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Papers

Ecological representativeness and total area protected by natural reserves in Ceará State, Brazil

Francisco Vladimir Silva Gomes [1]
Ana Maria Ferreira dos Santos [2]
Renan Gonçalves Pinheiro Guerra [3]
Liana Rodrigues Queiroz [4]
Marcelo Oliveira Teles de Menezes [5]
Marcelo Freire Moro [6]

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Abstract
Among the targets of the Aichi Accord, of which Brazil was a signatory, was the commitment to protect at least 17% of its terrestrial and continental waters and 10% of all marine and coastal areas by 2020. When the target window closed, Brazil had 30% of those projected continental and 27% of the marine areas protected. Those areas, however, are unevenly distributed throughout the country, with the Amazon region exceeding 30% of the projected protection, while only approximately 8% of the Caatinga region has been considered. In this study, we computed the coverage of 98 designated Conservation Areas (CAs) and an ecological corridor in Ceará State (CE) and evaluated their distributions among that state's various natural environments. Our results indicated that 92.6% % of the total officially protected areas corresponded to Uso Sustentável categories (US), which means sustainable use in English ,largely distributed among ecosystems outside the Caatinga domain, including coastal areas and humid and sub-humid enclaves. Those CAs contain rich bio- and geo-diversities of significant socioeconomic interest, although they do little to protect caatinga vegetation – the predominant ecosystem in the state. Additionally, the predominance of US CAs provide limited legal safeguards to biodiversity, especially among those CAs with low levels of legal protection, such as the category of Área de Proteção Ambiental (APA), which means Environmental Protection Areas in English , which account for the greatest coverage in the state. We conclude that the spatial configuration of state CAs is distant from ideal in terms of their extensions and representativeness, with few areas of protected caatinga vegetation and limited areas with full protection.

[1] Universidade Federal do Ceará - UFC, Fortaleza, CE, Brazil. vladimircambiental@gmail.com
[2] Secretaria de Planejamento Urbano e Ambiental de Caucaia, Caucaia, CE, Brazil. amariafs@gmail.com
[3] Programa Cientista-Chefe em Meio Ambiente– Secretaria do Meio Ambiente do Estado do Ceará, Fortaleza, CE, Brazil. renan.guerra@sema.ce.gov.br
[4] Instituto Verdeluz, Fortaleza, CE, Brazil. lianarq@yahoo.com.br
[5] Instituto Federal de Educação, Ciência e Tecnologia do Ceará – IFCE, Fortaleza, CE, Brazil. teles@ifce.edu.br
[6] Instituto de Ciências do Mar, Universidade Federal do Ceará - UFC, Fortaleza, CE, Brazil. marcelomoro@ufc.br

INTRODUCTION

Our planet is experiencing a biodiversity crisis, with elevated levels of extinction and wide losses of vegetation coverage as a result of human actions – especially those directly linked to habitat destruction, pollution, and the dissemination of exotic invasive species (VITOUSEK et al., 1997; ROYAL BOTANIC GARDENS, KEW, 2016). One of the most efficient strategies for protecting biodiversity and geodiversity, however, has been the establishment of protected areas (JUFFE-BIGNOLI et al., 2014).

The most recent report published by the Intergovernmental Panel of Climate Change (IPCC) reinforces the view that the maintenance of biodiversity resilience and ecosystem services at the global level will depend on the effective and equitable conservation of approximately 30% of the global land area and 50% of the freshwater and oceanic areas of our earth, including ecosystems that are still largely in their natural state (IPCC, 2022).

Protected areas are clearly defined and recognized geographic spaces that have specific conservation objectives and are effectively managed, whether by law or by other manners that guarantee their long-term conservation and the integrity of associated ecosystem services and cultural values (DAY et al., 2012). Conservation Areas (CAs) have important roles in the Brazilian strategy of protecting native species and reducing human pressure on designated territories (JUFFE-BIGNOLI et al., 2014).

The Sistema Nacional de Unidades de Conservação (SNUC), which is the Brazilian National System of Natural Conservation Areas - was created by Federal Law nº 9.985 (BRASIL, 2000), establishing criteria and norms for the creation, implantation, and administration of CAs. That system established 12 categories of CAs, distributed between two basic regimes for the use of their natural resources: Uso Sustentável (US), these areas where direct use of natural resources is permitted; and Proteção Integral (PI), which means Full Protection areas in English, these areas allow only indirect use of protected resources. Those two types of conservation strategies have been found to be useful for protecting biodiversity and natural landscapes, especially in the Caatinga domain (a deciduous, thorny, semiarid vegetation encountered in northeastern Brazil), which has already lost half of its total original vegetation cover (BRASIL, 2015; ANTONGIOVANNI et al., 2018).

The Caatinga domain is well-adapted to the largely semiarid regional climate, with its vegetation predominately composed of caatinga sensu stricto, although with enclaves of other vegetation types such as humid forests (largely associated with mountain ranges), savannas, rock fields, and coastal regions with open shrub vegetation and savannas, mangrove swamps, and semideciduous coastal forests (MORO et al., 2015; MORO et al., 2016). The original native caatinga vegetation has been severely altered since European/African occupation, with progressive deforestation to harvest firewood and the opening of areas for agriculture, cattle raising, and urban expansion (ANTONGIOVANNI et al., 2018; IBGE, 2020). The Caatinga domain lost 6 million ha of native vegetation between 1985 and 2020 alone, largely due to the expansion of agriculture and cattle-raising activities (PROJETO MAPBIOMAS, 2021). As such, planning strategies for the administration of those ecosystems as conservation areas are becoming increasingly urgent.

The use of geo-technologies for conservation and biodiversity planning take advantage of spatial techniques that can subsidize decision-making efforts. Picuno et al. (2019) stressed that Geographic Information System (GIS) tools are methodologically adequate and efficient for conservation planning, as they can manipulate a wide range of spatial and temporal information concerning landscapes.

From that perspective, the most recent estimate made by the International Union for Conservation of Nature (IUCN, 2020) indicated that 15% of the terrestrial area of the globe and 7% of its oceans have been designated as protected areas. Multilateral international meetings held during the 10th Conference of the Parties (COP10) discussed the conservation policies of the signatories of the Biological Biodiversity Convention (which includes Brazil). The participants sought to establish concrete actions to prevent biodiversity losses based on 20 goals. The Aichi 11 goal determined that until 2020:

> "At least 17% of terrestrial lands and continental waters and 10% of marine and coastal areas, considered of interest to conservation, ecosystem services, equitability, and efficiency in the management of protected areas, ecological representativeness and connectivity" (UNFCCC, 2010, p. 10).

In Brazil, 30% of the continental area and 27% of marine areas are considered Protected

Areas, which include (in addition to Conservation Areas) Indigenous Lands and "Quilombolas" (traditional areas occupied by previously enslaved peoples) (UNEP-WCMC, 2021). Although those numbers appear adequate, those protected areas are unequally distributed throughout Brazil, with some biomes such as the Amazon having large numbers of extensive CAs, while others, such as the Caatinga, have quite reduced CA coverages. Additionally, not all of those areas have available functional management tools, so although they constitute legally protected areas on paper, there is no effective protection of their ecosystems. Additionally, their distributions among the different Brazilian biomes are quite unequal (BRASIL, 2015). Globally, only 11.2% of the terrestrial CAs and 0.54% of the marine-protected areas are effectively managed (IUCN, 2020; UNEP-WCMC, 2022).

A survey published by Teixeira et al. (2021) noted that only 8% of the Caatinga domain area is legally protected by any type of CA, and that only 1.3% of that domain is included within full protection CAs. The distributions of those areas do not follow any pattern of representativeness, having extensive coverage of some ecosystems (including the overlapping of two CAs) but serious gaps in others.

Although Aichi goal number 11 is usually considered in terms of the percentages of protected areas, the text itself specifies that those areas should be "ecologically representative". The term representativeness, in a biological context, refers to the protection of the genetic biodiversity of species and higher taxa, including ecological and evolutive processes (SPALDING, 2007). Considering representativeness within the context of Ceará, an adequate network of CAs should include representative sites of the different ecosystems scattered throughout the state, from the most extensive ecosystem of Caatinga to smaller areas of humid forests, savannas, and coastal and marine systems (MORO et al., 2015).

The Aichi goals were officially adopted by the Brazilian federal government, although, under law, individual states have the autonomy (in partnership with the federal and municipal governments) to determine their own policies for the protection of the environment and create and administer CAs – thus collaborate in protecting natural ecosystems (BRASIL, 2015). It is important to note that although Ceará State is officially fully included within the Caatinga domain (IBGE, 2020) (at smaller scales many other different types of vegetation can be found in its territory due to its geo-diversity with mountains, coastal regions, the Sertaneja Depression, etc.) and climatic gradients. Most of the area of that state is occupied by the lowlands of the Sertaneja Depression and mountains with elevations between 800 and 1100 m.a.s.l. There are extensive sedimentary basins in the western, southern, and northeastern regions of the state, with coastal plains to the north (MORO et al., 2015). The predominant climate there is semiarid, although the windward sides of the mountains provoke orographic rainfall, and local geomorphologies and micro-climates allow many different vegetation types to flourish (MORO et al. 2015).

As such, Caatinga sensu stricto vegetation is widely distributed in the state within the low lands of the Sertaneja Depression, but there are also humid forests in the windward slopes of the mountains, distinct caatinga vegetation on the sandy soils of sedimentary basins, as well as areas of savanna and coastal vegetation (MORO et al., 2015). Evaluations of the representativeness of the coverage of CAs must therefore consider the principal types of ecosystems as well as the various phytoecological regions in Ceará State. The present work, therefore, sought to map the distribution of CAs in that state and evaluate their distributions among its different ecosystems.

Material and Methods

Within the general context of northeastern Brazil, Ceará comprises a reasonable diversity of natural landscapes within its approximately 149,000 km² (CEARÁ, 2017) with an estimated population of 9,240,580 residents (IBGE, 2022). Geologically, its largest areas are composed of Precambrian crystalline bedrocks, including the Sertaneja Depression and residual massifs (DA COSTA et al., 2020; LIMA et al., 2000). The structural and lithological diversities there have direct implications for the compositions of landscape mosaics, such as: the semiarid regions of the Sertaneja Depression and interior sedimentary basins, the humid residual massifs, and coastal landscapes (BRANDÃO; FREITAS, 2014; DA COSTA et al., 2020). Although the caatinga vegetation in crystalline bedrock areas is the principal vegetation type in the state, there are numerous other vegetations that are mapped in the Ceará Atlas as "phytoecological units". Together, they represent the diversity of terrestrial ecosystems in Ceará State (FUNDAÇÃO INSTITUTO DE PLANEJAMENTO DO CEARÁ, 1998; MORO et al., 2015), and are complemented by marine ecosystems.

Analyses of the ecological representativeness of the CAs

The mapping analyses used spatial cartographic shapefile overlays of the phytoecological units of Ceará State (as modified by Moro et al. (2015) from the Ceará Atlas (FUNDAÇÃO INSTITUTO DE PLANEJAMENTO DO CEARÁ, 1998) together with the archives of the Conservation Areas available through the Cadastro Estadual de Unidades de Conservação (CEUC – a state database of Conservation Areas in Ceará – updated in December/2021), available from the Secretaria de Meio Ambiente do Ceará (SEMA – the State environmental agency). Table 1 lists the cartographic layers used. A distance of 12 nautical miles was adopted (approximately 22 km) to define jurisdictional waters (BRASIL, 1993) and estimate marine areas under state control.

The data was manipulated using Quantum GIS software, version 2.18.24 (QGIS.ORG, 2022). The geodesic reference system used was SIRGAS 2000/UTM 24S. The phytoecological units of Ceará (FUNDAÇÃO INSTITUTO DE PLANEJAMENTO DO CEARÁ, 1998) were considered landscape categories (Figure 1), allowing the possibility of ecological representativeness analysis as established by Aichi Goal 11. We adopted the divisions of phytoecological units as proposed by Moro et al. (2015), modified from Figueiredo (1997), in which the natural environments of Ceará are divided into 11 categories of ecosystems and bodies of continental waters.

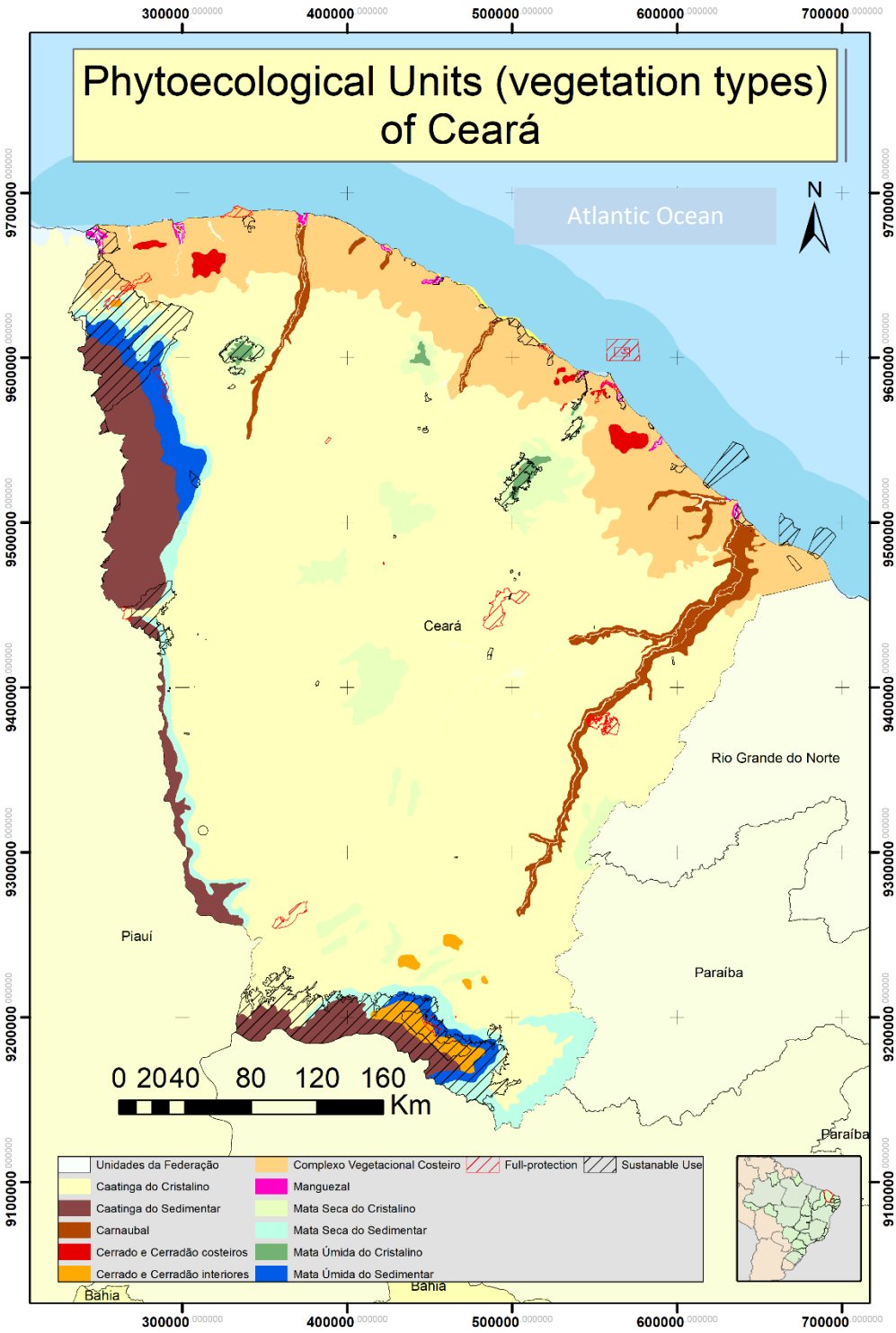
Criteria for the elimination of overlapping Cas

As the overlapping of CAs belonging to different categories is legally allowed, with the existence, for example Reserva Particular do Patrimônio Natural (RPPN, which means Private Reserve of Natural Heritage in english) within a larger APA, any overlapping CA areas were adjusted according to the following hierarchical criteria: when two areas overlapped, we considered only the most restrictive use-regime (PI > US; that is, a Parque Nacional (PN, which means National Park in English) contained within an APA would have its area considered only as a PN); 2) if two CAs were of the sustainable use category, we computed the area included within only the most restrictive CA category according to the SNUC (BRASIL, 2000) (e.g., if a RPPN was included within an APA, we considered the protected area as a RPPN); 3) in cases of overlapping CAs within the same category, we considered the greater hierarchical management level (Federal > State > Municipal). The supplementary data is available in the Figshare repository, through the following link: https://doi.org/10.6084/m9.figshare.18780662.

RESULTS

A total of 98 Conservation Areas and an ecological corridor were identified within Ceará State and registered in the CEUC database in 2021 (Table 1; Figure 1). Of that total, 76 (77.6%) were sustainable use CAs, with 37 being RPPNs, 28 APAs, and the remaining areas distributed between Reservas Extrativistas (RESEX – protected areas reserved for traditional populations to extract resources in a sustainable manner), Florestas Nacionais (FN– national forests, where extraction of natural resources is allowed given some restrictions and a management plan), and Áreas de Relevante Interesse Ecológico (ARIE – Small areas with little human occupation that harbor ecologically relevant attributes). Among the PI group (the category providing the greatest legal protection for biodiversity) only 22 (22.4%) were CAs: 9 PN, Parques Estaduais (PE – which means State Parks in English) or Parque Municipal (PM – which means Municipal Parks in English), while the rest were distributed between Refúgio de Vida Silvestre (REVIS – areas focused on conservation of wildlife), Monumento Natural (MONA – natural monuments), and Estação Ecológica (ESEC – ecological stations, where human uses are totally prohibited and human access is very restricted).

Figure 1 - Map of the Conservation Areas created within Ceará State, Brazil, up until December 2021. The map demonstrates the coverage of CAs in the different phytoecological regions. Proteção Integral: conservation areas under full legal protection; Uso sustentável: conservation areas where sustainable uses are allowed.



Source: The Authors (2022), based on the Atlas do Ceará (FUNDAÇÃO INSTITUTO DE PLANEJAMENTO DO CEARÁ, 1998).

PI represents full-protection nature reserves under Brazilian law; *US* represents nature reserves that allow direct human uses that are controlled and presumably sustainable. Different vegetation types represented in the map: Caatinga do Cristalino (deciduous forests and shrublands on crystalline terrains); Caatinga do sedimentar (deciduous forests and shrublands on sandy sedimentary terrains); Carnaubal (Riverine forests with endemic

carnauba palms); Cerrado e Cerradão Costeiros (cerrado coastal savannas and woodlands); Cerrado and Cerradão Interiores (inland cerrado savannas and woodland)s; Complexo Vegetacional Costeiro (Coastal vegetation - grasslands, shrublands and forests); Manguezal (mangroves); Mata Seca do Cristalino (deciduous forests on crystalline terrains); Mata Seca do Sedimentary (deciduous forests on sedimentary terrains); Mata Úmida do Cristalino (evergreen forests on crystalline terrains); Mata úmida do sedimentary(evergreen forests on sedimentary terrains).

In defining the total area of each phytoecological area, any overlapping bodies of water were not considered (for example, the Jaguaribe River and the Castanhão reservoir). The greatest phytoecological area was identified as the "Caatinga do Cristalino", which covers almost 70% of the state (Table 2).

Ceará has 1,214,396 hectares of its territory occupied by CAs in terrestrial areas and continental waters, which corresponds to 7.59% of the state; 85,446 additional hectares are protected marine areas, which corresponds to 3.10% of the marine ecosystems under state jurisdiction. Those numbers are significantly below the Aichi 11 goals for both terrestrial and marine environments, however. The CAs in the PI category in Ceará have a total area of only 88,920ha, divided among four types: Parques (PN, PE and PM), ESEC, MONA, and REVIS (Table 1). Together, the full protection CAs represent only 0.60% of the geographic extensions of the terrestrial ecosystems in the state.

The total area of the US group of CAs, on the other hand, is 1,125,476ha, representing approximately 7.56% of the terrestrial ecosystems within the state. The sustainable use CAs represent 92.68% of the protected coverage of all CAs in Ceará, excluding overlapping areas (Table 1). Most of that area is concentrated in the APA category, the least restrictive Brazilian category in terms of human use, followed by FN, RESEX, RPPNs, and AREI, which are more restrictive categories.

Table 1 - Total area (in hectares) of terrestrial nature conservation areas by their categories in Ceará state Brazil.

Use regime/category		**Area (ha)**
PI (7.32%)	PN, PE and PM	33,805.00
	ESEC	25,271.23
	MONA	24,757.73
	REVIS	5,086.15
	Sub-total	88,920.12
US (92.68%)	APA	1,037,549.91
	FN, Floresta Estadual (FE – which means State Forest in English) or Floresta Municipal (FM - Municipal Forests)	39,841.20
	RESEX	30,356.55
	RPPN	17,246.16
	ARIE	482.45
	Sub-total	1,125,476.09
* Ecological Corridor		16,129.75
TOTAL		**1.230,525.96**

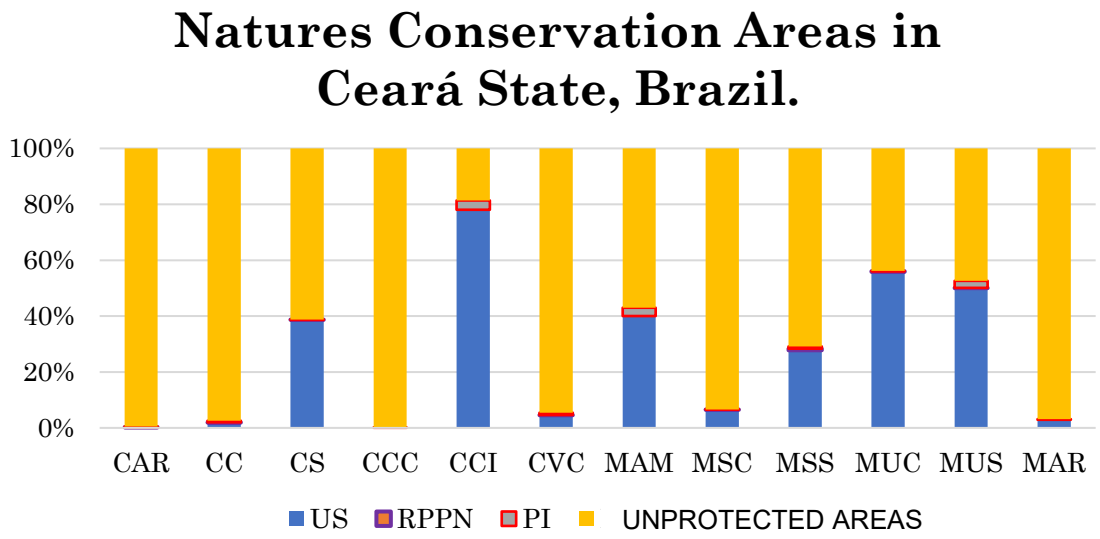
* Ecological corridors are not included in either the US or PI categories (BRASIL, 2000) and, as such, were not included in the database. They have been, however, legally created in Ceará State.

Source: The authors (2022).

Figure 3 evidences that the phytoecological unit with the greatest legal protection in relation to its total area is the interior cerrados (savannas), with 78.0% of its total area included within some CA. However, those interior cerrado environments have only limited dimensions within the state. The second phytoecological unit with the greatest land coverage is the humid forests on crystalline bedrock, with 55.8% of its area included within CAs (mostly APAs). The least protected phytoecological group is the coastal cerrados, with only 0.02% of that area protected in any way (Figure 3 and Table 2). Marine ecosystems

have only 3.10% of their total area protected. As such, the PI CAs generally represent only very small proportions of the protected areas in all of the phytoecological units of the state.

Figure 3 - Percentages of the Phytoecological Units of Ceará State under different protection regimes. US: Conservation areas that allow sustainable uses; RPPN: Private reserves; PI: Full protected conservation areas; Não Protegido: non protected areas.



Elaborated by the Authors (2022). Legend: US – Uso sustentável; PI –Proteção Integral; CAR – Carnaubal ; CC – Caatinga do Cristalino; CS – Caatinga do Sedimentar; CCC – Cerrados e Cerradões Costeiros; CCI – Cerrados e Cerradões Interiores; CVC; MAM – Manguezal; MSC- Mata Seca do Cristalino; MSS – Mata Seca do; MUC – Mata úmida do Cristalino; MUS – Mata úmida do Sedimentar; MAR – Ecossistemas Marinhos (which means Marine Ecosystems in English).
Source: The authors (2022).

Most of the coverage of CAs in Ceará is within the US category, especially the APA category; coverage by the PI category is considerably more restricted, with only 0.60% of the state protected by any CA in that category (Table 2). The phytoecological units with the greatest percentages of coverage by PI CAs (in terms of their total areas) are the Cerrados e Cerradões Iinteriores (3.39% protected by PI CAs) and Manguezais, which are 3.02% protected (Table 2). Mata Seca do Cristalino forests are not included in any PI CAs, and an area of Caatinga do Sedimentar was only recently protected by a PI CA through the creation of the Parque Estadual da Ibiapaba (most restrictive protected area category, located in Ibiapaba). The Mata Seca do Cristalino forests and the Complexo Vegetacional Costeiro also figure among the least protected ecosystems in terms of coverage by PI CAs.

Table 2 - Areas of different phytoecological units in Ceará State and the percentage of each type of ecosystem protected by US or PI CAs.

Phytoecological Unit	**Extension (ha)**	**% Percent of state area (%)**	**Protected by a PI CA (%)**	**Protected by a US CA (%)**
Caatinga do Cristalino	10,243,600	68.83	0.51	2.03
Complexo Vegetacional Costeiro	1,793,050	12.05	0.79	4.68
Caatinga do Sedimentar	832,340	5.59	0,10	38,70
Mata Seca do Cristalino	554,412	3.73	0.00	6.54
Mata Seca do Sedimentar	509,433	3.42	0.78	28.37
Carnaubal	372,140	2.50	0.30	0.19
Mata Úmida do Sedimentary	263,895	1.77	2.54	49.95
Interior Cerrado e Cerradão Interiores	106,726	0.72	3.39	78.03
Cerrado e Cerradões Costeiros	67,129	0.45	0.05	0.02
Mata Úmida do Cristalino	43,876	0,29	0.09	56.08
Manguezal	25,063	0,17	3.02	39.98
Ecossistemas Marinhos	2,759,534	--	0.20	2.89
TOTAL	**14,882,000.0**	**100.00**	**0.60**	**7.56**

Source: The authors (2022).

The phytophysiognomies that receive the greatest rainfall volumes, and therefore constitute environments that differ from the typical caatinga predominant within the state, including the Complexo Vegetacional Costeiro, the Cerrados Costeiros, the Mata Úmida do Cristalino and the Mata Úmida do Sedimentar forests, and the Mata Seca do Cristalino and Mata Seca do Sedimentar; they have 0.78% of their territories protected by CAs of the PI group. The driest phytophysiognomies of Ceará, such as the Caatinga do Cristalino, Caatinga do Sedimentar, Carnaubal, and the Cerrados e Cerradões Interiores have only 0.47% of their total areas covered by PI CAs.

It is important to note that those phytoecological units typical of the semiarid region cover, together, 77.28% of the territory of Ceará State, evidencing the preeminent necessity of establishing CAs in areas of caatinga *strictu sensu*.

Table 3 - Distribution of PI CAs (in hectares) by management categories in the phytoecological units of Ceará State, Brazil.

PI CONSERVATION AREAS						
	MANAGEMENT CATEGORY					
PHYTOECOLOGY	**ESEC 28.42 %**	**MONA 27.84%**	**PN, PE or PM 38.02%**	**REVIS 5.72%**	**TOTAL**	**%**
Manguezal	-	-	758,04	-	758,04	3.02
Mata úmida do Sedimentar	-	-	4,723.48	1,982.53	6,706.02	2.54
Complexo Vegetacional Costeiro	963.11	33.85	13,171.13	-	14,168.09	0.79
Caatinga do Cristalino	23,184.72	24,683.04	3,619.33	566.96	52,054.05	0.51
Cerrado e Cerradão interiores	-	14,74	1,109.54	2,497.54	3,621.43	3.39
Ecossistemas Marinhos	-	8.30	5.591,22	-	5,599.53	3.22
Carnaubal	1,123.41	-	-	-	1,123.41	0.30
Mata seca do Sedimentar	-	17.80	3,955.67	-	3,973.47	0.78
Mata úmida do Cristalino	-	-	-	38,74	38,74	0.09
Cerrado e Cerradões costeiros	-	-	34.19	-	34.19	0.05
Mata seca do Cristalino	-	-	-	0.37	0.37	0.00
Caatinga do Sedimentar		-	842.78	-	842.78	0.10
Total	**25,271.24**	**24,757.74**	**33,805.00**	**5,086.15**	**88,920.12**	**0.60**

Source: The authors (2022).

The ESEC category, the most restrictive, is responsible for only 28,42% of the total PI CAs. In terms of the total area of the state, ESECs cover only 25,276 (0.016%) hectares, representing the phytophysiognomies of the Complexo Vegetacional Costeiro, the Caatinga do Cristalino, and the Caatinga do Sedimentar. The category MONA represents 27.84% of all of the PI CAs, but consider only representative areas of the Complexo Vegetacional Costeiro, the Caatinga do Cristalino, Cerrado e Cerradões Interiores, and the Mata Seca do Sedimentar. The Parques (PN, PE and PM) category is the most common, representing 38.02% of all of the PI CAs, and is present in most phytophysiognomies, with the exception of Mata Úmida and Mata Seca do Cristalino and Caatinga do Sedimentar. The REVIS category covers only 0.72% of the areas of the PI CAs, helping to protect the Caatinga do Cristalino, and the Mata Úmida and Mata Seca do Cristalino forest phytoecological units.

The conservation areas that come the closest to composing a mosaic of protected areas are generally associated with "brejos de altitude" – humid forests associated with high elevations, such as those found in the Ibiapaba, Baturité, and Araripe ranges. With the exception of the Serra de Baturité CA, which has connectivity with other areas planned to compose the Rio Pacoti Ecological Corridor with conservation areas located in the Complexo Vegetacional Costeiro near the Fortaleza Metropolitan region, other groups of CAs remain unconnected and discontinuous and restricted to humid

areas, thus appearing as “islands” surrounded by degraded areas.

Table 4 - Distribution of US conservation areas (in hectares) according to their management categories in the phytoecological units of Ceará State, Brazil.

US CONSERVATION AREAS							
	MANAGEMENT CATEGORY						
PHYTOECOLOGY	APA	ARIE	FLORESTA (FN, FP and FM)	RES EX	RPPN	TOTAL RESULT	TOTAL % OF PROTECTED TERRITORY IN THIS CATEGORY
	92.19 %	0.04%	3.54%	2,70 %	1,53%		
Cerrado e Cerradão Interiores	49,159 .33	-	34,123.71	-		83,283	78,03
Mata Úmida do Cristalino	24,499 .63	-	-	-	106,81	24,606	56,08
Mata Úmida do Sedimentar	128,85 4.95	6.94	2,964.26	-	260,98	132,087.14	50,05
Manguezal	10,020 .38		-	-	-	10,020.38	39,98
Caatinga do Sedimentar	319,44 0.92	-	2,092.27	-	562.94	322,096.13	38,70
Mata Seca do Sedimentar	141,63 9.91	-	-	-	2,906.32	144,546.23	28,37
Mata Seca do Cristalino	35,947 .55	-		-	312.74	36,260.29	6,54
Complexo Vegetacional Costeiro	79,234 .53	65.1	-	1,205 .22	3,493.80	83,998.69	4,68
Caatinga do Cristalino	197,36 0.75	406,93	660,96	-	9,583.96	208,012.60	2,03
Ecossistemas Marinhos	50,695 .72	-	-	29,15 1.34		79,847.06	2,89
Carnaubal	685.09	-	-	-	-	685.09	0.19
Cerrado e Cerradões Costeiro	11.15	3.24	-	-	-	14.39	0,02
Total Result (hectares)	**1,037, 549.91**	**482.25**	**39,841.21**	**30,35 6.56**	**17,246.1 6**	**1,125,476.0 9**	**7,56**

Source: The authors (2022).

The analysis of the US categories indicated ample distributions of APAs in the different phytophysiognomies found in Ceará State. The US category of CAs is the most widely represented, precisely because it confers the lowest degree of protection but has the lowest cost of installation. That category exceeds the 17% suggested by Aichi in five phytophysiognomies in Ceará State: the Cerrados e Cerradões Interiores (78.03%), Mata Úmida do Cristalino (56.08%), Mata Úmida do Sedimentar (50.05%), Manguezais (39,98%), Caatinga do Sedimentar (38.70%), and Mata Seca do Sedimentar (24.74%). PN are found in the Cerrados e cerradões Interiores (protecting 31.7% of the area of those phytoecological units, especially the Floresta Nacional do Araripe, in english Araripe National Forest, as Protected Area of US) as well as in the Mata Seca do Sedimentar (0.57% of that phytoecological unit), Caatinga do Sedimentar (0.24%), and Caatinga do Ccristalino (0.01%).

RPPNs are found in the Mata Seca do Sedimentar (0.52%), the Mata Úmida do cristalino (0.24%), the Complexo Vegetacional Costeiro (0.19%), the Mata Seca do Cristalino (0.06%), and the Carnaubal (0.004%). The Cerrados e Cerradões Costeiros, Manguezal, and Cerrados e Cerradões Interiores are not protected within that category. AREIs are typically small areas (BRASIL, 2000), and it is necessary to describe their areas in their

respective phytoecological units using three decimal places. They occur in the Complexo Vegetacional Costeiro (0.02%), the Caatinga do Cristalino (0.003%), Cerrados e Cerradões Costeiros (0.6%), and Carnaubal (0.002%). Ceará contains only two RESEX, which were established in the Complexo Vegetacional Costeiro (covering 0.06% of the total area of that phytogeographic category) and in the Ecossistemas Marinhos. Those RESEXs help protect 3.97% of the Complexo Vegetacional Costeiro, while the rest of their areas protecting the Ecossistema Marinho, as will be discussed below.

In contrast to the PI CAs, which are almost exclusively quite small, US CAs occur in all of the ecosystems of Ceará State; some individual CAs exceed the 10% protection projected in some individual phytoecological units. On the other hand, most of the CAs in that group are concentrated in the APA category, which has some of the weakest use restrictions and provides little effective protection. The largest APAs were established in the high elevation humid forests (*brejos de altitude*) of the Araripe, Aratanha, Baturité, and Ibiapaba mountains; no large areas of that category were established in the Caatinga do Cristalino unit.

In regard to the Ecossistemas Marinhos, 27.33% of the area of the Parque Nacional de Jericoacoara (Jericoacoara National Park) covers marine ecosystems (corresponding to 2,347.4 ha), while the Parque Estadual Marinho Pedra da Risca do Meio (Pedra da Risca do Meio Marine State Park) includes only the oceanic environment.

The US category of CAs protect the largest Ecossistemas Marinhos areas, with RESEXs protecting 63.49%, followed by APAs (36.51%). Nonetheless, even summing all of the CAs, only a very small fraction of the Ecossistemas Marinhos is actually protected in Ceará State.

DISCUSSION

According to Instituto Brasileiro de Geografia e Estatística (IBGE, 2016), which is the Geographical and Statistical Brazilian Institute responsible for official geographical information in the country, approximately 2500 CAs are registered with the Ministério do Meio Ambiente (MMA), which is the Brazilian Federal Ministry responsible for the implementation of Brazilian environmental resources management, of which 798 are PI areas and 1,702 are considered US reserves. Ceará State itself is in a similar situation, with US CAs dominating the total number of protected areas and constituting the largest total protected area, although those proportions are more accentuated at the state than at the federal level. Brazil has 68.6% of its total number of CAs classified within the US group, while 92.6% of the protected areas in Ceará State are considered to be of US. The state has four times fewer PI areas than the country as a whole: 7.3% total, as opposed to 31.9% at the federal level. Those numbers indicate the fragile protection of biodiversity in Ceará State, as the USgroup makes up the large majority of conservation areas there but still falls below the 17% proposed by international treaties.

It is important to note that US CAs can be important conservation areas when securely allied to effective public policies of conservation that have been adopted by the human populations residing in those areas (or using their resources) – whether traditional communities that inhabit or sustainably exploit the CAs as Florestas (FN,FE and FM), RESEX, and Reservas de Desenvolvimento Sustentável, Sustainable Development Reserve (RDS, acronym in portuguese) is a category of protected area in Brazilian environmental policy, or landowners that have created and maintained RPPNs. Indigenous and Quilombolas lands can also effectively protect ecosystems, although Indigenous lands and designated Quilombolas lands constitute only a very small fraction of the territory of Ceará State.

Noting the importance of local participation in the management of US CAs, it is important to stress that, among all of the protection categories, APAs have the most fragile ability to protect ecosystems, but are exactly the category most widely used to create CAs in the state. In analyzing the APAs created in Ceará, it can be seen that they face numerous complications in attempting to conserve ecosystems: most APAs include private lands with ongoing economic activities that can impact and degrade natural ecosystems, including agriculture, cattle raising, and mining, as well as (nearby or even included) urban areas.

Therefore, while US CAs can, in principle, provide important mechanisms for conservation when allied to proactive management involving local communities, in practice, APAs have demonstrated only limited results in terms of protecting ecosystems. There are many recent cases of urban expansion and/or infrastructure interventions within APAs, resulting in significant losses of vegetation cover. Those actions can be legal if licensed by environmental organs, but demonstrate that large APAs do not,

in themselves, guarantee the perpetuity and conservation of natural ecosystems. Nonetheless, that category disproportionately covers large territorial expansions – revealing the limited degree of protection that those ecosystems currently experience.

A survey undertaken by Ziegler et al. (2019) demonstrated that state-level US CAs are largely represented by APAs, indicating the necessity of creating US areas in other management category, as well as PI CAs, to diminish those distortions.

It is also necessary to note that the distribution of CAs among the different ecosystems within Ceará is not equitable or representative. Most of the phytoecological units in the state are poorly represented in terms of CA coverage, and when coverage is evaluated in terms of PI CAs (with greater guarantees of legal protection for biodiversity) and even more inexpressive coverage is noted. Various CAs in Ceará State are also quite small, which reduces their capacity to protect and maintain larger species of the fauna. Studies undertaken in the Atlantic Forest by Chiarello (2000), for example, indicated that protected areas comprising more than 20,000 hectares are capable of sustaining viable populations of mammals weighing more than 1 kg. Protected areas, however, must contain at least 100,000 hectares to sustain mammals weighing more than 50 kg (TERBORG, 1992; NEWMARK, 1995; PAVIOLO et al., 2009). Additionally, there is no connectivity between most CAs, with the exception of reserves linked by the Rio Pacoti Ecological Corridor.

Protected areas in Ceará have only been concentrated in certain areas. The Caatinga do Cristalino (also known as caatinga *sensu stricto* (MORO et al., 2015) is the largest phytoecological unit in the state, but only 0.51% of that vegetation has been incorporated into PICAs. The CAs in Ceará tend to be concentrated in exceptional habitats within the overall caatinga, such as humid mountain and coastal areas, as was also noted by Menezes et al. (2010). It is not by chance that there is a certain overlapping of CAs in the state with areas protected by the law number 11.428, 'Lei da Mata Atlântica', which is the federal Atlantic Forest legislation to protect the Atlantic Forest. (BRASIL, 2006)

It is important to note that some CAs have very limited territorial extensions, with 11 of them occupying less than 20 hectares (eight RPPNs, two MONAs, and one ARIE). Although small vegetation fragments can protect the biodiversity of certain plant species, those same areas can generally only maintain self-sustaining populations of very small animals. Those small protected areas are nonetheless important, as they can act as ecological steppingstones, provide habitat for small animals, link landscapes, and facilitate genetic flow (LELES, 2019).

The overall spatial configurations of the CAs in Ceará are, however, quite distant from ideal and extremely inefficient from the point of view of logistics and administrative viability due to the existence of extensive uncontrolled areas between them (MENEZES et al., 2010).

As such, the contributions of PI CAs to attaining Aichi goals are minimal, as less than 1% of the area of the state is protected within that category. The amplification of the network of PI CAs should be a conservation goal in the state, requiring the localization, mapping, and safeguarding areas that are currently well-preserved, to guarantee the protection of their biodiversity.

The representativeness of the vegetation types in the different management categories of state CAs has been evaluated by other researchers, who stressed that while caatinga vegetation occupies a large part of the territory of Ceará State, it is 34 times less protected than environments linked to the Atlantic Forest (such as mata úmida forest enclaves) – revealing a distortion in the representativeness of the state system of conservation areas (ZIEGLER et al. 2019).

A study of the current coverage of CAs throughout the entire extension of the Caatinga domain in northeastern Brazil determined that only 8% was protected at any level, with most of the CA coverage corresponding to APAs, with only 1.3% of the total area of that domain being incorporated into PI CAs (TEIXEIRA et al., 2021). In Ceará, that situation is even more critical, as caatinga *sensu stricto* vegetation, the predominant ecosystem of that state, is still very poorly protected, with PI CAs occupying less than 1% of its area of occurrence. Although the Aichi goals are national (and not state) agreements, they can serve as references for state-level actions.

On a national scale, Brazil exceeds the 17% goal of protected phytogeographic areas, although the distributions of those CAs are not equitable throughout the country, with the caatinga domain holding only 8% of the CAs, and only 1.3% of the total area of caatinga vegetation is included within PI conservation areas (TEIXEIRA et al., 2021). It can be seen through the present study that Ceará is significantly lagging behind in the establishment of CAs in caatinga areas in relation to the country as a whole.

There has, however, been an expansion of the network of CAs in Ceará in recent years. Part of that expansion has occurred through the creation of new RPPNs, which are fruits of the efforts of private landowners to create small conservation areas within their rural properties. There has also been a positive creation of new CAs, including PI areas, by the government of Ceará State, especially notable through the creation of the Parque Estadual do Cocó (Cocó State Park in English), in 2017 and the Parque Estadual dos Cânions Cearenses do Rio Poti (Cânion Cearense do Rio Poti State Park in English), in 2021. It appears to us to be a favorable moment for the state government to expand its network of public CAs, focusing on phytoecological units that are less protected, and especially creating more PI or restrictive sustainable CAs, such as FE or ARIEs.

Considering the data gathered here, there is a marked deficit of CAs in the phytophysiognomies typical of semiarid ecosystems, such as Caatinga do Cristalino, and, at the same time, a significant lack of protection of all of the ecosystems of Ceará in terms of PI CAs. We repeat then the necessity of amplifying areas in Ceará State included in CAs, especially as PI reserves, to fulfill the already delayed Aichi goals.

FINAL CONSIDERATIONS

Our results indicate the necessity of expanding the numbers of conservation areas within Ceará State in all of its ecosystems, focusing on PI CAs in the caatinga do Cristalino and Caatinga do sedimentar phytophysiognomies. The creation of any new US CAs should emphasize those with greater legal protections of regional biodiversity (FN or ARIEs), because APAs, in general, permit many environmentally degrading activities (as long as they are licensed). The creation of more (of the more restrictive) ARIEs, Florestas, and RESEXs would represent a positive strategy.

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AUTHORS' CONTRIBUTION

The work is the result of a few years of collaboration between UFC and Sema and is headed by Francisco Vladimir. All authors contributed to the publication, with the following contributions:
Francisco Vladimir Silva Gomes conceived the work; performed the analysis and data processing; participated in data analysis. Wrote the text. Renan Guerra performed data analysis and processing; participated in data analysis; discussed the results; reviewed and approved the text. Ana Maria Ferreira participated in defining the structure and development of the work; discussed the data; discussed the results; reviewed and approved the text. Liana Queiroz participated in the data analysis; discussed the results; wrote the text. Marcelo de Oliveira Teles de Menezes participated in the data analysis; discussed the results; wrote the text. Marcelo Freire Moro conceived the work together with the first author; led the team; participated in data analysis; discussed the results; wrote the text.