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Article

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

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ABSTRACT

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 Silvânia National Forest, situated approximately 7 km from the urban center of Silvânia in the Goias 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; silvânia national forest; 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 turística; capacidade de carga turística; floresta nacional da silvânia; metodologia de cifuentes.

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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). Therefore, carrying capacity studies are commonly associated with environmental impact assessments. These studies consider the perceived saturation of tourists, density and level of use, frequency of encounters with other visitors, tolerance patterns, and expectations of the experience (McCool and Lime, 2001; Cole and Monz, 2004; Simón *et al*., 2004; Monz, 2006; Manning, 2011).

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.

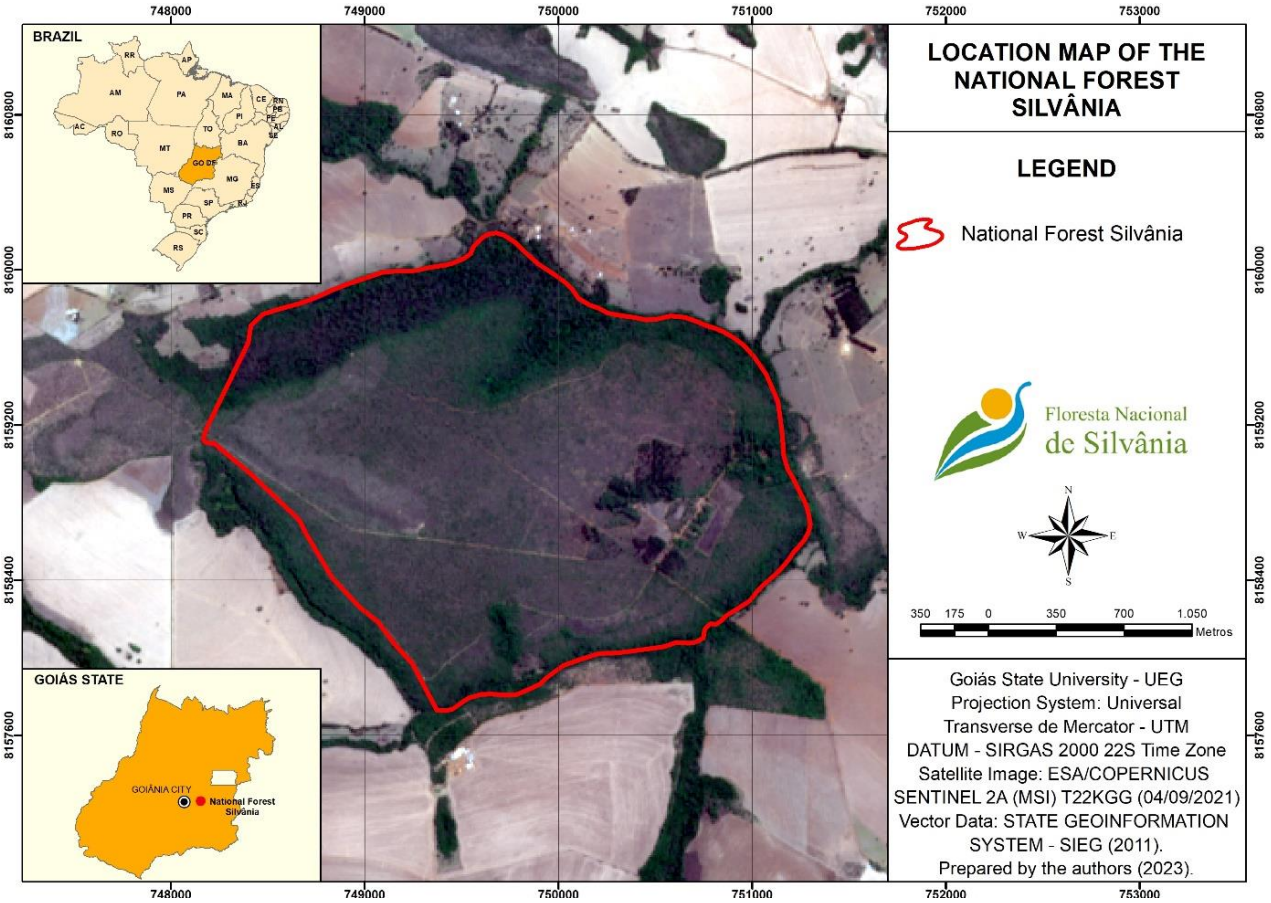

Figure 1: Location map of the National Forest Silvânia, Goiás. Sentinel-2 satellite images provided by Land View (https://eos.com/find-satellite/) were used to define the study area.

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).

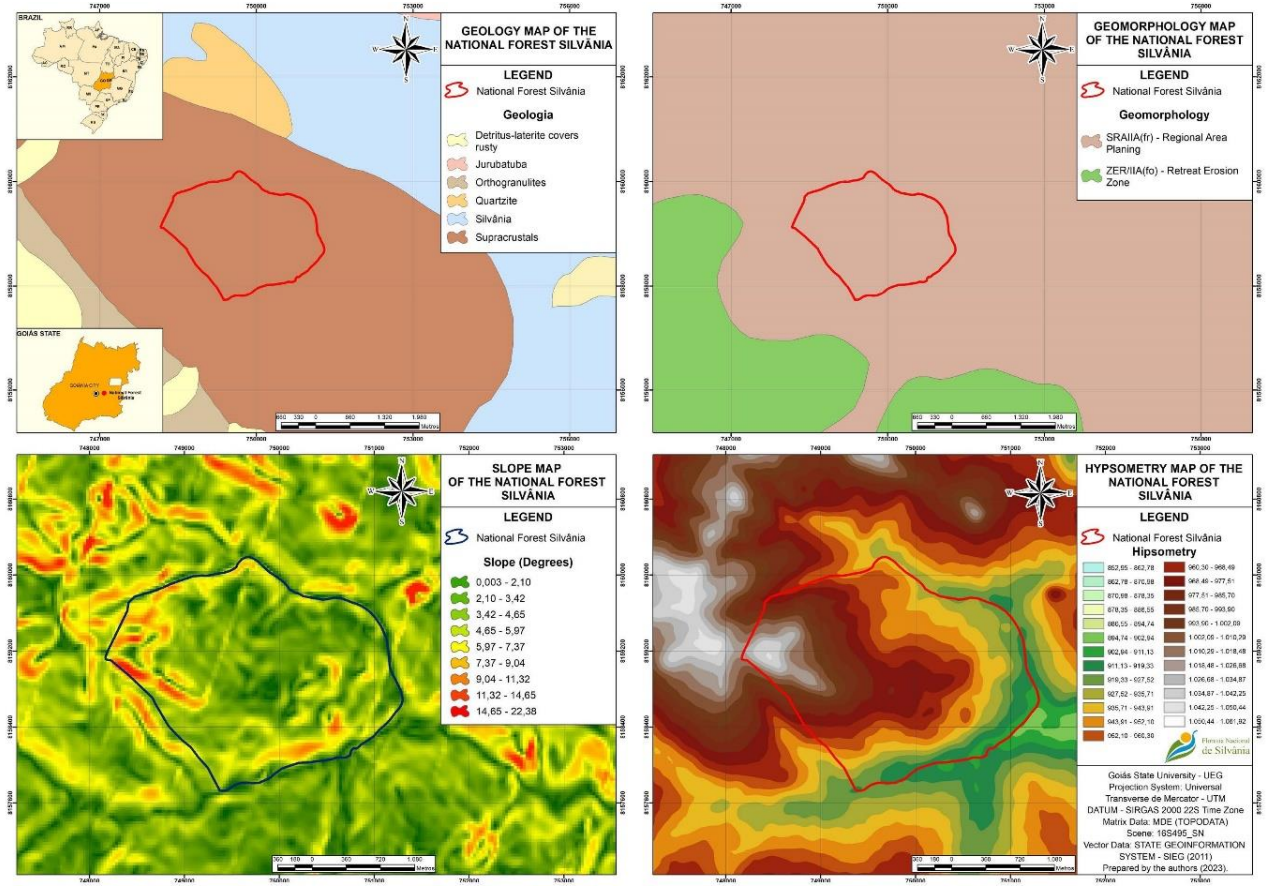

Figure 2: Mosaic view (a) showcasing various physical variables, including geology, geomorphology, slope, and hypsometry, within the National Forest Silvânia, Goiás. The maps were created using data compiled from multiple databases, incorporating information from the following sources: thematic maps 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 - Brazilian Institute 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 activities (ICMBIO, 2015).

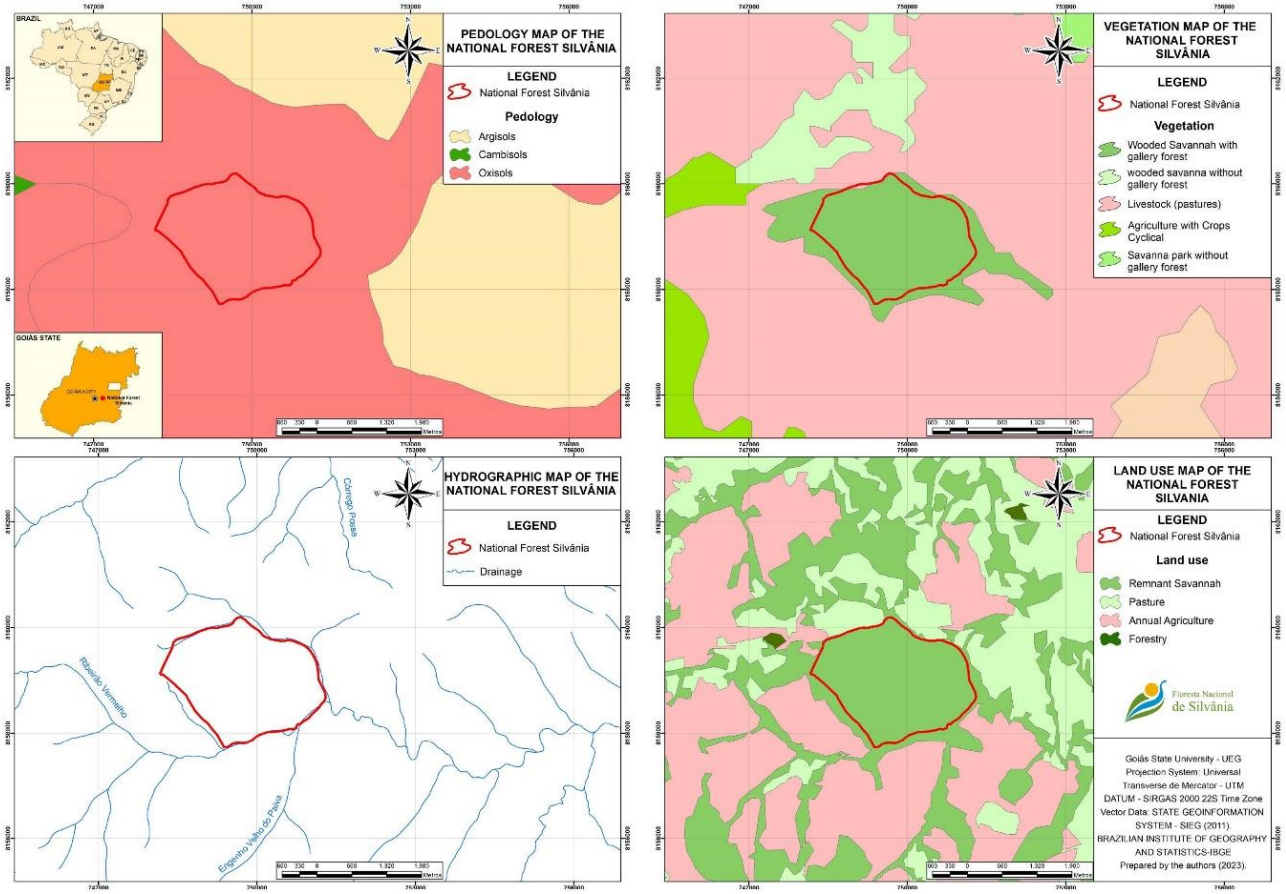

Figure 3: Mosaic view (b) showcasing various physical variables, including pedology, vegetation, drainage, and soil use within the National Forest Silvânia, Goiás. The maps were created using data compiled from multiple databases, incorporating information from the following sources: i) Thematic maps 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.

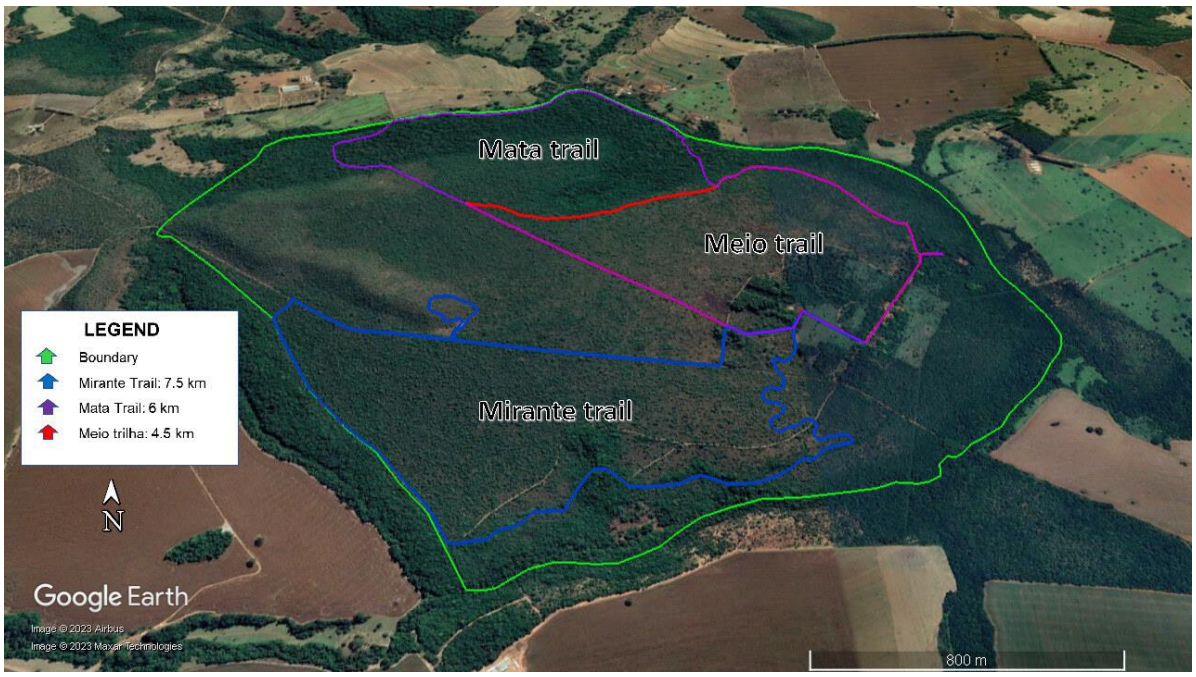

Figure 4. Color-Coded Representation of the Network of National Forest Trails in Silvânia: ICMBio's Trail Marking Standard (ICMBio, 2015). Image obtained by Google Earth (Maio, 2023).

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 ≥ RCC ≥ ECC

The formula for determining physical carring capacity is:

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

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:

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

Where: *M*1 = limiting magnitude of variable
Mt = total magnitude of variable

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

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:

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

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

$$P = NG \times \text{Number of people per group}$$

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.

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

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.

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.

	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

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).

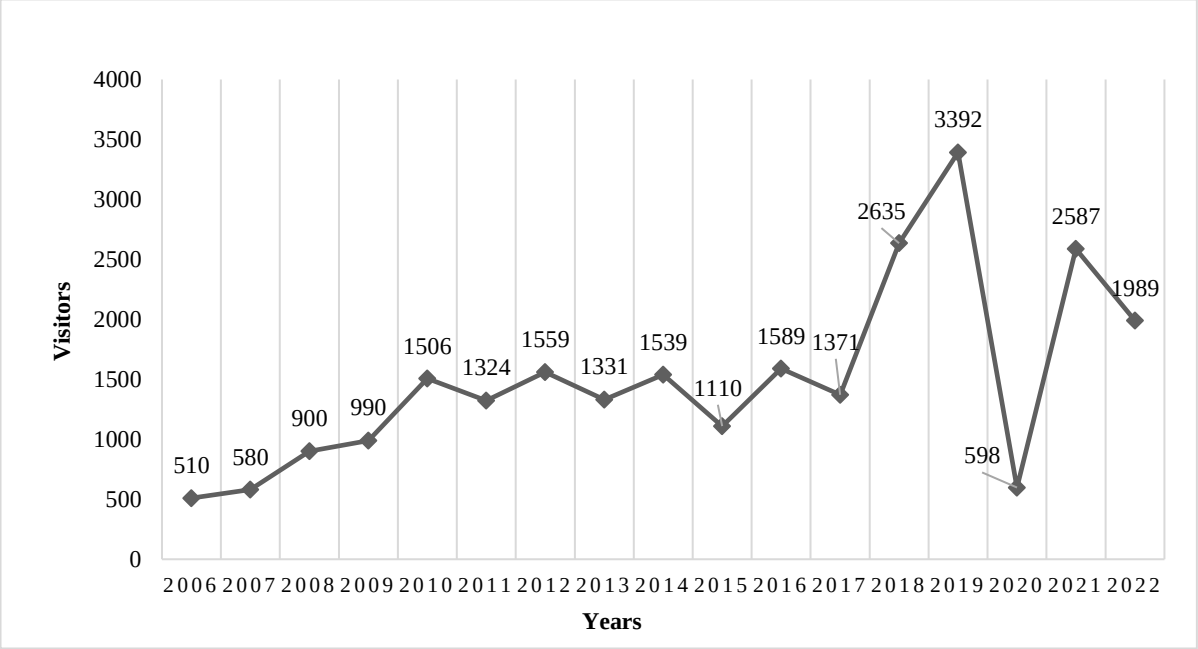

Figure 5 - Tourist Visitations Over Time in National Forest Silvânia.

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 receive more visitors than it has in the past. In 2019, the highest number of visits was recorded at 3392 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 reveals that the trails have not reached their maximum visitation capacity (Table 1). One potential method of increasing visits is through promotion on social media, newspapers, radio, and television. With this information, it can be concluded that the current number of visits is far 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, guarantee 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 devising future conservation strategies.

Conclusions

From this study, it becomes evident that distinct spatial and social constraints should be formulated for each emerging or established tourist destination. The peril 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 contentment. Regarding the National Forest 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 augmentation of its capacity to receive visitors. In order to foster greater sustainability, land managers need to elevate their development

goals while simultaneously reducing thresholds. This change in approach acknowledges that sustainability is attained through development and that sustainability itself becomes the impetus for future advancement. 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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