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ORIGINAL ARTICLE

Designing participatory planning processes for protected areas, promoting the social and economic development of the stakeholders involved: the case of Cotopaxi National Park (PNC) in Ecuador

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Abstract

Protected areas play a crucial role in biodiversity conservation worldwide, but often neglect the involvement of local communities. This study presents a participatory planning methodology for promoting social and economic development in protected areas, using Cotopaxi National Park (PNC) in Ecuador as a case study. The PNC represents an appropriate case study due to its diverse ecosystems and challenges related to grazing activities. The proposed methodology integrates a qualitative approach with the Social Network Analysis (SNA) and the Analytic Network Process (ANP) to design a sustainable management approach. Firstly, the SNA maps the stakeholder network, identifying key actors and their relationships. Secondly, interviews with influential stakeholders provide insights into their perceptions of influence, relationships, and strategies to enhance grazing activities. Thirdly, the ANP is used to analyze and prioritize management strategies. Finally, a novel sensitivity analysis was made to validate the results. The promotion of new opportunities for productive projects and alternative sources of income was the best-rated strategy for sustainable grazing. The proposed methodology can facilitate and improve the co-management of the protected areas and their governance. It allows the integration of environmental conservation objectives with the main concerns of the stakeholders, promoting social and economic development. This study confirms that stakeholders have different interests, sensitivities, and ways of understanding sustainability; thus, improving stakeholder communication and the involvement of additional actors, such as NGOs and government agencies, is crucial. The proposed integrated approach can be adapted to any participatory decision-making process related to the conservation of protected natural areas.

Keywords Protected natural areas · Analytic Network Process ANP · Multicriteria Decision-Making MCDM · Social Network Analysis SNA · Ecuador

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Introduction

The establishment of protected areas is an effective strategy that governments employ to guarantee the conservation of biodiversity (Rodrigues et al. 2004; Malhi et al. 2020; Fajardo et al. 2023). Despite their proven effectiveness (Science Based Targets Network 2020; Mi et al. 2023), the management of these areas often overlooks local communities, which bear the impacts of conservation actions while being vital in the use and protection of natural resources (Wells 1992; Bruner et al. 2001; Camacho-Benavides et al. 2013).

Protected areas are often used for different activities that sometimes conflict with conservation goals. Therefore, management strategies that balance these competing demands are needed (Miralles-Wilhelm 2021). Moreover, the complex and dynamic nature of protected area contexts requires the continuous monitoring, learning, and adjusting of management actions based on new information and feedback from stakeholders (Månsson et al. 2023).

The management of protected areas also involves collaboration with multiple stakeholders (Sparrow et al. 2020). The scientific literature on the management of natural areas with multiple stakeholders covers a wide range of topics (Hobbs et al. 2010; Cohen-Shacham et al. 2019). Numerous research works highlight the importance of employing scientific data to inform multi-stakeholder decision-making processes (Joshi et al. 2023). In the field of management, this concept is well-supported by academic research (Thorn et al. 2020). For instance, Learmonth (2006) argues for the integration of scientific knowledge into managerial practices, suggesting that decisions backed by scientific evidence are more likely to yield effective and efficient outcomes.

Disagreements among the stakeholders of natural protected areas represent a challenge involving their varying interests, the mismanagement of resources, and the market conditions that affect natural resource management (Thorn et al. 2020). In this context, any intervention requires comprehensive and participatory approaches (DelCurto et al. 2005; World Bank 2020) that integrate key elements, such as productivity, biodiversity, ecological changes, intergenerational equity, and cultural heritage (Stenseke 2006; Hernández-Guzmán et al. 2015).

To inform the participatory approaches, Social Network Analysis (SNA) technique has been applied to the management of natural resources (Prell et al. 2008, 2009), biodiversity conservation and landscape management (Calvet-Mir et al. 2015; Goggin et al. 2015), parks conservation (Romero-Gelvez and Garcia-Melon 2016; Yamaki 2017), environmental management (Salpeteur et al. 2017), and tourism promotion (Bianchi et al. 2020).

Participatory planning aims, among others, to guide decision-making more systematically and make it more transparent by focusing on the prioritization of actions. For the specific task of prioritizing actions, Multicriteria Decision-Making Methods (MCDM) have been widely used in decision processes for participatory planning involving multiple scenarios, stakeholders, and criteria (Chen et al. 2019; Kheybari et al. 2020). This study proposes the use of the Analytic Network Process (ANP) (Saaty 2001). Some previous ANP applications in the management of natural areas highlight its usefulness in compensating for differences in stakeholders' influence power, facilitating consensus, and demonstrating the effectiveness of participation during evaluation and decision-making processes (Bottero and Mondini 2008; García-Melón et al. 2012; Grošelj and Stirn 2015). Indeed, several case studies apply this approach to the co-management of protected areas using the ANP (e.g. Dragoi 2018; Ferretti et al. 2014; Grošelj et al. 2016; Lin & Lu 2013); however, most are bottom-up actions. Likewise, some studies mainly evaluate stakeholder participation and its relationship with governance but do not establish how to encourage such involvement (Wolfslehner and Vacik 2008; Wang et al. 2013; Hsin-Lung 2017; Aminu et al. 2017). However, ANP application should not be reduced to the prioritization of actions without stakeholder participation. Therefore, the use of suitable techniques to engage a large number of stakeholders and select experts is rare and yet widely recommended (Gonzalez-Urango et al. 2021).

The authors of this study have not found in the literature a methodological proposal combining the MCDM and the SNA for stakeholder-based strategic planning. At least not in the field of nature park management with socioeconomic as well as environmental objectives. This is despite the acknowledged merits of both approaches. Therefore, this study is based on the research question: How to design participatory planning processes for a protected area, promoting the social and economic development of the stakeholders involved, and their conservation objectives?

To illustrate the application of the proposed methodology, we focus on the management of the Cotopaxi National Park (PNC) in Ecuador. Since the PNC's establishment in 1975, conflicts have arisen among stakeholders, including private owners, hunters, tourists, and park managers. Thus, any intervention requires comprehensive and participatory approaches (DelCurto et al. 2005; World Bank 2020). Grazing practices inside the park have caused significant ecological and socioeconomic impacts. Moreover, grazing activities have led to significant changes in vegetation and land degradation, contributing to the deterioration of the park's conservation status, making sustainable grazing practices an essential aspect of PNC's future (Niederman et al. 2023; Canals et al. 2011; Czerny and Czerny 2020, Yulianti 2024).

In this context, the case study addressed in this research lies in the challenge posed by grazing in Cotopaxi National

Park (PNC), acknowledging grazing deep roots, diverse stakeholders involved, and PNC cultural and political complexities. The importance of the PNC lies in its rich biodiversity, tourism in the Cotopaxi volcano, and being the main source of water for the country's capital Quito with the river Pita.

The aim of this research is to propose a methodology that allows the authorities in charge of the management and conservation of a protected area to demonstrate the feasibility of building a participatory planning and decision-making process based on a multicriteria decision technique. The study integrates two well-established techniques: stakeholder mapping through SNA (Wasserman and Faust 2007) and the design and prioritization of management strategies using the ANP (Saaty 2001). By employing these techniques, this study aims to achieve a participatory approach to managing protected areas that harmonize environmental conservation with economic activities.

Materials and methods

Study area

Ecuador has 66 protected areas covering 14% of its landmass (MAE, 2022). This study will explore the PNC, situated in Ecuador's central Andes mountains, approximately 60 km from the capital. The PNC is one of Ecuador's protected areas established in 1975. This park, covering 33,393 hectares features the Cotopaxi volcano, a major tourist attraction, and is home to diverse fauna and flora within its four life zones (Holdridge 1967; MAE, 2010).

The main physical feature and tourist attraction of the park is the Cotopaxi volcano, at 5897 m above sea level, and four life zones (montane rainforest, subalpine pluvial paramo, alpine pluvial tundra, and snow forest) determined by the different altitudinal levels between 3400 and 5897 m above sea level. These four zones are home to approximately 17 species of mammals, 37 species of birds, and some species of amphibians and reptiles. The water system of the PNC consists of 18 micro-watersheds. The most important rivers originate from the Cotopaxi volcano, with the Pita River being the main source of water for the country's capital Quito. The PNC has an average monthly temperature of 8–16 °C. March and April are the rainiest months, while the driest months are July and August.

Grazing is one of the main activities carried out in the PNC by cattle and to a lesser extent, by cattle horses (wild horses without owners). This activity has been carried out for several decades, even before the creation of the PNC, so it is considered an ancestral activity that benefits local communities and herders. However, some of the moorlands in PNC Park have the lowest conservation status value since environmental monitoring has been carried out, mainly due to grazing (Jácome-Enríquez et al. 2013). Ranchers in the PNC often burn the grasslands to obtain new pasture for their cattle. The ranchers' territory comprises approximately 17,528 hectares (52% of the total area of the park).

The Ecuadorian Ministry of the Environment (MAE), responsible for PNC's management, has delineated ten conservation objectives, with particular emphasis on the recovery of ecosystems lost due to livestock and tourism activities (MAE 2011). Ranchers' grazing practices have caused significant ecological and socioeconomic impacts. Moreover, grazing activities have led to significant changes in vegetation and land degradation, contributing to the deterioration of the park's conservation status, making sustainable grazing practices an essential aspect of PNC's future (Yulianti et al. 2024; Canals et al. 2011; Czerny and Czerny 2020, Niederman et al. 2023).

Since the PNC's establishment, conflicts have arisen among stakeholders, including private owners, hunters, tourists, and park managers. Thus, any intervention requires comprehensive and participatory approaches for sustainable future practices (DelCurto et al. 2005; World Bank 2020).

Methodology

This is a qualitative and exploratory study that aims to design participatory planning processes for protected areas. To answer the research question, a three-phase methodology has been designed. Figure 1 illustrates the proposed methodological flow.

Phase 1: Mapping of the stakeholder network

The stakeholders mapping was carried out through the SNA. It is a methodology that applies graph theory to map interactions between nodes (individuals, institutions, or stakeholders) (Salpeteur et al. 2017; Song et al. 2018), and explore the dynamics of a network as a whole (Ghorbani et al. 2021; Hohbein et al. 2021). This mapping allows for the identification of network stability, key stakeholders, and link strength. In addition, SNA permits the qualitative evaluation of networks to reflect different attributes and influences between nodes (Romero-Gelvez and Garcia-Melon 2016).

Data collection To collect data, firstly, the identification of stakeholders was carried out following the strategies recommended by Zheng et al. (2016). An initial list was generated from the review of documents related to PNC management and later the snowball technique was used to obtain a broader list (Varvasovszky and Brugha 2000; Shi et al. 2020). Secondly, each actor was asked with whom they communicated in relation to the sustainability of grazing in the PNC. A total of 60 stakeholders were identified, of whom 39

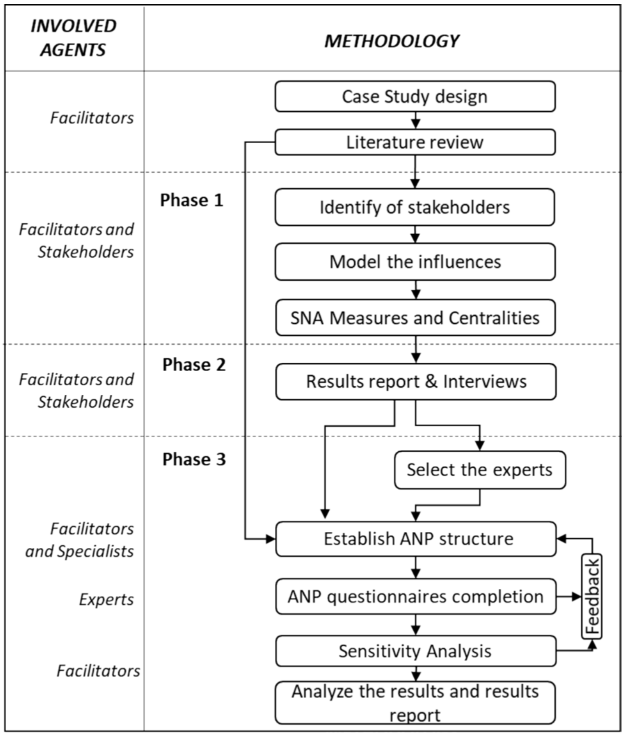


Fig. 1 Proposed research methodology

(65%) agreed to participate in the study and were classified into 7 groups (Table 1).

Data analysis To perform the SNA, the global information matrix (Supplementary Material 1) was built. It consists of an adjacency matrix in which all the actors are presented in rows and columns, and the entries are 0 s and 1 s depending on the absence or presence of a relationship between two actors. In the graphical representations of the network, the identified actors were represented as nodes, and those interactions between them were represented as ties (Rodríguez et al. 2023). Using the UCINET® software, two structural measures (network density and average degree) and three types of centrality measures (out/in-degree, out/in-closeness, and betweenness) were calculated (Borgatti et al. 2002; Wasserman and Faust 2007). These SNA indicators allowed us to understand the overall structure of the network and to identify the most central actors. For each centrality, the actors with the highest values were identified as the most influential ones and were invited to participate in the next phase of the study.

Table 1 Number of participants (nodes) for the SNA

Group	Number of participants
Park rangers	3
Local community	10
Academy	6
Tour operators	6
Government	2
Tourist representative	6
Ranchers	6
Total	39

Phase 2: Perception of influence among stakeholders and proposed strategies

The stakeholders identified as the most central in the previous phase were interviewed in order to find out their perception of both the results of the SNA, and of the influence and relationships between the stakeholders. In addition, some possible management strategies that can be adopted in the park to improve the development of grazing activities were discussed. In this phase, we considered important the participation of at least one representative for each stakeholder group.

Data collection Eight semi-structured interviews were conducted face-to-face. The interviews lasted around 2 h each. The script for conducting the interviews was in five parts: (1) General information of the interviewee; (2) Decision-making in PNC; (3) Livestock and grazing in the PNC; (4) Perception of relationships, influences and information flows among stakeholders; and (5) Possible strategies or alternative solutions.

Data analysis The interviews were recorded and transcribed in full with the consent of the interviewees. These texts were later verified with the interviewees. The eight interviews were coded and analyzed using qualitative content analysis (Gläser and Laudel 2013). We analyzed the qualitative findings in three different levels: the perception of the influences and connections, the decision-making process in the PNC, and the strategies aiming to improve grazing activities.

Phase 3: Analysis and prioritization of management strategies

The prioritization of strategies was carried out following the ANP method (Saaty, 2001). The ANP offers a structured approach for decision-making and problem evaluation. ANP represents the prioritization model as a network composed of various elements (such as criteria, indicators, and alternatives), which are organized into clusters and interconnected. This method accommodates complex, interdependent, and feedback relationships among the elements within a problem. The ANP procedure encompassing the following steps:

Identify the network's components and elements, along with their relationships. In this case, the decision elements are the alternatives, which are the management strategies aiming to improve the sustainability of grazing activities in the PNC, and criteria to evaluate the proposed strategies grouped into clusters.
Perform pairwise comparisons of the elements, utilizing Saaty's 1-to-9 scale.
Enter the resulting relative importance weights (eigenvectors) into pairwise comparison matrices to form the unweighted matrix.
Weight the blocks of the unweighted matrix using the corresponding priorities of the clusters, converting it into a column-stochastic weighted matrix.
Raise the weighted matrix to limiting powers until the weights converge and stabilize, forming the limit matrix.
Determine the prioritization of elements based on any of the columns in the limit matrix.
If the results reveal that some alternatives are closely ranked, conduct a sensitivity analysis to verify the robustness of the obtained ranking.

Data collection To identify elements of the network (ANP step 1), a bibliographic review was initially carried out based on a search for references using the following keywords: "protected areas", "management", "decision-making", "sustainable grazing", and "participatory planning". After screening and studying the findings, an initial list of strategies and evaluation criteria was proposed.

The process of defining strategies was complemented with the results of the interviews developed in phase 2. Then, with the active participation of a member of the Park Administration, the strategies were summarized and grouped.

Evaluation criteria were defined by a panel of specialists in the management of natural areas. They also establish influence relationships among criteria. Three specialists participated in this panel:

ES1 Specialist in Management of Protected Natural Areas (more than 25 years of experience).
ES2 Specialist in Management of Natural Resources (20 years of experience).
ES3 Engineering Geologist and PhD in Earth Sciences (more than 15 years of experience).

Subsequently, a group of seven experts (EXP1–EXP7) chosen after the application of the SNA evaluated the importance of the criteria and the proposed alternatives (ANP step 2). Each expert received (via email and in person) a standard ANP comparison questionnaire. The questionnaire was composed of two parts. The first part consisted of the assessment of the influence between criteria, and the second part consisted of the evaluation of the different alternatives in relation to the established criteria (Fig. 2).

Once the final results were obtained, these were sent to all participants along with a survey to find out their satisfaction with the process. The survey consisted of three statements related to the questionnaires were understandable; the form of participation was simple; and the result is feasible. These satisfaction items were scaled from "Very dissatisfied" to "Very satisfied".

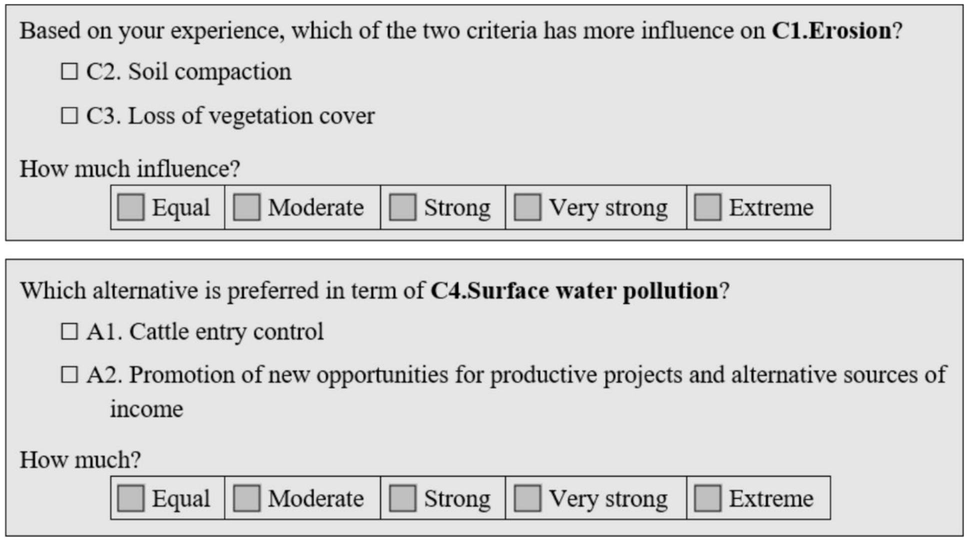
Data analysis The responses of the experts were treated individually and grouped. To obtain the group results, the geometric mean was applied to the judgments of the stakeholders, as recommended by Saaty (2001). When inconsistency in the judgments was found, the participant was asked to revise their judgments. All the data were processed with the Superdecisions Software (ANP steps 3–6).

Finally, a novel sensitivity analysis based on different scenarios was proposed to validate the robustness of the results (ANP step 7). The scenarios were defined by assigning a relative importance to each expert/group of expert (Ishizaka and Labib 2011), based on the argument that some stakeholders have greater influence, so they may be in a position to exercise it and, therefore, impose their interests and affect the perception of the alternatives among the rest of the stakeholders (Brenner and Job 2006). Six scenarios were designed as follows:

Scenario 1 (S1) considers all sectors equally. When two or more experts from the same group participate in the prioritization. The judgments of these experts were unified in such a way that all groups had the same participation in the calculation of the group result. In this case, two experts from the academy participated, which gives this sector a greater participation in the global result. In this scenario, the global result was calculated as follows:

$$GRS1 = \sqrt[6]{EXP1 * EXP2 * \frac{EXP3 + EXP4}{2} * EXP5 * EXP6 * EXP7} \tag{1}$$

Scenario 2–6 (S2–S6) was defined on the basis of the centralities calculated in the SNA. Each centrality was normalized. The contribution of each expert to the global result was determined by the product of the weight that each expert has been given in the ANP by the importance of the expert obtained in each centrality. The global result of the criteria


Based on your experience, which of the two criteria has more influence on **C1.Erosion**?

☐ C2. Soil compaction

☐ C3. Loss of vegetation cover

How much influence?

☐ Equal	☐ Moderate	☐ Strong	☐ Very strong	☐ Extreme

Which alternative is preferred in term of **C4.Surface water pollution**?

☐ A1. Cattle entry control

☐ A2. Promotion of new opportunities for productive projects and alternative sources of income

How much?

☐ Equal	☐ Moderate	☐ Strong	☐ Very strong	☐ Extreme

Fig. 2 Example of a question used for the ANP questionnaire

and alternatives, in these scenarios, was calculated from the sum of these contributions and not from the geometric mean.

$$GR_{(S2-S6)} = \sum_{j=1}^{7} a_j * b_j \tag{2}$$

where $S2$ is the scenario 2 defined for the out-degree, $S3$ scenario 3 defined for the in-degree, $S4$ scenario 4 defined for the out-closeness, $S5$ scenario 5 defined for the in-closeness, $S6$ scenario 6 defined for the betweenness, j the expert, a is the priority given for each expert to the criteria and alternatives in the ANP, and b is the weight of the expert.

Results

Phase 1: Stakeholders mapping through the Social Network Analysis

The network that represents the communication between the stakeholders in issues related to grazing in the PNC was built (Fig. 3). The result is a decentralized network, in which a single central actor is not identified. The density of the network is 4.2% of the possible relationships. This is a low density, where few stakeholders act as brokers.

Table 2 shows the general results for the SNA measures for stakeholders. The most central stakeholders, in terms of degree centrality (out and in), are ID01 (park ranger) and ID19 (researcher). They have the highest number of connections; thus, they are crucial for information flow. Notably, ID14 (a natural areas management specialist) has numerous outgoing connections but receives limited information. Local community, government, and ranchers have a very low degree of centrality. Overall, many stakeholders have degree values below 2, confirming that this is a disconnected network.

As regards closeness centrality, ID01, ID19, ID23, ID28, and ID34 show higher values. ID02 and ID13 gain importance, particularly ID13 for enhancing network connections and stakeholder engagement. ID01 stands out in betweenness centrality, followed by ID19, indicating their crucial role in the information flow regarding grazing sustainability. Stakeholders ID2, ID13, ID14, ID28, and ID34, also help by filling structural holes in the network i.e. they act as bridges between non-redundant contacts in the network (Fig. 3).

Eight actors with the highest centrality values were identified as the most influential ones. Seven of them accepted to participate in the next phase of the study: ID01 (park ranger), ID13 (local community), ID14 (academy), ID19 (academy), ID23 (tour operators), ID28 (tourist representative), ID34 (rancher). In addition, although government actors were not among the most influential, a representative of the Ministry of Environment (ID26) was interviewed in order to learn about their perception of the issue. This person agreed to an interview, but not to participate in the next phase of prioritization of strategies.

Phase 2: Perceptions of influence among stakeholders and proposed strategies

Regarding the perception of the influences among stakeholders and the causes behind the connections between them, the interviewees emphasized that stakeholder influence relies on informal relationships shaped by tradition, exercised through power relations inherited from the cattle contexts:

…influence is exerted through example, respect or inherited power relations that no longer exist, but generate behavioral inertia (ID34).

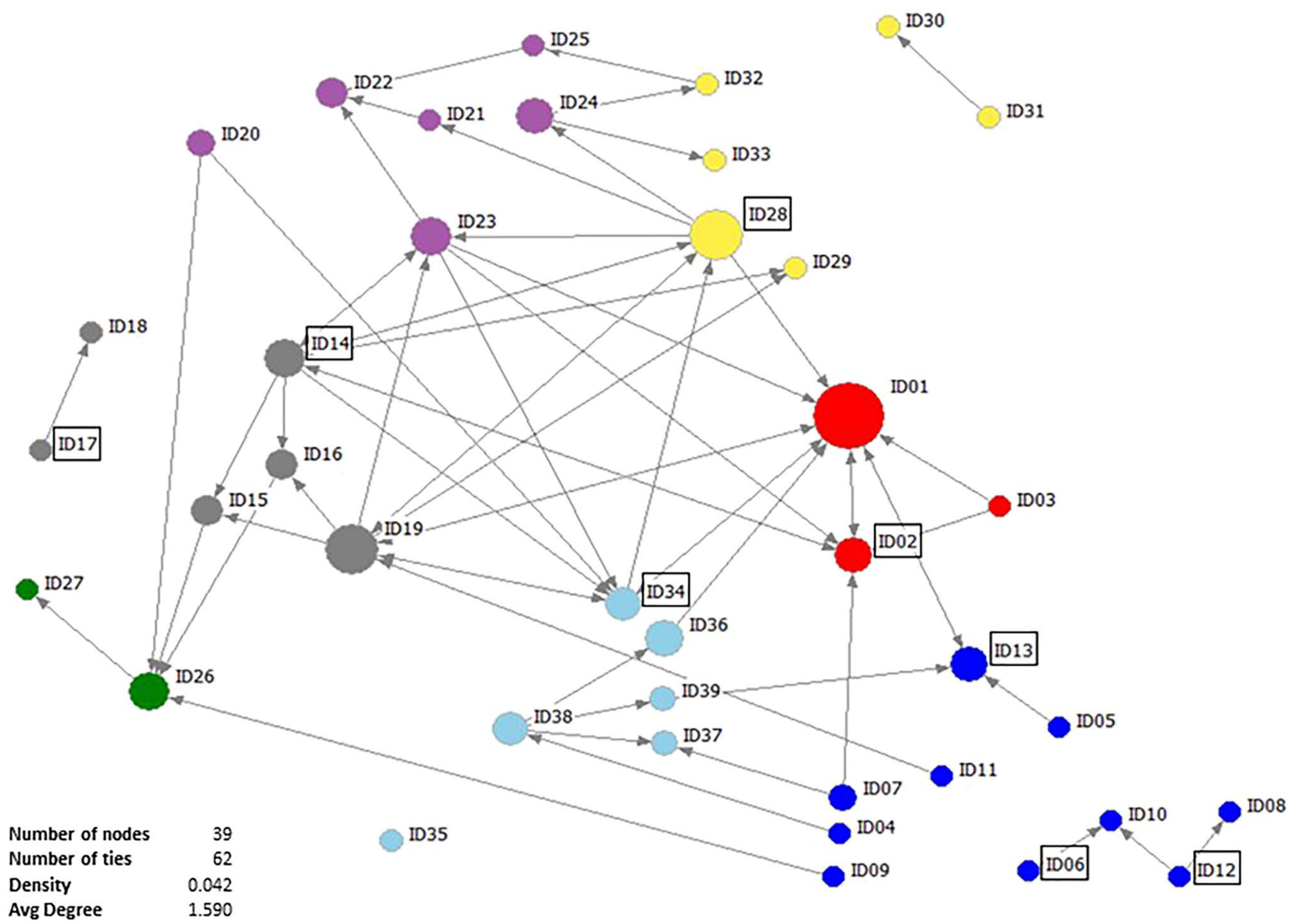


Fig. 3 Actors network (rangers: red; local community: blue; academy: grey; tour operators: purple; government: green; tourists: yellow; ranchers: light blue)

The influence of ranchers comes from the ranching tradition in the PNC (ID14).

As the SNA reveals, the stakeholders interviewed highlighted that the actors are disconnected and unaware of each other. Tourists and the local community are not perceived as key actors. The roles of park rangers and the academy lack clarity, with the latter feeling undervalued. Public stakeholders, including political leaders, are not recognized as influential due to perceived self-interest. The Ministry of Tourism has limited connections but is expected to gain influence as the PNC's exploitation continues (Table 3).

Another result observed here is the role of the Ministry of Tourism. It has limited connections and its perceived as but is expected to gain influence as the PNC's economic development continues (Table 3).

The second level of the results is the decision-making process in the PNC. As some of the interviewees state (Table 3), decisions related to the management and conservation of the park are made independently by the Ministry of the Environment. Only park rangers are considered means for communication and implementation of actions. They are also responsible for enforcing the regulations for park's conservation; however, they do not have the necessary tools to carry out effective control.

Finally, regarding the strategies aiming to improve grazing activities, the interviewees proposed the following strategies:

– Cattle entry control, it is considered to be the most effective because it will generate immediate results.
– New economic activities, our interviewees advocate for ecotourism as an emerging activity. Others mentioned rodeos or roundups of wild horses that live in the park.
– The introduction of other livestock species, such as vicuñas or llamas.

Table 2 Measures for the nodes[a]

	Actor type	Out-degree	In-degree	Out-closeness	In-closeness	Betweeness
ID01[b]	Park Rangers	4	8	225	223	130.50
ID02[b]		2	5	227	232	32.67
ID03		2	0	233	342	0.00
ID04	Local Community	1	0	243	342	0.00
ID05		1	0	252	342	0.00
ID06		1	0	334	342	0.00
ID07		2	0	229	342	0.00
ID08		0	1	342	334	0.00
ID09		1	0	327	342	0.00
ID10		0	2	342	326	0.00
ID11		1	0	224	342	0.00
ID12		2	0	326	342	0.00
ID13[b]		1	3	242	232	36.00
ID14[b]	Academy	7	2	215	243	40.50
ID15		1	2	327	235	16.00
ID16		1	2	327	235	16.00
ID17		1	0	334	342	0.00
ID18		0	1	342	334	0.00
ID19[b]		7	4	214	232	109.17
ID20	Tour operators	2	0	226	342	0.00
ID21		1	1	334	248	1.17
ID22		0	3	342	220	0.00
ID23[b]		5	3	223	241	21.50
ID24		2	1	313	248	51.00
ID25		1	1	334	267	2.00
ID26	Government	1	4	334	225	20.00
ID27		0	1	342	237	0.00
ID28[b]	Tourist representative	5	3	215	240	84.00
ID29		0	2	342	235	0.00
ID30		0	1	342	334	0.00
ID31		1	0	334	342	0.00
ID32		1	1	327	257	19.00
ID33		0	1	342	257	0.00
ID34[b]	Ranchers	3	5	222	231	43.50
ID35		0	0	342	342	0.00
ID36		1	1	235	327	36.00
ID37		0	2	342	319	0.00
ID38		3	1	229	334	22.00
ID39		1	1	252	327	2.00

[a]Graded colour scale: lowest values are red, midpoints are yellow, and highest values (the most central actors) are green

[b]Actors with the highest centrality values

Table 3 Illustrative quotes

Aspect	Representative quotation	Interviewee
Perception of the influences among stakeholders	…our work (in the academy) is not welcomed by some stakeholders	ID19—academy
	Some public actors, such as political leaders, only defend particular interests and not the common or public ones	ID28—tourist
	Domestic tourists are not key players in the network	ID14—academy
	The Ministry of Tourism… until very recently had not interfered in PNC affairs	ID01—park ranger
Decision-making at PNC	… people from outside are invited to these meetings …usually not because the people who work here are experts in their field	ID26—Ministry of Environment
	There is no record of any complaints from park rangers and no action has been taken… They preferred not to fine and to talk to the offenders…	
	It is a "Top-Down" decision-making process in which the Ministry of the Environment decides on the measures to be adopted without prior consultation	ID19—academy
	We have no effect on the offenders… imagine a $10 fine! That's nothing…	ID1—park ranger
	… the park ranger notifies us (ranchers) of the new measures adopted, without any type of participation…	ID34—rancher

Phase 3: Analysis and prioritization of management strategies based on the application of the ANP

Decision model

In the first part of the decision model, the strategies were defined. A table summarizing the strategies proposed by the interviewees in the previous phase and the findings of the literature review (Table 4) was built. These strategies were used as input for the definition of the final strategies to be included as alternatives in the model.

The above strategies were summarized and grouped. Three solution strategies were proposed as alternatives to the decision model:

A1. Cattle entry control: Delimiting the entire perimeter of the PNC, fencing off the most frequent accesses to the PNC for cattle, and improving patrol routes.

A2. Promotion of new opportunities for productive projects and alternative sources of income: Arranging possible business alternatives and incorporating them into the PNC's catalog of services and offers, supporting the necessary investments, and incorporating them into the traditional activities protected by the Ecuadorian government.

A3. Implementation of state subsidies for pastures: Stabling as much as possible on cattle farms, supporting the investments to provide services to the farms with stabling, establishing networks for the purchase and sale of food produced in other areas of Ecuador, and implementing a subsidy scheme if necessary.

Table 4 Strategies to improve the sustainability of grazing

Alternative	Source
1. Restricting the number of animals allowed per hectare or restricting the access	Díaz-Pereira et al. (2020); Floate et al. (2005); interviews
2. Promoting new economic activities	Fan et al. (2022); interviews
3. Introducing other livestock species	Interviews
4. Controlling the number of animals	Teague and Kreuter (2020)
5. Preventing overgrazing by reducing animal pressure	Díaz-Pereira et al. (2020)
6. Increasing carrying capacity by improving soil quality and vegetation enhancement	Díaz-Pereira et al. (2020); Teague and Kreuter (2020)
7. Incorporating regenerative practices	Teague and Kreuter (2020)
8. Monitoring soil quality in grasslands and rangelands	Wang et al. (2021)
9. Creating an incentive scheme	Cinner et al. (2018)
10. Addressing the proximate causes of illegal grazing, such as lack of pasture and water for cattle on their farms	Matungwa et al. (2022)

Table 5 Evaluation criteria

Cluster	Criteria	Definition	Reference
1. Soil deterioration	C1. Erosion	Produced by the footsteps of cattle which deteriorate the soil structure	Blanco Sepúlveda and Nieuwenhuyse (2011); Nunes et al. (2011)
	C2. Soil compaction	Produced by the intense trampling of cattle, which causes the soil to lose its structure, and become more mixed and compact	Quiroga et al. (2009); Blanco Sepúlveda and Nieuwenhuyse (2011)
	C3. Loss of vegetation cover	Produced by the burning of grasslands and by the trampling of cattle, neither of which allows the growth of new herbaceous shoots	Agnoletti (2007); Teague et al. (2011)
2. Water pollution	C4. Surface water pollution	Produced by cattle excrement, which ends up in watersheds	Strauch et al. (2009)
	C5. Groundwater pollution	Produced by the filtration of contaminants from cattle excrement	Nautiyal and Kaechele (2007); Strauch et al. (2009)
3. Air pollution	C6. Emissions into the atmosphere	Produced by the burning of grasslands carried out by ranchers to obtain new grassland regrowth	Savadogo et al. (2007); Solomon et al. (2007)
4. Property rights and limits	C7. Land tenure	Reference to the problem of property rights of some farms inside the park	Solomon et al. (2007); Himley (2009)
	C8. Delimitation of the PNC	Absence of physical delimitation of the park	Busch et al. 2006; Himley (2009)
5. Socioeconomic aspect	C9. Job opportunities and economic income	Diversification of opportunities for economic income from the natural resources of the PNC	Barkmann et al. (2008); López-i-Gelats et al. (2011)
	C10. Pastoral farming tradition	Right of the inhabitants to maintain the economic activity carried out for centuries	MacLeod and McIvor (2006); Williams (2011)

Subsequently, the criteria to evaluate the proposed strategies through the multicriteria decision model based on the ANP technique were established. Taking into account the findings of a bibliographic review, the specialists determined the list of evaluation criteria. They were organized into five clusters (Table 5).

Following the ANP methodology, an influence matrix was built (Supplementary Material 2). In this, the three specialists established the influence relationship between criteria in such a way that one (1) means that the element in the row influences the element in the column. For example: C1 influences criteria C3, C4, and C8 and the three alternatives. The ANP network (Fig. 4) was built from the previous matrix.

Prioritization

The stakeholders identified as the most prominent in the SNA were invited to participate in the prioritization process. Hereinafter, these stakeholders will be referred to as experts:

EXP1 Park ranger of the PNC (ID1): Responsible for the management of the PNC. Extensive experience in the conservation and management of natural areas.
EXP 2 Local community (ID13): Community leader with extensive relations with various sectors of the park. Lives and carries out their economic activities in the area.
EXP 3 Academy (ID14): Specialist in management of natural areas.
EXP 4 Academy (ID19): Researcher in environmental issues, sustainability and conservation of natural resources.
EXP 5 Tour operator (ID 23): Manager of a well-known tour operator linked to the PNC and naturalist guide at the PNC for 6 years.
EXP 6 Tourist representative (ID28): Activist and member of an active group of hikers visiting the park. Experience in forest management.
EXP 7 Rancher (ID34): Livestock entrepreneur, leader in the sector.

Each of the experts received the ANP questionnaire and once the data was processed, we obtained the prioritization of alternatives and criteria global and for each expert. The main result is the degree of influence of each criterion and

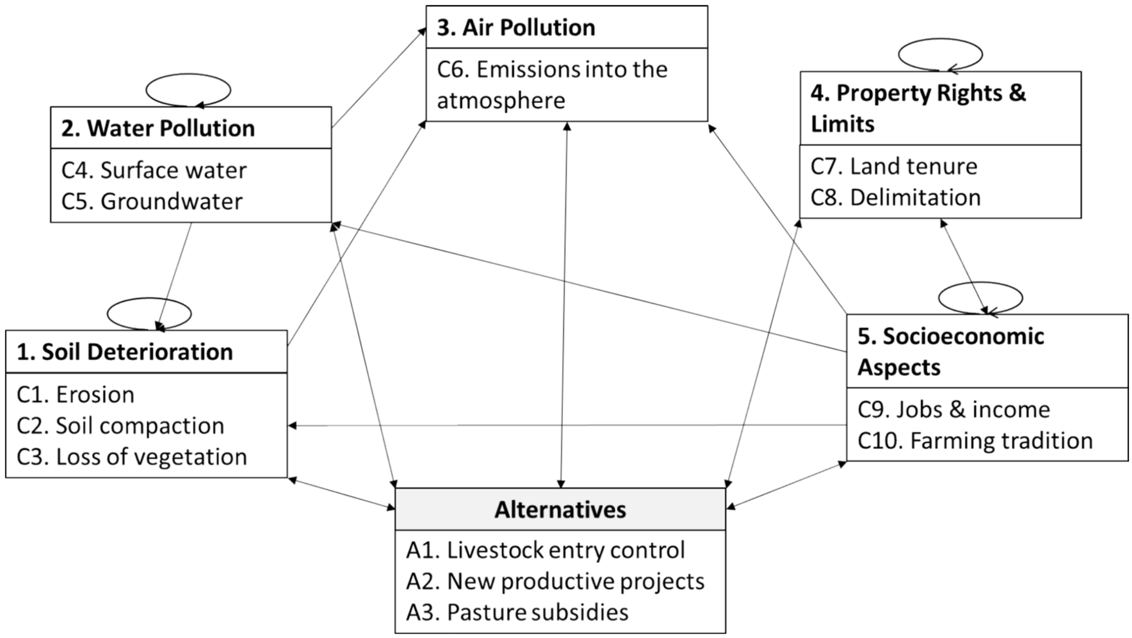


Fig. 4 Case Study Network Model. Five clusters with evaluation criteria and one with alternatives. Arrows between clusters indicate influence relationships. The feedback arrows represent the influence relationships between criteria of the same cluster

alternative in the sustainability of grazing in the context of the management of the PNC.

Table 6 shows the overall weight of each of the criteria. The criteria that most affect the sustainability of grazing in the PNC are those corresponding to air and water pollution (clusters 2 and 3). The most influential criterion is C6 Emissions to the atmosphere from grassland fires, followed by C4 Surface water contamination, C5 Groundwater

Table 6 Importance of criteria [a]

Cluster	Criteria	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	EXP7	Global
1. Soil Deterioration	C1 Erosion	0.09	0.04	0.11	0.08	0.07	0.05	0.04	0.08
	C2 Soil compaction	0.06	0.01	0.03	0.07	0.03	0.06	0.03	0.04
	C3 Loss of vegetation cover	0.11	0.07	0.18	0.15	0.10	0.10	0.05	0.12
2. Water Pollution	C4 Surface water pollution	0.18	0.09	0.16	0.24	0.17	0.18	0.03	0.16
	C5 Groundwater pollution	0.24	0.05	0.20	0.13	0.13	0.22	0.06	0.15
3. Air Pollution	C6 Emissions into the atmosphere	0.22	0.10	0.23	0.24	0.39	0.29	0.09	0.24
4. Property Rights and Limits	C7 Land tenure	0.02	0.12	0.02	0.01	0.02	0.02	0.14	0.03
	C8 Delimitation of the PNC	0.02	0.14	0.02	0.03	0.03	0.03	0.13	0.05
5. Socioeconomic aspect	C9 Job opportunities and economic income	0.02	0.19	0.02	0.03	0.02	0.02	0.14	0.05
	C10 Pastoral farming tradition	0.03	0.20	0.03	0.03	0.05	0.04	0.29	0.07

[a]Graded colour scale: lowest values are red, midpoints are yellow, and highest values are green

Table 7 Importance of alternatives [a]

	EXP1	EXP2	EXP3	EXP4	EXP5	EXP6	EXP7	Global
A1 Livestock entry control	0.17	0.24	0.46	0.78	0.31	0.68	0.08	0.37
A2 New productive projects	0.65	0.28	0.26	0.15	0.63	0.24	0.68	0.44
A3 Pasture subsidies	0.18	0.48	0.28	0.07	0.07	0.08	0.24	0.19

[a]Graded colour scale: lowest values are red, midpoints are yellow, and highest values are green

contamination, and C3 Loss of vegetation cover. The criteria that received the least evaluation were the groups of Property rights and limits and Socioeconomic aspects (Clusters 4 and 5). The criteria related to environmental sustainability stand out over the economic and social criteria.

On the other hand, the analysis of the individual assessments of the experts allows a decision profile for each participant to be defined, finding some common points and identifying discrepancies between the priorities of the stakeholders (Table 6). Three groups can be identified: the first group (EXP1, EXP3, and EXP4) considers that the environmental criteria are the most influential. On the contrary, it gives very little importance to the criteria of the socioeconomic clusters. In the second group (EXP5 and EXP6), the preferences are along the same lines. However, there is a much more marked preference for environmental criteria, especially C6. Finally, in the third group (EXP2 and EXP7), clusters 4 and 5 are the most important, while the environmental receives medium–low ratings.

Regarding the alternatives, as can be seen in Table 7, the preferred alternative is A2, the generation of new opportunities for productive projects (44%), closely followed by A1, the physical delimitation of the PNC and the control of livestock income (37%), with A3, subsidy for pastures, a long way below them (19%). It should be noted that the higher the values of the alternatives, the more they contribute to solving the problem.

EXP7, the actors directly affected, are totally against the limitation of their activity (A1); however, they recognize the need to promote productive alternatives for the sector. The preference of EXP1 and EXP5, meanwhile, is more heavily influenced by an environmental concern (A2), in line with the preferences demonstrated in the evaluation of the criteria. For these two stakeholders, the best path is to reduce and, if possible, eliminate livestock activity in the park. Experts EXP3, EXP4, and EXP6, also with a clear environmental concern, support a restrictive alternative that allows control and short-term results, such as the prohibition of the entrance of the cattle to the park. For these stakeholders, it is urgent to take actions that prevent the environmental degradation of the park. Finally, EXP2 is the only expert to consider that ensuring the income of ranchers through pasture subsidies should be the priority of park management.

Table 8 Sensitivity analysis

	Global	S1	S2	S3	S4	S5	S6
C1 Erosion	0.08	0.07	0.08	0.07	0.07	0.07	0.07
C2 Soil compaction	0.04	0.04	0.05	0.04	0.04	0.04	0.05
C3 Loss of vegetation cover	0.12	0.11	0.13	0.10	0.11	0.11	0.12
C4 Surface water pollution	0.16	0.15	0.17	0.15	0.15	0.15	0.17
C5 Groundwater pollution	0.15	0.15	0.16	0.15	0.15	0.15	0.17
C6 Emissions into the atmosphere	0.24	0.24	0.25	0.21	0.23	0.22	0.23
C7 Land tenure	0.03	0.04	0.03	0.05	0.05	0.05	0.04
C8 Delimitation of the PNC	0.05	0.05	0.04	0.06	0.05	0.06	0.04
C9 Job opportunities and economic income	0.05	0.05	0.04	0.06	0.06	0.06	0.05
C10 Pastoral farming tradition	0.07	0.08	0.06	0.10	0.09	0.10	0.07
A1 Livestock entry control	0.37	0.33	0.46	0.34	0.40	0.38	0.43
A2 New productive projects	0.44	0.48	0.38	0.47	0.41	0.42	0.40
A3 Pasture subsidies	0.19	0.19	0.16	0.19	0.19	0.20	0.17

Sensitivity analysis

Table 8 shows the global results of the six scenarios. Detailed calculations for each scenario are found in Supplementary Material 3.

In reference to the criteria, there are no significant changes in the assigned weights. As to the alternatives, despite slight variations, A2 remains well-valued in most of the scenarios. It should be noted that, although S2–S6 are interesting to analyze, they represent an undesirable since all the experts should be considered equally important in decision-making.

Discussion

The proposal presented here has been able to identify the stakeholders involved in the environmental management of the PNC, has been able to present the environmental management problem of the PNC and the alternatives to solve it as a prioritization model, which has allowed for structured and transparent participation of the most influential actors among the stakeholders.

The results obtained confirm that carrying out participatory planning processes for the management of protected areas is viable (Calvet-Mir et al. 2015; Cohen-Shacham et al. 2019). In contrast to the few previously identified participatory processes, the active participation of stakeholders in this study demonstrates an interest in adapting their current conditions in order to maintain the stability of the park, as long as they are considered during the development of solutions and allowed to carry out activities that guarantee their living conditions and income. These results are complemented by the following discussion.

Social Network Analysis to map stakeholders and analyze their influence

As introduced, various authors apply the SNA for the identification and analysis of stakeholder influence in relation to an issue that binds them (Ghorbani et al. 2021). SNA is based on the exchange of information, currency, materials, etc. The usual method for analyzing stakeholder influence in decision-making is to identify information exchanges (Gonzalez-Urango et al. 2021). Thus, the most influential actors are considered to be those actors from whom more actors demand information and who demand information from more actors.

The number of information exchange relationships between actors determines the density of the network. The denser the network, the more relationships and mutual influences between actors. In the case of the present study, the density of the network is very low. This means that there is little communication between the stakeholders on issues related to environmental management and grazing in the PNC. This low communication was known to some specialists, according to the interviews, and the SNA result confirmed their intuitions. The lack of communication between many of the actors leads to problems being solved through solutions that do not have sufficient support due to a lack of debate and agreement.

The reasons behind the lack of participation are both physical and cultural. On the one hand, there are long distances with rough terrain between the actors, and telephone networks are no substitute for the lack of face-to-face meetings. On the other hand, there are old disputes (mainly between ranchers and park rangers, and government and local communities), differing interests, varying training levels, and a certain lack of participatory management practices (Smythe et al. 2014).

Furthermore, the SNA can help to improve network density and stakeholder participation. For example, this could be achieved by introducing relationships that enhance connections, particularly within stakeholder groups or with stakeholders having low centralities but can fill structural gaps, such as specific local community representatives (ID06 and ID12) and academics (ID17). The local community, despite being profoundly impacted by PNC livestock activities, lacks influence and prominence in the network, implying a need for their increased engagement. Finally, although they did not appear in the snowball technique, the need to include NGOs, other industries (like the water industry), and the Ministry of Tourism or Agriculture was also identified.

Application of the Analytic Network Process to the prioritization of management strategies in protected areas

ANP was used to model the problem of discussing the best strategies for environmental management of the PNC. ANP is very appropriate in cases such as the one presented in this paper, where information is incomplete and, of what information is available, some is qualitative and some is uncertain (Ligardo-Herrera et al. 2018). ANP makes it possible to identify alternative courses of action and the criteria by which they are evaluated, and to organize all the elements as a network of influences. This way of approaching the problem aligns well with the SNA used for stakeholders. Once the model is generated, ANP takes advantage of expert knowledge, i.e. it does not need quantitative information and can work with the judgements that experts make for each comparison.

The reflections and debates that ANP comparisons provoke help to complete the information and reinforce its certainty. Stakeholders were able to present their arguments and listen to those of the other experts. ANP encourages structured participation around objectives for the PNC, alternatives for achieving them, and reasons for preferring one alternative over another.

In the case study, the ANP results highlight environmental over socioeconomic criteria. However, there is a clear difference between the experts representing local communities and ranchers and the rest. These experts clearly prioritized property and socioeconomic criteria. These results show and evaluate the well-known confrontational position of both factions. Fortunately, for these same experts, the sensitive aspects of the property rights and boundary criteria were less important than the socioeconomic criteria. "Land tenure" and "Delimitation of the PNC" have been a contentious issue since the park's establishment in 1975. The process allowed for a better understanding of the positions of each actor, helping to put the focus on providing alternative incomes for ranchers and local communities, as well as promoting the pastoral farming tradition.

Among the environmental criteria, air pollution due to burning for pasture renewal is the most influential criterion. Surface and groundwater pollution are also very influential. These three criteria account for more than 50% of the influence of the criteria. Hence, the alternatives that best contribute to avoiding these practices are the ones that will obtain the best prioritization.

The "Promotion of new opportunities for productive projects and alternative sources of income" was the best-rated strategy, which means that it should be prioritized. The strategy promotes new opportunities for productive projects and alternative sources of income for local farmers while decreasing the environmental burden. Hence, it is the strategy that more contributes to the agreed goals for the PNC. This strategy is implemented by means of projects linked to crafts, organic agriculture, or ecotourism (ecological tours, lodging, and transport). In any case, the "Livestock entry control" alternative is rated close to the previous one. Therefore, it should also be given priority, although it is an alternative that receives very different individual evaluations and will surely be controversial.

Despite differences among stakeholders, satisfaction surveys showed that experts and stakeholders were generally "satisfied" to "very satisfied" with the results. Experts appreciated the thorough data collection and clarity of the process and outcomes.

Sensitivity of results to the importance of actors

To assess the robustness of the results and better understand the influence of the importance of the actors, six scenarios have been developed. In the first, the two experts from the academy are combined into one so that all interest groups have equal representation. The changes with respect to the overall result are small for the criteria, and slightly more noticeable for the alternatives.

However, when the experts' judgments are affected by a value that reflects their influence according to the SNA indicators, changes in the criteria remain insignificant but changes in the alternatives may be relevant. This raises a dilemma: prioritize the alternatives based on the judgments without being affected by the influence of the actors (ideal situation) or affected (more realistic situation). Indeed, the actors did not agree on the alternative to prioritize most for the management of the PNC. Although the actors leave the participation session knowing the overall result and the individual results of the participants, those with more influence may respect the agreements to a greater or lesser extent.

For example, if taking into account the influence of experts according to the Outdegree indicator or the Betweenness indicator, alternative A1: "Livestock entry control", is preferred to A2: "New productive projects". This is because the academy experts prefer alternative A1 and are the ones with the highest Outdegree, scoring very well in Betweenness too.

As previously mentioned, authors still do not agree on which of the SNA indicators best represents the influence of the actors, and recommend combining them (Romero-Gelvez and Garcia-Melon 2016). This complicates the decision on how to reflect the influence of the actors when prioritizing criteria or alternatives. In any case, the literature is also not uniform on whether or not to give importance to experts, and on what basis to do so (Ligardo-Herrera et al. 2018). If it was decided to also prioritize the experts, the analysis presented here has a more "realistic" approach compared to that of other authors who base the prioritization on the quality of the judgments: consistency, certainty in their judgments, etc. (Boix-Cots et al. 2023). An influential expert can get his preferred alternatives prioritized, without needing to have a high quality in his judgments.

On the other hand, this proposed procedure also allows to neutralize the influence of some stakeholders while increasing the presence and commitment of others. Based on the results, and depending on the aims, new forms of stakeholder participation could be added. For instance, combining public consultations (written, incl. online), public hearings and stakeholder dialogues (Vetulani-Cęgiel and Meyer 2021), with more elaborated tools such as the stakeholder participation model CATCH proposed by Lupo Stanghellini and Collentine (2008) or the capacity-building stakeholder participation (CBSP) model proposed by Kadurenge et al. (2017). The literature related to stakeholder management and other forms of collaboration can also make interesting contributions in this regard (Lindner et al. 2023).

Conclusions

The proposed methodology can facilitate and improve the co-management of the protected areas and their governance. It has been applied to a national park with a long-standing overgrazing problem and has allowed the integration of environmental conservation objectives with the main concerns of the stakeholders, promoting strategies for social and economic development. It can be adapted so as to be applicable to any participatory evaluation related to the conservation of protected natural areas. Another of its strengths is that it turns a complex problem into a model that is more transparent, communicable, and debatable.

The main limitations are associated with the techniques used. As far as the SNA is concerned, it is worth mentioning the low participation of some stakeholders and the non-inclusion of traditionally excluded stakeholders. The use of complementary qualitative techniques could help to complement these doubts. As for the ANP, the proposal to combine the ANP with other MCDM techniques could reduce the extent of the comparison instruments used. Finally, these exercises must be continuously updated, given the dynamics of change in the community and the (dis)appearance of actors that may imply changes in the governance of the park.

Therefore, as one future line of research, the network of interest groups will be completed with those that have been identified as necessary, although they did not appear in the snowball technique. The network will also be densified by establishing contacts to fill in the gaps and complete the communication paths. During the process, the SNA and the ANP will be updated to maintain and improve participation.

In another future line of research, the stakeholder influence study will be completed. On the one hand, the implications for the realism of planning, but also the moral implications of taking into account the influence of stakeholders in collective decision-making will be studied. On the other hand, which indicators best reflect the greater or lesser influence of stakeholders will be studied, as well as how to aggregate this information into their judgments. Finally, how to manage stakeholder influences in relation to the setting and achievement of the PNC's conservation objectives will be explored.

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