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Ecotourism carrying capacity of the

Cotopaxi National Park, Central Ecuador

Capacidad de carga ecoturística del Parque Nacional Cotopaxi, Ecuador Central

Capacidade de carga de ecoturismo do Parque Nacional Cotopaxi, Equador Central

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Abstract

The present research is based on the calculation of the ecotourism carrying capacity of the trails and tourist sites of the Cotopaxi National Park (PNC), according to an established methodology, for which a variety of thematic maps were considered. These were used to calculate the real carrying capacity, which together with the management capacity of the park, its effective carrying capacity was calculated. The limiting magnitudes of the correction factors were obtained through in situ measurements, using the "Total Station M3" topographic equipment, which determined the lengths of the trails with corresponding problems, in addition to the use of Geographic Information Systems (GIS). The results obtained from the Effective Carrying Capacity (ECC) of the main trails of the PNC, reflect that the trails Limpiopungo lagoon and Parking lot –José Rivas shelter, with CCE values of 1086 people/day and 635 people/day respectively, are only exceeded during Ecuadorian national holidays.
KEYWORDS: effective carrying capacity; Geographic Information Systems; ecotourism; Cifuentes methodology; Cotopaxi National Park.

Resumen

La presente investigación se basa en el cálculo de la capacidad de carga ecoturística de los senderos y sitios turísticos del Parque Nacional Cotopaxi (PNC), según una metodología establecida, para lo cual se consideró una variedad de mapas temáticos. Estos sirvieron para calcular la capacidad de carga real, que junto con la capacidad de manejo del parque, se calculó su capacidad de carga efectiva. Las magnitudes límite de los factores de corrección se obtuvieron a través de mediciones in situ, utilizando el equipo topográfico “Estación Total M3”, que determinó las longitudes de los senderos con problemas correspondientes, además del uso de Sistemas de Información Geográfico (SIG). Los resultados obtenidos de la Capacidad de Carga Efectiva (ECC) de los senderos principales de la PNC, reflejan que los senderos Laguna Limpiopungo y Estacionamiento –Refugio José Rivas, con valores de CCE de 1086 personas/día y 635 personas/día respectivamente, son solo excedida durante las fiestas patrias ecuatorianas.
PALABRAS CLAVE: capacidad de carga efectiva; sistemas de información geográfica; ecoturismo; metodología Cifuentes; Parque Nacional Cotopaxi.

Resumo

Esta pesquisa baseia-se no cálculo da capacidade de carga do ecoturismo das trilhas e locais turísticos do Parque Nacional Cotopaxi (PNC), de acordo com uma metodologia estabelecida, para a qual foram considerados diversos mapas temáticos. Eles foram usados para calcular a capacidade de carga real, que, juntamente com a capacidade de gerenciamento do parque, foi usada para calcular sua capacidade de carga efetiva. As magnitudes limitantes dos fatores de correção foram obtidas por meio de medições in situ, utilizando o equipamento topográfico ‘Estação Total M3’, que determinou os comprimentos das trilhas com os problemas correspondentes, além do uso de Sistemas de Informações Geográficas (GIS). Os resultados obtidos a partir da Capacidade de Carga Efetiva (CCE) das principais trilhas do PNC refletem que as trilhas Laguna Limpiopungo e Estacionamento-Refugio José Rivas, com valores de CCE de 1.086 pessoas/dia e 635 pessoas/dia, respectivamente, só são ultrapassadas durante os feriados nacionais equatorianos.
PALAVRAS-CHAVE: capacidade de carga efetiva; sistemas de informações geográficas; ecoturismo; metodologia Cifuentes; Parque Nacional Cotopaxi.

1. Introduction

The tourist carrying capacity of natural areas has been the subject of several investigations since the last century, while the first studies being those that only considered the biophysical component of the area (Dias *et al.*, 2012; Canestrelli & Costa, 1991; O'Reilly, 1986; Watson & Kopachevsky, 1996; Saveriades, 2000; Mexa & Coccossis, 2017). Starting in the 1960s, to calculate the tourist carrying capacity of a place, the social component is also considered (Lickorish, 1958; Wagar, 1964; Lickorish & Kershaw, 1956). In addition, within the investigations of tourist carrying capacity, the socioeconomic and cultural component is beginning to be taken into account, as well as the quality of the visitor's experience (Lindberg *et al.*, 1997; McCool & Lime, 2001; Zhang *et al.*, 2017). In this sense, the tourist carrying capacity was calculated of the public use areas of the Guayabo National Monument, Costa Rica, considering the natural and anthropic characteristics of the place, and applying some correction or reduction factors, as well as taking into account the management capacity of the natural area, in order to obtain the maximum number of tourists that can visit the site, without generating significant environmental impacts or with the least possible impact, thus guaranteeing sustainable management of the area (Váscones, 2013; Cifuentes, *et al.,* 1999; Gutiérrez *et al.*, 2021). Similarly, the calculation was performed of the tourist carrying capacity of Tamandaré Beach, Brazil, in order to include said site in the planning of sustainable tourist destinations (Dias, et al., 2012). Hereby, the calculation of the management capacity of the area is included, based on the installed capacity and the adequate capacity of the place (Coccossis, 2022; Butler, 2020).

It should also be noted that the carrying capacity must refer to ecotourism, that is, to the activity that combines passion for travel with concern for the environment. The experts who have dealt with the subject suggest sustainability, conservation and the participation of the local community as objectives of ecotourism (ArmijosRobles *et al.*, 2022; Ross & Wall, 1999; Cobbinah *et al.*, 2015). In addition, they attribute the ability to achieve the objectives of sustainable development in regions with ecotourism potential (Menjura & Vásquez, 2020; Stone & Wall, 2004; Kiss, 2004). Also, other authors suggest that ecotourism has been defined as an important component within sustainable tourism (Wall, 1997; Cater, 1993; Pforr, 2001). Ecotourism seeks the development of tourism focusing on natural areas that are responsible for caring for the environment and seeking adequate well-being of the communities (Cañon & Galvis, 2020).

Based on the aforementioned, for the development of this research, we considered a well-established methodology, which determines the maximum number of visits that an area can receive, for which the physical, biotic, social and management characteristics of a natural area. It consists of three calculation phases, being the Physical Load Capacity (CCF), the Real Load Capacity (CCR), and the Effective Load Capacity (CCE). To calculate each of these phases, it has been required to have previously calculated various parameters, such as the Management Capacity of the area (CM). As a study area we chose the Cotopaxi National Park (PNC), within the Andean Ecuador, which is one of the main attractions of domestic and foreign tourists.

2. Study area

The Cotopaxi National Park (PNC) was created in 1975 and was declared a National Park within the National System of Protected Areas in 1979 (FIGURE 1). The PNC has an area of 33,393 ha, its main tourist attraction being the active Cotopaxi Volcano with a height of 5,897 meters above sea level (Jacome *et al.*, 2013; Mora *et al.*, 2022; Aguilera and Toulkeridis, 2005). The main objective of the park is the conservation of the natural resources present in this area, especially the Cotopaxi volcano, which is its main tourist attraction, especially due to its devastating past with farreaching hazards and its recent signs of activity (Rodriguez *et al.*, 2017; Toulkeridis *et al.*, 2015; Echegaray-Aveiga *et al.*, 2020; Vaca *et al.*, 2016; Toulkeridis & Zach, 2017; Padilla Almeida *et al.*, 2022). It is necessary to mention that it was the first National Park within continental Ecuador and the second National Park

of Ecuador (Ministry of Tourism, 2009). Currently, in the country there are 60 protected natural areas, of which 11 are considered national parks, among them the Cotopaxi National Park, which is the most important in continental Ecuador (Ecotec University, 2021).

FIGURE 1. Location of the Cotopaxi National Park within central Ecuador

It should be noted that a protected area is a geographically defined surface and established by a law or legal norm, in order to meet certain conservation objectives (Aguirre, 2014). Likewise, it can be pointed out that protected natural areas are clearly determined geographical spaces, recognized and managed through legal regulations, in order to achieve the long-term conservation of nature, its ecosystem services and its associated cultural values (Dudley, 2008). Protected areas are areas of land and/or seas specially dedicated to the protection and maintenance of biological diversity, as well as natural resources and associated cultural resources, and managed through legal means or other effective means (IUCN, 1998). In Ecuador, protected areas represent approximately 20% of the national territory. These areas fall within the highest category of protection in accordance with national environmental legislation (MAATE, 2023).

According to the Constitution of the Republic of Ecuador of 2008, the protected natural areas make up the National System of Protected Areas (SNAP), which was subdivided into four subsystems, one of the most important of which is the 'Heritage of State Natural Areas' (PANE), which contains national parks such as the PNC. The Cotopaxi National Park has various tourist trails, among which may be highlighted as the Limpiopungo Lagoon trail, Parking -José Rivas Shelter trail, the Rumiñahui volcano trail and the Springs trail (FIGURE 2).

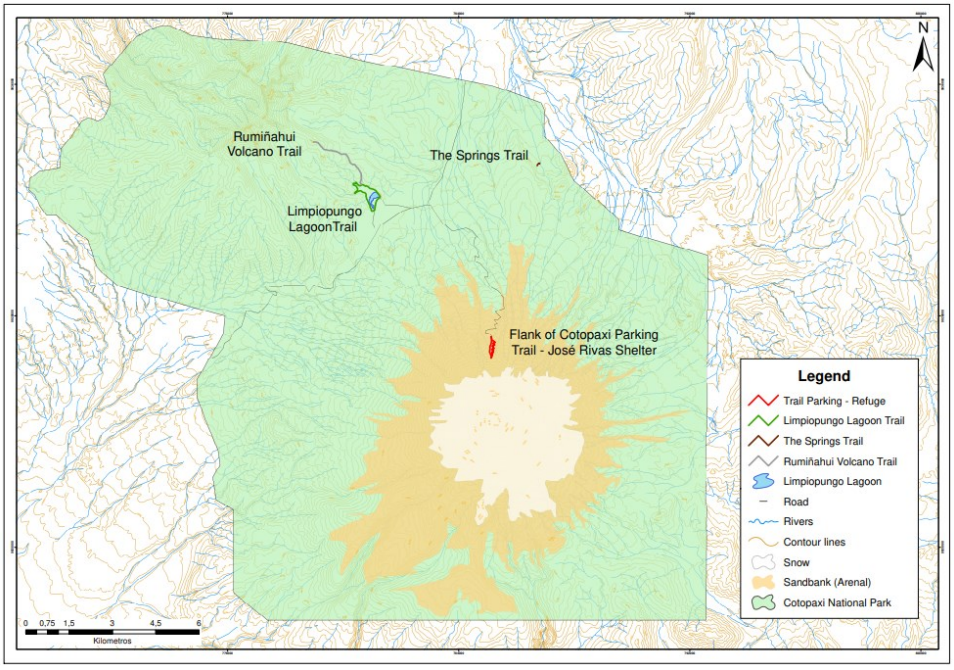

FIGURE 2. Map of the PNC and the ecotourism trails

3. Methodology

To calculate the ecotourism carrying capacity of the PNC trails and tourist sites, the used methodology was illustrated in FIGURE 3.

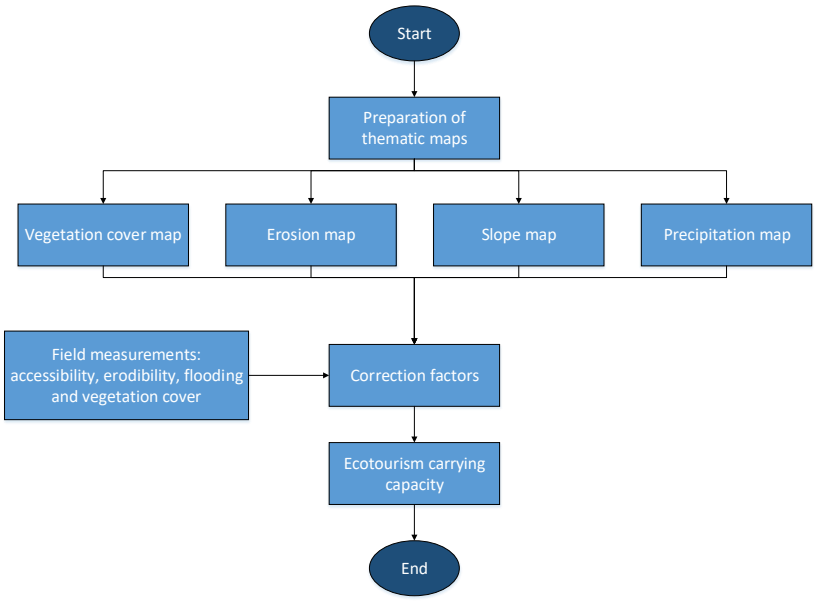

FIGURE 3. Research methodology applied in the current study

3.1 Preparation of thematic maps

In order to obtain the correction factors, necessary to calculate the actual carrying capacity of the different trails and tourist sites in the park, we proceeded to obtain a variety of maps including the erosion (FIGURE 4A), vegetation cover (FIGURE 4B), isohyets (FIGURE 4C) and slopes (FIGURE 4D), which will provide the information required for each of the correction factors. For this, we first proceeded to obtain the general base map with a scale of 1:50,000, where the main trails of the park are located.

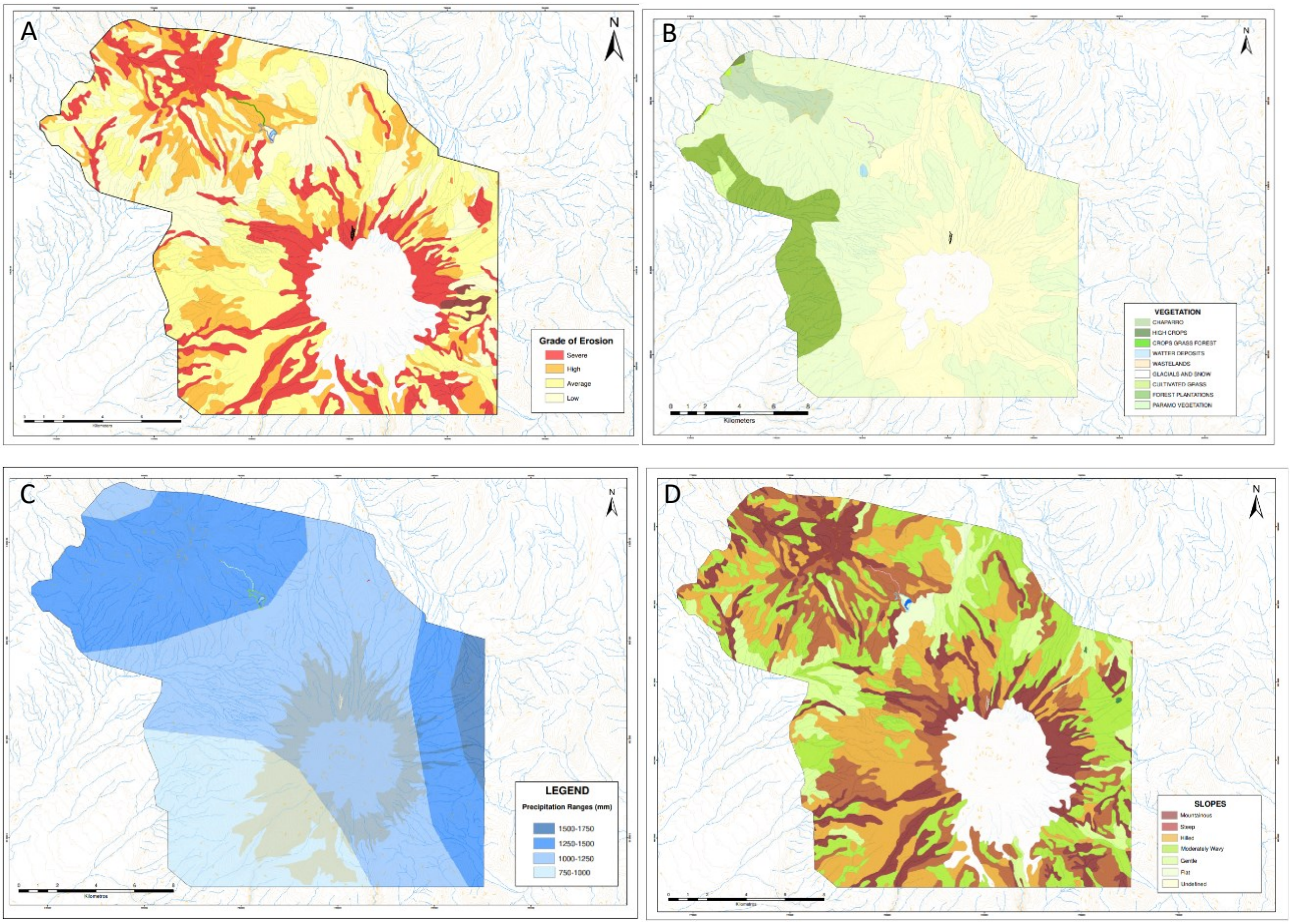

FIGURE 4. Thematic maps of the PNC. A: Erosion; B: Vegetation cover; C: Isohyets; D: Slopes.

Next, the 1:5000 scale maps were digitized for each of the four National Park trails, obtaining the following maps, which will later be used to calculate the ecotourism carrying capacity (FIGURE 5)

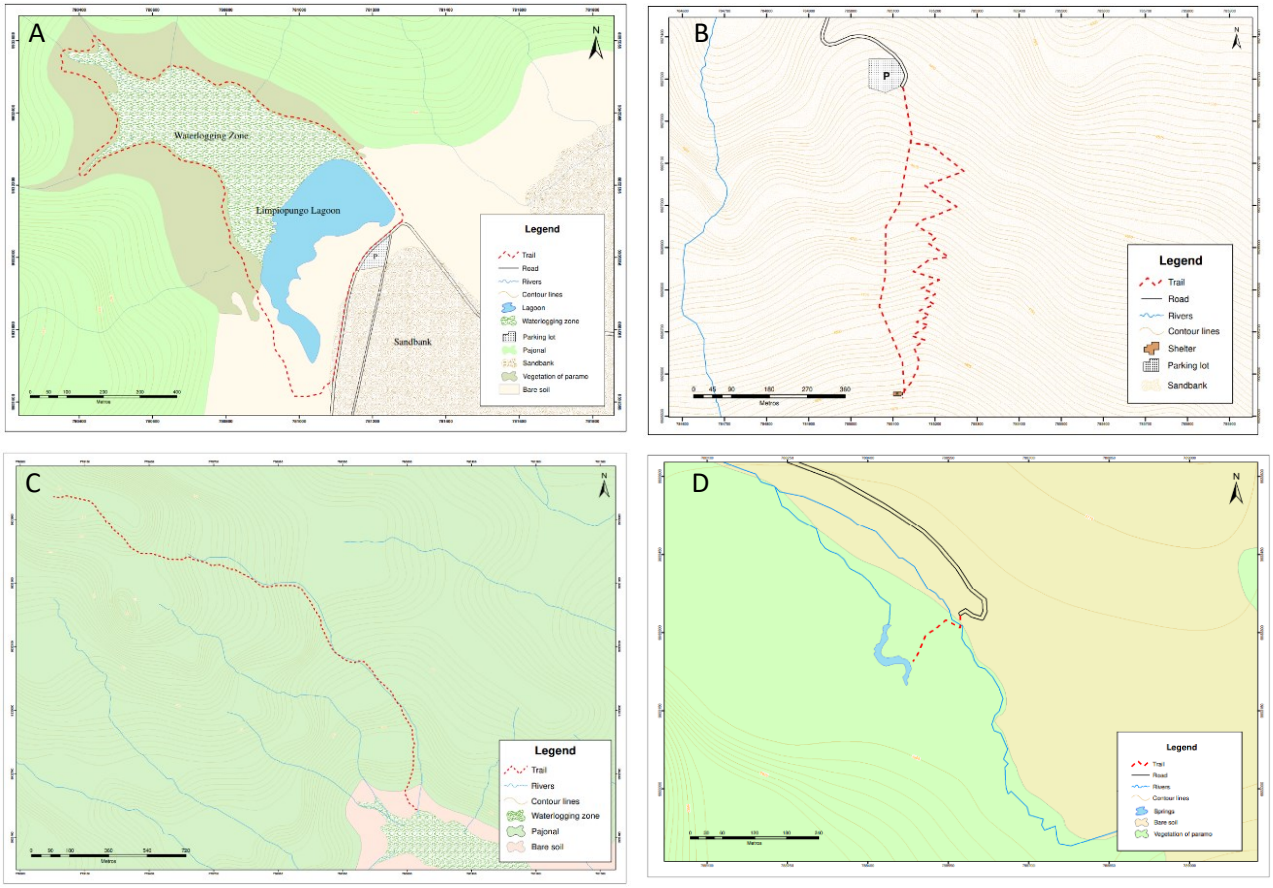

FIGURE 5. Map of the PNC ecotourism trails. A: Limpiopungo Lagoon trail; B: Parking lot – Shelter trail; C: Rumiñahui Volcano trail; D: The Springs trail

Following, the length of the trails was calculated using ArcGIS, the results of which are presented as well as the location within the PNC (FIGURE 6).

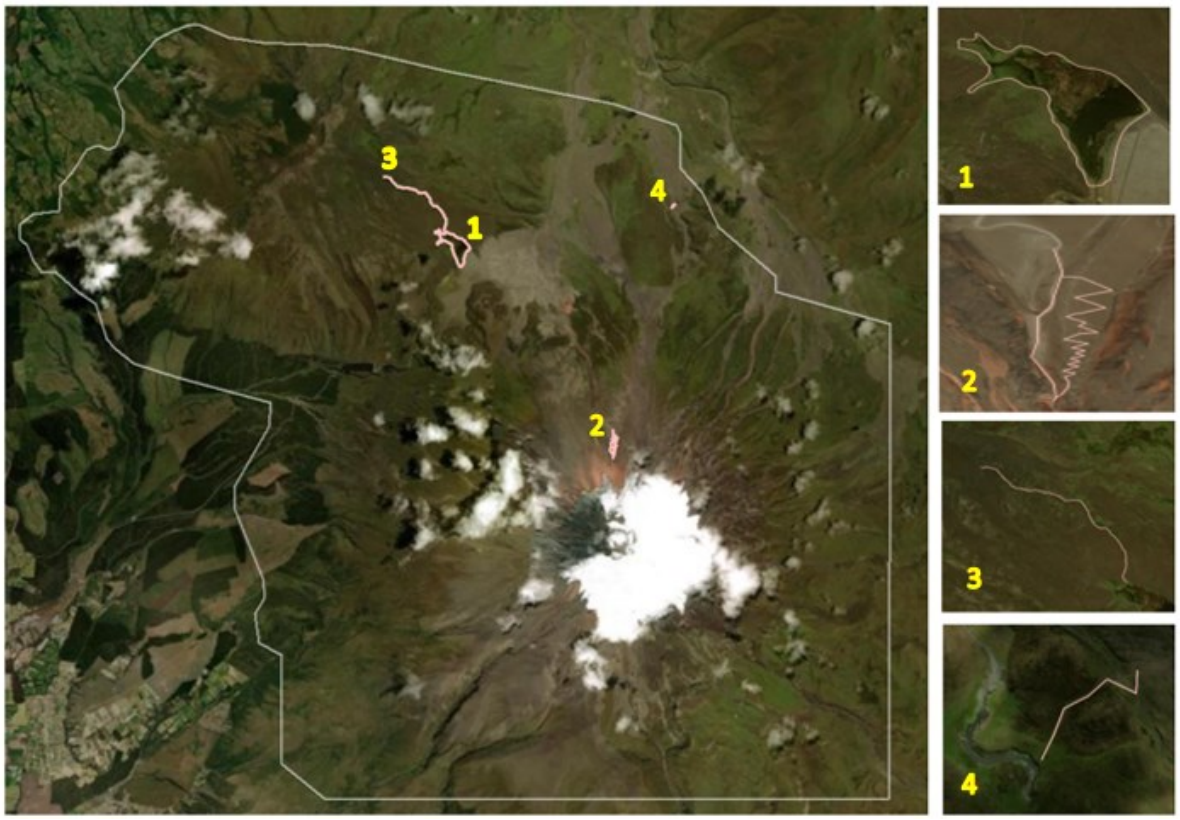

FIGURE 6. Location and lengths of trails. 1: Limpiopungo lagoon (2905 m); 2: Parking lot on the slope of the Cotopaxi volcano -José Rivas Shelter (2140 m); 3: Rumiñahui volcano (4606 m); 4: The Springs (158 m)

3.2 Calculation of the ecotourism carrying capacity of the trails

We performed a variety of calculations based on the methodology of Cifuentes *et al.* (1999) and Gutiérrez *et al.* (2021), which included separate calculations of the Physical Load Capacity, the Real Cargo Capacity the Effective Load Capacity, the Correction Factors and finally the Management Capacity.

3.2.1 Physical Load Capacity (CCF)

The Physical Load Capacity corresponds to the maximum limit of visits that can be made to the area or tourist site during the day. This is obtained through the relationship between the visit factors (visit hours and time), the space available in the area or trail, and the need for space that each visitor needs.

3.2.2 Real Cargo Capacity (CCR)

The Real Cargo Capacity corresponds to the maximum limit of visits, which is obtained from the CCF, of a tourist site, for which it is necessary to apply correction factors, the same ones that depend on the characteristics of the area of interest.

3.2.3 Effective Load Capacity (CCE)

The Effective Load Capacity corresponds to the maximum limit of visits that are obtained from the CCR capacity, for which it is necessary to consider the management capacity of the study area.

3.2.4 Correction Factors

The correction factors are those that allow reducing the physical carrying capacity, according to the physical, biotic and social characteristics of the

area of interest. These factors can be soil erosion, accessibility, precipitation, waterlogging, and vegetation cover. Once all the correction factors have been calculated, the real load capacity (CCR) is expressed through the following formula:

$$CCR = CCF * FC_1 * FC_2 * FC_n \quad (1)$$

Where:

CCR: Real Load Capacity

CCF: Physical Load Capacity

FC_1: Variable 1 correction factor

FC_2: Correction factor of variable 2

FC_n: Correction factor of variable n

3.2.5 PNC Management Capacity

The management capacity (CM) of a protected area is measured by three main indicators, being personnel, infrastructure and equipment. In this way, the MC is a function of the three indicated indicators, and can be calculated using the following formula:

$$CM(\%) = \frac{Personnel\ (\%) + Infrastructure\ (\%) + Equipment\ (\%)}{3} \quad (2)$$

In order to calculate the ecotourism carrying capacity of the trails, we followed the mentioned methodology by using the given thematic maps (erosion, vegetation cover, isohyets, slopes and ecotourism trails), in addition to field measurements, as performed to obtain the correction factors, such as accessibility, erodibility, flooding, precipitation and vegetation cover, thus resulting to the physical, real and effective carrying capacity.

3.3 Ecotourism Carrying Capacity

3.3.1 Ecotourism carrying capacity of the Cotopaxi Park Trail – José Rivas Shelter Trail

To calculate the total length of this path, one outbound path and one return path were considered. For the outbound trail of the Cotopaxi Parking to the Jose Rivas Shelter, a zigzag variant resulted to a length of some 1377 m, while the return trail reached some 763 m. In this way, the total length of the path (mt) is 2140 meters. Additionally, some more variables have been elaborated as summarized in TABLE 1, which have led to further calculations such as number of visits among others.

TABLE 1. Data of the Cotopaxi volcano Parking – José Rivas Shelter trail

Variables	Quantity	Unit
Total length of the trail	2140	meters (m)
Surface or distance from a person	1	meters (m)
Visiting hours	9	hours (h)
Duration of the tour	3	hours (h)

Number of people per group		16	people
Distance between groups		50	meters (m)
Precipitation	Number of months per year	8	months
	Number of weeks per month	4.34	weeks
	Number of days per week	7	days
	Number of hours per day	3	hours (h)
Hours open to the public	number of weeks	52	weeks
	Number of days per week	7	days
	Number of hours per day	9	hours (h)
Handling Capacity		60	%

Calculation of Number of Visits (NV):

$$Number\ of\ visits = \frac{Visiting\ hours\ (hours\ open\ to\ the\ public)}{Time\ needed\ to\ visit\ the\ trail}$$

$$NV = \frac{9\ Hours}{3\ Hours}$$

$$NV = 3$$

Calculation of Physical Load Capacity (CCF):

$$Physical\ Load\ Capacity = \frac{trail\ length}{area\ occupied\ by\ a\ person} * NV$$

$$CCF = \frac{S}{sp} * NV$$

$$CCF = \frac{2140m}{1m} * 3$$

$$CCF = 6420\ people/day$$

For the calculation of the Real Load Capacity (CCR), some corrections as factors have been considered and performed such as social, accessibility and precipitation factors. The calculation of the social factor is essential, since it includes the number of people that must be part of each visiting group, the distance between each member and the separation distance between groups. To calculate the number of groups (NG), 16 people per group were considered (number of people assigned to each visiting group in the country's protected areas), with a person-to-person separation of 1 meter, giving a total 16 meters long that the group occupies. The separation between groups on this trail was considered 50 meters as recommended elsewhere (Cifuentes *et al.*, 1999).

Calculation of the Number of Groups (NG):

$$Group\ length = 16m$$
$$Separation\ between\ groups = 50m$$
$$Distance\ required\ by\ each\ group = 16m + 50m$$
$$Distance\ required\ by\ each\ group = 66m$$
$$Number\ of\ Groups = \frac{Total\ length\ of\ the\ path}{Distance\ required\ by\ each\ group}$$
$$NG = \frac{2140\ m}{66\ m}$$
$$NG = 32.42$$

Calculation of number of people (P). The number of people who can be simultaneously on the trail is calculated, based on the following equation:

$$Number\ of\ people = Number\ of\ Groups * Number\ of\ people\ per\ group$$
$$P = NG * Number\ of\ people\ per\ group$$
$$P = 32.42 * 16$$
$$P = 518.79$$

To calculate the limiting magnitude (ml) of the social factor, it is necessary to know the total magnitude (mt), which is equal to the total length of the trail (which was obtained by applying GIS tools), as well as the number of people who they could be simultaneously on the path (P).

$$limiting\ quantity = overall\ magnitude - number\ of\ people$$
$$ml = mt - P$$
$$ml = 2140\ m - 518.79\ m$$
$$ml = 1621.21\ m$$

According to the explained methodology, to calculate the social correction factor (FCsoc), the following formula is followed that uses the total magnitude (mt) and the limiting magnitude (ml), calculated previously.

$$Social\ Correction\ Factor = 1 - \frac{limiting\ magnitude}{total\ magnitude}$$

$$FCsoc = 1 - \frac{ml}{mt}$$
$$FCsoc = 1 - \frac{1621.21}{2140}$$
$$FCsoc = 0.242$$

It follows the identification of the limiting magnitude for erodibility (mlero). Hereby, according to the erosion and slope maps, there is a degree of severe erosion and a steep slope. In the first section of the trail (parking lot - ridge - parking lot), giving a limiting magnitude of 138 meters (round trip), data that was measured in the field with the M3 Total Station equipment.

$$Limiting\ quantity\ due\ to\ erodibility = 138\ m$$
$$mlero = 138\ m$$

Calculation of the Correction Factor for erodibility (FCero):

$$Correction\ factor\ for\ erodibility = 1 - \frac{limiting\ magnitude}{overall\ magnitude}$$
$$FCero = 1 - \frac{mlero}{mt}$$
$$FCero = 1 - \frac{138}{2140}$$
$$FCero = 0.936$$

Next, we performed the calculation of the correction factor for precipitation (FCprec). For the calculation of this correction factor, the isohyet map was used, in which there is an average precipitation degree of 1000 to 1500 mm. In addition, the precipitation data of the study area, from the National Institute of Meteorology and Hydrology (INAMHI), were considered, which present a range of 1000 to 2000 mm per year, with higher rainfall from January to May and from October to December (INAMHI, 2022). Thus, for the calculation of the correction factor for rainfall, eight months were considered. Furthermore, we calculated the limiting hours due to precipitation (hlprec). For this calculation, according to what was previously explained, for the limiting magnitude due to precipitation, eight months, 4.34 weeks per month, seven days a week that the park is open to the public, and an average of three days were taken into account with daily hours of rainfall between 2:00 p.m. - 5:00 p.m. as restricted hours within the given visiting hours.

$$hlprec = months * weeks * days * hours$$
$$hlprec = 8 * 4.34 * 7 * 3$$
$$hlprec = 729\ h$$

It followed the calculation of the total hours that the park is open to the public (ht). For this calculation, we established 52 weeks of the year, seven days a week, and nine hours a day that the park is open to the public (08:00 am – 05:00 pm).

$$ht = weeks * days * hours$$
$$ht = 52 * 7 * 9$$
$$ht = 3276\ h$$

Finally we proceed to calculate the correction factor for precipitation:

$$Correction\ Factor\ for\ precipitation = 1 - \frac{limiting\ magnitude}{overall\ magnitude}$$
$$FCprec = 1 - \frac{mlprec}{mt}$$
$$FCprec = 1 - \frac{729}{3276}$$
$$FCprec = 0.777$$

To conduct the calculation of the Correction Factor for accessibility, the slope map and the work carried out in the field were considered, since the first section of the path is steeper, which makes accessibility kind of difficult for tourists. Thus, the limiting magnitude for accessibility is equal to 138 meters.

$$Correction\ Factor\ for\ precipitation = 1 - \frac{limiting\ magnitude}{overall\ magnitude}$$
$$FCacc = 1 - \frac{mlacc}{mt}$$
$$FCacc = 1 - \frac{138}{2140}$$
$$FCacc = 0.936$$

Finally, we proceed to calculate the real load capacity, multiplying the physical load capacity by the previously calculated correction factors.

Calculation of the Real Load Capacity:

$$CCR = CCF(FCSoc * FCero * FCacc * FCprec)$$
$$CCR = 6420(0.242 * 0.936 * 0.936 * 0.777)$$
$$CCR = 1059\ persons/day$$

For this calculation, it has been necessary to obtain the handling capacity (CM%) of the park, which will be multiplied by the actual carrying capacity. According to the consultations carried out and based on the established field visits, it is possible to be determined that the management capacity of the PNC is approximately 60%.

$$Effective\ Load\ Capacity = Actual\ Load\ Capacity * Handling\ Capacity\ (\%)$$

$$CCE = CCR * CM$$

$$CCE = 1059 * 0.6$$

$$CCE = 635 \frac{persons}{day}$$

3.3.2 Ecotourism carrying capacity of the Limpiopungo Lagoon trail

Following the indicated methodology and with the general data of Table 1, we proceed to calculate the CCE, for this, only the new data on the length of the trail (2905 m) and the duration of the visit (1.5 h), with which the following results are obtained, resulting to LV=6 and CCF=17430 people/day. For the calculation of the Real Carrying Capacity, the following correction factors were considered such as for social factor NG=44; P=704; ml=2200 m, being a FCsoc of 0.242.

The Precipitation correction factor (FCprec) is of about 0.777, while the Flooding Correction Factor (FCane) needed to be calculated. For the calculation of the limiting magnitude due to flooding, the slope map was taken into account, in which it is observed that there are sections of the trail with a flat slope, which was verified through field observations. The measurements were made of sections of the trail prone to flooding, which were measured with the M3 Total Station topographic equipment, in order to obtain more precise measurements. In this way, the total section of the trail with waterlogging problems (mlane) was measured, whose value is 126 m. In this way we obtained:

$$FCane = 1 - \frac{mlane}{mt}$$

$$FCane = 1 - \frac{126}{2905}$$

$$FCane = 0.956$$

This correction factor for vegetation cover (FCcob) was considered, due to the fact that the trail crosses fragile vegetation cover (paramo), which warranted the calculation of a limiting magnitude. In this sense, by the measurements carried out in the field, the limiting magnitude for vegetation cover is equal to 1230 meters.

$$FCcob = 1 - \frac{mlcob}{mt}$$

$$FCcob = 1 - \frac{1230}{2905}$$

$$FCcob = 0.576$$

Finally, the calculation of the real load capacity is carried out, multiplying the physical load capacity by the previously calculated correction factors.

$$CCR = CCF(FCSoc * FCprec * FCane * FCcob)$$
$$CCR = 17430(0.242 * 0.777 * 0.956 * 0.576)$$
$$CCR = 1811\ persons/day$$

While the Effective Load Capacity has been:

$$CCE = CCR * CM$$
$$CCE = 1811 * 0.6$$
$$CCE = 1086\ persons/day$$

3.3.3 Ecotourism carrying capacity of the Rumiñahui Volcano trail

For this trail, the new data to establish have been the length of the trail (9221 m) and the duration of the visit (3.5 h). This resulted to a NV of 2 and a CCF of 18424 people/day. To calculate the Real Carrying Capacity, the following correction factors were obtained NG=139.58; P=2233; ml= 6978 m; FCsoc=0.243 and FCprec=0.777. Later, we also calculated the Accessibility Correction Factor (FCacc). According to the slope map, there is a limiting magnitude for accessibility of 626.5 meters (1,253 roundtrip meters), which corresponds to the first section of the trail, which starts from the Limpiopungo Lagoon.

$$FCacc = 1 - \frac{1253}{9221}$$
$$FCacc = 0.864$$

The limiting magnitude due to erodibility (FCero) was calculated with information from the erosion and slope map, thus having the last section of the trail with characteristics of severe erosion and a mountainous slope. This last section of the trail that reaches the slopes of the Rumiñahui Volcano, is 341 meters long (682 meters round trip).

$$FCero = 1 - \frac{682}{9221}$$
$$FCero = 0.926$$

According to the measurements carried out in the field, the limiting magnitude due to vegetation cover (FCcob) is equal to 795 meters (1590 meters round trip).

$$FCcob = 1 - \frac{1590}{9212}$$
$$FCcob = 0.827$$

In this way, the CCR is obtained, being:

$$CCR = CCF(FCSoc * FCero * FCacc * FCprec * FCcob)$$
$$CCR = 18424(0.243 * 0.926 * 0.864 * 0.777 * 0.827)$$
$$CCR = 2298\ persons/day$$

And the Effective Load Capacity as:

$$CCE = CCR * CM$$
$$CCE = 2298 * 0.6$$
$$CCE = 1379\ persons/day$$

3.3.4 Ecotourism carrying capacity of the Springs trail

For the Springs trail, the new data to consider have been the length of the trail (158 m) and the duration of the visit (0.5 h), with which we obtained NV of 18 and CCF of 2844 persons/day.

For the Real Carrying Capacity, the social factor yielded NG=3.95; P=39.5; ml= 118.5 leading to a FCsoc=0.250. The Precipitation correction factor (FCprec) has been of 0.777.
In this way, the CCR is obtained:

$$CCR = CCF(FCSoc * FCprec)$$
$$CCR = 2844(0.250 * 0.777)$$
$$CCR = 553\ persons/day$$

And an Effective Load Capacity:

$$CCE = CCR * CM$$
$$CCE = 553 * 0.6$$
$$CCE = 332\frac{persons}{day}$$

In this way, all the data obtained of the different paths regarding their real and effective physical load capacity have been summarized in TABLE 2.

TABLE 2. Physical, Real and Effective Load Capacity of the PNC trails

Name / site	Physical Load Capacity (CCF)	Real Load Capacity (CCR)	Effective Load Capacity (CCE)
Limpiopungo Lagoon Trail	17430 people/day	1811 people/day	1086 people/day
Cotopaxi Volcano Parking Trail – José Rivas Shelter Trail	6420 people/day	1059 people/day	635 people/day
Rumiñahui Volcano Trail	18424 people/day	2298 people/day	1379 people/day
The Springs Trail	2844 people/day	553 people/day	332 people/day

According to the existing literature and national and international experiences, the total ecotourism carrying capacity of the PNC can be obtained, adding the carrying capacities of the sites with the greatest tourist concurrence. For the present case, it corresponds to adding the carrying capacities of the trails Limpiopungo Laguna Trail (1087 people/day) and Cotopaxi Volcano Parking Trail – José Rivas Shelter Trail (635 people/day). That is, the total capacity of the PNC is 1722 people/day, and it should be noted that this is a referential value that will vary, depending on whether tourists visit a single site or prefer to visit the two sites with the highest influx, for which take into account the ecotourism carrying capacity of each trail.

Based on the statistical data of the PNC, and also on the current performed calculations, it can be noted that the ecotourism carrying capacity of the park has only been exceeded on national holidays, which should be considered to perform the corresponding control measures. Thus, based on the tourism statistical data in the PNC (MAATE, 2022), the influx of tourists to the park increased in 2022, especially on the holidays of Carnival (4 days) and Easter (3 days), in which 6939 and 6420 visitors arrived, respectively. It means that the average of visitors per day was 1735 and 2140 respectively. Besides, in the previous main holiday, due to the Independence of the city of Guayaquil (8, 9 y 10 de October 2021), the number of visitors was about 6000, which means about 2000 tourists/day.

In this context, the calculated carrying capacity of the PNC (1722 people/day) is surpassed only in the Ecuadorian holidays. The environmental impacts due to this high influx of tourists are basically those due to the lack of tourism control. Thus, the main impacts are due to the generation of solid waste, which contaminate the air, water and soil components. Likewise, uncontrolled tourism causes alterations in the landscape and loss of biodiversity. Moreover, according to Loaiza (2018), there are various environmental impacts caused in ecological zones by uncontrolled tourism. Among them, the most representative are the different types of pollution to the environment by the different residues emitted by uncontrolled tourist activity, the excess population and its agglomeration in protected areas, land use problems, ecological breakdown, damage to nature, and inadequate management of waste from the corresponding tourism.

Finally, a tourists entering control program should be implemented in the Cotopaxi National Park, in order to avoid all of those environmental impacts just mentioned previously, especially during the national holidays.

4. Conclusions

The Cifuentes methodology for calculating the tourist carrying capacity was very applicable to the Cotopaxi National Park, obtaining very good results for the ecotourism carrying capacity of the park's trails and tourist sites. Also, the GIS tools were very useful for the analysis of the correction or reduction factors of the physical load capacity, through obtaining thematic maps including vegetation cover, erosion, slopes and isohyets.

The ecotourism carrying capacity of the trails and tourist sites of the national park depends a lot on several factors such as length of the trail, number of tourists per group, condition of the trail (accessibility, erosion, slope, waterlogging) and precipitation, in addition to the management capacity of the park in terms of infrastructure, equipment and personnel.

The number of visitors to the various trails and tourist sites in the park depends to a great extent on the state in which said trails and sites are maintained and located, thus, the trail in the best conditions for visiting is the one to the Limpiopungo Lagoon, which is visited by approximately 60% of tourists, then there is the trail to the José Rivas Refuge, which despite having a steep slope, is visited by approximately 40% of tourists, while the trails in less condition for visits, that are the path to the Rumiñahui Volcano and the one to the Springs, having a much lower tourist influx.

According to the calculations made, the trails with the highest ecotourism carrying capacity are Rumiñahui Volcano with 1,379 tourists/day and Limpiopungo Lagoon with 1,087 tourists/day.

Finally, according to the statistical data of the PNC, and based on the current performed calculations, it can be noted that the tourist carrying capacity of the park has only been exceeded on national holidays, which should be considered to carry out the corresponding control measures.

Finally, the least ecotourism carrying capacity corresponds to The Springs Trail, with 332 tourists/day. This is due to the relatively far location of such a trail and also because of the lack of dissemination and publicity.

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