a capacidade de carga turística da Floresta Nacional de Silvânia, utilizando o método de Cifuentes. Os resultados indicaram que a área tem a capacidade de receber mais visitantes, desde que o monitoramento contínuo da biodiversidade seja mantido para evitar impactos negativos. A análise enfatiza a importância de uma gestão que equilibre o aumento do turismo com a conservação dos recursos naturais, promovendo um desenvolvimento sustentável e alinhado aos objetivos de preservação.

Finalmente, no **Capítulo 4** focou na percepção dos visitantes sobre os SEC na Floresta Nacional de Silvânia, considerando fatores socioeconômicos. A educação foi identificada como a variável mais importante para a percepção dos SEC, destacando o potencial da área como um recurso cultural, recreativo e ecológico. Este capítulo sublinha a importância de incorporar a educação ambiental e o envolvimento dos visitantes no processo de gestão e valorização dos SEC, promovendo maior engajamento e compreensão sobre a importância da biodiversidade e sua relação com o turismo.