

## Analysis of the Carrying Capacity of Tourist Attraction Sites in Central Amazonia, Brazil

### *Análisis de la capacidad de carga de los atractivos turísticos en la Amazonía Central, Brasil*

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**Resumen.** Evaluar la capacidad de carga en los atractivos turísticos es fundamental para medir y monitorear el impacto del flujo de usuarios en los atractivos de uso público y privado, especialmente en áreas protegidas. El turismo convencional, sin una planificación adecuada en la región amazónica, puede promover la degradación ambiental en los senderos de los atractivos. En este contexto, el objetivo de este estudio fue determinar la capacidad de carga turística (CCT) de los senderos en los atractivos turísticos de Presidente Figueiredo, Amazonas, considerando el estado de degradación forestal en esos locales. Para determinar la CCT, se utilizó el método de Cifuentes *et al.* (1999), dividido en tres niveles: físico (CCF), real (CCR) y efectivo (CCE). Según los resultados obtenidos, destacamos los atractivos que presentaron una óptima CCE como: “Neblina” (77 personas día<sup>-1</sup>), “Complejo de Iracema Falls” (90 personas día<sup>-1</sup>) y “Cachoeira da Onça” (39 personas día<sup>-1</sup>). Además, hubo una moderada degradación forestal en los senderos de las atracciones “Perema” (40.3%), “Santuario” (26.9%), “Galo da Serra” (26.9%) y “Pedra Furada” (26.1%). Estos resultados pueden ayudar en la planificación turística de Presidente Figueiredo, garantizando de forma sostenible el control y monitoreo permanente de visitas en estos atractivos de la región.

**Palabras clave:** impacto ambiental, monitoreo ambiental, turismo sostenible, degradación forestal, Presidente Figueiredo.

**Abstract.** Assessing the carrying capacity of tourist attractions is essential for measuring and monitoring the impact of users visiting attraction sites, both private and public, especially those in protected areas. Without proper planning, conventional tourism can promote environmental degradation along the trails of attraction sites in the Amazon region. The objective of this study was to determine the tourist carrying capacity (TCC) of trails in tourist attraction sites in the Presidente Figueiredo municipality, state of Amazonas, Brazil, considering the degree of forest degradation in these locations. TCC was determined using the method of Cifuentes *et al.* (1999), which classifies carrying capacity into three levels: physical (PCC), actual (ACC), and effective (ECC). The results identified trails with a highly satisfactory ECC: “Neblina” (77 visitors day<sup>-1</sup>), “C. Iracema Falls” (90 visitors day<sup>-1</sup>), and “Cachoeira da Onça” (39 visitors day<sup>-1</sup>). In addition, there was moderate forest degradation along the trails of the “Perema” (40.3%), “Sanctuary” (26.9%), “Galo da Serra” (26.9%), and “Pedra Furada” (26.1%).

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attraction sites. These results could support tourism planning in Presidente Figueiredo to control and implement regular monitoring to attain sustainable tourism.

**Keywords:** environmental impact, environmental monitoring, sustainable tourism, forest degradation, Presidente Figueiredo.

## INTRODUCTION

In the Amazon, tourism activities should be supported by sustainable tools, such as the carrying capacity, to reduce the impacts of environmental degradation in protected areas. This is especially important in public areas of great ecological and scenic relevance that provide cultural ecosystem services (Bachi *et al.*, 2020). Tourism in protected areas is considered an alternative to generating financial income by applying environmental sustainability policies involving the participation and empowerment of the local inhabitants (Reis *et al.*, 2013, 2018).

A prevalent issue in tourist attractions located in the Central Amazon is the lack of regular monitoring of tourist activities, which can cause degradation and environmental issues, threaten the local economy, and generate changes that affect biodiversity and the environment, reducing the quality of life of the local inhabitants and overloading ecosystems (Cavalcante and Lopes, 2017). For example, in the *Presidente Figueiredo* tourist attraction sites, particularly those located in the “*Caverna do Maroaga*” Environmental Protection Area (EPA), Reis *et al.* (2013) identified environmental impacts in two tourist attraction sites in the region in addition to areas affected by deforestation, mainly along the “*Mutum*” stream, the primary watercourse supplying these attraction sites.

In this way, tourism can be conceived both as an opportunity and a threat to the conservation of forests and biodiversity (Limberger and Pires, 2014) this research both qualitative and quantitative, aimed at assessing and characterizing such studies developed with the participation of Brazilian researchers, through bibliographic method on secondary sources, having been researched in the Annals of the Brazilian Congress on Protected Areas, the annals of the seminars of the National

Association of Postgraduates in Tourism, the Annals of Tourism Research Seminar in MERCOSUR and national periodicals with qualis capes higher or equal than B3. The results pointed to a concentration of production in the south and southeast, the most used method was developed by Cifuentes (1992, the latter being typical of conventional tourism without planning criteria or environmental awareness. Traditional tourism promotes inadequate and ineffective development, generating pressure and deterioration in the attraction sites in the study area (Endres, 1998; Delgado, 2007; Reis, 2010b; Reis *et al.*, 2018). Given this situation, this study is the first to analyze tourist carrying capacity in an important region of tourist attractions in the Amazonas, Brazil, to set the basis and be used as a reference to replicate in other latitudes and locations in the Amazon. The aim is to support tourism planning and management as an alternative for sustainable development in the Amazon region (Comune, 1991).

To note, there are related studies on the tourist carrying capacity that were conducted in various places around the world, particularly in tropical areas. Examples are the works of Cifuentes *et al.* (1990); Rodrigues (1992); Amador *et al.* (1996); Acevedo-Ejzman (1997); Mitraud (1998); Cifuentes *et al.* (1999); Girón and Guevara (2003); Boggiani *et al.* (2008); Lobo *et al.* (2009); Rodríguez-Rodríguez and Zúñiga-Meza (2013); Soria-Díaz and Soria-Solano (2015); Teixeira and Oliveira (2015), besides multiple examples addressing different climatic zones.

Likewise, as an indicator and due to its easy application, carrying capacity allows the measurement and evaluation of natural areas open to the public. This concept includes ecological capacity (impact on physical and biological resources) and social capacity (impact on the visitor's experience). The carrying capacity considers the proposal by Cifuentes *et al.* (1999) as one of the most extensively used methods in tourism research (Limberger y Pires, 2014) this research both qualitative and quantitative, aimed at assessing and characterizing such studies developed with the participation of Brazilian researchers, through bibliographic method on secondary sources, having been re-

searched in the Annals of the Brazilian Congress on Protected Areas, the annals of the seminars of the National Association of Postgraduates in Tourism, the Annals of Tourism Research Seminar in MERCOSUR and national periodicals with qualis capes higher or equal than B3. The results pointed to a concentration of production in the south and southeast, the most used method was developed by Cifuentes (1992, being one of the emerging tools for the evaluation and proper management of ecosystems (Ruschmann, 1993; Delgado, 2007; Han *et al.*, 2018).

In the state of Amazonas, particularly in the *Presidente Figueiredo* municipality, according to the work of Reis *et al.* (2013, 2018) and the government of the State of Amazonas, AmazonasTur, and Seplan (2008), there is a need to promote and carry out carrying capacity research in the region. These studies would allow better control over the flow of visitors to public and private tourist attraction sites, especially those within protected areas, to implement or integrate these mechanisms into management plans of protected areas to improve the quality and management of tourism.

In this sense, the carrying capacity tool in the tourist attraction sites evaluated in the region will promote the development of sustainable tourism as a strategy to encourage ecotourism<sup>1</sup> and forest conservation guided by management criteria and according to environmental sustainability.

## OBJECTIVE

The objective of this work was to analyze the carrying capacity of trails running across tourist attractions in the *Presidente Figueiredo* municipality, Amazonas, considering forest degradation in those areas. This methodology considered three carrying capacity levels (physical, accurate, and effective) and their relationship with forest degradation,

taking and evaluating the data in the field within a humid tropical forest in the state of Amazonas, Brazil.

## MATERIAL AND METHODS

The study area comprises 3424 km<sup>2</sup> and is located 105.5 km from the city of Manaus (capital of Amazonas state), specifically in the *Presidente Figueiredo* municipality, home to a tropical forest that harbors rivers, streams, caves, and waterfalls. The climate is equatorial tropical humid (Af in Köppen's classification), with a mean annual temperature of 27°C and maximum and minimum temperatures of 38°C and 20°C, respectively. Annual precipitation is around 2400 mm. The vegetation is of the ombrophilous type, typical of an equatorial tropical forest that houses dense and exuberant forest species (Gadelha, 2006; Munhoz, 2010; Reis *et al.*, 2018).

### Selection criteria

In this study, fifteen (15) tourist attraction sites were selected based on accessibility and location criteria, with a preference for those with easy access, located on the right and left margins of highways BR-174 and AM-240, *Presidente Figueiredo* municipality, State of Amazonas, Brazil (Figure 1). We selected attraction sites within and outside the “*Caverna do Maroaga*” Environmental Protection Area (APA, for its acronym in Portuguese), particularly those close to deforested areas, using data on forest cover loss up to 2017 from the Project for Satellite Monitoring of Deforestation in the Legal Amazon of the National Institute for Space Research (PRODES/INPE), and, above all, those with access trails to natural attributes (Table 1).

The tourist attraction sites evaluated are located in public and private areas. The type of use of each attraction site by community members and users depends on its geographic location and the natural access conditions (Reis, 2010a). On the other hand, one of the main factors indicating natural areas managed as attraction sites was the high frequency of visits and the type of recreation developed or its potential use for tourism, spa, field research,

<sup>1</sup> Ecotourism (in natural heritage) is a sustainable form of natural resource-based tourism that focuses primarily on experiencing and learning about nature and that is ethically managed to be low-impact, non-consumable, and locally-oriented (control, benefits, and scale) (Fennell, 1999, 2015).

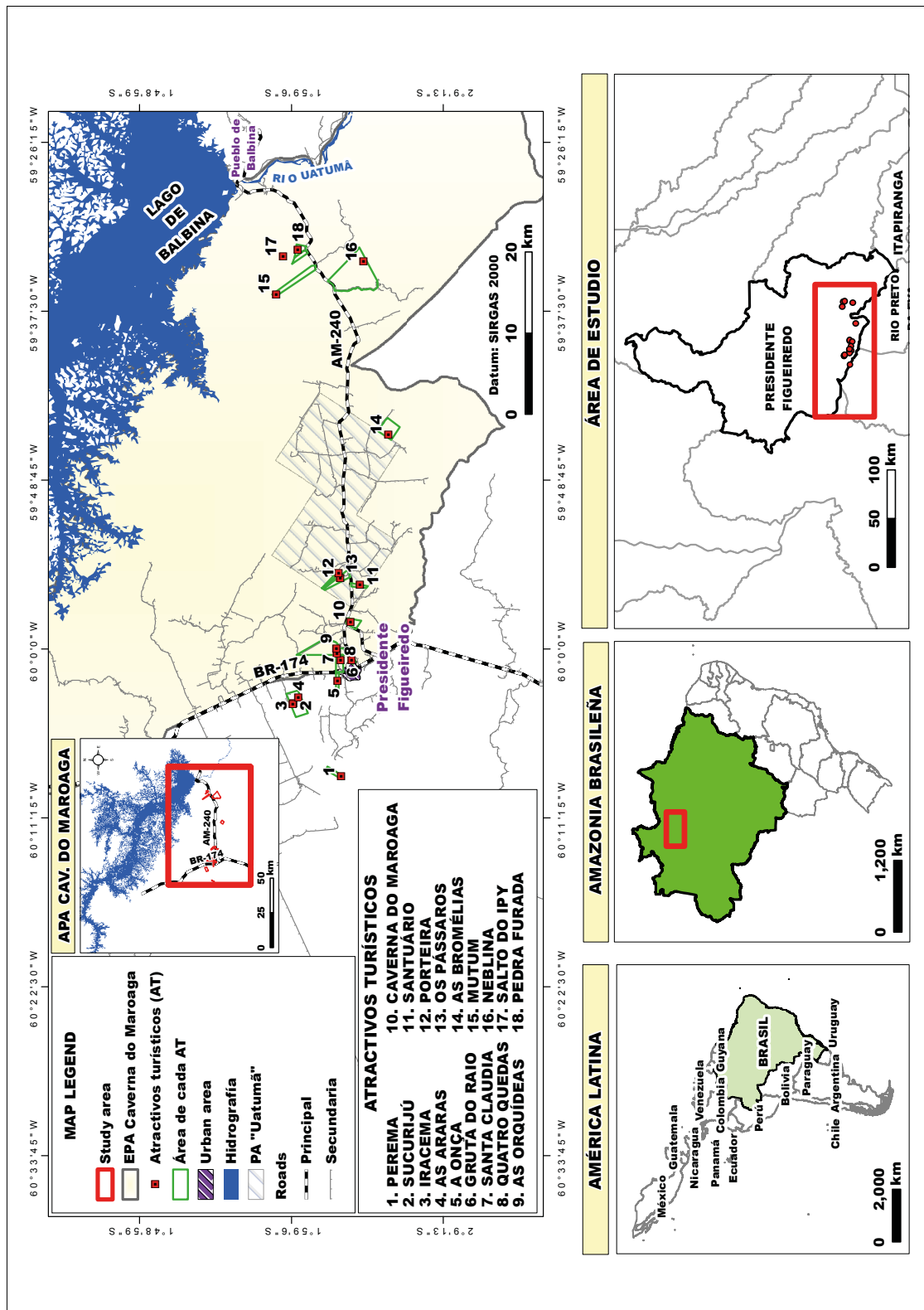


Figure 1. Location of the study area, Presidente Figueiredo, Amazonas state, Brazil. Source: elaborated by the author.

Table 1. Trails of the evaluated tourist attraction sites located in Presidente Figueiredo, Amazonas.

Nº	TRAILS	LENGTH (m)	WIDTH (m)	GEOGRAPHIC COORDINATES			
				DEPARTURE		ARRIVAL	
				LATITUDE	LONGITUDE	LATITUDE	LONGITUDE
1	“Perema”	235.7	1.5	2° 2’21.08”S	60° 8’21.50”O	2° 2’24.51”S	60° 8’27.49”O
2	“Sucurijú-Iracema”	880	2	1°59’3.04”S	60° 3’38.96”O	1°59’6.64”S	60° 3’39.98”O
3	“As Araras”	1146.1	1.2	1°59’31.81”S	60° 3’13.39”O	1°59’15.25”S	60° 3’33.95”O
4	“C. da “Onça”	1101.6	2	2° 2’9.82”S	60° 1’38.41”O	2° 2’10.37”S	60° 2’7.67”O
5	MNP Galo da Serra - “Gruta do Raio”	408.8	1.5	2° 3’1.70”S	60° 0’46.79”O	2° 3’7.88”S	60° 0’45.12”O
6	“Santa “Claudia	318.6	2.5	2° 2’18.19”S	60° 0’55.03”O	2° 2’22.68”S	60° 0’45.70”O
7	MNP das Orquídeas - “Quatro Quedas”	535.5	1.5	2° 2’11.70”S	60° 0’1.91”O	2° 2’7.95”S	60° 0’15.85”O
8	MNP das Orquídeas - “As Orquídeas”	1580.4	1.5	2° 2’50.77”S	60° 0’22.33”O	2° 2’8.08”S	59°59’59.56”O
9	MNP Caverna do Maroaga	2054.00	1.5	2° 2’58.19”S	59°58’27.71”O	2° 2’57.39”S	59°58’27.23”O
10	“Santuário”	556.8	1.5	2° 3’24.94”S	59°55’50.38”O	2° 3’42.50”S	59°55’44.53”O
11	“As Bromélias”	1569.6	1.5	2° 4’50.44”S	59°45’35.09”O	2° 5’34.71”S	59°45’42.16”O
12	“Mutum”	367.8	1.5	1°58’15.42”S	59°36’22.31”O	1°58’6.19”S	59°36’22.37”O
13	“Neblina”	5939.85	2	2° 1’45.56”S	59°35’30.35”O	2° 3’54.53”S	59°34’9.85”O
14	“Salto do Ipy”	377.1	1.2	1°58’40.61”S	59°33’47.50”O	1°58’33.85”S	59°33’49.98”O
15	“Pedra Furada”	241.3	1.5	1°59’35.44”S	59°33’18.09”O	1°59’31.83”S	59°33’21.87”O

MNP = Municipal Natural Park.

Source: elaborated by the author.

hiking, and wildlife observation. Some attraction sites, such as “*Santa Claudia*”, restrict public access because of a private spring fountain.

This study investigated the influence of human pressure on the biophysical environment along the trails of these attraction sites. Unsustainable tourist activities such as conventional tourism may reduce natural resources, including forest loss or degradation in public and private areas (Medeiros and Moraes, 2013). We used the tourist carrying capacity (TCC), a methodology developed by Miguel Cifuentes in 1992 and improved in 1999, considered a simple and user-friendly tool com-

pared to other methods (Limit of Acceptable Change, LAC, among others), to calculate the number of visits per day that a tourism location can support, considering physical, biological, environmental, social, and management variables. This methodology was developed to control and reduce the adverse impacts of conventional tourism, promote sustainable tourism, and provide a high degree of satisfaction to users. In this work, the tourist attraction sites evaluated are restricted to the natural attributes of the study area, according to the routes of trails within or near natural attractions (forests, waterfalls, caves, and others).

## Field Data Collection

Field data were collected in fifteen (15) tourist attraction sites. The data collected were trail length and width using an analog tape measure (winch, 50 m), georeferenced data with GPS navigation (GARMIN model 76CSx), slope with an inclinometer (%), and description of the biophysical characteristics in a field notebook, to calculate the physical and actual carrying capacity of each trail. Surveys consisting of closed questions were also conducted with public officials, private officials, and landowners to determine the current status of the handling capacity of each tourist attraction, which is essential to calculate the effective carrying capacity.

## Tourism Carrying Capacity (TCC)

We used the methodology by Cifuentes (1992, 1999) to determine the flow of visitors to the tourist attraction sites evaluated. This methodology establishes the maximum number of visits per day that a tourist area (natural, cultural, historical) can hold according to its physical, biological, environmental, and handling conditions. TCC includes three categories: Physical Carrying Capacity (PCC), Actual Carrying Capacity (ACC), and Effective Carrying Capacity (ECC).

### Physical Carrying Capacity (PCC)

The maximum number of visits that a given attraction site can support was determined according to the area and time available (visiting hours and duration of visits). The following equation was applied Cifuentes, 1992; Cifuentes *et al.*, 1999):

$$PCC = \frac{S}{sp} * NV \quad (1)$$

Where:

$PCC$  = Physical Carrying Capacity (number of visits day<sup>-1</sup>);  $S$  = overall trail length (m);  $sp$  = distance traveled per person (m);  $NV$  = number of times that a trail can be visited by the same person in one day. This variable is estimated with the following equation:

$$NV = \frac{H_v}{T_v} \quad (2)$$

Where:

$H_v$  = visiting hours (hours day<sup>-1</sup>);  $T_v$  = time needed to visit each trail (hours visit<sup>-1</sup> person<sup>-1</sup>).

### Actual Carrying Capacity (ACC)

ACC was determined with the PCC and correction factors (CF) defined based on the characteristics of each location (physical, environmental, social, and management variables). The following equation was applied (Cifuentes, 1992; Cifuentes *et al.*, 1999):

$$CF_x = 1 - \frac{Ml_x}{Mt_x} \quad (3)$$

Where:

$CF_x$  = correction factor for variable “x”;  $Ml_x$  = limiting magnitude of variable “x”, and  $Mt_x$  = total magnitude of variable “x”.

In this study, variables were used according to the particular characteristics of each trail. The following variables were considered: social, erodibility, accessibility, precipitation, sunlight, waterlogging, vegetation (forest degradation), and biological (wildlife disturbance). Table 2 summarizes the CFs considered (Cifuentes *et al.*, 1999).

After calculating the CFs, the ACC was determined using the following equation (Cifuentes *et al.*, 1999):

$$ACC = PCC * CF_X * CF_Y ... * CF_Z \quad (4)$$

Where:

$ACC$  = actual carrying capacity (number of visits day<sup>-1</sup>);  $PCC$  = physical carrying capacity (number of visits day<sup>-1</sup>);  $CF_{xyz}$  = correction factor (xyz).

### Effective Carrying Capacity (ECC)

ECC was calculated by multiplying ACC by handling capacity (HC) according to the following equation (Cifuentes *et al.*, 1999):

$$ECC = ACC * HC \quad (5)$$

Where:

$ACC$  = actual carrying capacity (number of visits day<sup>-1</sup>);  $HC$  = handling capacity.

Table 2. Correction factors and their respective equations.

N°	CF	Equation	Description
1	Social	$CF_{soc} = 1 - \frac{ml}{S}$	ml = trail limiting magnitude (m); S = overall trail length (m)
2	Erodibility	$CF_{ero} = 1 - \frac{(cpe * 1) + (cpea * 1,5)}{S}$	cpe = trail length with erodibility issues (m) cpea = trail length with high erodibility issues (m); S = overall trail length (m)
3	Accessibility	$CF_{acc} = 1 - \frac{(cdd * 1) + (cdda * 1,5)}{S}$	cdd = trail length with displacement difficulties (m); cdda = trail length with high travel difficulties (m); S = overall trail length (m)
4	Precipitation	$CF_{pre} = 1 - \frac{hl}{ht}$	hl = limiting hours of rainfall per year; ht = hours per year that the trail is open.
5	Sunlight	$CF_{sol} = 1 - (\frac{hsl}{ht} * \frac{cs}{S})$	hsl = limiting hours of sunlight per year; ht = hours per year that the trail is open; cs = trail length without cover (m); S = overall trail length (m)
6	Waterlogging	$CF_{ench} = 1 - \frac{cench}{S}$	cench = trail length with waterlogging issues (m). S = overall trail length (m)
7	Vegetation	$CF_{veg} = 1 - \frac{cva}{S}$	cva = length of trail with affected vegetation (m); S = overall trail length (m)
8	Biological or wildlife disturbance	$CF_{bio} = 1 - \frac{dla}{daa}$	dla = limiting days per year (reproduction, gestation, nesting); daa = days per year that the trail is open to tourists

To calculate HC, infrastructure, equipment, and personnel variables were established, which are directly related to handling the flow of visits. According to Cifuentes *et al.* (1999), these criteria adequately represent all the options to assess and determine HC; they can provide the necessary indicators to obtain a good approximation. They were selected based on their facility of measurement, analysis, and availability of information for each tourist attraction site. Each variable comprises four criteria: quantity, state, location, and functionality. For the “Personnel” variable, only the quantity criterion was considered.

The percent scale (Table 3) used to evaluate the criteria of each variable is an adaptation of the standard of the International Organization for Standardization (ISO 10004), which was tested and used in quality evaluation studies of services offered by public and private companies to measure the degree of user satisfaction (Cifuentes *et al.*, 1999).

The HC was calculated using the following equation (Cifuentes *et al.*, 1999):

$$HC = \left( \frac{Infr + Equip + Pers}{3} \right) * 100 \quad (6)$$

Where:

Infr = Infrastructure; Equip = Equipment; Pers = Personnel.

the number of visitors per trail was determined with the following equation (Cifuentes *et al.*, 1999):

$$VD = \frac{ECC}{NV} \quad (7)$$

Where:

VD = visitors per day to the trail of the tourist attraction site (visitors day<sup>-1</sup>);

ECC = effective carrying capacity (number of visits day<sup>-1</sup>);

NV = number of times that the trail can be tra-

Table 3. Rating scale adapted from ISO 10004.

%	Score	Assessment
≤ 35	0	Unsatisfactory
36 - 50	1	Marginally satisfactory
51 - 75	2	Satisfactory
76 - 89	3	Very satisfactory
≥ 90	4	Highly satisfactory

veled by the same person in a single day (number of visits day<sup>-1</sup> person<sup>-1</sup>).

## RESULTS AND DISCUSSION

### Physical Carrying Capacity (PCC)

Considering the PCC values calculated for the fifteen trails of tourist attraction sites (Figure 2), those with the lowest PCC were “*Santa Claudia*”

(7292.70 visits day<sup>-1</sup>), “*Quatro Quedas*” (7803.3 visits day<sup>-1</sup>), and “*Santuário*” (8113.6 visits day<sup>-1</sup>). By contrast, those with the highest PCC were “*Caverna do Maroaga*” (13150.86 visits day<sup>-1</sup>), “*As Orquídeas*” (12655.86 visits day<sup>-1</sup>), and “*Bromélias*” (12569.37 visits day<sup>-1</sup>).

However, the results obtained herein for the “*Caverna do Maroaga*” trail differ from those reported by Porto *et al.* (2013), who determined a PCC of 11,272.95 visitors per day. In that case, it was confirmed that PCC should be expressed as “number of visits day<sup>-1</sup>” rather than “visitors day<sup>-1</sup>” because the number of visits per day (NV) is related to the visiting hours (hours day<sup>-1</sup>) and the estimated time spent by a person during a visit to the trail (hours visit<sup>-1</sup>). That is to say, it not only determines the maximum number of visits that a given trail can host but also helps prevent the overload of visitors in these ecosystems and formulate a tourism management policy to improve the control of visit flow (Liu *et al.*, 2020).

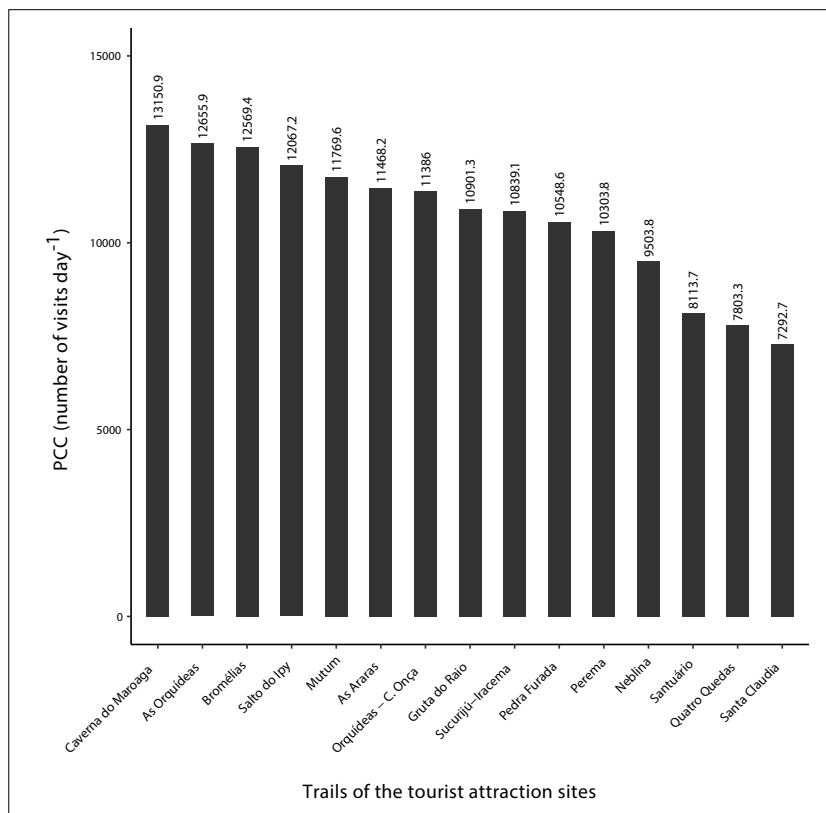


Figure 2. Physical carrying capacity (PCC) of the trails evaluated.



For example, in the “*Santuário*” trail — a private protected area — the estimated PCC was 8113.7 visits day<sup>-1</sup>. In contrast, in the “*Quatro Quedas*” trail — a public protected area — the PCC was 7803.3 visits day<sup>-1</sup>. Although these two attraction sites have different “statuses” (private versus public), they yielded similar results. This similarity derives from the relationship between total trail length and the number of visits per day. Hence, the delimitation and length of each trail, the criteria of space per person, visiting hours, and the estimated time spent by each visitor during the tour in these trails define the maximum visit flow per day that a given trail is able to support. In addition, the PCC values estimated in the present study reflect the spatial and temporal conditions of these sites. Thus, the criteria related to some parameters may be modified over time (depending on the scenario) and, therefore, affect the subsequent PCC results.

### Actual Carrying Capacity (ACC)

Considering the ACC values calculated for the fifteen trails evaluated, those with the lowest ACC were “*Quatro Quedas*” (429.77 visits day<sup>-1</sup>), “*Bromélias*” (467.51 visits day<sup>-1</sup>), and “*Neblina*” (475.42 visits day<sup>-1</sup>) (Figure 3).

The social CF was not considered to estimate ACC for the trails “*Perema*”, “*Pedra Furada*”, “*Santa Claudia*”, “*Mutum*”, “*Salto do Ipy*”, and “*Gruta do Raio*” because these trails have a shorter total length (<450 m) and hold a visit flow of over twenty-five times per visitor in a single day, considering one meter as the space required by one visitor. In other words, applying this factor would further limit the carrying capacity but would not define it as a limit factor for the entire trail but as an alternative for dynamic and efficient tourism management to redistribute tourist flow (Chen *et al.*, 2021). In this context, the ACC of 541 visits day<sup>-1</sup> reported by Porto *et al.* (2013) for the “*Caverna de Maroaga*” trail was similar to the

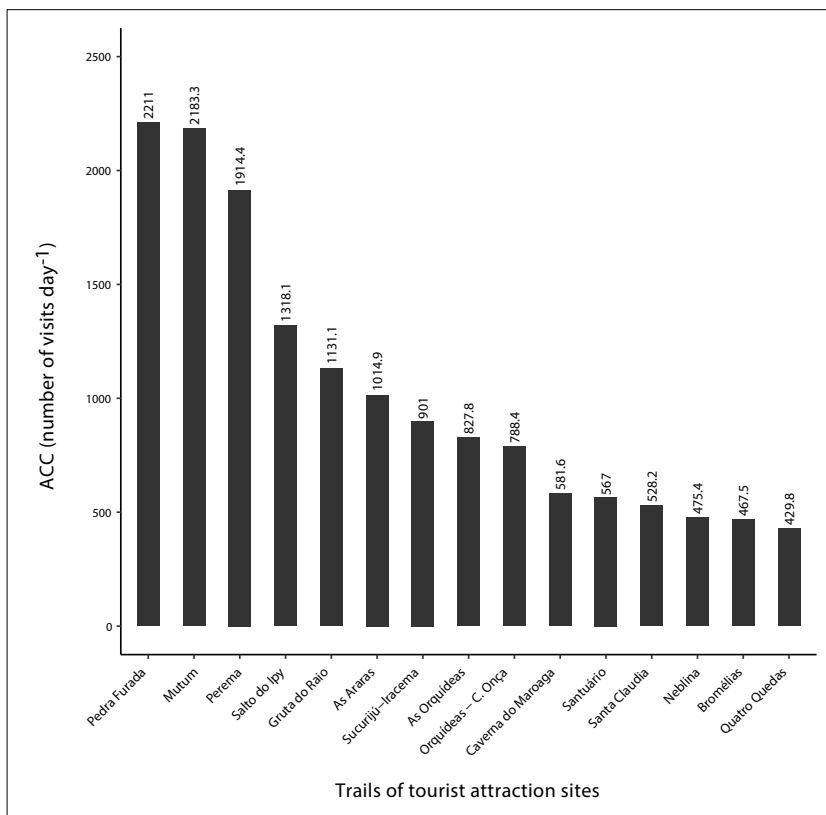


Figure 3. Actual carrying capacity (ACC) of the trails evaluated.

value calculated in the present study (581.58 visits day<sup>-1</sup>). The CFs (Social CF, Wildlife Disturbance, Erodibility, and Accessibility) reduced the ACC values despite being carried out on the same trail; the differences between ACC values are due to the biophysical conditions and evaluation criteria established and measured at the time. These results reflect a multifaceted state because various factors influence the biophysical conditions and their performance according to the particular characteristics of each tourist attraction site.

In this context, despite the similarity with the studies conducted by Porto *et al.* (2013), we consider that the ACC estimated in the present study is insufficient to propose adequate tourism management and establish guidelines to improve the control of visits. The characteristics of the “*Caverna de Maroaga*” trail can experience relatively significant changes in the short- and mid-term due to the lack of information, maintenance, or a more efficient control of the visit flow in this trail. In addition, if correction factors are not properly evaluated, either in their field application or due to a lack of understanding of the methodology, there will be “biases” in the data that may lead to incorrect results, especially when working with secondary data (sunlight, precipitation, and wildlife disturbance). However, it is highlighted that most of the CFs influenced the ACC values due to the physical geography and the particular conditions of each tourist attraction site. The carrying capacity should be established considering the lowest possible impacts aiming not to affect the vulnerability of forest ecosystems that provide ecosystem services (scenic beauty, maintenance of biodiversity, and regulation of natural cycles) (La Notte *et al.*, 2017; Bachi *et al.*, 2020). Close attention should be paid when the maximum limit of visitors is approached or exceeded (tourist overload) because the optimal visit flow levels at a tourist attraction site vary according to the type of tourist, activities, and territory (Chen *et al.*, 2021). The Cifuentes method (1992, 1999) focuses only on quantitative data or figures and highlights that managers of each tourist attraction site are responsible for managing and handling tourism rather than for numbers (Lobo *et al.*, 2013).

### Effective carrying capacity (ECC)

The trails that attained the lower ECC values (Figure 4) were “*Bromelias*” (133.51 visits day<sup>-1</sup>), “*Quatro Quedas*” (183.49 visits day<sup>-1</sup>), “*Neblina*” (245.63 visits day<sup>-1</sup>), and “*Caverna do Maroaga*” (276.86 visits day<sup>-1</sup>). In general, those attraction trails can receive that limited visit flow due to the poor state of the infrastructure, equipment, and personnel, which represents a handling capacity (HC) assessed as “marginally to moderately satisfactory”.

However, they show better conditions of forest conservation, which allows visitors to enjoy ecosystem services (shade, scenic beauty, etc.) during their travel along the trail with a minimum human impact (Figure 4). It is also worth noting that trails with a good HC, such as “*Complexo do Iracema Falls*” and “*Cachoeira da Onça*”, did not attain a high ECC due to the influence of CFs on the estimated values.

In addition, it is expected that the lower the estimated ECC value, the lower the concern regarding the number and management of visitors to the trails, considering the suggested maximum number of visitors per day that the local ecosystem is able to support. Given this scenario, the carrying capacity should be managed comprehensively and closely related to the basic services offered in any category, such as interpretation, accommodation, and food services. As regards the latter, the contractors in charge of providing these services should be monitored to prevent impairing ecotourism management. Human resources should be incorporated to implement strategies that favor the conservation of tourist resources, preventing their deterioration; they should always be present for the recreation of visitors, which contributes to the sustainability of ecotourism as a conservation strategy. All the above informs managers to make short-, mid-, and long-term decisions once the tool provides early warnings that identify environmental, biological, and social imbalances. This strategy will translate into proper considerations to support ecotourism activities that are feasible and consistent with the management plan of each protected area.

The ECC of the trails evaluated is the recommended maximum visit flow per day. The number of visits should be respected as indicated and pro-

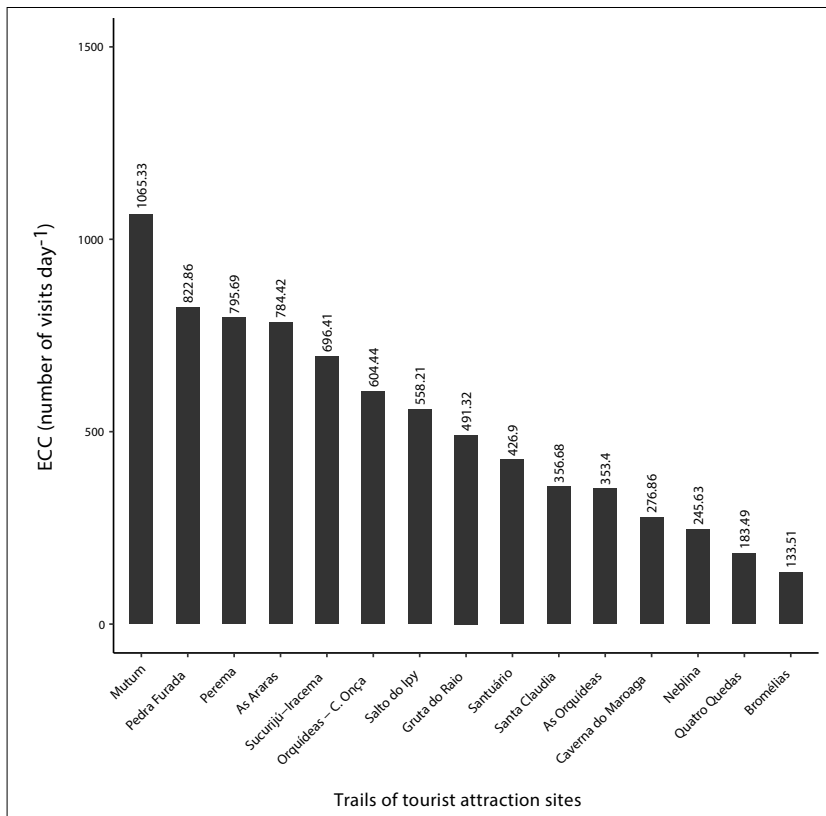


Figura 4. Effective Carrying Capacity (ECC) of the trails evaluated.

posed in this present study to promote sustainable tourism quality in terms of visits and low impact. Accordingly, the deterioration of the biophysical environment that could compromise the conditions (correction factors) and management of these tourist attraction sites is avoided or reduced. In this sense, based on the recommended visit flow, the trails “Complexo do Iracema Falls” (*C. Sucuriú*, *Iracema*, and *de Araras*), “Cachoeira da Onça” and “*C. Neblina*” showed the highest number of visitors per day and year, while the trails “*Quatro Quedas*”, “*Santa Claudia*”, and “*Bromélias*” obtained lower ECC values (Figure 5). It is worth noting that this carrying capacity varies over time; therefore, action strategies and conservation measures should follow this dynamic behavior (López-Dóriga *et al.*, 2019).

### Analysis of Forest Degradation in Tourist Attraction Sites

The state of forest degradation (in terms of forest degradation by the impact of human activities, spe-

cifically on trails) and deforestation in the tourist attraction sites evaluated showed that the vegetation CF is directly related to forest degradation, driven by human activities and pressures (e.g., deforestation, forest clearing/burning, areas undergoing forest regeneration, pollution), causing impacts and changes in the local landscape. Figure 6 shows that the trails with the most significant impact on vegetation were “*Perema*” (40.3%), “*Santuário*” (26.9%), MNP “*Galo da Serra*” (26.9%), and “*Pedra Furada*” (26.1%). In addition, the percentage of areas of attraction sites that suffered the heaviest deforestation as of 2017, according to PRODES/INPE land-cover data, were “*Santuário*” (39.9%), “*Santa Claudia*” (38.6%), “*Mutum*” (33.8%), and “*Salto do Ipy*” (24.3%).

Most of these attraction sites showed a “good” environmental conservation status because their natural attributes (e.g., forest, waterfall, grotto) were in favorable conditions to receive visits from users. However, some of them (except for “*C. da*

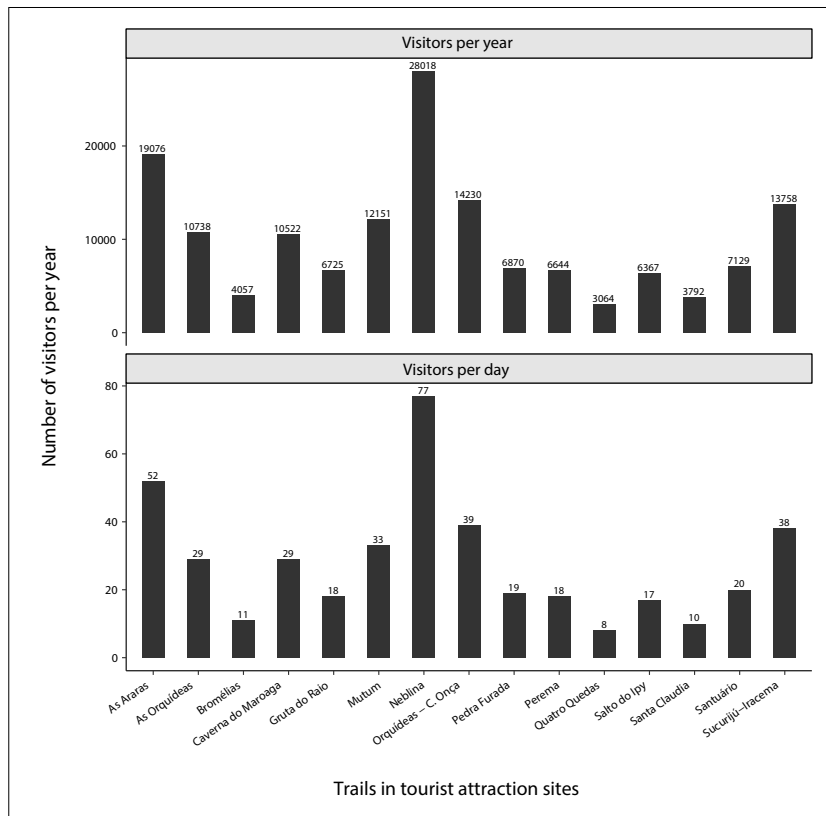


Figure 5. Recommended number of visitors (per year and day) to each trail evaluated.

*Onça*” and “*Complexo do Iracema Falls*”) lack suboptimal tourist infrastructure to provide a high degree of satisfaction to visitors. For example, “*Santuário*”, the attraction site with the best tourist infrastructure (along with “*C. da Onça*” and “*Complexo do Iracema Falls*”), was the site with the most significant loss of forest cover (39.9%) according to land-cover data from PRODES/INPE (2018). In addition, this site has an environmental license for aquaculture activities issued by the Amazon Environmental Protection Institute (IPAAM) regarding fish farming of *Colossoma macropomum* in a semi-intensive farming system in nine nurseries with a total area of 4.24 ha, classified by the IPAAM as a “medium” potential polluter/degrader.

The percent loss of forest cover as of 2017, specifically in tourist attraction sites, is related to the previous deforestation due to the construction and expansion of tourist infrastructure (hotels, restaurants, swimming pools) as tourist attractions, such as “*Santuário*” (39.9%) and “*Santa Claudia*”

(38.6%), which showed high values of forest cover loss. In addition, in the case of “*Mutum*” (33.8%) and “*Salto do Ipy*” (24.3%), the previous and current deforestation are related to slash-and-burn agriculture, pastures, and livestock raising. Reis *et al.* (2013) sendo necessário obter informações sobre o processo de visitação. Com esse intuito, foi analisada a percepção e preferências dos visitantes dois atrativos turísticos naturais da Área de Proteção Ambiental (APA also observed that the “*Porteira*” and “*Sanctuary*” sites already had a significant impact due to deforestation along the *Mutum* River, considered the watercourse that sustains these attractions. Besides, the local managers lack controls or monitoring of visits, management plans, public use plans, route circuits, or on-site signaling, so that the intervention of environmental agencies in the ecological licensing and monitoring of these attraction sites became a critical aspect.

Other studies on deforestation highlight the influence of road infrastructure on deforestation

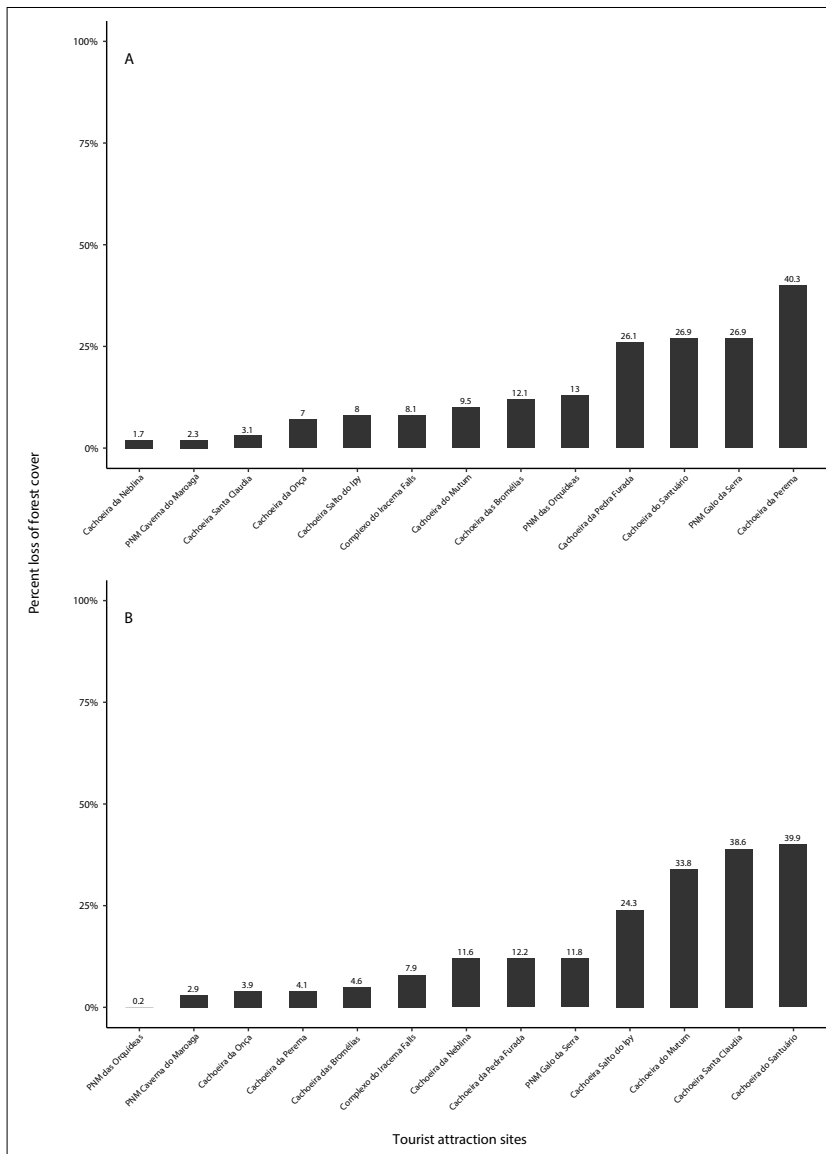


Figure 6. Percent loss of forest cover as of 2017. A) Total trail length; B) area per attraction site.

in the study area. For example, Reis and Pinheiro (2010) reported that deforestation in the “*Caverna do Maroaga*” EPA was concentrated along highways BR-174 and AM-240, rural settlements, and the margins of Permanent Preservation Areas (APP, for its acronym in Portuguese). This observation was confirmed in the present study, which found the same deforestation trend in attraction sites located along highways (BR-174 and AM-240) and in rural settlements, such as “*Santuário*” (39.9%), “*Santa Claudia*” (38.6%), “*Mutum*”

(33.8%), and “*Salto do Ipy*” (24.3%). In addition, these results agree with the study carried out by Massoca (2010) within the framework of the Settlement Project – PA “*Uatumã*” of the National Institute of Colonization and Agrarian Reform – INCRA of Brazil, indicating that the opening and expansion of secondary roads and forest clearing and burning for agriculture are more common in rural settlements. Therefore, it affects the areas of tourist attraction sites near or within the protected area, which is precisely the case of the

“*Bromelias*” attraction site that is under anthropic pressure.

Although the use of tourist carrying capacity based on the methodology developed by Cifuentes (1992, 1999) is adequate for the present study, this approach involves some limitations. In this sense, Delgado (2007) considers it an incomplete methodology abundant in subjective and qualitative aspects related to tourism that yield a “magic” figure on the maximum number of visits, arguing that it cannot be decisive when stating that a certain number of visitors will have no impact on the environment. Although this method essentially provides a quantitative result, it does not necessarily represent a final estimate of the carrying capacity and can also be used as a criterion to estimate the impact of other tourism management strategies (Pires, 2005). In this regard, the correct application of the methodology should be conducted along with impact monitoring, given the need to set indicators of the limit or threshold, whose value determines the acceptability of the measured change. These indicators inform managers about the deterioration of natural values and the satisfaction level of visitors or the local community before these become unacceptable. In addition, depending on the results of monitoring activities, the carrying capacity of a given site may be modified (increased or decreased) according to the range of indicators (understood as the assessment of the impact and performance of tourism management in those places). In this way, monitoring and tourist carrying capacity set the grounds for negotiation and agreement with site managers, prioritizing the conservation of natural resources, environmental education, and the quality of visit care and satisfaction.

Despite these limitations, the Cifuentes methodology (1992, 1999) is most commonly used (62%) in tourism research, followed by the Limit of Acceptable Change, LAC (18%), due to its facility of application relative to other methods (Limberger and Pires, 2014). This method proposes a maximum level of users that a tourist area is able to support with minimum environmental impact and the highest degree of user satisfaction possible, oriented to sustainable environmental conservation (Ruschmann, 1993; Teixeira y Oliveira, 2015;

Perruolo Laneti and Camargo Roa, 2017; Han *et al.*, 2018). Its application is recommended as it is an effective and relevant approach for specific areas, particularly highly vulnerable ecosystems and protected areas, to avoid the deterioration or, in extreme cases, loss of natural attributes (Cupul-Magaña and Rodríguez-Troncoso, 2017). In addition to guiding managers to alleviate tourist overload (He y Xie, 2019; Chen *et al.*, 2021).

In summary, our results on the carrying capacity and forest degradation in the trails of the tourist attraction sites evaluated reflect the need to promote the application of this tool in public and restricted areas. This is particularly important in protected areas that include vulnerable ecosystems to avoid the degradation or loss of their unique characteristics and promote the lowest possible impact from the flow of visits. There is an urgent need to encourage further detailed studies as part of permanent control, monitoring, and management activities, considering other tourist attraction sites not evaluated in the study area.

## CONCLUSIONS

Although deforestation slightly affects forest areas in the tourist attraction sites analyzed, it was observed that most of these areas require attention in terms of conservation, natural attributes, or the presence of vulnerable ecosystems. This is due to the threats of human pressure that boost the reduction of forest cover in public and private areas. Forest degradation and loss compromise the tourist carrying capacity of trails in tourist attraction sites. The results obtained in the present study highlight attraction sites such as “*Neblina*” (77 visitors day<sup>-1</sup>), “*Complexo do Iracema Falls*” (90 persons day<sup>-1</sup>), and “*Cachoeira da Onça*” (39 persons day<sup>-1</sup>), which showed an acceptable maximum number of users per day and were assessed as having a highly satisfactory effective carrying capacity.

Despite the limitations mentioned above, it is essential to have methods for estimating the carrying capacity of tourist attractions since the actors involved can contribute to the continuous follow-up and monitoring of tourist activities in

*Presidente Figueiredo*. Other technical-scientific criteria (sustainability indicators, environmental and social impact assessment methods, among others) should also be considered to support managers in decision making for the efficient management of visit flows to these areas, in addition to setting the basis and reference for further in-depth studies and lines of research related to the management, management, control, and regular monitoring of tourist flows.

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