

## Opinion Article

# Caatinga: the scientific negligence experienced by a dry tropical forest

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### Abstract

Seasonally dry tropical forests (SDTFs) provide a habitat for a diverse number of species and cover significant land areas. Yet, the amount of scientific research they have attracted is minimal. Recently, an international debate on the generality, consequences and forces keeping SDTFs in a position of relative negligence has begun. This paper assesses and compares biodiversity-related knowledge across the major Brazilian ecosystems to verify in which extent the Caatinga vegetation (a mosaic of scrubs and patches of seasonally dry forest) has been scientifically unappreciated. In fact, Caatinga attracted the lowest scores from semi-quantitative indexes describing biodiversity-survey efforts and knowledge status, with a negligible number of papers published internationally. Caatinga also supports fewer research teams and senior researchers as compared to humid tropical forests (Amazonia and Atlantic Forest). Both the knowledge index and number of published papers were explained by a model combining ecosystem area (km<sup>2</sup>), inventory index plus the current number of research teams or senior researchers assigned to Brazilian ecosystems. These findings reinforce the notion that SDTFs have experienced lower scientific efforts, but also reveal an apparent connection between institutional capacity, production/accumulation of scientific knowledge and conservation efforts. Although the research agenda for reconciling land-use and biodiversity conservation has been launched, current institutional anemia across SDTFs is likely to limit its impacts and achievements.

**Key-words:** biodiversity conservation, biodiversity-related knowledge, capacity-building,

### Resumo

As florestas secas tropicais têm atraído poucos investimentos de ciência e de conservação, mas agora um debate internacional procura entender a generalidade, as conseqüências e as forças que tem mantido estas florestas em relativa negligência. Neste artigo nós examinamos o conhecimento sobre a biodiversidade dos principais ecossistemas brasileiros, de forma a avaliar em que extensão a Caatinga (um mosaico de florestas secas e vegetação arbustiva) tem sido investigada. Como esperado, a Caatinga apresentou os escores mais baixos em termos de esforço de pesquisa e geração de conhecimento, com um número muito pequeno de artigos publicados em revistas internacionais. A Caatinga apresentou, também, o menor número de grupos de pesquisa e pesquisadores seniores se comparada com as florestas úmidas (Amazônia e floresta Atlântica). Tanto o índice de conhecimento como o número de artigos publicados se mostraram relacionados com a área dos ecossistemas, com o índice de inventários e com o número de equipes e pesquisadores seniores devotados a cada ecossistema. Nossos resultados suportam a noção de que as florestas tropicais secas têm recebido atenção reduzida, mas também sugerem uma aparente conexão entre capacidade institucional, produção/acumulação de conhecimento e esforços de conservação. Embora já exista uma agenda de esforços tentando reconciliar o uso da terra com a conservação da biodiversidade, a anemia institucional das regiões de floresta seca pode limitar os avanços e os impactos esperados.

**Palavras-chave:** conhecimento da biodiversidade, conservação da biodiversidade, formação de recursos humanos,

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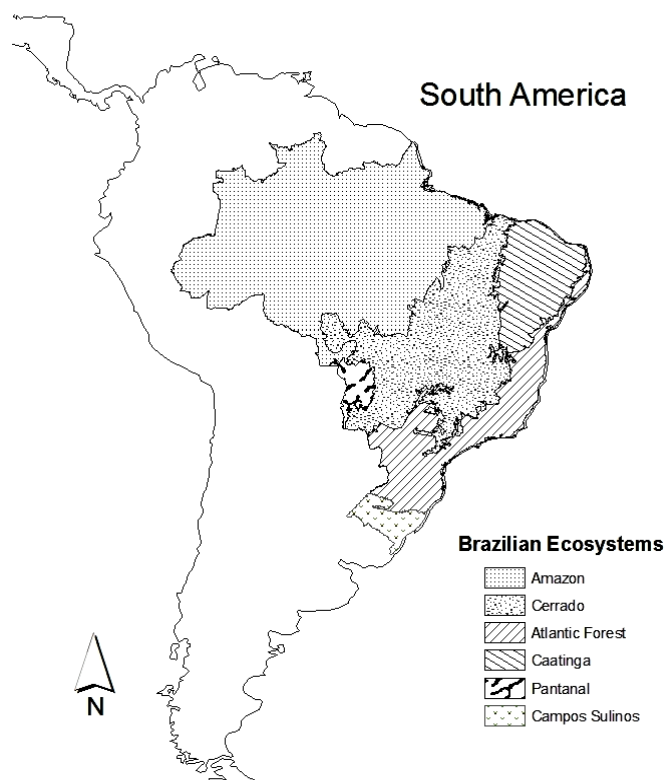
## Introduction

Seasonally dry tropical forests— SDTFs [1, 2] account for a substantial part of all tropical and subtropical forest coverage, and many SDTFs are currently recognized as global hotspots due to significant levels of both species richness and endemism [3, 4, 5, 6]. Surprisingly, SDTFs have received much less attention than humid tropical rain forests in terms of research effort; in the last five decades < 20% of the articles on tropical forest have addressed SDTFs, most of them from a limited number of sites and/or research groups [7]. Moreover, elevated economic appeal, limited knowledge and reduced conservation effort have driven many dry forests to become extremely threatened [8, 9], despite their resilience in particular regions such as the Guanacaste area in Costa Rica [10, 11]. In Central and South America, less than 1% of this “ecologically, socially and economically essential ecosystem” has been converted into protected areas, and globally just 4.9% has been protected by any kind of conservation effort [12].

Such research and conservation bias/deviation has finally attracted international attention and an informative debate has emerged, focusing on the generality, consequences and forces keeping SDTFs in a position of relative negligence [7, 13]. This timely debate joins others addressing required research agenda for tropical ecosystems in a context marked by increasing human disturbances [14, 15, 16]. At least two main reasons have been advocated to explain past and current STDF negligence: the public perspective on tropical forests as idyllic and luxurious habitats worthy of protection has not incorporated SDTFs (i.e., pallid conservation appeal) and SDTFs usually exhibit high economic value associated with goods and services that can be extracted from vegetation or from agricultural soils [17]. Actually, the SDTFs’ suitable habitat for crops and cattle raising (e.g., flat and accessible lands with seasonal climates) have fuelled massive habitat loss worldwide [18, 19]. Regardless of the reasons for the lack of public interest a full understanding of such negligence is challenging to document because SDTFs differ from their counterparts in terms of ecosystem extension. Moreover, they expand over national frontiers and human cultures with variable, if not contrasting, backgrounds relative to science and conservation initiatives [see 2, 12, 38].

Brazil is a mega-diverse country [20] and its territory is covered by a myriad of ecosystems: humid tropical forests (most in the Amazon and Atlantic region), savannas (Cerrado vegetation), wetlands (Pantanal), grasslands (Campos Sulinos) and a well delimited and large block of STDF: the Caatinga vegetation [21, 22]. The Atlantic Forest and Cerrado have been recognized as hotspots for biodiversity conservation, while the Amazon Forest, Pantanal and the Caatinga vegetation (hereafter Caatinga) achieved the status of Global Wilderness [23]. Brazil’s scientific and conservation efforts have already achieved global recognition [24]: Brazil currently ranks 13<sup>th</sup> (1st in Latin America) in terms of ISI-referred papers [25]. Moreover, Brazilian institutions have provided comprehensive diagnosis about its main ecosystems [26, 27], which offer an interesting opportunity to examine the drivers for unbalanced efforts relative to both biodiversity-related knowledge and conservation efforts.

Here we assess information on insects, a highly diversified and environmentally-sensitive group [28, 29, 30], to infer the Caatinga status relative to biodiversity-related knowledge. We also evaluate the scientific institutional capacity currently allocated to this singular biota. By comparing Caatinga scores to those from the other major Brazilian ecosystems (i.e., Atlantic and Amazonian Forest, Cerrado and Pantanal) we are able to examine to what extent the Caatinga biota has experienced a low-priority status as predicted by the negligence hypothesis. We elect the limited institutional capacity (i.e., reduced autochthon intelligentsia) as a clear bottleneck for a more comprehensive panorama about the Caatinga biological heritage. Such anemia, in fact, is expected to compromise any perspective of achieving sustainable development via a science-policy-public approach as claimed for SDTFs [31, 32].



**Fig. 1. Major Brazilian ecosystems, including the Caatinga vegetation– one of the Seasonally Dry Tropical Forests (SDTFs) of South America [2, 21].**

### The Caatinga vegetation: from concept to institutional capacity

The Caatinga is a mosaic of scrub vegetation and patches of dry forest [38], which has been referred to in the literature either as a seasonally dry tropical forest [2, 21, 22, 23] or as a shrubland ecosystem [12]. Despite such disagreement [19], probably caused by the occurrence of low-stature vegetation stands across the Caatinga region, it has been demonstrated that the Caatinga woody flora (shrubs and trees) consists of dry forest species rather than savanna ones [2, 22, 33, 34]. Because of this marked biogeographic feature, Caatinga is considered here as a SDTF biota following previous authors' wide concept or perspective of SDTFs [see Portillo-Quintero and Sánchez-Azofeifa for a review]. Entirely disposed within Brazil's borders (Fig. 1), Caatinga covers over 800,000 km<sup>2</sup> and represents around 10% of the Brazilian landmass. The predominant Caatinga landscape (Fig. 2) refers to flattened depressions (300-500 m a.s.l.), which are submitted to a rainfall regime ranging from 240 up to 900 mm/year and a 7-11-mo dry season [33, 34]. Collectively, Caatinga, Pantanal, Cerrado and Campos Sulinos represent a wide range of seasonal ecosystems (from to SDTFs to grasslands), which cover nearly 50% of Brazilian territory (Table 1). Humid or less seasonal ecosystems are represented by two immense blocks of tropical forest (Amazonia and the Atlantic Forest), which cover the other half of the Brazilian territory [35]. In addition to Caatinga, patches of deciduous forest across the Atlantic Forest region have been also assigned as SDTFs in the Brazilian territory [36]. Caatinga biodiversity yields over 1,000 vascular plant species in addition to 187 bees, 240 fish species, 167 reptiles and amphibians, 516 birds, and 148 mammal species, with endemism levels varying from 9% in birds to 57% in fishes [37]. Current biodiversity scores are several times higher than previous assessments, but equal to or higher than those recorded in other semi-arid biotas around the globe [38].

Table 1. Major Brazilian ecosystems with their respective major vegetation type, area, rainfall and cover.

Brazilian ecosystems	Major vegetation type	Ecosystem area (km <sup>2</sup> ) <sup>1</sup>	Rainfall range (mm)	% of Brazilian territory
Caatinga	SDTF	844,453	240-900	9.9
Cerrado	savanna	2036,448	1100-1600	23.9
Atlantic Forest	tropical forest	1110,182	1000-4000	13.04
Amazonia	tropical forest	4196,943	1400-3000	49.3
Pantanal	savanna	150,355	1000-1400	1.77
Campos Sulinos	grasslands	176,496	1250-1600	2.07

Recent biodiversity assessments and syntheses commissioned by Brazilian governmental agencies (e.g., science, technology and environment-related agencies) offered a comparative perspective on biodiversity-related knowledge across Brazilian ecosystems [26]. Caatinga attracted the lowest scores from a semi-quantitative index describing knowledge status; roughly the knowledge index varied from 0.33 (Caatinga) to 1.67 (Atlantic Forest), but interestingly the Amazonia with its nearly 4.3 millions km<sup>2</sup> achieved only 1.25 (Table 2). In addition to Caatinga, other seasonal ecosystems, such as Campos Sulinos and Cerrado, attracted intermediate scores; i.e. average scores offered by dozens of scientists (*i.e.*, taxa experts) that evaluated knowledge status [39]. Similarly, Atlantic Forest and Amazonia have been much more heavily inventoried than Caatinga and the other seasonal ecosystems: one survey in the Caatinga in comparison to 15 in the Atlantic Forest and 43 in the Amazonia. Overall, humid ecosystems accounted for over 80% of insect surveys assessed by Lewinsohn and Prado [39].

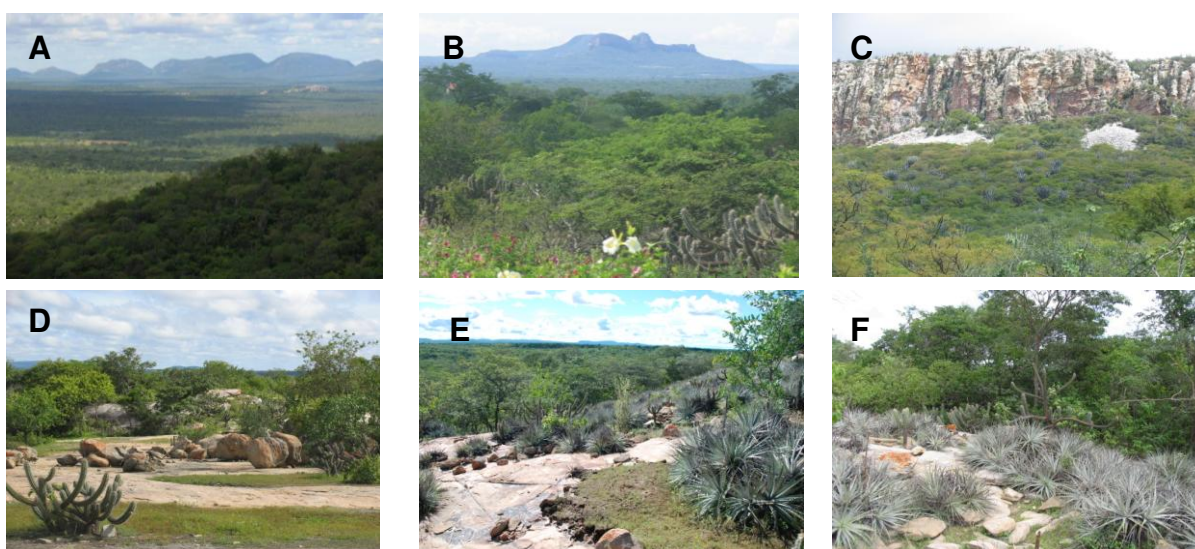


Fig. 2. The Caatinga vegetation: A, B and C refer to forest stands, while D, E and F refer to scrub vegetation dominated by Cactaceae and Bromeliaceae species. Photos by Inara Leal.

From 1945 to 2008, 3,472 insect-related papers from our targeted ecosystems were recorded in the ISI Web of Knowledge, but only 32 (< 1%) referred to Caatinga specifically (Fig. 3). It is worth mentioning that just a single paper addressed Lepidoptera in the Caatinga, an insect group considered as bio-indicator across tropical ecosystems [28]. Even Coleoptera, the most speciose group of insects have been poorly examined, with only 2 studies published up to 2008. Lewinsohn et al. [40] inferred that the knowledge across Brazilian biomes and habitats is not equal, with the Caatinga and Pantanal in need of more studies compared with the Atlantic Forest, the Amazon and Cerrado. Caatinga supports fewer research teams (47) and senior researchers (220) as compared to Amazonia and Atlantic Forest (Fig. 4); e.g. 0.000261 researcher/km<sup>2</sup> devoted to Caatinga while this figure doubled to the Atlantic Forest (0.000560); but note that the 567 researchers assigned to Amazonia represent just 0.000133 researcher/km<sup>2</sup>. Even more revealing is the fact that both the knowledge index adopted by researchers and total number of papers recorded in the Web of Science (1945-2008) were explained by a model combining ecosystem area (km<sup>2</sup>), inventory index plus the current number of Brazilian research teams or senior researchers assigned to the Brazilian ecosystems (adjusted R<sup>2</sup> > 0.9 from stepwise regressions analyses, p < 0.05 for all explanatory variables) according to CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) research platform (<http://lattes.cnpq.br>).

Table 2. Major Brazilian ecosystems with their respective sampling and knowledge indexes, and number of insect inventories.

Brazilian ecosystems	Sampling index (Invertebrates) <sup>1</sup>	Knowledge index (Invertebrates) <sup>2</sup>	No. of insect inventories <sup>3</sup>
Caatinga	0.33	0.33	1
Cerrado	1.1	1.2	11
Atlantic Forest	1.67	1.67	15
Amazonian Forest	1.25	1.25	43
Pantanal	0.89	1	0
Campos Sulinos	0.78	0.8	Not informed

<sup>1</sup> [39]. Medium values of the sampling degrees (0 = none, 1 = bad, 2 = good, 3 = excellent) attributed to the taxa of each group, for Brazilian biome.

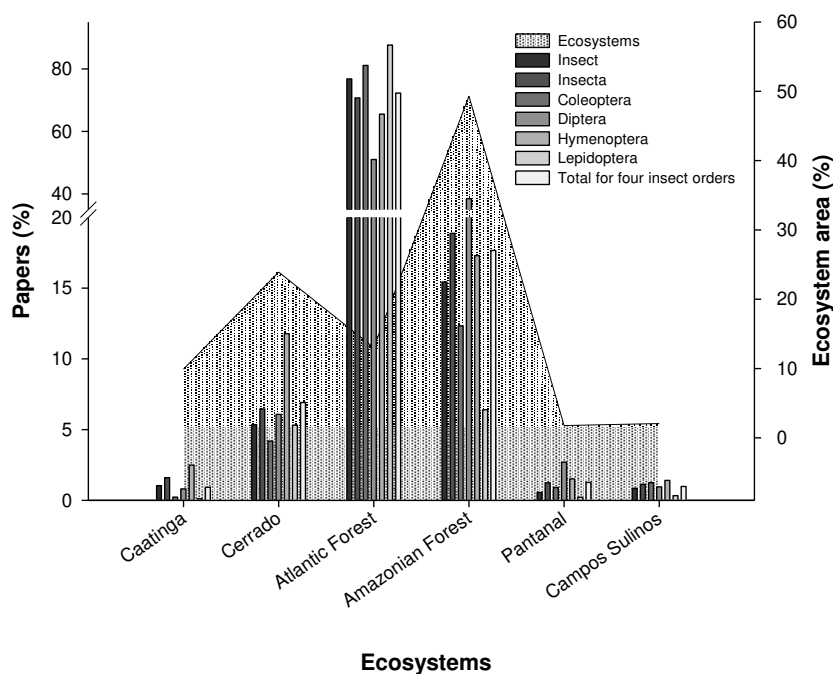
<sup>2</sup> [39]. Medium values of the knowledge degrees (0 = none, 1 = bad, 2 = good, 3 = excellent) attributed to the taxa of each group, for Brazilian biome.

<sup>3</sup> [39]. Insect inventory in Brazil, in the different biomes reported in Zoological Record vols. 122 to 135 (published approximately among 1985 and 1999).

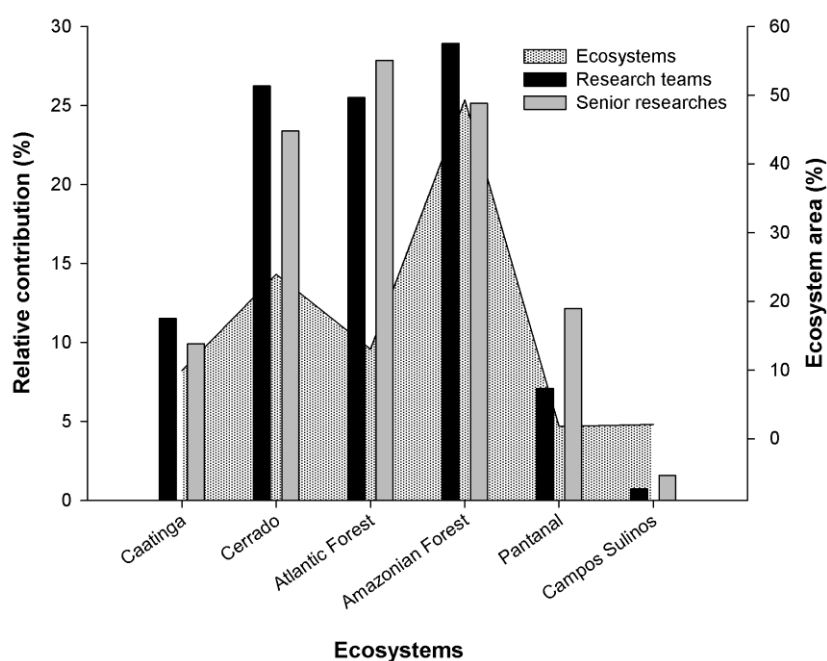
## The negligence of SDTFs and the way forward

It is clear that biodiversity-related knowledge, in particular insect examinations, in the Caatinga biota is much lower than the knowledge already accumulated on humid ecosystems such as Amazonia and the Atlantic Forest. Such findings reinforce the notion that SDTFs have experienced lower scientific efforts, and because of this many outstanding biotas remain scientifically unappreciated [see Fig. 3]. However, trends documented in the Brazilian ecosystems suggest that such relative negligence is not an idiosyncrasy of SDTFs, but rather this condition is shared with other seasonal (and not perceived as luxurious) ecosystems such as the Pantanal and Campos Sulinos. Even humid and highly appealing ecosystems, such as the Amazonian tropical forest, remain poorly investigated when accumulated knowledge considers ecosystem area.

In fact, the relative Caatinga negligence is not a novelty for Brazilian society and scholars. Brazil was recently ranked fourth relative to published papers addressing any aspect of SDTFs; it was behind Costa Rica, Mexico, and Venezuela [31], despite the fact that Brazil leads scientific production in Latin American and has achieved increasing global importance in terms of scientific production and conservation efforts [24, 41]. Caatinga negligence publicly emerged in the 90's as biodiversity-related information was required in order to support the election of priority areas for biodiversity conservation and public policies to anchor initiatives for sustainable development of Brazilian regions [26]. After comprehensive syntheses of available information, including those from biological collections, it was revealed that 50% of the entire Caatinga territory has been neglected by biodiversity surveys, and estimates of total species richness for many taxonomic groups remain missing [26, 42, 43]. Such a gap contrasts to the fact that the Caatinga region was occupied by European populations earlier and was developed faster than Amazonia, Cerrado, Pantanal and Campos Sulinos, which remained occupied by natives for centuries after European arrival in the American continent [44].



**Fig. 3. Relative number of published papers addressing insects (bars) and its main orders across major Brazilian ecosystems according to Web of Science; 3,472 papers published between 1945 and 2008.**



**Fig. 4. Relative number of research teams and senior researchers, which are developing biological investigations across major Brazilian ecosystems. Source: Plataforma Lattes, Conselho Nacional de Desenvolvimento Científico e Tecnológico — CNPq ([www.cnpq.br](http://www.cnpq.br)). Seniors refer to those scientists acquainted with CNPq grants for productivity in biological sciences (2,216 records).**

In addition to reinforcing the notion the SDTFs remain poorly investigated, we revealed an apparent connection between institutional capacity, here expressed in terms of research teams or senior researchers and production/accumulation of scientific knowledge (using insects as indicator). Additionally, we greatly suspect that limited institutional capacity has constrained biodiversity-conservation efforts in the Caatinga biota; particularly those initiatives ruled/demanded by scientific institutions or teams. Between 1985 and 1996, Caatinga captured only 7.2% of millions of U.S. dollars made available for Brazilian environmental agencies, the worst score across Brazilian ecosystems [45] and less than what Caatinga represents in terms of national territory (~10%). As predicted by the negligence hypothesis, noticeable investments were applied to Amazonia and Atlantic Forest regions. Likewise, the Atlantic Forest received nearly 48% percent of all funds applied via PROBIO facility between 1996 and 2005 [46]. PROBIO has been the main financial and political instrument adopted by the Brazilian government to promote sustainable development and achieve those goals committed with the Biodiversity Convention [46]. Additionally, most external funding goes to the Amazon region, whereas far fewer resources are dedicated to environment challenges in other threatened ecosystems such as the Caatinga [47]. With these inequitable investments, Caatinga biodiversity remains poorly described and unprotected (< 1% of protected area coverage). Unfortunately, approximately 28 million people live in poverty in the area, forming one of the most miserable and environmentally fragile regions of South America [48].

Institutional anemia, precarious knowledge and deficient/marginal conservation efforts (any of them a clear evidence of the negligence or low-priority condition experienced by SDTFs) constitute a system with negative feedback loops; as a result, cause-effect connections are not straightforward. This system probably benefits from, but also sustains mediocre levels of formal conservation education as observed throughout Latin America [49]. But such findings clearly indicate the way to move forward. Some SDTFs have finally been recognized as either Hotspots for Biodiversity Conservation [24] or Wilderness Areas of the World [23]. Regardless of any status, SDTFs are experiencing increasing levels of degradation as even lands previously

considered as agriculturally marginal are experiencing conversion into crop fields via advances on technology [17]. Such extensive conversion of natural into human-modified landscapes [13], which in many situations drive singular biotas to desertification, renders SDTFs to be the most endangered ecosystem across the tropics [50]. For example, nearly 20% of the entire Caatinga territory is experiencing desertification and this fragile ecosystem is expected to confront drastic shifts on patterns of rain distribution in response to global warming, thus scaling-up poverty-driven degradation [48, 51]. In this scenario marked by rapid and drastic environmental shifts, precarious biodiversity-knowledge and governance, increasing social pressure and high dependence on natural resources, sustainable development approaches political propaganda rather than knowledge-supported ground initiatives [38].

As already argued [7, 31], the SDTFs call for integrated and multidisciplinary conservation/research projects focused on three major targets: (1) the expansion of basic species- and niche-based research; (2) increasing the biological and ecological knowledge base; and, finally, (3) inclusion of human dimensions on research and conservation planning [7, 52]. In other words, we must close the immense information gap regarding biodiversity ecology and distribution, ecosystem response to human disturbances, biodiversity use by human populations and better-practices (from extractive to industrial primary production such as soy bean plantations) as a *sine qua non* requirement to render sustainable development a more realistic possibility.

Objectively, society must rapidly reduce the institutional anemia experienced by some SDTFs and other seasonal ecosystems by expanding local institutional capacity and research networks (i.e., aggressive capacity-building) with the task of (1) informing stakeholders the costs and benefits from general land use patterns and those imposed by public policies, and (2) developing and transferring the better-practices required for using natural resources sustainably. It is unacceptable that Brazil, a top-ranking biodiversity country, supports less than a dozen of academic programs in conservation biology [49] without any program specifically devoted to Caatinga. Research agenda for reconciling land-use and biodiversity conservation across SDTFs has already been launched by experts [31, 38], but current institutional anemia is likely to limit its impacts and achievements via a science-policy-public approach.

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