Journal of Environmental Management 272 (2020) 111083

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: http://www.elsevier.com/locate/jenvman

Research article

Improving the management effectiveness and decision-making by stakeholders' perspectives: A case study in a protected area from the Brazilian Atlantic Forest

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ARTICLE INFO

Keywords:
Protected area management
RAPPAM
Land use and land cover
Conservation planning
Atlantic forest

ABSTRACT

Assessing management effectiveness in protected areas is a fundamental instrument to achieve socio-biodiversity protection goals. This study aimed to analyze the management effectiveness of Cunhambebe State Park (from now on, "PEC") in the State of Rio de Janeiro in Brazil, from the perception of stakeholders and the multi-temporal analysis of land use and land cover between 1998 and 2018. We used the Rapid Assessment and Prioritization of Protected Area Management method for a participatory approach. Seventy-two indicators were used and applied to assess the perception of stakeholders related to the Advisory Council. The management effectiveness of PEC was classified as moderately satisfactory (63.41%). Indicators of "Legal security", "Vulnerability", "Site design and planning" and "Financial resources" revealed the weaknesses and threats of management and what should be the priority projects for better effectiveness. Through the multi-temporal analysis, we identified that the advances of pasture and urban areas are the highest pressures and threats, as perceived by stakeholders. In our case study, we provide evidence of actions that must be performed by the PEC management team. These actions must consider the weaknesses and threats presented by the SWOT analysis. Finally, we recommend some political and management measures: 1) Financial resources for the land regularization of areas overlapping with PEC, 2) Guidelines about PEC areas must be included in the Master Plans of municipalities that cover PEC limits, 3) Technical assistance to improve land management, and 4) Strengthen environmental education initiatives at all school levels.

1. Introduction

Protected areas (PA) are important to biodiversity conservation and their significance at the local scale is vital for both management planning and assessment. PAs play a critical role in providing nature's benefits and a variety of materials fundamental to people's physical well-being and for maintaining cultural diversity (IPBES et al., 2019). PAs help achieve sustainable human-nature interactions. In addition, they are a source of leisure/tourism related income, enhancing social and economic benefits for local communities (Mace, 2014; Bonet-García et al., 2015). Therefore, PAs are considered strategic areas for the implementation of major environmental agreements, such as those proposed in the Convention on Biological Diversity (CBD) for 2010 and the Aichi targets for 2020 and post-2020 (Stoll-Kleemann, 2010; Visconti et al., 2019).

Research on protected areas management involving socio-ecological approaches is an important tool in conservation science and management (e.g. Palomo et al., 2014; Ferraro and Pressey, 2015). PA management should be tailored to the particular demands of the site, given that each protected area has a variety of biological and social

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https://doi.org/10.1016/j.jenvman.2020.111083
Received 3 November 2019; Received in revised form 6 July 2020; Accepted 10 July 2020
Available online 15 July 2020

characteristics, pressures and uses (Hockings et al., 2006). Thus, PA management presents different challenges because it is governed by social interactions among stakeholders and institutions interacting in both directions with dynamic ecosystems in heterogeneous landscapes (Ellis et al., 2019). Decentralized and participatory management to promote the engagement of stakeholders are necessary, lining up conservation and socioeconomic practices (Reed et al., 2009, 2017). Studies carried out in the Brazilian Atlantic Forest support the idea that the success of PAs is linked to participatory management strategies (Castro et al., 2006). However, most PAs are managed using a mixture of centralizing and decentralizing approaches in which the State assumes a central role in the management of the PA, but delegates some management responsibilities to local communities and involved stakeholders (Soliku and Schraml, 2018).

Brazilian legislation (Federal Law 9.985/2000) establishes the participation of social actors linked to "full protection" protected area (e.g. National Parks - category II of the International Union for Conservation of Nature/IUCN) with the formation of an Advisory Council. The presidency of this council is held by the public agency responsible for the administration of the PA and the other representatives are from public agencies, civil society organizations, landowners in overlap with the PA, or traditional communities living in and around the PA (Brasil, 2000). However, the Brazilian management of PAs is still predominantly carried out through top-down approaches (Bockstael et al., 2016), often more linked to political motivations than to conservation (Adams, 2003). The reality is that the human dimensions of biodiversity conservation, especially of stakeholders, remain underused in many conservation decisions and actions (Bennett et al., 2017).

The Brazilian Atlantic Forest is a case in point: this biome has many PAs and it has suffered significant deforestation due to the exploitation of commodities (Ribeiro et al., 2009). Only 30% of this biome is located inside PAs, 9% of which are full protection areas (IUCN Categories I-IV) and 21% sustainable use areas (IUCN Categories V and VI) (Rezende et al., 2018). In the state of Rio de Janeiro, Cunhambebe State Park (PEC) is a PA in IUCN category II, and it represents an important remnant of the Atlantic Forest with more than 38,000 ha (INEA, 2015). The great relevance of this protected area is mainly related to water ecosystem services, which contribute to the formation of the Ribeirao das Lajes dam, a strategic reservoir to supply the metropolitan region of Rio de Janeiro city (approx. 12 million people). Therefore, it is extremely necessary for developing research with decision-makers to improve its management effectiveness, biodiversity conservation and human well-being.

1.1. Protected areas management and effectiveness

The effectiveness of the protected area helps achieve the objectives for which the area was created. That is to conserve a range of natural values, including ecosystem function and services, biodiversity, and human-wildlife interactions (Hockings et al., 2006). To ensure better effectiveness, the management must identify the potentialities and vulnerabilities of the landscape, while incorporating social participation. In 2000, the IUCN published the first document with the conceptual framework and guidelines for assessing effectiveness. The working group created in 1997, came to be represented by a thematic program within the World Commission on Protected Areas (CMAP). Since then, these guidelines are still adopted and applied by most of the tools and/or methodologies (see Hockings et al., 2000).

The assessment of the management effectiveness is a key factor for long-term sustainability (Joppa et al., 2013) and it provides information on how PAs protect the ecosystem values and provide benefits to communities. Another important factor in the PA management is the monitoring of changes in land use and land cover using geospatial information, which is essential for a better understanding of landscape dynamics over time (Rawat and Kumar, 2015). Remote sensing can be used to monitor land cover changes using multi-temporal satellite data and to study the relationship between the human influence on land cover and its consequences on the environment over time (Zurqani et al., 2018). Many changes in land cover driven by socio-economic causes affect biodiversity, land degradation, and water resources, accentuating climate change and other negative effects on the maintenance of ecosystem services (Lee et al., 2019).

1.2. Environmental management perceptions

Among researchers studying environmental management and conservation, the term "perceptions" is often used to understand how an individual understands or evaluates an action, experience or a policy (Bennett, 2016). In the PAs management, decision-making is based on individual perceptions. When understanding PAs as socio-ecological systems, collaborations should be flexible, based on social learning, and involving state and non-state actors, often at multiple levels, aiming to negotiate and coordinate adaptively the management of these systems (Chaffin et al., 2014).

Mace (2014) recognized that a better understanding of human dimensions of conservation is required. It is essential to conduct surveys that substantively capture the perceptions of stakeholders and link them to the local context, social dynamics, and ecological outcomes (Martín-López and Montes, 2014; Bennett, 2016). Monitoring the perceptions and the effectiveness of management is a necessary component of environmental management, and it is also useful to know if the PA is performing the desired function (Barber et al., 2012). Assessing the effectiveness of PAs management remains a concern for policymakers and it includes the appropriate and responsible use of conservation funds (Gong et al., 2017). Thus, measuring the impact of conservation interventions is essential to improve long-term effectiveness and guide the allocation of limited financial resources (Barber et al., 2012).

1.3. Goals and objectives

It is important to concentrate efforts to improve the effectiveness of existing PAs, instead of only investing in increasing the areas of PAs (Kere et al., 2017). The originality of this study is the use of a multidisciplinary approach combining stakeholders' perceptions, multitemporal analysis of land use/cover and field observations. In this research, we examine how stakeholders' perceptions of management effectiveness, associated with geospatial information, can improve decision-making processes in a PA. We specifically aimed to answer: i) what is the perception of stakeholders about the management effectiveness of PEC? Ii) how can we associate the analysis of changes in land use and cover with the perception of stakeholders? And iii) how can the participatory assessment of management effectiveness improve the role of decision-makers in the conservation of PEC?

2. Methodology

2.1. Study area

Cunhambebe State Park (PEC) was created on June 13, 2008 and falls under the authority of INEA (state environmental agency). It covers areas in the municipalities of Angra dos Reis, Mangaratiba, Rio Claro and Itaguaí, with a total area of 38,053.05 ha (Fig. 1). It comprises part of the region located between the coordinates 22°46′10″S and 23°03′01″S and 44°21′40″W and 23°52′60″W. It is a part of an ecological corridor called Tinguá-Bocaina, important for protecting the Atlantic Forest. In an international context, PEC is part of the Atlantic Forest Biosphere Reserve (RBMA), a project linked to the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Rylands and Brandon, 2005). The Brazilian Atlantic Forest is the most ancient Brazilian forest, and a biodiversity hotspot that is highly threatened by climate change (Myers, 2000; Brancalion et al., 2019).

PEC features vegetation of Submontane, Montane and Altomontane

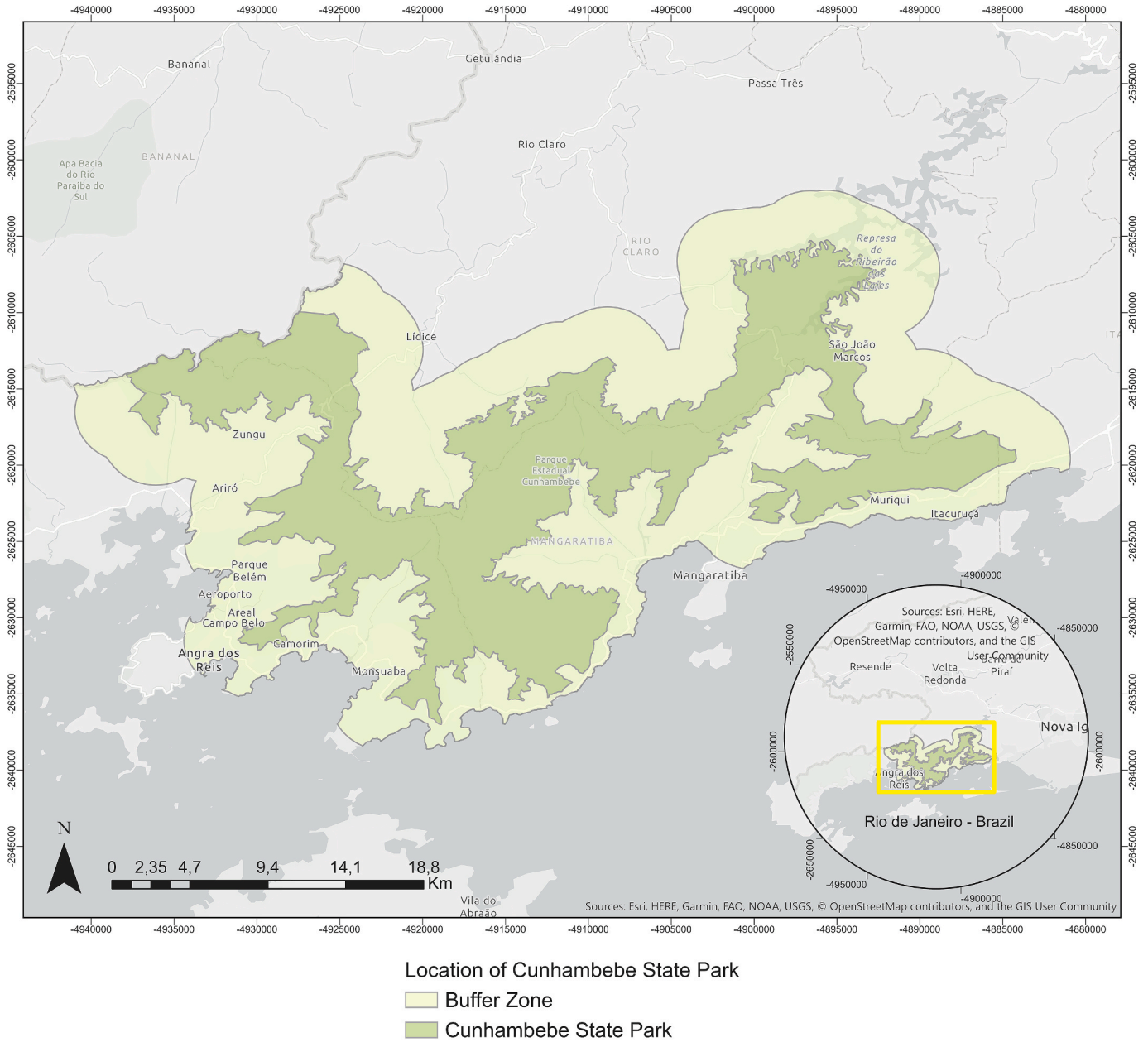

Fig. 1. Location map of Cunhambebe State Park and its Buffer Zone.

Dense Ombrophilous Forest, and Submontane and Montane Semi-deciduous Seasonal Forest (Maurenza et al., 2018). It represents an important PA for the protection of the Atlantic Forest biodiversity, with more than 730 species of flora, 25 being endangered (MMA Ordinance No. 443/2014) and 20 endemic species from Rio de Janeiro (Maurenza et al., 2018). Some species are even endemic and threatened with extinction, such as *Justicia meyeniana* (Nees) Lindau, *Annona parviflora* (A.St.-Hil.) H. Rainer, *Begonia ramentacea* Paxton and others. Regarding fauna, PEC has a great species richness, among which we can mention the *Brachyteles arachnoides*, *Leopardus pardalis*, *Puma concolor* and the *Cuniculus paca*, which are all on the list of endangered species. In the PEC region, there is also a remarkable diversity of birds, with species of conservation interest, such as the *Aburria jacutinga*, the *Amadonastur lacernulatus* and the *Hemitriccus furcatus* (INEA, 2015).

Among the ecosystem services (ES) related to PEC, we highlight the conservation of natural landscapes and the historical, archaeological and cultural heritage ("São João Marcos Archaeological Park" in buffer zone), the opportunity for leisure and educational activities, and the protection of biodiversity. The great relevance of this park is also related to water ecosystem services, which contribute to the formation of the Ribeirão das Lajes dam. This water reservoir is strategic for the state of Rio de Janeiro, being used to provide water to the metropolitan region of the city of Rio de Janeiro - with an estimated population of around 12 million people. The main reflection of social and environmental problems in this region, is the fragmentation of the Atlantic Forest, due to the rupture in the main ecological interactions and changes in taxonomic, functional and phylogenetic diversity of the remaining communities (Lopes et al., 2009). In addition, there are problems of soil degradation due to erosion, poor pasture practices, and loss of water quality in local watersheds (INEA, 2015).

2.2. Multidisciplinary approach

The research was conducted based on a multidisciplinary approach and data collection and analysis involved five methods: participatory workshop (Rapid Assessment and Priorization of Protected Area

Management - RAPPAM), participant observation, documentary analysis, SWOT analysis and multi-temporal analysis for land use and land cover (Fig. 2).

In the documental analysis, among the main documents examined are the PEC Management Plan and the Master Plans of Municipalities that cover PEC. The participant observation was carried out by following up the meetings of the Advisory Council during 2017 and 2018. Also, field expeditions in the four municipalities that surround PEC were carried out to visually inspect the different land uses, the dynamics of landscape occupation and its social, environmental, and economic aspects. The strengths, weaknesses, opportunities, and threats (SWOT) related to the perception of RAPPAM indicators were also analyzed.

A multidisciplinary approach using an appropriate mix of indicators provides a more complete assessment for measuring the management effectiveness and generate results that can be utilized for adaptive management. To access stakeholders' perceptions, we used the RAPPAM method (Ervin, 2003) with adaptations to reduce the PEC manager's subjectivity in the evaluation process. Qualitative methods (participant observation and documentary analysis) were used to better understand stakeholders' perceptions since their helpful to learn about the social-ecological context (Albuquerque et al., 2014). In addition, we used the SWOT analysis for support the formulation of management actions at different levels of governance. Also, remote sensing and GIS techniques were used to understand the past, evaluate the present and adapt management for future issues, with low operating costs, and with good accuracy (Holloway and Mengersen, 2018). This combination of methodologies contributes to the literature by exploring the management effectiveness assessment of PAs based on a multidisciplinary approach. Benefits of applying a multidisciplinary approach were demonstrated by previous studies on land use change (e.g. Barreto and Drummond, 2017; Bockstael et al., 2016), thus allowing a more comprehensive understanding of management effectiveness.

2.3. Stakeholders analysis and management effectiveness

The stakeholders' perception was based on the RAPPAM method (Ervin, 2003), with a total of 72 questions, divided into 6 categories and 16 modules (Table 1). The RAPPAM questionnaire (Appendix A) was applied to 22 stakeholders who are members of the PEC Advisory Council (see Appendix B) in a participatory workshop, discussing the questions presented to decide on a single answer for each indicator. The PEC's Advisory Council is formed by stakeholders from public organizations, private institutions, civil society organizations, and non-governmental organizations.

The quantitative methodology proposed by RAPPAM is based on assigning values to the questionnaire responses. For category I, the responses were analyzed according to the values assigned to each evaluation criterion, according to Table 2.

In the remaining categories, the answers received the values according to what was established in Table 3, and the values were presented as a percentage of the maximum possible score. That is, the proportionality obtained by the answers of the indicators' questions (Ervin, 2003). The questions could be answered in four options: "Yes", "Predominantly yes", "Predominantly no" or "No". A "Yes" answer indicates full or near full agreement with the indicator. A "Predominantly yes" answer indicates almost total agreement with the indicator. On the other hand, the "No" answer suggests total disagreement with the indicator, and a "Predominantly no" answer indicates almost total disagreement with the proposed indicator.

The category I was analyzed to pressures in the last five years and threats in the next 5 years. The category II was evaluated to understand

Table 1
Categories and modules presented in the questionnaire used to apply the RAPPAM method to PEC stakeholders.

Category		Module
I	Pressures and threats	Pressures; Threats.
II	Context	Biological importance; Socio-economic importance; Vulnerability.
III	Planning	Objectives; Legal security; Site design and planning.
IV	Inputs	Staffing; Communication and information; Infrastructure; Financial resources.
V	Processes	Planning; Decision-making; Research, monitoring and evaluation.
VI	Outputs	Management outputs.

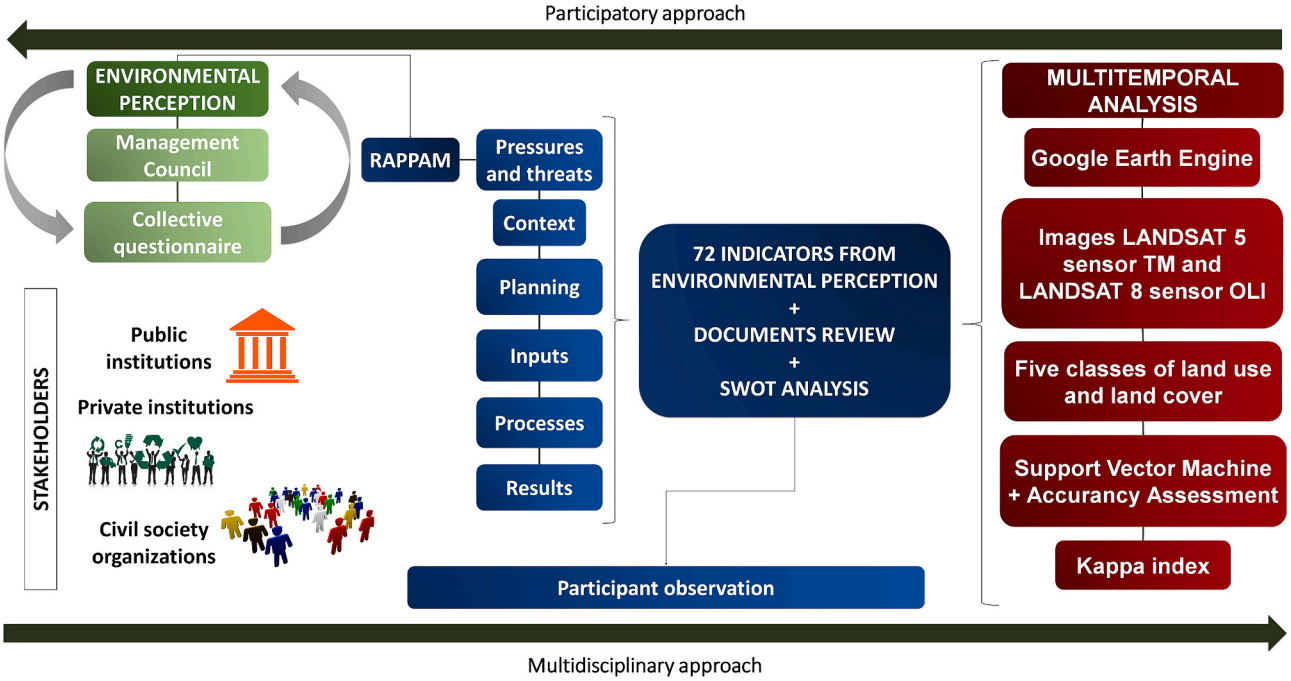

Fig. 2. Methodological proposal used in this study.

Table 2
Assignment of values to responses provided to category I questions, about pressures and threats based on the RAPPAM method.

Extent	Impact	Permanence	Degree
Throughout = 4 (>50%)	Severe = 4	Permanent = 4	Severe (>48)
Widespread = 3 (>15–50%)	High = 3	Long term = 3	High (32–48)
Scattered = 2 (>5–15%)	Moderate = 2	Medium term = 2	Moderate (16–32)
Localized = 1 (>5%)	Mild = 1	Short term = 1	Mild (1–16)

Table 3
Assignment of scores to the responses of category II to VI, as established by the RAPPAM method.

Alternative	Score	Percentual (%)
Yes (Y)	5	100
Predominantly yes (PY)	3	60
Predominantly no (PN)	1	20
No (N)	0	0

Source: Adapted from Ervin (2003).

the perception of stakeholders related to the area context, allowing to infer knowledge about the biological and socioeconomic importance, and vulnerability. This information supported discussions on management effectiveness, related to the results. The measurement of management effectiveness is based on categories III, IV V and VI (planning, inputs, process, and outputs) (Equation (1)). As a parameter of management effectiveness, we determined the unsatisfactory effectiveness (0–35%), little satisfactory (36–50%), moderately satisfactory (51–75%), satisfactory (76–90%) or very satisfactory (91–100%), as presented by Cifuentes et al. (2000).

$$ME = \frac{\left(\frac{\sum x_3}{n3}\right) + \left(\frac{\sum x_4}{n4}\right) + \left(\frac{\sum x_5}{n5}\right) + \left(\frac{\sum x_6}{n6}\right)}{4} \quad (1)$$

where:

ME = Management effectiveness.
x_3 = effectiveness of planning indicators.
x_4 = effectiveness of inputs indicators.
x_5 = effectiveness of process indicators.
x_6 = effectiveness of outputs indicators.
n_3 = number of planning indicators.
n_4 = number of inputs indicators.
n_5 = number of process indicators.
n_6 = number of outputs indicators.

2.4. SWOT analysis

This analysis was carried out to identify the factors that contribute to or hinder better management effectiveness, based on the indicators of the RAPPAM method. The SWOT analysis was adapted from the perspective of conservation planning, considers ecological and social aspects (Scolozzi et al., 2014; Comino and Ferretti, 2016). Principal component analysis (PCA) was performed to correlate the RAPPAM modules and strengths, weaknesses, opportunities, and threats of the swot analysis using the CANOCO statistical package (Ter Braak and Smilauer, 2002).

2.5. Multitemporal analysis

A landscape analysis of land use and land cover was conducted for the years 1998, 2003, 2008, 2013 and 2018, based on the supervised classification of multispectral data. The images were obtained from the Google Earth Engine (GEE) platform, using images from the LANDSAT 5 sensor TM (1998, 2003 and 2008) and LANDSAT 8 sensor OLI (2013 and 2018) satellites, with 30 m resolution. The GEE has routines that can combine images (for a particular date range) to find the best cloud-free pixel which when re-assembled creates cloud-free images for a particular region (Gorelick et al., 2017). Thus, the selection of images represents the entire period of the year analyzed, including environmental changes.

We perform data normalization (band composition), which can reduce image noise and classification errors when using images with different sensors. The color composition for the images was 5(R), 4(G), 1 (B) for those from LANDSAT 5 sensor TM, and 6(R), 5(G), 1(B) for those from LANDSAT 8 sensor OLI. These compositions were defined according to The United States Geological Survey (USGS. United State Geological Survey, 2019). In the ArcGIS Pro® software, using the "segmentation tool", the classification was object-based. Training and validation samples were collected for five land use and land cover classes, which were: forest, pasture, water, urban area, and exposed soil (Fig. 3).

Object-based classification is a way to combine visual interpretation and pixel-based classification, allowing this method to be used in different themes due to the process of detecting and distinguishing different geographical objects (Veljanovski et al., 2011). Classes were therefore determined according to pressures and threats pointed out by the stakeholders, allowing inferences about the spatialization and control of socio-environmental conflicts to be made. Field visits were made to identify vegetation patterns in the image. In addition, in a complementary manner, the patterns of land use and land cover observed in the images available in Google Earth were also used.

The classifier defined for this work was the Support Vector Machine (SVM). It is the least susceptible to noise, correlated bands and an unbalanced number or size of sites inside each class and is widely used among researchers (ESRI, 2019). To verify the quality of the classification, we used the tool integrated to the ArcGIS Pro® software called Accuracy Assessment that elaborates the Computer Confusion Matrix (CCM). In this step, we use the raster image (for each year) as input data with its respective classification. This CCM forms a matrix of confusion with errors of omission and commission and derives an index of agreement (Kappa index) (Viera and Garret, 2005). The closer the result is to one, the more accurate the analysis is (Santos et al., 2012). From the information provided by the stakeholders about the occurrence of fires in PEC and BZ, we decided to spatialize fire outbreaks during the analyzed period. For the analysis of fire outbreaks, the INPE database for the years 2003, 2008, 2013 and 2018 was used. We did not find fire outbreaks for the year 1998.

3. Results

3.1. Pressures, threats, and land use

The results of the pressures and threats, using the RAPPAM method, are shown in Fig. 4. Among the pressures identified, "urban occupation" was recognized as the one that can cause the most problems to PEC and its surroundings, reaching the maximum degree (d = 64), followed by the occurrence of "fires" (d = 48) and "deforestation" (d = 24). As for the threats, "real estate speculation" also reached its maximum degree (d = 64), followed by "urban occupation", "animal trafficking" and "budget cuts", at the same degree (d = 48). According to the RAPPAM method, pressures are forces, activities, or events that have already had a detrimental impact on the integrity of the protected area. Threats are potential or impending pressures in which a detrimental impact is likely to occur or continue to occur in the future (Ervin, 2003).

The pressures "urban violence" (d = 18) and "hunting" (d = 12) and the threats "animal trafficking" (d = 48) and "drug trafficking" (d = 27), although they have lower degrees, are also important for management actions. They are related to the vulnerability of access to the PEC for illegal practices and the difficulties in monitoring these practices.

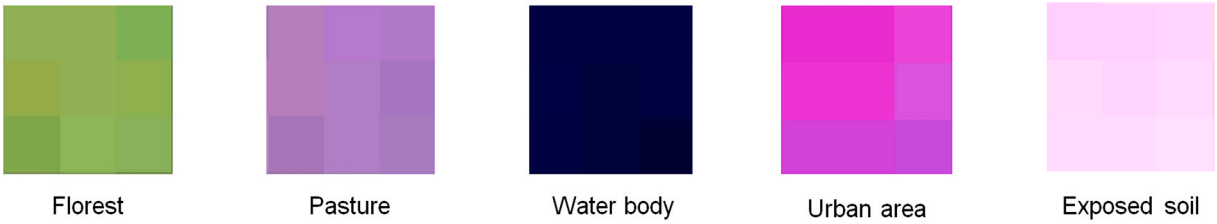

Fig. 3. Pixel patterns collected to compose the training and validation of land use land cover samples.

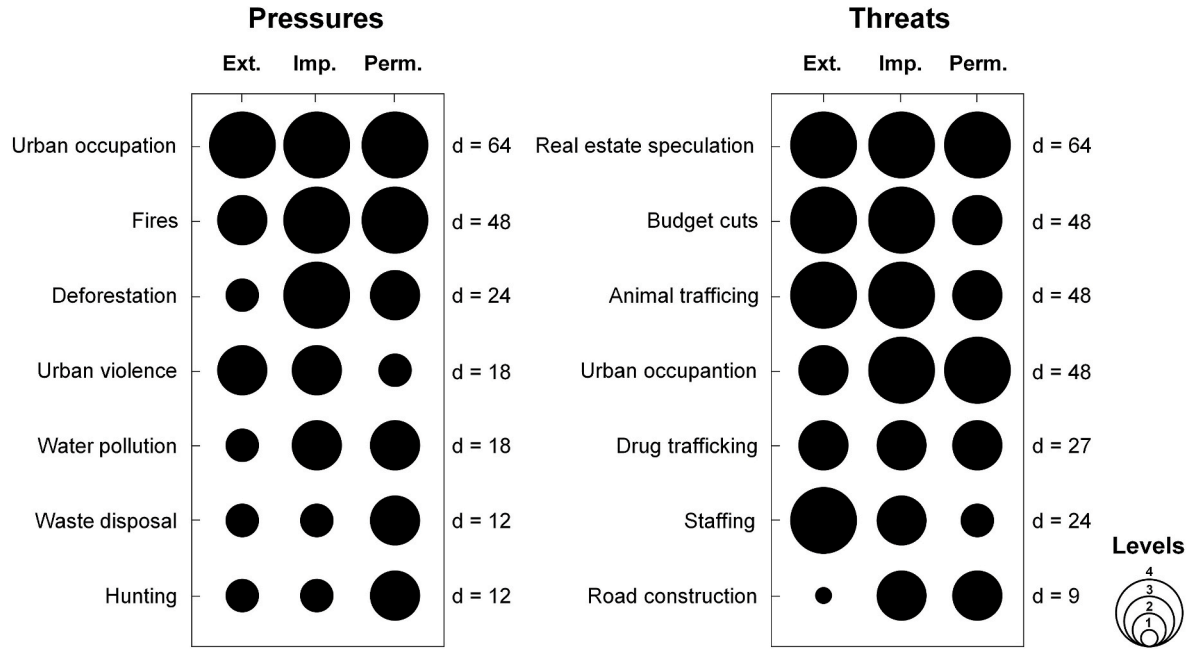

Fig. 4. Levels of pressures and threats related to Cunhambebe State Park, reported by stakeholders during the application of the RAPPAM method. Legend: Ext.: extent; Imp.: impact; Perm.: permanence; d: degree.

Threats as "budget cuts" and "reduction of staffing" revealed problems of origin from the state environmental agency (INEA), reaching, respectively, 48 and 24°. Other pressures and threats, such as "water pollution", "irregular waste disposal" and "road construction", reached lower degrees (see Fig. 4).

In the analysis of fire outbreaks for the studied period, it was possible to verify that the occurrences of these fires are coincident with areas that concentrate more agricultural activities, such as those of greater use for pasture, corroborating the information provided by stakeholders (Fig. 5).

The pressures and threats "deforestation" and "urban occupation" were verified by the monitoring of land use and land cover (Fig. 6). The Kappa index values obtained in the multitemporal analysis on the quality of the supervised classification for the years 1998, 2003, 2008, 2013 and 2018 were, respectively, 98%, 96%, 93%, 93% and 91%, considered satisfactory values (Landis and Koch, 1977). The dynamics of land use and land cover in percentage terms are presented in Fig. 7.

Considering the dynamics of land use and land cover over the 20 years of monitoring, the creation of the PEC in 2008 reduced deforestation rates from −48.3 ha/year (between 1998 and 2008) to −27.4 ha/year (between 2008 and 2018) in the PEC area. In the buffer zone, the same pattern was observed, with a reduction in deforestation rates from - 573.7 ha/year (between 1998 and 2008) to −358 ha/year (between 2008 and 2018). The creation of the PEC also reduced the rate of increase in pasture in the PEC area, which went from 38.1 ha/year (1998–2008) to 30.1 ha/year (2008–2018). However, in the buffer zone, the rate of areas converted to pasture increased from 373.1 ha/year (1998–2008) to 448.8 ha/year (2008–2018) (see Fig. 8).

Regarding the exposed soil class, before the creation of the PEC, it was observed an increase of this class both in the PEC area (an increase of 1.1 ha/year, between 1998 and 2008) and in the buffer zone (an increase of 19.5 ha/year, between 1998 and 2008). After the creation of the PEC, the exposed soil areas started to reduce at a rate of −10.6 ha/year (2008–2018) in the PEC area, and −230.3 ha/year in the buffer zone (2008–2018). Urban occupation, identified by the stakeholders as one of the main pressures and threats in the RAPPAM method, was observed in the multitemporal analysis. It is observed that in 2008, the year in which the PEC was created, there is a reduction in the urban area class in the PEC area. As of that year, the urban area increased at a rate of 5.7 ha/year (2008–2018). In the buffer zone, the pressure for urban areas increases even after the creation of the PEC, with rates of 92.6 ha/year (1998–2008) and 140.2 ha/year (2008–2018) (see Fig. 8). The areas of water bodies showed a reduction in the rates of increase after the creation of the PEC, probably related to the increase in demand. Inside the PEC area, rates went from 12.2 ha/year (1998–2008) to 1.5 ha/year (2008–2018), and in the buffer zone the rate went from 81.6 ha/year (1998–2008) to 0.8 ha/year (2008–2018).

3.2. Stakeholders' perception of biological importance, socio-economic importance, and vulnerability

Category II of the RAPPAM method indicates the perception of stakeholders about the context of the area. The modules "Biological importance" and "Socio-economic importance" obtained the highest

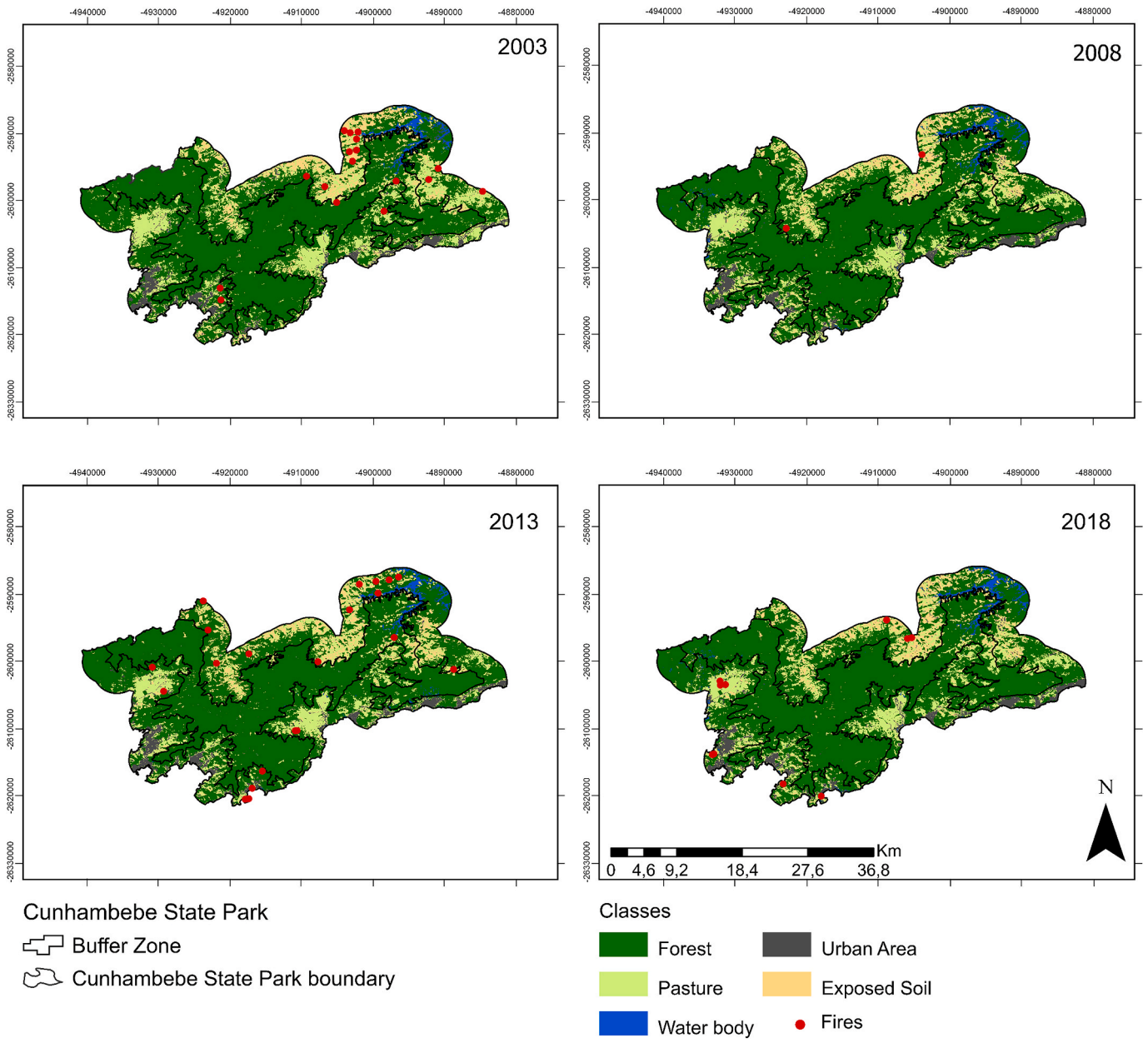

Fig. 5. Records of fires that occurred in the boundaries of Cunhambebe State Park and its Buffer Zone in 2003, 2008, 2013 and 2018.

values in the quantitative analysis (100.0% and 92.0%, respectively). The biological importance perceived by the stakeholders revealed the ecological value of the PEC, since the park plays a crucial role in the landscape, with rare or endangered species, and even high levels of endemism. For "Socio-economic importance", the stakeholders highlighted the recreational and scientific value that PEC presents. They also reinforced the need for more scientific research and the elaboration of a database containing all the information about the researches completed and/or those that are in progress in PEC. In relation to the "Vulnerability" indicators reached a level of 12.0%. Stakeholders highlighted the ease of access to illegal practices and the difficulty of monitoring the area. Also, they pointed conflicts between cultural practices in the region and the objectives of PEC, political pressure regarding decision-making and the difficulty of recruitment and retention of employees (staffing).

3.3. Management effectiveness

The average management effectiveness of PEC calculated based on categories III to VI of the RAPPAM method (planning, inputs, processes, and outputs) equivalent to 63.33% can be considered moderately satisfactory. (Table 4).

3.3.1. Planning

Category III achieved a low level of effectiveness (38.66%), highlighting a large discrepancy between the "Objectives" (84.0%) and the "Legal security" (32.0%) and "Site design and planning" modules (0.0%). Stakeholders consider that specific biodiversity-related objectives are clearly defined in the Management Plan, that management policies and plans are consistent with the PEC objectives, and that PEC employees and administrators understand the objectives and policy of the protection area. In terms of Legal security, stakeholders reported the occurrence of unsettled disputes regarding land tenure or use rights, and which consider that the boundary demarcation is inadequate to meet the

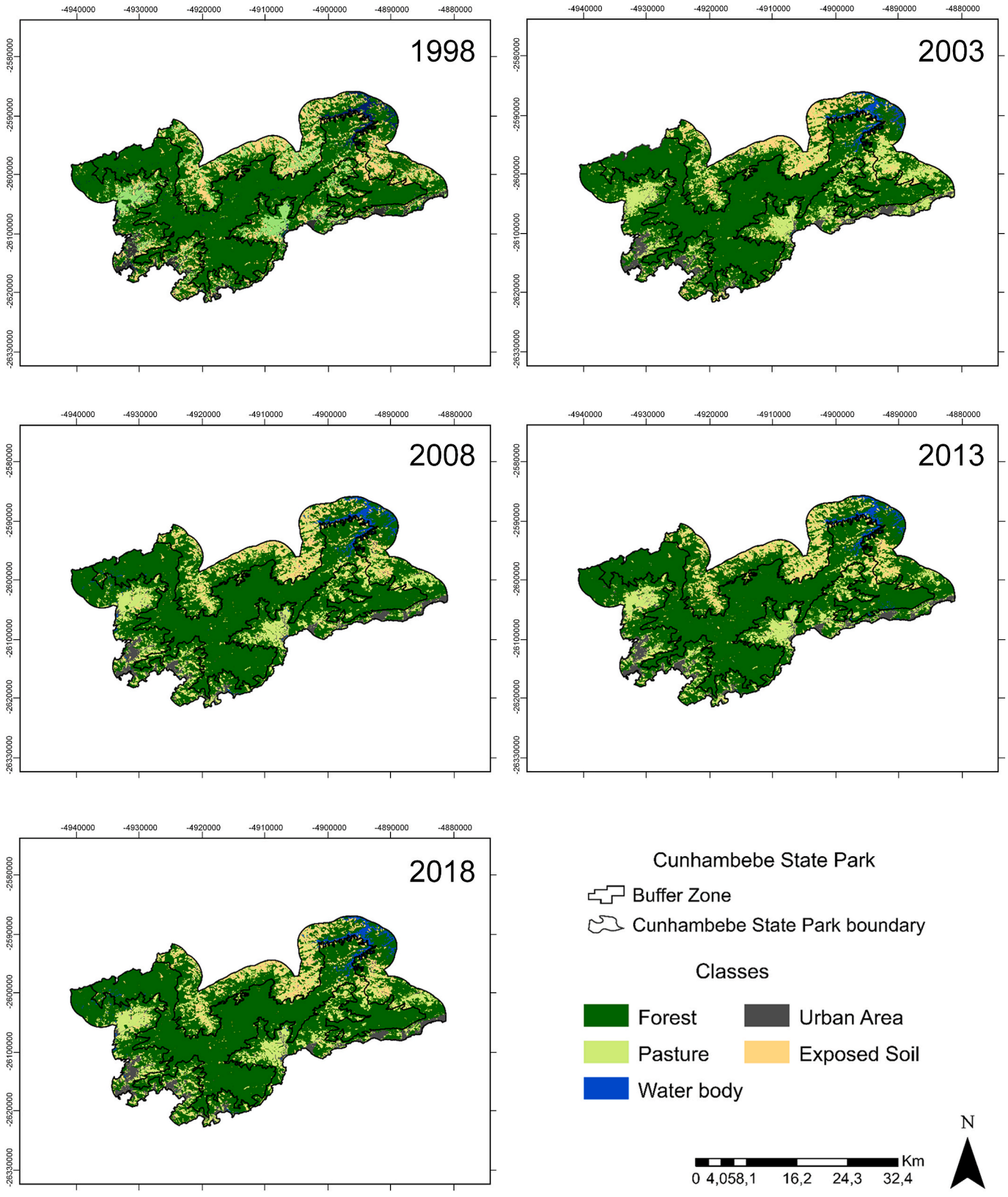

Fig. 6. Land use and land cover maps of Cunhambebe State Park and its Buffer Zone for the years 1998, 2003, 2008, 2013 and 2018.

PEC objectives. Also, they indicated that the staff and financial resources are inadequate to conduct critical law enforcement activities. In terms of site design and planning, all indicators received negative evaluations by stakeholders.

3.3.2. Inputs

Inputs include staff, communication, infrastructure, and finances achieving a moderate level (60.0%). In the "Staffing" module (72.0%), stakeholders indicated that staff members have adequate skills, receive

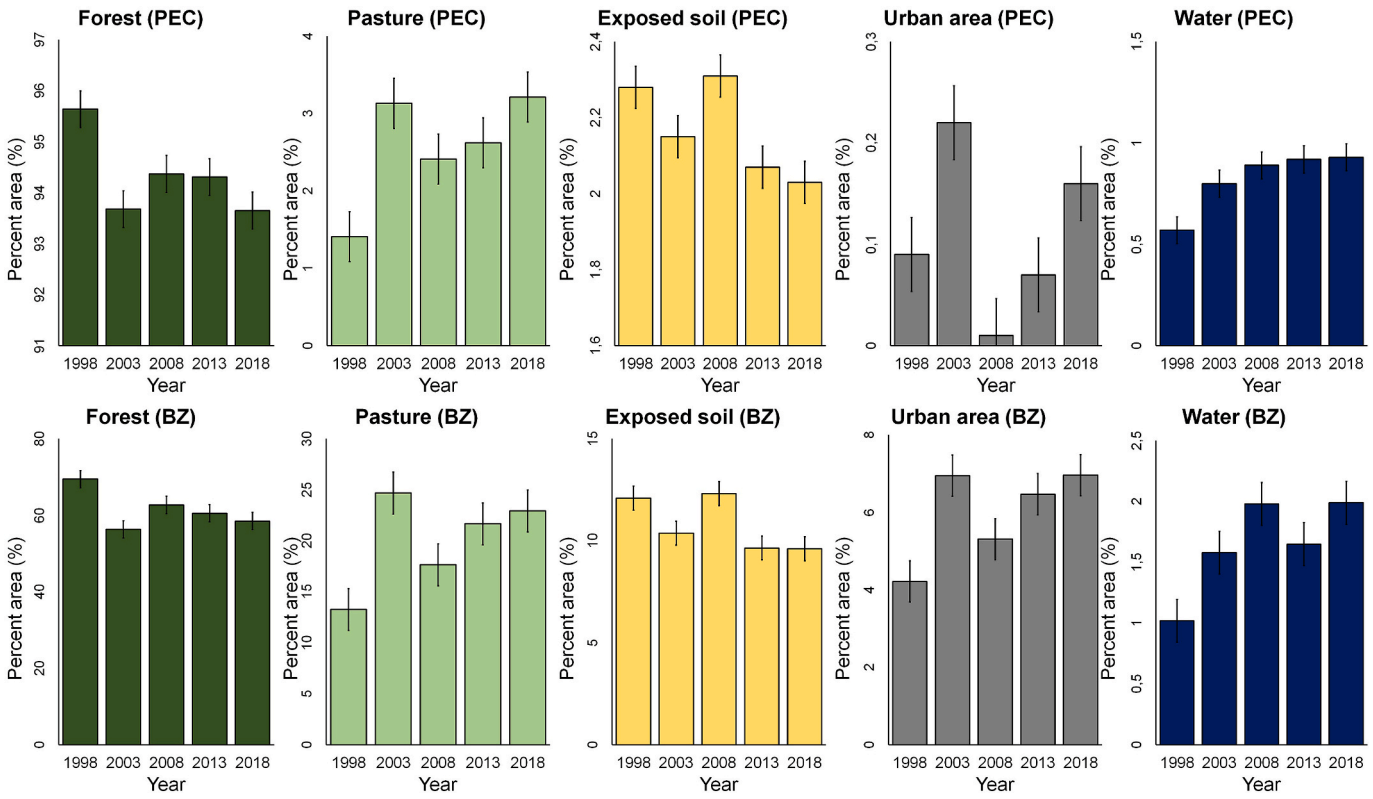

Fig. 7. Dynamics of land use and land cover in Cunhambebe State Park (PEC) and its Buffer Zone (BZ), from 1998 to 2018.

Fig. 8. Pasture and urban areas development in the Buffer Zone of PEC.

training appropriate and are periodically reviewed. On the other hand, the number of staffing is insufficient to effectively manage the area. According to the manager, more than 12 new employees would be needed, most of them for the position of park ranger. The "Communication and information" module (72.0%) was positively assessed for the appropriate means of communication between field and office staff, and

Table 4
Scores' evaluation for the management effectiveness of the PEC.

Management categories and modules	Effectiveness (%)
Planning	
Objectives	84,0
Legal security	32,0
Site design and planning	0,0
Average	38,6
Inputs	
Staffing	72,0
Communications and information	72,0
Infrastructure	72,0
Finances	24,0
Average	60,0
Process	
Planning	84,0
Decision-making	92,0
Research, monitoring and evaluation	84,0
Average	86,7
Outputs	
Management outputs	68,0
Average	68,0
Total average	63,3

systems for collecting and processing new data. In this module, the criticism was related to the absence of ecological and socioeconomic data in management planning.

The PEC infrastructure (72.0%) was considered adequate to visitor use, including ensure accessibility, and to perform management activities by the staff. Stakeholders also reported the lack of adequate transport infrastructure for performing management activities. The most critical situation in this category was related to the "Finances" module (24.0%). It was pointed out that financial management practices do not allow efficient and effective management and that the allocation of financial resources is not adequate to the priorities and objectives of the PEC. In addition, medium and long-term funding is inadequate, and the financial outlook is not stable.

3.3.3. Process

The category V reached the highest level (87.0%) between the categories of assessment of management effectiveness. In the "Planning" module (84.0%), stakeholders made observations about the Management Plan. They consider that the Management Plan is comprehensive, but it has not a practical approach to achieve management objectives. They also indicated the need for a review to improve the inventory of natural and cultural resources for planning. Despite this, the indicators on strategy for addressing PEC threats and pressures, and specific targets for achieving management objectives received high scores.

Regarding the "Decision making" module (92.0%) stakeholders stated that there is clear internal organization, with transparent management decision making and that the PEC staff collaborates regularly with partners. They also pointed out that the participation of local communities in the decision making could be greater. At last, in the module "Research, monitoring and evaluation" (84.0%) despite the high score, were indicated actions that can improve management effectiveness, such as more accurate monitoring of the impact of legal and illegal practices on the PEC and prioritization of critical research and monitoring.

3.3.4. Outputs

Management outputs are the specific products and services accomplished by protected area staff, volunteers, and community members. The "Management outputs" module (68.0%), highlighted some challenges for the management of the PEC: scores on "Land regularization" and "Site restoration and mitigation efforts" reached the lowest values. These are reflected financial resources, staffing, public policies, and efforts by the State of Rio de Janeiro. As positive evaluations, stakeholders clarified projects and actions for "Community outreach and education efforts", "Visitor and tourist management", and "Wildlife or habitat management".

3.4. Strengths, weaknesses, opportunities e threats (SWOT analysis)

Principal component analysis (PCA) provided interesting insight of SWOT framework. Principal component 1 (PC1) explained 57.96% of the total variance, and principal component 2 (PC2) explained 23.19%. Together they explained 81.15% of the variance in the original data (Fig. 9). Four groups were identified, separating the RAPPAM modules in strengths, weaknesses, opportunities, and threats (SWOT) according to the stakeholders' perceptions.

The "Communication and information", "Socio-economic importance", "Biological importance", "Decision-making" and "Objectives" modules are strengths in PEC management planning. These modules reached a level of effectiveness ranging from 72% to 100%. PCA shows that strength is directly related to indicators 1 and 5 in these modules. The "Planning", "Research, monitoring and evaluation", "Infrastructure", "Staff" and "Management outputs" modules are opportunities to improve PEC management effectiveness, reached levels of effectiveness between 68% and 84%, with indicators 2, 3 and 4 directly related. On the other hand, weakness is defined by the "Legal security" module (level 32% in effectiveness). And as threats to management effectiveness, are the modules "Site design and planning", "Vulnerability" and "Finances" (levels 0%–24%).

4. Discussion

4.1. Stakeholders' participation

Through participant observation, we observed that local stakeholders (e.g. representatives of local communities) were more engaged in decision-making. On the other hand, stakeholders from state or private organizations showed less interest in the activities of the Advisory Council. The social and physical distance, followed by the feeling of not belonging, may be one of the reasons for this difference in attitudes and behaviors (Kovács et al., 2015; Mathevet et al., 2016). For this, social learning involved in participatory management processes is increasingly becoming a normative goal for environmental management and policy-making (Reed et al., 2010). Exchanging information between the stakeholders is a way to improve management, and this information should then reach the broader public through social interaction and processes (Shackleton et al., 2019). Therefore, there are social and political issues associated on stakeholder preferences and participation, especially those related to the centralized management model used to PEC from the INEA. (Bockstael et al., 2016).

4.2. Setting the linkages between RAPPAM method and multi-temporal analysis

Linking the results of the RAPPAM method with the monitoring of land use and land cover, we realized that the perception of stakeholders was efficient in indicating the scope, severity, prevalence, and distribution of a variety of threats and pressures. According to the perception of stakeholders, the main pressure (urban occupation) is linked to the main threat (real estate speculation). Multitemporal analysis indicated an increase in the urban area within the PEC area and in the buffer zone. Data from the 2010 Demographic Census, realized by Brazilian Institute of Geography and Statistics (IBGE), show that the Costa Verde Region (region where PEC is inserted) had the second highest population growth in the state of Rio de Janeiro, with an increase in population of more than 90%, when compared data from the 1991 and 2010 Census (Dominguez and Coelho, 2013). This result associated with the lack of monitoring of the PEC, also indicated by the stakeholders, may explain the increase in urban areas, even within the PEC area.

The increase in urban area also brought problems related to security.

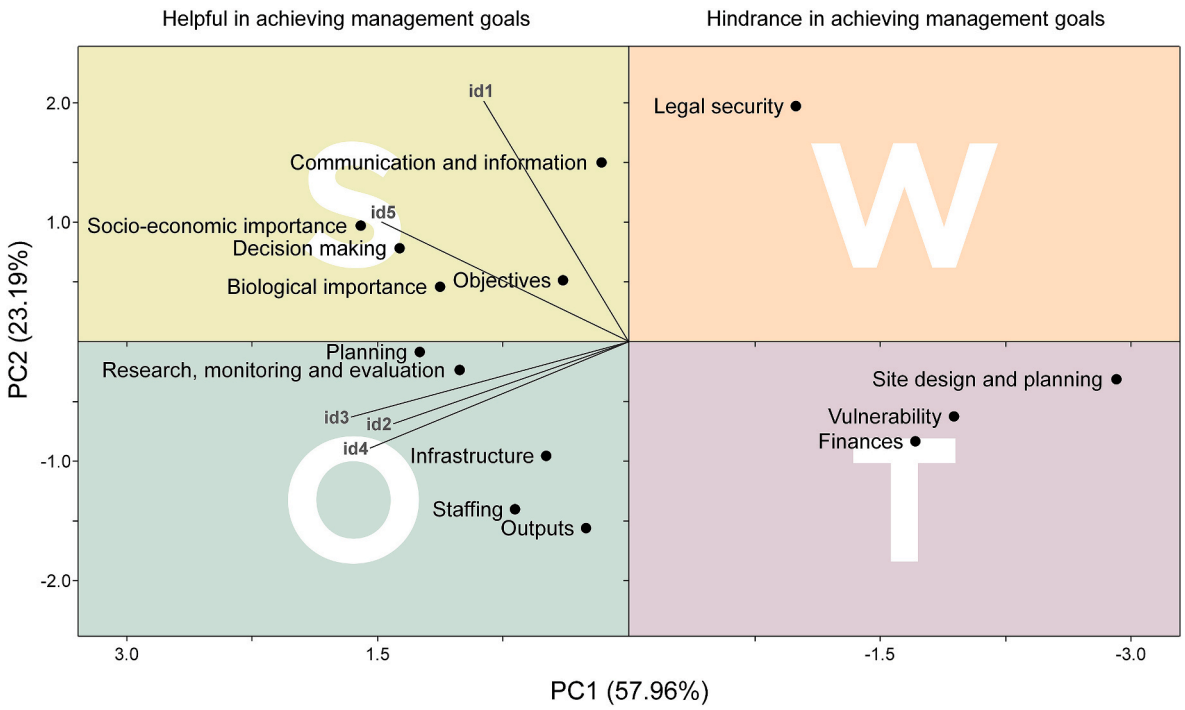

Fig. 9. Principal compenent analysis of distribution of streghts, weakness, opportunities and threats by SWOT analysis from the RAPPAM modules.

Direct consequences of this problem are perceived on the illegal practices in PEC (traffic of wild animals, drug trafficking, urban violence, fires, hunting), due to the difficulty of inspection. In the Vulnerability module, indicators revealed the ease of access for illegal practices associated with the difficulty of monitoring has made the PEC a vulnerable protected area. In this context, stakeholders justified their views by reporting examples of problems in PEC areas dominated by drug dealers and conflicts between *milícias* (paramilitary groups formed by active and retired policemen), trafficking and the armed forces of the State. The conditions of insecurity and difficulty for monitoring due to armed conflicts may generate losses of biodiversity and provision of ecosystem services, as pointed out in the study by Grima and Singh (2019).

Through the multitemporal analysis we also observed that there is a link between the occurrence of fires and deforestation (indicated by the stakeholders as serious pressures) with the land use for pasture. Throughout the evaluated period, while that forest areas are reduced (increased deforestation), there is an increase in areas used for pasture (Fig. 7). In the analysis of fire outbreaks, the occurrences of these fires are coincident with areas used for pasture (see Figs. 5 and 6). Stakeholders reported that one of the main reasons for the occurrence of fire outbreaks is the use of fire to "improve the soil quality" for pasture. This cultural practice was presented as quite common among those rural landowners who have livestock as an important source of income for their agricultural activities. It was pointed out by the stakeholders that the main responsible for the occurrence of fire outbreaks are the ranchers, who insist on making use of this cultural practice in the management of the pasture areas. As this practice is carried out in an uncontrolled manner, it can result in fires in forest areas, contributing to deforestation.

This set of factors (deforestation, conversion into pastures, and recurrent fires) indicated by the perception of the stakeholders and verified in the multitemporal analysis in the PEC, have been occurring in the Brazilian Atlantic forest for at least two hundred years (Joly et al., 2014; Scarano and Ceotto, 2015). Previous studies have demonstrated that there is a massive presence of anthropogenic pastures in this biome (Strassburg et al., 2014) with a long history of land use and degradation that led to increased fire frequencies (Sansevero et al., 2020). In field observations in the PEC area and in the buffer zone, we also observe the occurrence of areas with degraded and abandoned pastures, a widespread pattern of land use in the Brazilian Atlantic Forest (Strassburg et al., 2014; Alves-Pinto et al., 2017). These transformations lead to biodiversity losses, drastic changes in community structure and ecosystem functioning, and, consequently, affect the provision of important ecosystem services (Shimamoto et al., 2018; Sansevero et al., 2020).

The State Secretariat for the Environment (SEA) and the State Secretariat for Health and Civil Defense (SESDEC) instituted the "Plan for the Prevention and Control of Forest Fires in the State of Rio de Janeiro", aiming at reduction of damage to the natural environment, especially in protected areas such as parks. The Integrated Forest Fire Management Center is responsible for coordinating emergency actions in the event of critical forest fires and short, medium, and long-term preventive actions (INEA, 2015). During the participatory workshop, stakeholders also highlighted the need to promote projects with possible alternatives to management land for local communities in the PEC buffer zone. They highlighted the importance of conservation agriculture systems, such as the agroforestry system.

4.3. Specific issues in the RAPPAM method

The high levels of effectiveness in the modules of biological and socio-economic importance expressed the perception of stakeholders about the ecosystem services provided by the PEC, in summary, related with provisioning and regulating services. Stakeholders also highlighted the recreational/educational value of the PEC, related to cultural ecosystem services. This offers a great potential for fostering sustainable landscape management, for example, by raising awareness about this ecosystem services and their relevance for human well-being in environmental education and land management (Plieninger et al., 2015).

Management effectiveness (63.33%) covers and summarize the stakeholder's perception for Planning, Inputs, Processes, and Outputs. The low level of effectiveness in the Planning category (III) reveals management failures related to conflicts between activities of local

communities and the objectives of the PEC. Stakeholders expressed high criticism about the site design and planning. There was a lack of coherence between the PEC category (full protection) and its location or limits, since the stakeholders highlighted problems related to the adequacy of PEC zoning and land use in the buffer zone. For example, the overlap with a rural settlement “Fazenda Rubião", which has 27.0% of its area overlapped with PEC. There are also overlaps with Traditional Communities (Quilombo Community do Alto da Serra and Indigenous Land Guarany de Bracuhy) in buffer zone.

The establishment of a protected area can reduce the resources of local communities and limit development opportunities (He et al., 2012). The PEC Management Plan recommends that a term of commitment be signed between INEA and small landowners, in order to mitigate the conflict generated by the creation of PEC and land use (INEA, 2015). However, stakeholders reported a difficulty between the PEC manager and small landowners, resulting in conflicts and occurrences of inspection by park rangers. In addition, the lack of financial resources indicated by stakeholders in the category IV (inputs) also contributes to conflicts of land regularization. The land regularization is one of the greatest obstacles to the management of Brazilian parks (Fontoura, 2014). So, the development of alternative, small-scale livelihood projects can contribute to reducing land use conflicts with surrounding landowners and improve management effectiveness (Vuohelainen et al., 2012).

Regarding the categories of Process (V) and Outputs (VI), most management processes and outputs are consistent and adequate for achieving the PEC objectives. The high levels of modules in these categories demonstrated the engagement of civil society and stakeholders in the management planning and decision-making on PEC. There is a consensus that protected areas have limited prospects without the cooperation and support of local people, especially in developing countries (Wells and McShane, 2004). Protected areas management should attempt to engage stakeholders more deeply in explicitly defining the objectives of project interventions, in monitoring progress, in learning from experience, and in systematically documenting and disseminating findings (Wells and McShane, 2004).

4.4. Dealing with SWOT analysis

The SWOT analysis based on PCA considering all indicators analyzed showed that there was a clear distinction between RAPPAM modules (Fig. 9), where the modules that helpful in achieving management goals have positive values of PC1, in contrast to the modules that hindrance in achieving management goals, with negatives values. This separation identified key management priorities and warning spots to support strategic planning actions that can improve PEC management effectiveness. The most severe threats to management effectiveness are related to site design and planning. Most of them, about unsettled disputes regarding land tenure or use rights. In addition, the area has a high vulnerability for illegal activities, and staff and financial resources are inadequate and of the area to conduct critical law enforcement activities (Legal security).

The Brazilian cultural and political heritage, the historical record of the state environmental agencies that manage the protected areas, and the complexity of the land problem are determining factors of obstacles to the processes of regularization of land use and ownership (Rocha et al., 2010). To resolve these questions, diverse alternative legal and administrative instruments must be deployed to regularize land issues and, therefore, make management actions for conserving the PEC more effective. We can assume that an adaptation of the Master Plans of the municipalities in which the PEC is inserted for greater integration with the PEC Management Plan would be a strategy to initiate better ordering of land use and reduce conflicts. Only one of the municipalities mentioned PEC in its Master Plan, although in a generic way. If there is no prioritization of environmental sustainability in the guidelines of these plans, conservation and conflict management strategies are likely to be ineffective since the condition of ecosystems within PAs will probably be an indirect result of management actions to mitigate pressures and threats (Cook et al., 2014).

In this study, SWOT analysis identified the threats and weaknesses that should be the priorities to support the subsequent phases of correcting management actions. Similar to the study of Comino and Ferretti (2016), the innovative value of this research stems not only from the integrated methodological approach based on the combination between spatial analysis, indicators systems and the traditional SWOT analysis, but also from the contextual characteristics and physical extension of the area under investigation. Moreover, the integrated and innovative framework proposed in this paper has also international significance, thanks to the possibility of replicating the research strategy and methodological approach in other contexts. In addition, different segments of government and civil society can benefit from our results since the development of an action plan must include priority recommendations, identify agencies or departments responsible for implementing the changes and ensure that financial, technical, administrative and political support is sufficient to make these changes (Ervin, 2003).

5. Regard attention: brazilian environmental management calls for help!

In Brazil’s current scenario, it is extremely important to point out the socio-political issues by a participatory approach that involves the management of PA and its conflicts. For example, national parks are at risk with pending legislation is approved (Ruaro et al., 2020). The administration of President Jair Bolsonaro is dismantling the country’s social-environmental policies, jeopardizing the governance of globally important ecosystem services (Escobar, 2019; Levis et al., 2020). The reduction in financial resources allocated to the two federal environmental agencies, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and the Chico Mendes Institute for Biodiversity Conservation (ICMBio), show the risks for nature and people (Oliveira and Araújo, 2020).

According to Geldmann (2015), when funding and resources are directed to sites under greater threat, they have a greater impact, potentially including the reduction of biodiversity loss. Our reality of vulnerability of legal instruments and financial resources for the maintenance and management of PA (not exclusive to national PA) requires that scientists seek to better integrate their investigations into the reality of socio-environmental problems. According to Levis et al. (2020) the global consequences of the newly degraded governance system in Brazil imply that all stakeholders share a common interest: making Brazil’s ecosystems resilient. Scientific efforts can help boost participatory governance against government attitudes (Levis et al., 2020). Thus, our case study supports social participation and improves data quality and understanding by stakeholders and decision-makers.

6. Conclusion

Our study generates insights that can support decision-making by PEC managers, local stakeholders, and researchers, also contribute to the international debate on forest conservation projects based on sustainable land use and participatory approaches. Overall, the perception of management effectiveness reveals the need for investments in projects that improve the adequacy of land use in the buffer zone. Additionally, fundraising should be strategically designed according to management goals. Such a strategy should not only be designed for better land use in the buffer zone, but also to improve monitoring, enforcement power, and recruitment of skilled staff. Our findings emphasize that the highest pressures and threats are represented by the advance of pasture areas and urban occupation, as perceived by stakeholders.

Most of the conservation measures proposed by stakeholders (e. g. conservationist agricultural systems) face difficulties in their implementation. In order to facilitate the implementation of these measures,

we provide evidence of actions that must be performed by the PEC management team, in accordance with the Management Plan ("Integration with the AP region", "Environmental protection" and "Operationalization"). Moreover, these actions must consider the threats and weaknesses presented by the SWOT analysis. We also recommend political and management measures:

- Political measures: 1) The State of Rio de Janeiro needs to guarantee financial resources for the land regularization of areas overlapping with the PEC in order to reduce conflicts over land use, and 2) the governments of municipalities that cover PEC limits must include guidelines in reference to the area of PEC in the Master Plans for the sustainable integration between urban development and PEC.
- Management measures: 1) The INEA needs to provide technical assistance to landowners for improve land management (e. g. workshops and training for agroforestry production systems) and 2) strengthen environmental education initiatives at all school levels to increase awareness of PEC among local communities. Among other guidelines, our proposals for the municipal education plan are class days outdoors in PEC, annual seminars about PEC, and practical studies about the ecosystem services and landscapes of PEC.

Declaration of competing interest

This research was approved by the Committee for Ethics in Research on Human Beings of the Federal Rural University of Rio de Janeiro (Protocol No. 1042/17) and was licensed by the State Environmental Institute of Rio de Janeiro (Protocol No. 006/2018). In this study, all authors contributed to the its conception and design. Material preparation, data collection and analysis were performed by Marcondes Geraldo Coelho Junior, Eduardo Carvalho da Silva Neto, Barbara Pavani Biju, Athila Leandro de Oliveira and Ana Alice de Oliveira Tavares. The first draft of the manuscript was written by Marcondes Geraldo Coelho Junior. Vanessa Basso, Ana Turetta, Acacio de Carvalho and Jerônimo Sansevero contributed to the critical review of the results and the manuscript. Also, all authors commented on previous versions of the manuscript, and all authors read and approved the final manuscript. This manuscript has not been submitted to any other journal or any other systems of publication. We have read and understood your journal's policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

CRediT authorship contribution statement

Marcondes Geraldo Coelho Junior: Conceptualization, Methodology, Funding acquisition, Data curation, Investigation, Formal analysis, Writing - original draft. **Bárbara Pavani Biju:** Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Software. **Eduardo Carvalho da Silva Neto:** Data curation, Formal analysis. **Athila Leandro de Oliveira:** Data curation, Formal analysis. **Ana Alice de Oliveira Tavares:** Data curation, Formal analysis. **Vanessa Maria Basso:** Project administration, Data curation, Formal analysis, Validation, Writing - review & editing. **Ana Paula Dias Turetta:** Data curation, Formal analysis, Validation, Writing - review & editing. **Acacio Geraldo de Carvalho:** Data curation, Formal analysis, Supervision, Validation, Writing - review & editing. **Jerônimo Boelsums Barreto Sansevero:** Data curation, Formal analysis, Validation, Writing - review & editing.

Acknowledgements

The authors would like to thank the stakeholders of Advisory Council and the Instituto Estadual do Ambiente do Rio de Janeiro, the Graduate Program in Environmental and Forest Sciences at Federal Rural University of Rio de Janeiro, and the Doctoral Program in Environmental Engineering of the University of Porto. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. J.S thank CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for the productivity grant (Bolsas de Produtividade em Pesquisa – PQ).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2020.111083.

Extent is related to the extent of the impact of the activity. Impact refers to the level at which the pressure/threat affects, directly or indirectly. Permanence is the time required for the affected resource to recover with or without anthropic intervention. The degree is the product of the three criteria evaluated. Source: Adapted from Ervin (2003).

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