

# Tourism Carrying Capacity Assessment on Serra Da Calçada Trails

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**Abstract** - “Serra da Calçada” mountain is considered a prominent region attractive for ecotourism and sports practices such as trekking and mountain biking due its cultural landscape, physical and environmental characteristics and qualities of are. Besides its rocky outcrops of quartzite and iron hosts important headwater and endemic vegetation The recovery of degraded trail opened by the use of motorized sports vehicles in the past and the need for rational use for the conservation of local resources justify the study of the tourist carrying capacity of the trails. This paper presents the results found for the trails *Estrada de Resgate e Prevenção de Incêndio*, *Gota* and *Forte de Brumadinho*, chosen among others from the diverse system, and compares them to analogous reference studies. The study recognizes tourist carrying capacity as a valid tool to assist planning and management decisions with appropriate adjustments and periodic reviews.

**Keywords:** Serra da Calçada; Ecotourism; Trails; Tourism Carrying Capacity.

## 1. Introduction

Serra da Calçada is a mountain chain located at the southern sector of the Belo Horizonte, capital of the Minas Gerais State, Brazil, that rises along the border of the municipalities of Brumadinho and Nova Lima. This mountain is part of Serra do Espinhaço, an even more extensive mountain range of approximately 1,100 km. It was granted by UNESCO the title of Biosphere Reserve in the year 2005 [1]. Serra da Calçada, located in the Brumadinho municipality, is surrounded by the Serra do Rola Moça State Park, housing condominiums and the town of Nova Lima (Fig. 1A). It has been protected by the State Institute of Historical and Artistic Heritage of the Minas Gerais State since this site has high biodiversity, water resources and archaeological heritage with important ecological, cultural, historical and touristic values. It hosts a representative preserved *campo rupestre* fragment over both hematite and quartzite outcrops [2] and harbours several headwaters, extending over 10 km and 4000 ha. Brazilian *campo rupestre* vegetation grows on soils over ironstone or quartzite rock outcrops, which are shallow and sandy soils that occur 900–1500 m above sea level, hosting high levels of plant species richness and endemism [3] [4] [5]. Such outstanding plant biodiversity is maintained by a natural pattern of soil fertility evidenced by elevated soil humified organic matter, CEC and nitrogen contents as well as a marked low C:N ratio [6] [7] [8] [9]. However, both the biodiversity and the ecosystem services provided by the high C-and N-based soil fertility have been degraded by mining activities [4] [9], anthropogenic fires [10] and radical sports.

Geologically, the region is recognized as Proterozoic of the Minas Super Group, hosting hematite deposits. This supergroup consists of two types of banded iron formations; the dolomitic and quartz itabirites with a canga surface covering friable and compact haematite; and a phyllite base [11]. The soil is shallow, litholic and originates from the weathering of rocks rich in K<sub>2</sub>O, MgO, CaO e P<sub>2</sub>O<sub>5</sub>, whether due to abiotic factors such as water and wind, or biotic due to the action of lichens that continually provide nutrients to the vegetation through the dissolution of rocks [12]. The canga and quartzite help with soil retention, infiltration and replenishment of the water source. The quartzite rocky outcrop headwaters that form tributaries of the Paraopeba River which contributes to the water supply of the Metropolitan Region.

The Sinclinal Moeda hydrogeological domain is considered the main structure for storing and regulating underground water resources in the *Quadrilátero Ferrífero*. The elongated high parts are characterized as a recharge area. The discharge areas of the Cauê aquifer occur in contact with the phyllites of the Batatal formation (places with more dissected relief) mainly in contact with the Gandarela Formation or in regions of faults and fractures in the Moeda Syncline. The discharge sectors house the main springs registered in the mountains. The region relief is mountainous to steep with a prominent feature, where the ridges are supported by iron formations and quartzites, in sharp and inclined shapes depending on the dip of the layers, often showing the rocky outcrop [13].

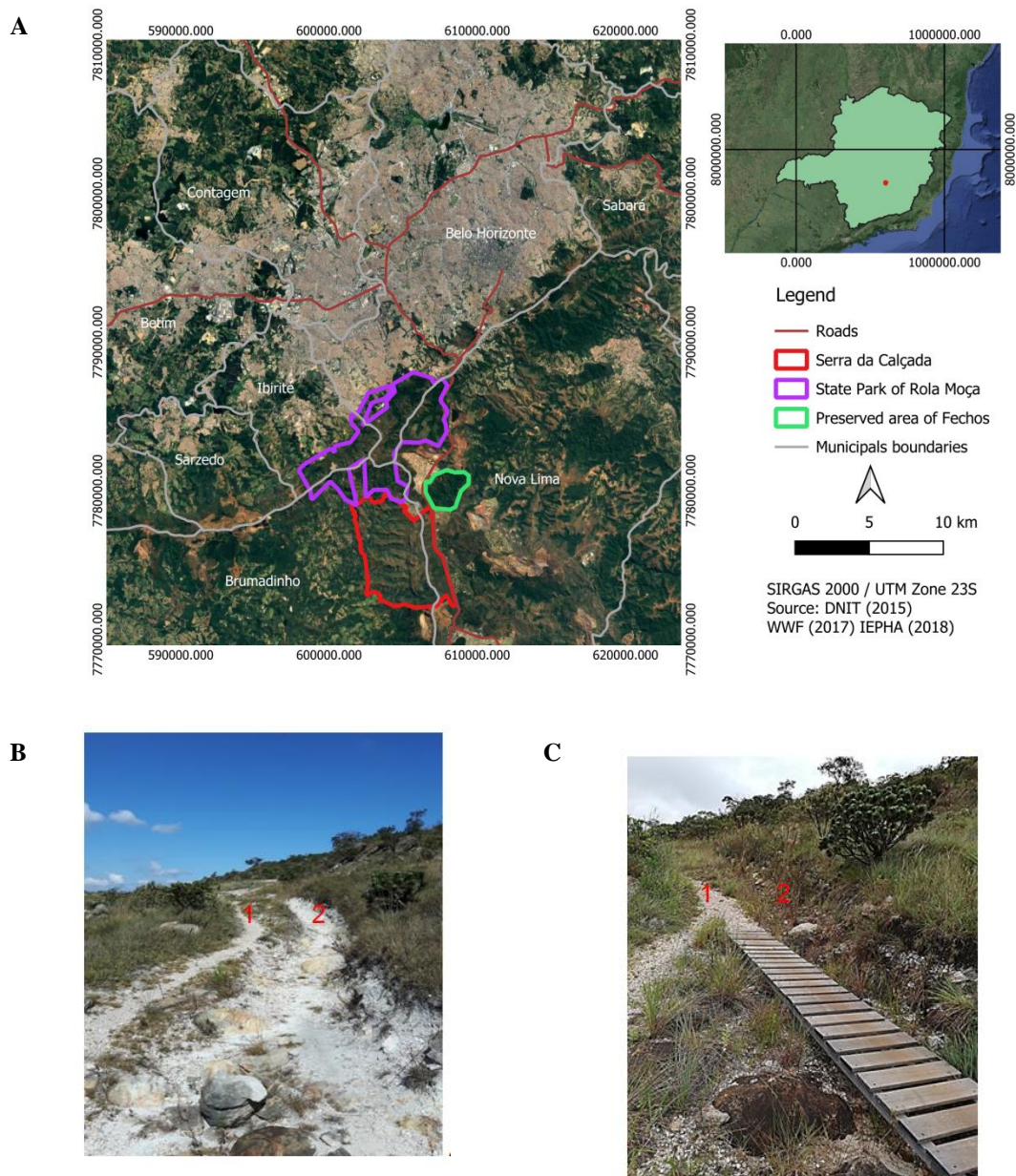


Fig. 1: **A**: Location map of Serra da Calçada Mountain **B**: Trial of *Gota* in Serra da Calçada before and **C**: after rehabilitation.

Tourism can have positive or negative impacts on the natural environment and on some factors that affect the balance [14]. Ecotourism is a segment that uses natural heritage in a sustainable way, with protected areas being attractive due to their contact with natural environments and the scenic beauty of their landscapes. In this point, the use of trails for sports is a reality that is growing in several regions of the world. However, the challenge is maintaining them and recovering eroded areas.

Poorly structured trails with poor drainage and slope generate erosion, loss of vegetation, soil compaction with water pooling, soil and spring degradation [15]. Monitoring them makes it possible to identify ongoing problems with water retention, slippery soils and steep slopes. Such information supports the manager in trail recovery decisions [16]. The natural qualities and cultural landscape of the Serra da Calçada region attract visitors, hikers and mountain bikers, and has established itself as a well-known trail system in Brazil for sports. This proves the potential for ecotourism and adventure sports in the region and, at the same time, indicates the need for rational use for the conservation of local resources. Knowing the carrying capacity is one of the strategies for protecting them by generating a stability reference.

In the last decades, the Serra da Calçada has been used for sports and recreational activities such as trekking and biking as well as motor and jeep crossing. Trails constructed in this grassland ecosystem for moto and jeep crossing have severely impacted this campo rupestre, largely damaging the quartzite outcrops and the native vegetation, the main consequences thereof were accelerated erosive processes as well as the deviation of the water from its original paths and lost of endemic species. Considering the biotic and abiotic impact caused by the nonsustainable use of trails in the campo rupestre, the Minas Gerais State Public Prosecutor's Office (MPMG) has restricted their use for vehicles, motor and jeep crossing and is currently only allowing trekking and mountain biking (Fig. 1B) as well as encouraging the rehabilitation of these sites as well as the protection of these trails. Gota Trail (Fig. 1C) study demonstrates the rehabilitation of severely eroded outcrops in headwaters using native species from local high-altitude fields [17].

Tourism carrying capacity [18] is a practical procedure used to establish clearer guidelines for planning and managing the management and visitation of the site under study. Determining the carrying capacity must be based on the objectives of the protected area, which define the management category and limit uses in each sector. Three levels are considered: Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC) and Effective Carrying Capacity (ECC). PCC is the relationship between available space and the need for space per visitor. It takes into account the total area of the trail and the time needed for visitation. RCC is then determined by applying correction or reduction factors to PCC, which are specific to the characteristics of each site. Finally, the ECC takes into account the adaptable limit of use by considering the management capacity of the area's administration (relationship between Installed Capacity - the number of people, equipment and infrastructure available and Adequate Capacity - the minimum amount of installed capacity needed). Carrying capacity is dynamic and relative, as it depends on human judgments and decisions. Therefore, periodic reviews should be made in this sequential process of planning and adjusting management.

This work aims to estimate the carrying capacity of ecotourism trails for the purposes of preservation and protection of a listed area in the Serra da Calçada.

## 2. Materials and methods

Among the existing trails in the Serra da Calçada region (Fig. 2), three were selected - *Estrada de Resgate e Prevenção de Incêndio* (A), *Gota* (B) and *Forte de Brumadinho* (C) - due to their distinct physical characteristics (Fig. 3).

The *Estrada de Resgate e Prevenção de Incêndio* (A) starts at the access gate near the Retiro das Pedras neighborhood. It runs for 7.3 km in a north-south direction, along the crest of the mountain, almost parallel to the BR-040 highway. The average altitude is 1,470 m and the slope is predominantly less than 10%, being less steep compared to the other trails in the region, as well as being the widest. The estimated cycling time is 24 minutes, with low difficulty of access and route.

The *Gota* trail (Fig. 3B) is located at the geographical coordinates of 605654.21 E; 7776659.90 S. Its total length is 1,028.00 meters and it was considered a one-way trail with variable width. The average altitude is 1,468.00 meters with slopes ranging from 2.0 to 14.8%. It takes approximately 40 minutes to walk the trail and 10 minutes by bicycle. The third trail studied, *Forte de Brumadinho* (C), is 845 meters long. In almost 1/3 of the trail (231 meters), the slopes are greater than 20%, making it the trail with the greatest slope and the most difficult to access. The average altitude is 1,412 meters and the average time spent on the route is 7 minutes by bike or 25 minutes on foot.

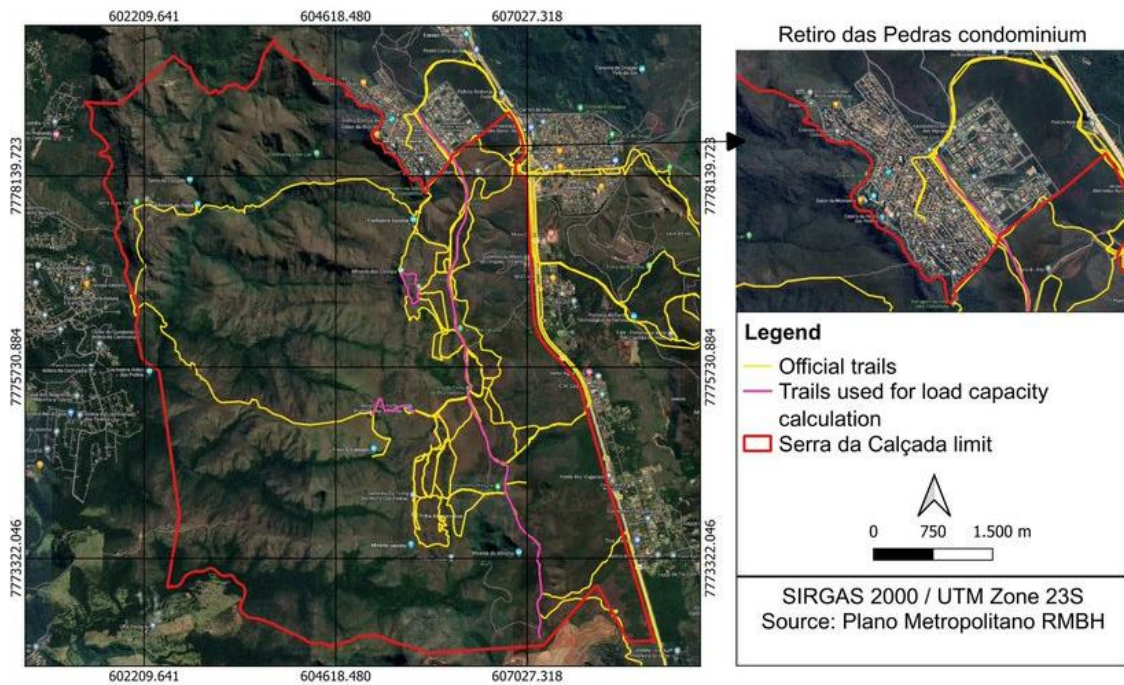


Fig. 2: Official trails of Serra da Calçada and around the study area.



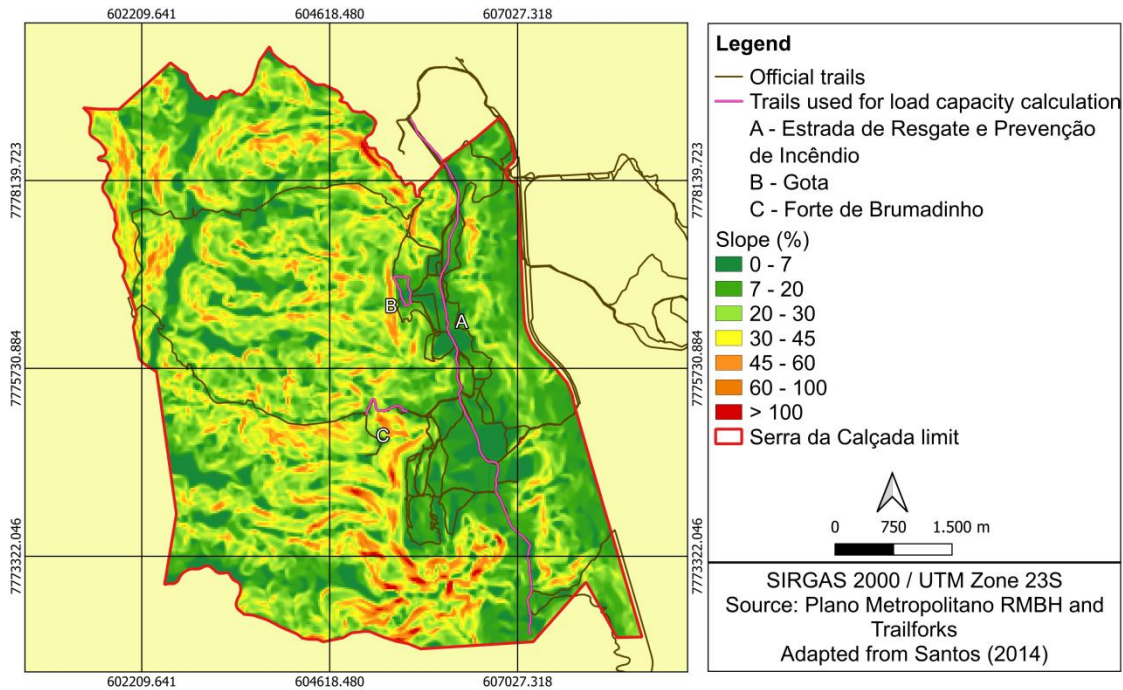


Fig. 3: Map of slopes and location of Serra da Calçada trails.

The trails presented have different characteristics and carrying capacity results that can be indicators for local use. Visitor access to the site generally starts at 5am and ends at 8pm every day, i.e. 15 hours for calculating the carrying capacity of the trails. During fieldwork activities and especially via crowdsourcing data made available on the website, information is collected and the basic criteria for the trails are identified. Each visitor - pedestrian - occupies an area of approximately 2.0m<sup>2</sup>, or 2.0 linear meters of trail. To avoid interfering with visitation, groups of 5 people were considered and the minimum distance between groups was 100m per visit.

The trails are open 15 hours a day and each visit to the *Estrada de Resgate e Prevenção de Incêndio* trail lasts 90 minutes, each visit to the *Gota* trail 40 minutes and the visit to the *Forte de Brumadinho* trail approximately 25 minutes (Table 1).

Table 1: Parameters used to calculate the load capacity of the trails *Estrada de Resgate e Prevenção de Incêndio*, *Gota* and *Forte de Brumadinho*

Parametes	Estrada de resgate e prevenção de incêndio	Trilha Gota	Forte de Brumadinho (In Deep)
Trail opening time (hours per day)	15	15	15
Occupied area by each visitor (m <sup>2</sup> )	2m <sup>2</sup>	2m <sup>2</sup>	2m <sup>2</sup>
Time spent by the group - bicycle and on foot (minutes)	25 min. 90 min.	11 min. 40 min.	7 min. 25 min.
Trail length (meters)	7,300.00	1,000.00	845.00

Number of visitor groups	66	9	7
Length of trail required by each group of 5 people (meters)	660.00	90.00	70.00
Number of visits per person in groups of 5 with 100 meters spacing between groups	11	22	36

Source: elaborated by the author

It can be assumed that each person could make 11, 22 and 36 visits per day respectively. Once the trails have been selected and the necessary information has been collected, the Physical, Real and Effective load capacities are calculated, respectively.

The carrying capacity is calculated for each trail or site. As it is a generic method, adaptations can be made according to the resources, time, circumstances and information available and it acts as an indicator of the tolerance or resilience of the trails. To determine the Physical Load Capacity, the formula is applied:

$$PCC = \frac{V}{a} \cdot S \cdot t \quad (1)$$

Where: V = 1 visitor; a = occupied area by each visitor (m<sup>2</sup> per visitor); S = total area visited or, in this case, of the trail (m<sup>2</sup>); t - number of visits per day per visitor.

*Estrada de Resgate e Prevenção de Incêndio*: PCC = (1 visitor/2m<sup>2</sup>) . (660 m<sup>2</sup>) . (11 visits/day/visitor) = 3,630 visits/day

*Gota Trail*: PCC = (1 visitor/2m<sup>2</sup>) . (90 m<sup>2</sup>) . (22 visits/day/visitor) = 990 visits/day

*Forte de Brumadinho Trail*: PCC = (1 visitor/2m<sup>2</sup>) . (70 m<sup>2</sup>) . (36 visits/day/visitor) = 1,260 visits/day

Based on the PCC, the maximum number of visits to the site can be established by calculating the Actual Carrying Capacity - RCC. Correction factors - CF - are applied according to the particular characteristics of the trail, obtained by considering physical, ecological, social, environmental and management variables.

$$RCC = PCC \cdot \left(100 - \frac{CF1}{100}\right) \cdot \left(100 - \frac{CF2}{100}\right) \cdot \left(100 - \frac{CFn}{100}\right) \quad (2)$$

$$FC = \left(\frac{LM}{TM}\right) \cdot 100 \quad (3)$$

Where: CF = Correction factor; LM = limit magnitude of the variable; TM = total magnitude of the variable.

### 3. Results and Discussion

The Effective Carrying Capacity - ECC - takes into account the limit of acceptable use considering the management capacity of the area's administration (

Table 2).

Table 2: Carrying Capacity of trails *Estrada de resgate e prevenção de incêndio*, *Gota* and *Forte de Brumadinho*.

Fatores de correção e Capacidade de Carga	Estrada de resgate e prevenção de incêndio	Trilha Gota	Forte de Brumadinho (In Deep)
PCC - Physical carrying capacity (visits/day)	3,630.00	990.00	1,260.00

CFs - Limiting solar insolation correction factor	35.00%	35.00%	35.00%
CFp - Precipitation correction factor	12.50%	12.50%	12.50%
CFe - Erodibility correction factor	5.40%	47.66%	85.00%
CFa - Accessibility correction factor	2.74%	21.40%	28.81%
CFt - Correction factor track closure maintenance	7.69%	7.69%	7.69%
RCC - Real Carrying Capacity (visits/day)	1,753.00	213.00	71.00
MC - Management capacity	70.00%	70.00%	70.00%
ECC - Effective Carrying Capacity (visits/day)	1,227.00	149.00	50.00

Source: elaborated by the author

In three similar cases, Cifuentes' methodology [18] was applied to study the load capacity and discuss the correction factors applied and the results found. The first is the Davi trail [19] located on private property in Mucajaí, in the state of Roraima. The second applies the methodology to five trails in the Serra do Cipó National Park [20] in Minas Gerais, while the last [21] presents a case study of the "Mare a Mare" mountain trail in Corsica.

Compared to the results presented for the Davi trail in Mucajaí, on private property and with little infrastructure, the specific carrying capacity in the study area was higher at 133.00 visits per day, 32% more. Analyses of the five quartzite trails in the Serra do Cipó National Park [20] determine areas at risk of degradation, characterize potential and restrictions on use. They also showed similar carrying capacity results to those found on the Serra da Calçada trails, ranging from 145.83 to 156.28 people per day. Therefore, the estimated carrying capacities for the area are consistent.

However, other factors may be associated with the impacts on the trails. According to Barthod-Prothade and Leroux [21], in the case study of the "Mare a Mare" mountain trail in Corsica, a French Mediterranean island, the high number of visitors, approximately 800 people in a short period of time, is not the biggest impact, but the presence of animals on the trails can compromise the sustainability of tourism activity there. Therefore, the training of managers and decision-makers should be based on the concepts of territorial resilience and planning with a systemic approach for the development of sustainable tourism.

In the case of Serra da Calçada, forest fires are one of the main risks to local heritage and tourism. Another factor to consider is the lower number of visitors during the week compared to weekends, reducing the impact. Therefore, these aspects should be analyzed in conjunction with the carrying capacity of the trails. The relationship with the surrounding community and local visitors during the recovery and use of the spaces, as well as other initiatives to benefit the protection of Serra da Calçada are fundamental to the success of the interventions over time, the maintenance of the trails and the whole complex.

#### 4. Conclusion

The Serra da Calçada region is a historical heritage site and is used for sports such as trekking and mountain biking. Maintenance of the trails is necessary for their preservation and for ecotourism in the region. Knowledge of tourist carrying capacity is a useful tool for monitoring and managing the area.

Carrying capacity is relative, dynamic and subject to human decisions. Therefore, it is not expected to be the solution to all of the area's visitation problems. It is more of a tool to aid planning and management decisions, subject to periodic reviews and adjustments. The Effective Carrying Capacities - ECC - for the *Estrada de Rescure e Prevenção de Incêndio*, *Gota* and *Forte de Brumadinho* trails were calculated in isolation. However, the trails in the region are interconnected, creating a large system of trails that extends beyond the limits of the Serra da Calçada protected area, along the entire Serra da Moeda and in the directions of Itabirito, Nova Lima, Brumadinho and Serra do Rola Moça. The carrying capacity of these trails is compatible with tourist use.

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