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Land use and occupation in conservation units in semi-arid

Thais Sousa Menezes Teixeira[1*], Gabriela Macêdo Aretakis de Almeida[2], Rejane Magalhães de Mendonça Pimentel[3]

[1] Programa de Pós-Graduação em Desenvolvimento e Meio Ambiente, Centro de Filosofia e Ciências Humanas, Universidade Federal de Pernambuco, Recife, Pernambuco, Brasil. 50740-570. *Autor correspondente: thais.teixeira@ufpe.br. [2] Universidade do Estado da Bahia, Departamento de Tecnologia e Ciências Sociais, Juazeiro, Bahia, Brasil. 48904-711. gabiaretakis@gmail.com. [3] Universidade Federal Rural de Pernambuco, Departamento de Biologia, Rua Manoel de Medeiros, S/N, Dois Irmãos, Recife, Pernambuco, Brasil. 52171-900. rejane.pimentel@ufrpe.br.

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R E S U M O

O mapeamento do uso e da cobertura da terra, combinado com o sensoriamento remoto e a modelagem ambiental, permite o monitoramento preciso das mudanças ambientais e de suas implicações para o clima, a hidrologia e os ecossistemas. Transformações recentes na cobertura vegetal no Brasil afetaram os biomas e as interações superfície-atmosfera, exigindo o uso de novos modelos hidrológicos, como o SUPer, especificamente adaptados às condições semiáridas. Nesse contexto, o estudo avaliou as mudanças no uso e na ocupação da terra em Unidades de Conservação em condições semiáridas no Brasil, a fim de subsidiar estratégias eficazes de conservação e gestão ambiental. Dados do MapBiomas (1985-2023) e modelos hidrológicos da plataforma SUPer foram combinados, utilizando Análise de Componentes Principais (ACP) para avaliar 20 variáveis ambientais na Sub-bacia 69. Observou-se uma redução significativa da vegetação natural, especialmente em formações de savana e floresta, devido à expansão de áreas agrícolas, de pastagens e urbanas. As variáveis com maior influência no uso da terra foram a precipitação total e a evapotranspiração potencial. Os impactos socioambientais associados a atividades antrópicas, como a agricultura extensiva, a pecuária e a instalação de parques eólicos, também foram identificados. Essas pressões ameaçam a integridade ecológica da região, afetando a biodiversidade, a biomassa vegetal e a disponibilidade hídrica. Conclui-se que a conservação efetiva do Mosaico do Boqueirão da Onça (MBO) requer planejamento integrado, monitoramento contínuo e ações para o uso sustentável dos recursos naturais, com a participação das comunidades locais e a implementação de políticas públicas adequadas. O aporte técnico e científico tem-se mostrado relevante para a gestão ambiental de áreas protegidas em regiões semiáridas.
Palavras-chave: Sistema de Unidades de Resposta Hidrológica de Pernambuco; Mosaico Boqueirão da Onça; Análise de Componentes Principais.

Land use and occupation in conservation units in semi-arid

A B S T R A C T

Land use and land cover mapping, combined with remote sensing and environmental modeling, enables precise monitoring of environmental changes and their implications for climate, hydrology, and ecosystems. Recent transformations in vegetation cover in Brazil have affected biomes and surface-atmosphere interactions, requiring the use of new hydrological models, such as SUPer, specifically adapted to semiarid conditions. In this context, the study aimed to evaluate changes in land use and occupation within Conservation Units in Brazil's semiarid region to support effective conservation and environmental management strategies. Data from MapBiomas (1985-2023) and hydrological models from the SUPer platform were combined, using Principal Component Analysis (PCA) to evaluate 20 environmental variables in Sub-basin 69. A significant reduction in natural vegetation was observed, especially in savannah and forest formations, with the expansion of agricultural areas, pastures, and urban areas. The variables with the greatest influence on land use were total precipitation and potential evapotranspiration. Socio-environmental impacts associated with anthropogenic activities, such as extensive agriculture, livestock farming, and the installation of wind farms, were also identified. These pressures threaten the ecological integrity of the region, affecting biodiversity, plant biomass, and water availability. The conclusion is that effective conservation of the Boqueirão da Onça Mosaic (MBO) requires integrated planning, continuous monitoring, and actions aimed at the sustainable use of natural resources, with the participation of local communities and the implementation of public policies. Technical and scientific input has proven relevant for the environmental management of protected areas in semiarid regions.
Keywords: Hydrological Response Unit System for Pernambuco; Boqueirão da Onça Mosaic; Principal Component Analysis.

Introduction

Global population growth, coupled with rising consumption patterns, has led to increased energy demand, heightened pressure on natural resources, and highlighted the need to transition to a more diversified and environmentally sustainable energy matrix. Energy generation and consumption are intrinsically linked to significant environmental impacts and to the exploitation of finite fossil resources, thereby reinforcing the urgency of adopting integrated energy-efficiency and source-diversification measures (Cruz et al., 2023).

In this context, systematic mapping of land use and land cover constitutes a strategic tool for territorial management and biodiversity conservation, providing essential support for public policy formulation and the planning of mitigation and adaptation measures. Spatial and temporal monitoring allows us to identify areas under anthropogenic pressure and assess dynamics that affect the integrity of natural landscapes and Conservation Units (CUs) (Marques et al., 2017).

In Brazil, although the electricity matrix has a high share of renewable sources, the predominance of large hydroelectric projects has significant socio-environmental implications (Ferreira et al., 2024). Furthermore, dependence on rainfall patterns makes these systems vulnerable to climate change, compromising hydrological predictability and water security (Galbiatti-Silveira, 2018). Conversely, the rapid expansion of alternative renewable sources, especially wind energy, has occurred in ecologically important areas; the Caatinga biome accounts for over 90% of national wind generation, owing to favorable climatic and geomorphological conditions (Neri et al., 2019; ABEEólica, 2022).

Although wind farms are considered relatively sustainable from an emissions perspective, their implementation and operation affect the landscape and biodiversity. There is evidence of changes in migration patterns and the composition of bird communities (Cabrera-Cruz et al., 2020; Falavigna et al., 2020), increased bat mortality (Valença e Bernard, 2015), and potential changes in the distribution and behavior of large mammals due to habitat loss and increased anthropogenic disturbance (Esteves e Campos, 2022). Furthermore, less-documented impacts, such as microclimatic changes and structural responses of vegetation adjacent to the projects, have been highlighted in recent literature (Kaffine, 2019; Liu, Li, & Wang, 2022).

Focusing on investigating these dynamics, remote sensing tools and land-cover time series, such as those provided by MapBiomas, have proven essential for enabling large-scale annual analyses of land use and land cover. Traditional hydrological models, notably SWAT, are often used to simulate processes in watersheds; however, they have limitations when applied to semiarid environments due to the complexity of intermittent flows, the non-continuous infiltration and recharge processes, and the high rainfall variability characteristic of the Caatinga.

In this scenario, the SUPer (Hydrological Response Unit System for Pernambuco) model emerges as the most appropriate alternative for semiarid regions, as it incorporates procedures and parameterizations that better represent local hydrological processes and enables scenario assessments at the Sub-basin scale. Despite its potential, applications of SUPer, in conjunction with multivariate techniques, to quantify and prioritize the determinants of land-use and land-cover changes in Conservation Units of the Caatinga biome remain scarce.

This study focuses on the Boqueirão da Onça Mosaic (MBO), located in northern Bahia state, which consists of an Environmental Protection Area (APA), a National Park (PARNA), and a Wildlife Zone (ZVS), all created in 2018. These units, despite their recent development, face multiple pressures, including traditional hunting and logging practices and the expansion of wind farms exploiting the region's mountain ranges. These pressures make it urgent to produce scientific knowledge to inform the management and management plans of the MBO Conservation Units.

The literature lacks studies that integrate hydrological modeling adapted to the semiarid region (e.g., SUPer) with multivariate analysis (e.g., Principal Component Analysis - PCA) to identify and quantify the predominant environmental and anthropogenic drivers of land-use and land-cover changes, specifically in Conservation Units of the Caatinga biome. This study aims to fill this gap by providing empirical evidence that can guide conservation and territorial planning decisions in the MBO.

In this context, the main objective of this study was to identify and quantify the key climatic and anthropogenic drivers of land-use and land-cover change in the Boqueirão da Onça Mosaic, using an integrated approach that combines MapBiomas time series, SUPer hydrological modeling, and multivariate analysis (PCA).

Methods

Characterization of the study area

The study was conducted in the Boqueirão da Onça Mosaic (MBO) of Conservation Units (Environmental Preservation Area - APA, National Park - PARNA, and Wildlife Zone - ZVS), established by Decrees No. 9,336 and 9,337, April 5, 2018. Boqueirão da Onça is a mosaic of conservation units, covering almost 900,000 hectares. The APA encompasses 505,692.00 ha, and the PARNA comprises 346,908.10 ha. This area includes the Wildlife Zone (ZVS), which contains Toca da Boa Vista, located in Campo Formoso, Bahia; it is considered the largest cave in the Southern Hemisphere, with more than 114 km of mapped galleries (Auler & Smart, 2004).

The Boqueirão da Onça Conservation Units are situated in the São Francisco River basin, highlighting karst formations and paleontological and archaeological sites. The mosaic is in northern Bahia, within a dry tropical forest known as the "Caatinga", which is the native vegetation of the semiarid region of Northeast Brazil (Figure 1).

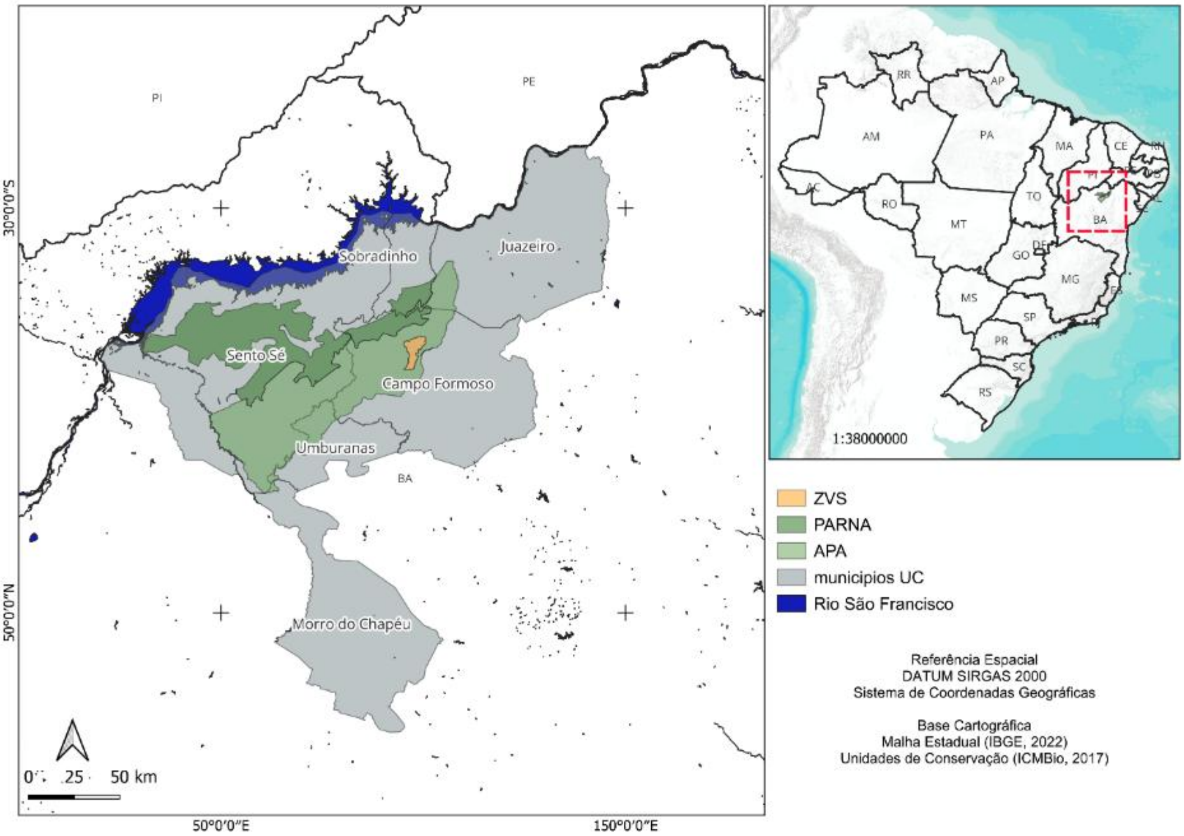


Figure 1. Location of the Boqueirão da Onça Mosaic (MBO), state of Bahia, Brazil.

The climate is classified as BSh by Köppen (1918), which ranges from semiarid to arid, with dry periods from May to October and rainy periods from November to April (Marengo et al., 2011). Average annual temperatures range from 23°C to 27°C. The rainfall regime is characterized by scarcity, exhibiting marked spatiotemporal irregularity and prolonged dry periods, during which most precipitation occurs in three months, with an annual average of less than 800 mm (Marengo & Bernasconi, 2015).

The Boqueirão da Onça Conservation Units are situated in the São Francisco River Basin (Moura, 2021), the third-largest basin in Brazil, spanning approximately 639,219 km² and supporting a diverse range of economic activities. Environmental and hydrological conditions in this region are influenced by both human activities, including agriculture, and climatic factors (Fernandes et al., 2021).

The Caatinga vegetation does not have a single physiognomy throughout its extent; it is quite diverse, with the following standing out: shrubby caatinga, arboreal caatinga, cerrado stricto sensu, rocky fields, riparian forests, and anthropized areas (Giulietti et al., 2004). The study area includes savanna, steppe savanna, and contact areas (Figure 2). The soils are predominantly Neosols, characterized as shallow, young, and nutrient-poor (Santos et al., 2018). The region has a significant speleological, paleontological, archaeological, faunal, and floristic heritage (Freitas et al., 2020).

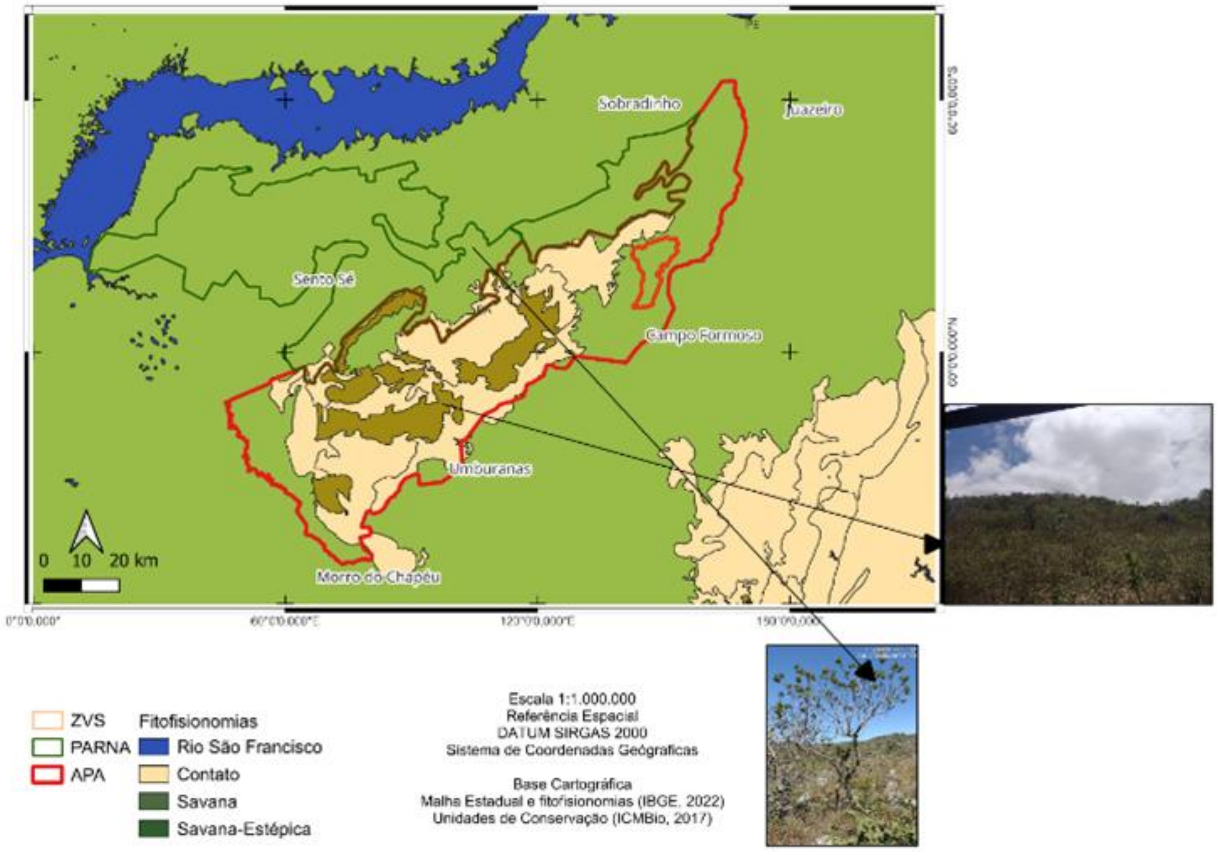


Figure 2. Phytogeographic regions of the Boqueirão da Onça Conservation Units, in the state of Bahia, Brazil.

Geospatial data

Geospatial land use and land cover data were extracted from the MapBiomas Project Brazil (MapBiomas Project Brazil, 2022) using images from collection 9 for 1985 and 2023. Considering each of the maps extracted from Mapbiomas, a section was created for Conservation Units using QGIS. After this, the Zonal Histogram tool was used to calculate the number of pixels for each use for the two years analyzed. Then, absolute and percentage variation analyses were performed in Excel.

In representing the current situation, secondary data were collected for the physical and biological characterization of the study area, from public databases, the Brazilian Institute of Geography and Statistics (IBGE), the Chico Mendes Institute of Biodiversity (ICMbio), and the Institute of Environment and Water Resources of Bahia (INEMA).

Land Use and Occupation Data

Land use and occupation data were obtained through the SUPer platform, an interactive hydrological and water quality modeling system that utilizes the Soil and Water Assessment Tool (SWAT). The system provides an interactive web interface with secondary base maps, from which input data (Tibúrcio et al., 2023) and output data (tables, graphs, and maps) are generated. This study used input commands to model land use and occupation in the Conservation Units selected for the study (Table 1).

Table 1. Input commands for modeling in the SUPer platform (Hydrological Response Unit System for Pernambuco), to characterize land use and occupation in Conservation Units in the semi-arid region of Brazil.

Parameter	Information
Scenario name	Real situation / São Francisco - 084 (2)
Climate data	Standard
Start of modeling	01/04/1961

End of modeling	31/03/2021
Time series	58 years
Model warm-up	2 years
Frequency for output data	Diary
Model version	SWAT 2012 rev. 664

Hydrologic Response Units (HRUs) are SUPer's output units used to generate scenarios that inform land use and occupation. The São Francisco River basin comprises 352 subbasins and 5,836 HRUs. HRUs are areas with similar land use, relief, and soil properties, representing the model's fundamental calculation unit.

In this study, for model application, 20 variables were preselected (Table 2) for Sub-basin 69, which is entirely located within the Boqueirão da Onça Environmental Protection Area (Figure 3). This Sub-basin comprises 13 HRUs; however, only four land uses associated with the lowest slope class (0–2) were considered, since such areas are assumed to be more susceptible to anthropogenic occupation due to their ease of use and accessibility (Table 3). This assumption is supported by geomorphological studies showing that flat landforms - such as plateaus and colluvial ramps - are predominantly used for agriculture and pasture (Oliveira, 2021).

Table 2. Pre-selected variables for the Sub-basin 69 contained in the Boqueirão da Onça Environmental Protection Area (APA).

	SUPer Legend	**Variable**
1	PRECIP	Total precipitation in the HRU (mm H2O)
2	PET	Potential evapotranspiration (mm H2O)
3	ET	Amount of water removed by evapotranspiration (mm H2O)
4	SW_INIT	Soil water content at the beginning of the time period (mm H2O)
5	SW_END	Soil water content at the end of the time period (mm H2O)
6	PERC	Amount of water that percolates out of the root zone (mm H2O)
7	DA_RCHG	Amount of water entering the deep aquifer from the root zone (mm H2O)
8	REVAP	Water in a shallow aquifer returning to the root zone (mm H2O)
9	SURQ_GEN	Surface runoff generated during the interval of time (mm H2O)
10	SURQ_CNT	Contribution of surface runoff to the reach (mm H2O)
11	TLOSS	Amount of water removed from tributary channels by transmission (mm H2O)
12	LATQGEN	Contribution of lateral flow to achieve (mm H2O)
13	TMP_AV	Average air temperature for the time period (°C)
14	TMP_MX	Average daily maximum air temperatures for the time (°C)
15	TMP_MN	Average daily minimum air temperatures for the time (°C)
16	CSOL_TMP	Average soil temperature over time (°C)
17	CSOLAR	Average daily solar radiation by period (MJ/m2)
18	TMP_STRS	Number of days of temperature stress
19	BIOM	Total plant biomass (metric tons/ha)
20	IAF	Leaf area index

Table 3. Hydrologic Response Units (HRUs) of Sub-basin 69, which is entirely located within the Boqueirão da Onça Environmental Protection Area.

HRU	**Land use**	**Soil**	**Slope class**		**Slope**	**Slope length**	**Area (ha)**	**Fraction**
1	RNGE	CX	0	2	0.01423	121.95	266.71	0.26291
2	PAST	LA	8	>9	0.28790	9.15	5.18	0.00510
3	PAST	LA	2	8	0.04678	91.46	5.96	0.00587
4	PAST	LA	8	>9	0.13819	24.39	6.36	0.00627
5	CRDY	CX	0	2	0.00754	121.95	33.47	0.03299
6	AGRL	CX	2	8	0.04821	91.46	44.14	0.04351
7	PAST	CX	0	2	0.01288	121.95	71.33	0.07031
8	AGRL	CX	0	2	0.01373	121.95	76.77	0.07568
9	RNGB	CX	8	>9	0.12618	24.39	89.39	0.08812
10	RNGB	RL	8	>9	0.12382	24.39	90.58	0.08929
11	RNGB	CX	2	8	0.05199	60.98	92.16	0.09085
12	RNGE	CX	2	8	0.04854	91.46	111.55	0.10996
13	RNGB	RL	2	8	0.05218	60.98	120.99	0.11927

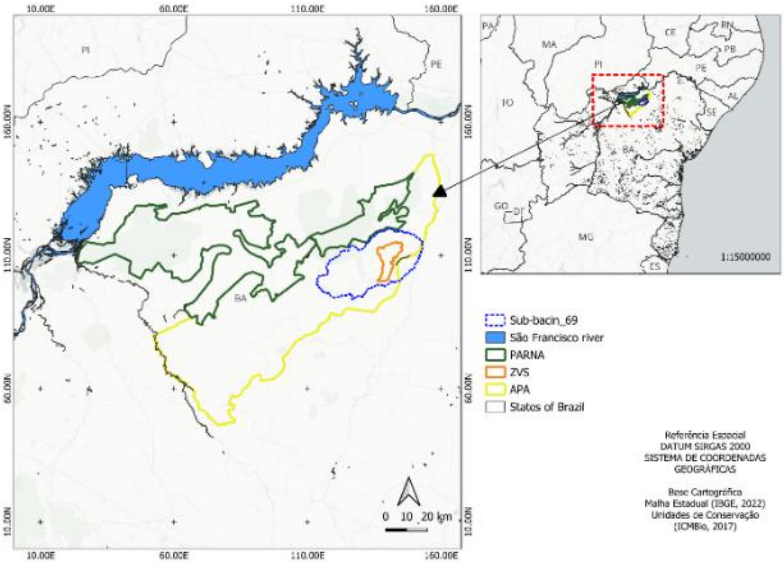


Figure 3. Sub-basin 69 within the Boqueirão da Onça Environmental Protection Area (APA), Northeast Brazil.

Statistical analysis

Data transformation for standardization was performed using the formula z = (raw score - mean)/ standard deviation, followed by Spearman's correlation analysis of all preselected variables from Sub-basin 69 (Table 2). Correlation analysis was conducted to assess potential similarities among the data. Principal Component Analysis (PCA) was then applied to the monthly averages from 1961 to 2021 using the free Past 4.11 software (Hammer et al., 2001).

Results

Spatiotemporal evolution of land use and occupation

The 1985 map shows that the study areas were occupied by savanna formations and land-use mosaics, as well as pasture areas (Figure 4a). The 2023 land use and occupation map shows that all natural vegetation types showed reductions in both the Savanna Formation (SF) and the Forest Formation (FF) areas. In contrast, pasture and agricultural lands expanded during this period, while urban areas within the APA boundaries increased over the years (Figure 4b).

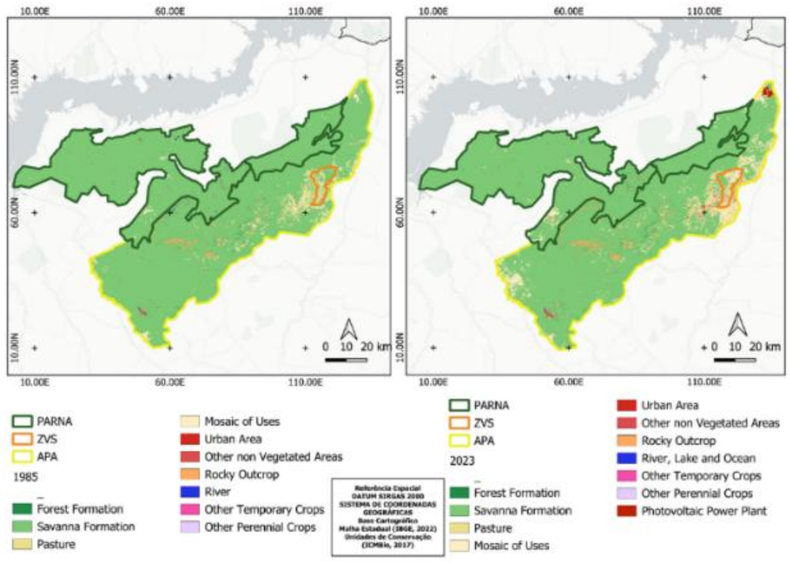


Figure 4. Land use and occupation for the years 1985 (a) and 2023 (b) in the Boqueirão da Onça Conservation Units (UCs), Northeast Brazil.

In the APA, there was a significant reduction in the Savanna Formation (-8%) and the river (-71%), combined with significant growth in the Pasture (+118%), the Mosaic of Uses (+73%), and agricultural areas. Furthermore, new Photovoltaic Energy areas emerged, which did not exist in 1985. Urban Area more than tripled (+265%), indicating strong urban expansion (Figure 5a). In the PARNA, there was a moderate reduction in the Savanna Formation (-6.8%) and an expansion of the Mosaic of Uses (+68%), with small reductions in non-vegetated areas and pastures, indicating a regeneration trend (Figure 5b). In the Wildlife Zone there was a small reduction in Savanna Formation (-2.7%), offset by a slight increase in forest (+13.5%), with a very strong expansion of the Mosaic of Uses (+88%) and a significant increase in non-vegetated areas (+100%) and temporary agricultural areas (+350%), which may indicate anthropic pressure (Figure 5c).

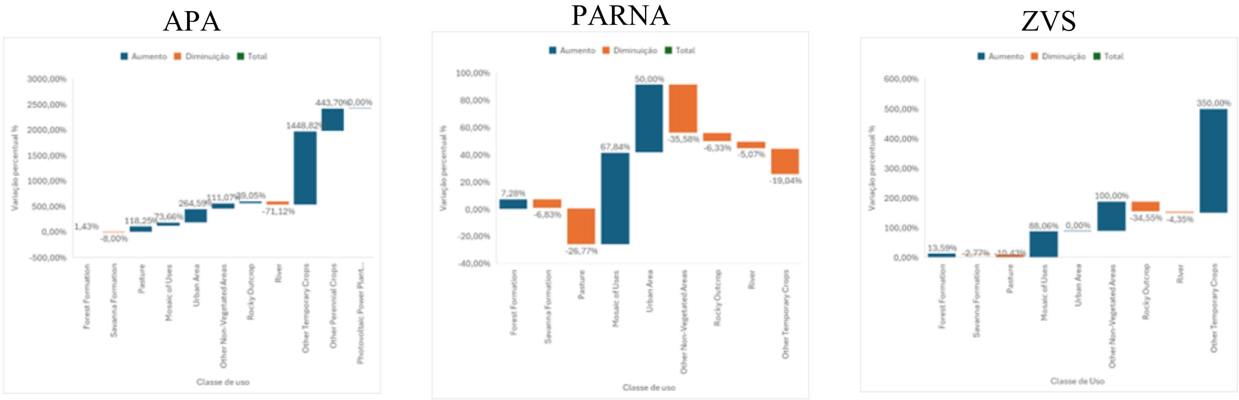


Figure 5. Percent Change (%) of Land-use Classes in the Boqueirão da Onça Conservation Units (CUs), Northeast Brazil.

Environmental modeling

The environmental modelling used 20 HRU maps, representing SUPer's output units. It generated one scenario with land-use and occupation data and created tables, graphs, and maps. The data extracted from the SUPer platform corroborate the literature, reporting low total precipitation (457.53 mm/year), high evapotranspiration potential (2,274.54 mm), and high rates of water removed by evapotranspiration (355.94 mm/year) (Figure 6). In addition to these conditions, the temperature ranges from 30ºC to 24ºC. After analyzing the data extracted from SUPer, the variable TLOSS (amount of water removed from tributary channels by transmission, mm H2O) was removed because it contained only zeros throughout the analysis period for all uses. The same occurred for TMP_STRS (Number of days of temperature stress), BIOM (Total plant biomass), and LAI (Leaf Area Index) for the RNGE use (Range-grasses).

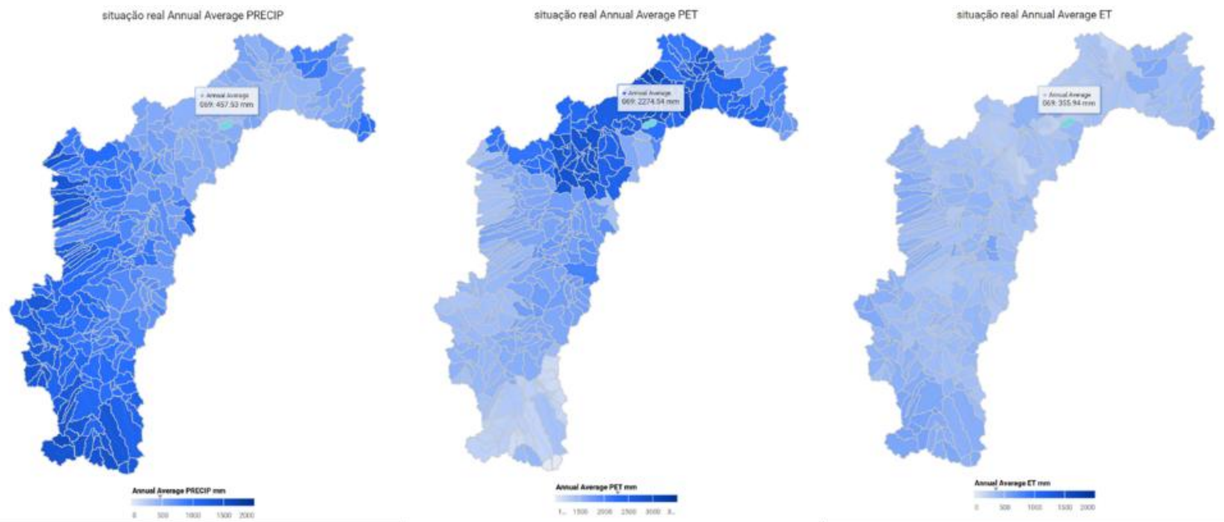


Figure 6. Precipitation (PRECIP), potential evapotranspiration (PET), and amount of water removed by evapotranspiration (ET) in Sub-basin 69 and its location in the São Francisco Basin.

Among all the variables analyzed by PCA, those that best explain the data are Total Precipitation in the HRU (mm H2O) and Potential Evapotranspiration (mm H2O) for all existing uses in Sub-basin 69 (Table 4). The correlation matrix was used to assess the similarity between the 20 variables and, after a high correlation (≥ 0.90) was found, the following variables were excluded: SW_INIT - Soil water content at the beginning of the period (mm H2O); SW_END - Soil water content at the end of the time (mm H2O); SURQ_GEN - Surface runoff generated during the time interval (mm H2O); SURQ_CNT - Contribution of surface runoff to the reach (mm H2O); TMP_MX - Average daily maximum air temperatures for the period (°C); TMP_MN - Average daily minimum air temperatures for the period (°C).

Table 4. Eigenvalues of the correlation matrix and selected principal components for the uses AGRL/Generic Agricultural Land, PAST/Pastures, RNGE/Range-grasses, CRDY/Mosaics of Different Crops, and Slope Class (0-2).

USES	**PRECIP**	**PET**	**ET**	**PERC**	**DA_RCHG**	**REVAP**	**LATQGEN**	**TMP_AV**	**CSOL_TMP**	**CSOLAR**	**TMP_STRS**	**BIOM**	**LAI**
AGRL													
PC summary													
Eigenvalue	4,62	2,81	1,60	1,10	0,97	0,48	0,41	0,27	0,26	0,22	0,13	0,10	0,03
Proportion of variance	35,52%	21,65%	12,34%	8,44%	7,43%	3,72%	3,13%	2,11%	1,97%	1,70%	1,02%	0,73%	0,23%
Cumulative proportion of variance	35,52%	57,17%	69,51%	77,95%	85,38%	89,10%	92,23%	94,34%	96,31%	98,01%	99,03%	99,77%	100,00%
Component selection	Selected	Selected	Selected										
PAST													
PC summary													
Eigenvalue	3,834	2,879	1,622	1,27	0,9362	0,7472	0,5694	0,3746	0,2611	0,2043	0,1737	0,1025	0,02584
Proportion of variance	29,49%	22,15%	12,48%	9,77%	7,20%	5,75%	4,38%	2,88%	2,01%	1,57%	1,34%	0,79%	0,20%
Cumulative proportion of variance	29,49%	51,64%	64,11%	73,89%	81,09%	86,84%	91,22%	94,10%	96,10%	97,68%	99,01%	99,80%	100,00%
Component selection	Selected	Selected	Selected	Selected									
RNGE													
PC summary													
Eigenvalue	4,118	2,878	1,099	0,7841	0,5376	0,2786	0,1289	0,08883	0,07957	0,006998			

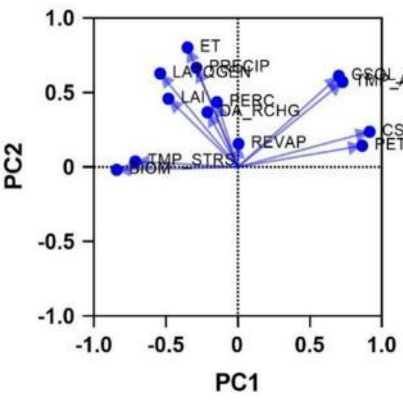
Proportion of variance	41,18%	28,78%	10,99%	7,84%	5,38%	2,79%	1,29%	0,89%	0,80%	0,07%			
Cumulative proportion of variance	41,18%	69,96%	80,95%	88,79%	94,17%	96,96%	98,25%	99,13%	99,93%	100,00%			
Component selection	Selected	Selected											
CRDY													
PC summary													
Eigenvalue	4,415	2,713	1,754	1,444	0,9668	0,5199	0,366	0,2681	0,1704	0,126	0,1125	0,106	0,03936
Proportion of variance	33,96%	20,87%	13,49%	11,11%	7,44%	4,00%	2,82%	2,06%	1,31%	0,97%	0,87%	0,82%	0,30%
Cumulative proportion of variance	33,96%	54,82%	68,32%	79,42%	86,86%	90,86%	93,68%	95,74%	97,05%	98,02%	98,88%	99,70%	100,00%
Component selection	Selected	Selected	Selected	Selected									

The correlation matrix revealed that for RNGE, CRDY, and AGRL, there was a high correlation (≥ 0.90) between TMP_AV - Mean air temperature for the period (°C) and CSOL_TMP - Mean soil temperature in the period (°C). Considering the PAST, there was a high correlation between REVAP and CSOL_TMP (≥ 0.90).

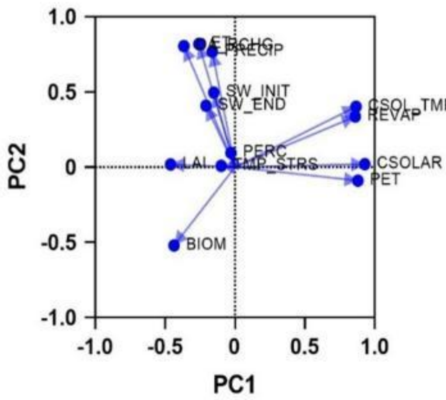
Principal component analysis showed that the interaction between precipitation (PC1) and potential evapotranspiration (PC2) is modulated differently by land use and land cover (Figure 7). In temporary crop areas (AGRL), precipitation emerged as the primary controlling factor for hydrological and productive processes, exhibiting a strong positive correlation with variables such as LAI, recharge, and actual evapotranspiration. This pattern indicates a high dependence on rainfall patterns, highlighting the importance of temporal planting planning and the adoption of practices that optimize infiltration and soil water storage. In pastures (PAST), biomass production was strongly associated with water availability and sensitivity to evapotranspiration, suggesting vulnerability to prolonged water deficits that can compromise forage productivity and exacerbate degradation processes, necessitating adaptive management, such as rotational grazing and conservation techniques. On the other hand, native pasture grass areas (RNGE) demonstrated greater hydrological resilience, with vectors closer to the origin in the principal component space, indicating less influence from PET and a greater capacity to maintain ecosystem functioning under water-deficit conditions. This result reinforces the role of native formations in hydrological regulation, baseflow maintenance, and support for ecosystem services.

Finally, agricultural crop mosaics (CDRY) showed a high correlation with PET, solar radiation, and average temperature, demonstrating greater sensitivity to atmospheric conditions and a greater risk of heat and water stress. This scenario demands management strategies that prioritize efficient irrigation use, permanent soil cover, and conservation practices to reduce evaporation and increase productive resilience.

Other Temporary Crops (AGRL)



Pastures (PAST)



Range-grasses (RNGE)

Mosaics of Different Agricultural Crops (CDRY)

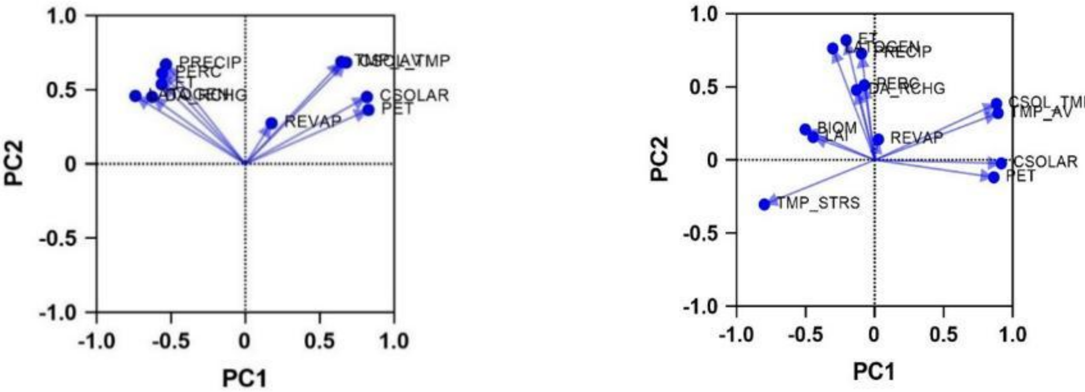


Figure 7. Main variables that influence the different land uses in Sub-basin 69, contained in the Boqueirão da Onça Environmental Protection Area.

Discussion

Historically, the Caatinga has been under significant pressure from occupation and exploitation; however, among Brazilian biomes, it is the most biologically understudied (Leal et al., 2005). The diversity of the Caatinga's geological landscapes provided a magnificent evolutionary setting for the dispersal of many unique and species-rich plant lineages, unmatched in any other dryland in the world (ICMBIO, 2023). Furthermore, according to Oliveira & Gouveia (2024), although recent research has advanced, the Caatinga continues to receive less investment. It has a slower rate of scientific production than other Brazilian biomes.

In recent decades, the Caatinga biome has undergone significant transformations in land use and cover, as revealed primarily by analyses of MapBiomas data. A study conducted by Rocha et al. (2024) showed that between 1985 and 2019, native Caatinga vegetation was reduced by approximately 11%, equivalent to a loss of more than 6.6 million hectares. A significant expansion of anthropogenic areas accompanied this reduction: agriculture grew by 284%, while pastures increased by 62% in the same period.

In addition to the loss of natural vegetation, a significant increase in areas designated for urban infrastructure and agricultural use was observed, which intensifies the fragmentation of the biome (Rocha et al., 2024). These changes in land use are also associated with phenomena such as desertification and environmental degradation, as discussed by Silva et al. (2022), who analyzed desertification centers and highlighted the direct relationship between the loss of vegetation cover and the intensification of erosion and the reduction in soil quality.

At the municipal level, analyses such as that of Lima & Almeida (2017) in the municipality of Brejinho, Pernambuco, indicate the continued replacement of native vegetation with pastures and agriculture, with direct impacts on greenhouse gas (GHG) emissions. Similar results were reported by Moura et al. (2019) in the Sertão Paraibano region, using MapBiomas Collection 5. They found that the prevalence of pastures and agriculture was detrimental to the region's typical savanna formations.

The creation of Conservation Units (CUs), especially Environmental Protection Areas (APAs), faces a series of challenges related to land use and occupation, particularly in regions already affected by human activity. As several studies point out, these areas are generally located in areas with consolidated human occupation, which limits the implementation of restrictive-use measures and hinders compatibility between environmental conservation and socioeconomic activities (Medeiros & Young, 2011; Fonseca et al., 2019). In many cases, the absence of detailed zoning and the lack of social participation in the APA creation process contribute to land conflicts and the overlapping of incompatible uses, such as intensive agriculture, urban expansion, or mining (Pinto & Drummond, 2020). Furthermore, institutional fragility and the scarcity of resources for oversight and management severely limit the effectiveness of these CUs, thereby compromising their conservation and sustainable land-use objectives.

The newly established Boqueirão da Onça Conservation Units (CCUs) face significant challenges, primarily related to land use and occupation. Traditional practices such as slash-and-burn agriculture, vegetation burning, and extensive cattle and goat farming alter and fragment forest areas (Silva & Barbosa, 2017). A study conducted in Catimbau National Park, in the Caatinga (Brazil), found that chronic anthropogenic disturbance (CAT) is a key factor influencing biodiversity and that the disturbance pressures (cattle, logging, and human pressure) were independent of one another (Arnan et al., 2018).

According to Laurance et al. (2012), urban expansion, combined with poaching pressure, has been widely documented as one of the main threats to biodiversity, significantly affecting wildlife, including within protected areas. Although the primary reason for this activity is subsistence, in many regions, motivation extends beyond basic food needs (Dias et al., 2020). Furthermore, large wild mammals are driven away by human presence; for example, the ocelot (*Leopardus pardalis*) was more frequently detected in areas far from human settlements, whereas the jaguar (*Panthera onca*) was more commonly detected in areas far from wind farms. Other species, such as the puma (*Puma concolor*) and the jaguarundi (*Herpailurus yagouaroundi*), have occupied locations near watercourses (Dias et al., 2019).

In vegetation, landscape modification by human activities ranges from the annual removal of 10.35 million cubic meters of wood (Riegelhaupt & Pareyn, 2010), to effects on biomass production, as reported by Pagotto et al. (2025) evaluating chronic anthropogenic disturbance and reduced precipitation on the woody biomass of *Pityrocarpa moniliformis* in a dry Caatinga forest, where they obtained higher values in more humid and less disturbed sites (90.41 ± 54.75 kg), while the lowest values were observed in drier, but also less disturbed, sites (36.40 ± 18.39 kg).

Modification of dry forests, such as the Caatinga, can also favor the spread of invasive species, altering successional trajectories during regeneration and thus shifting communities toward a new functional and structural composition (Quirino et al., 2025). Furthermore, species richness is expected to decline by 8% to 41% under climate change scenarios in the semiarid region of Brazil (Maciel et al., 2025). These authors also found that the areas with the greatest species loss are associated with high-disturbance classes.

Tropical dry forests have been converted into mosaics of secondary forests, agricultural land, and pastureland (Singh, 1998; Pulla et al., 2015; Silva et al., 2017). In this scenario, human disturbances that completely remove aboveground biomass can drastically decrease species abundance, potentially reduce shoot viability, and exclude species without a persistence mechanism (Vanderlei et al., 2024). Consequently, taxonomic, functional, phylogenetic, and genetic diversity are limited (Pausas & Keeley, 2014; Almeida-Rocha et al., 2020). The data obtained from SUPer for these Conservation Units are unprecedented. They can guide public policy for the region encompassing the Boqueirão da Onça Mosaic, a recently created environmental protection area that faces several impacts from human activities. Investments in ecological education, combined with stricter regulations on activities with high potential for pollution and enhanced environmental monitoring in the MBO area, can mitigate negative impacts on local biodiversity and ensure the effective preservation of this remnant caatinga, which is crucial for maintaining ecosystem services.

Conclusion

Although its creation was effective in 2018 due to human occupation, the Boqueirão da Onça APA faces challenges in balancing the use of existing natural resources, as it is a sustainable-use conservation unit.

The conservation of native areas, combined with the adoption of sustainable land-use technologies, is essential to mitigate the impacts of climate variability and to ensure water and production security in the medium and long term.

This study advances conservation area management by offering valuable insights to researchers, managers, and decision-makers interested in promoting nature conservation and sustainable development.

The direct relationship between vegetation loss over the years highlights the urgency of combating deforestation. Preserving biodiversity and ecosystem services is crucial to the economic security of local communities.

By understanding the socio-environmental dynamics that affect a protected area, managers will be better equipped to address conservation challenges, promote the active participation of local communities, develop strategies for the sustainable use of natural resources, and ensure the ecological integrity of the protected area.

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