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CLIMATE CHANGE AND "CAMPOS DE ALTITUDE": FORECASTS, KNOWLEDGE AND ACTION GAPS IN BRAZIL

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ABSTRACT
The recently published report of the Intergovernmental Panel on Climate Change (IPCC) acknowledges high altitude ecosystems in Latin America and elsewhere as some of the most vulnerable to climate change. The Brazilian Panel on Climate Change (PBMC, from the acronym in Portuguese) also recognizes the vulnerability of Brazilian high mountain ecosystems, but points out to a significant gap in data and knowledge. This paper briefly reviews the contents in these reports that refer to high altitude ecosystems and cross-compare with biological data available for such formations in Brazil. Emphasis is given to non-forest ecosystems, namely the so-called campos de altitude, and specific data and knowledge gaps are highlighted. The implementation of the existing policy called National Program for Research and Conservation of Mountain Ecosystems would be an important step to fill this gap.
Keywords: biodiversity monitoring; campos de altitude; climate change; high altitude ecosystems; non-forest ecosystems.

INTRODUCTION

Climate change causes impacts on natural and human systems on all continents and oceans, but evidence of such impact is strongest and most comprehensive for natural systems (IPCC 2014). The recently launched fifth assessment report of the IPCC (Intergovernmental Panel on Climate Change) recognizes high altitude ecosystems as some of the most vulnerable among such natural systems (Magrin et al. 2014). Brazil is not particularly known for its mountains, to which until very recently, there were no specific environmental policies (Martinelli 2007). Historically, mountain areas in Brazil were treated as part of other biomes or biogeographic regions, even though the Convention of Biological Diversity – of which Brazil is a signatory party – gives specific treatment to mountains since 2002. The creation of the National Centre for Plant Conservation (or Centro Nacional para Conservação da Flora - CNCFlora) at the Botanical Gardens of Rio de Janeiro in 2008 (Scarano & Martinelli 2010, Scarano 2014) has attempted to change this scenario and led the launching of a national program for research and conservation of mountain ecosystems (http://aplicacoes.jbrj.gov.br/materias/11_03_2011%281%29.html) in 2011.

Despite this recent recognition of the relevance and peculiarity of mountain ecosystems in Brazilian environmental policy, there remains a notable gap in data and knowledge about such habitats. This is of particular concern in face of climate change. The Brazilian Panel on Climate Change (PBMC) has recently mentioned the vulnerability of such ecosystems, but largely based on literature referring to high altitude mountains outside Brazil (Souza-Filho et al. 2014). For instance, it is well known that species with geographic range restricted to mountains (known as elevation specialist) are most frequent in the Americas than anywhere else (Laurance et al. 2011). Based on examples from the Andes and Sierra Madre, these species (birds and mammals in particular) are vulnerable to global warming because they have low thermal tolerance and a limited capacity to survive heat waves. Moreover, Laurance et al. (2011) also explain that these species of birds and mammals have small geographic ranges and that their high energy requirement (as compared to ectotherms as lizards, for instance) translates into a comparatively larger area requirement. Similarly, high mountains provide key ecosystem services for both highlands and lowlands, related to water and food security, soil provision and cultural services (Körner & Ohsawa 2005) – all of which are challenged by climate change.

Mountain ecosystems add up to some 25% of the planet´s continental surface and can be found in all climatic zones. Variation in topography, geology and isolation from other mountains partly explain the often high biological diversity of such ecosystems worldwide (Körner 2002) and also in Brazil (Martinelli 2007). Of course, this variation is also translated into a broad diversity of ecosystem types that comprise forests, savannas, grasslands, rocky outcrop vegetation and wetlands. Martinelli (2007) has provided the most detailed account of mountain vegetation types in Latin America alongside with a thorough list of Brazilian mountains. Among the Brazilian types, non-forest formations include the so-called campos de altitude (present both at the Atlantic forest and the Amazon biome at an altitudinal range from 1,200 m a.s.l. to ~ 3,000 m a.s.l) and the campos rupestres (within the Cerrado biome, at lower altitudes ranging from 1,000 to 2,000 m a.s.l.; see Fernandes et al. 2014). The campos de altitude vegetation is predominantly formed by shrubs, herbs and grasses in interspersed rocky outcrops, shallow soils and occasional bogs (Ribeiro et al. 2007), and will be the main focus of this paper.

This paper aims to review some of the main threats to neotropical high altitude non-forest ecosystems posed by climate change, while comparing them to some of the available biological data on Brazilian campo de altitude ecosystems and species. Furthermore, we examine the available environmental policy framework in the country to propose actions that would reduce knowledge gaps so as to promote effective conservation of such habitats under a climate change scenario.

PROJECTIONS AND FORECASTS

There is a remarkable absence of climate change projections for such types of ecosystems and their local species in Brazil. Recent reviews for Brazil and Latin America (Magrin et al. 2014, Souza-Filho et al. 2014) make no reference for existing projections for non-forest species at high altitude in Brazil, such as those from campos de altitude. Some of the generalization and projections about the effects of climate change on biodiversity and ecosystem services for other high altitude ecosystems available in the literature might serve as indication of the type of threats the Brazilian campos de altitude are exposed to. The expected effects of climate change in these ecosystems include habitat reduction, species shifts in distribution, population decline, and modifications in phenology. In addition, there is broad consensus around the notion that the faster and more severe the rate of climate change, more severe will be the biological consequences (Brook et al. 2008). In the case of high altitude ecosystems, there is enough evidence suggesting that global warming should reduce available land to species adapted to such habitats, especially plants (Spehn et al. 2002; Perez-Garcia et al. 2013). There are also projections that species invasions might increase in high mountain areas (Bellard et al. 2013; Bertelsmeier et al. 2013). In the tropics, high Andean ecosystems are expected to face exceptionally strong warming effects during the 21st century because of their altitude (Bradley et al. 2006). For instance, projections of vertebrate species turnover in the Andes Mountains until 2100 are as high as 90% for emission scenarios varying from low (B1) to mid-high (A2) (Lawler et al. 2009).

The recent IPCC report has also highlighted that, in addition to climate change impacts at the individual species level, biotic interactions will be affected, which include modifications in plant phenology and consequent plant-animal interactions, structure of ecological networks, predator-prey interactions, and non-trophic interactions among organisms (Magrin et al. 2014). Such shifts in species distribution and persistence and also in biotic interactions may imply loss of representativeness of many species. Even existing protected areas would have little effect for protection of such species under such scale of climate change (Heller & Zavaleta 2009).

Moreover, high altitude ecosystems provide a series of crucial ecosystem services for millions of people (Buytaert et al. 2011), which include agricultural products, watershed protection, soil protection, and tourism and creation (Körner & Ohsawa 2005). Since biodiversity safeguards such key ecosystem services, if biodiversity is threatened by climate change it can be expected that impact upon biodiversity might have a direct effect on ecological flows that are vital to human well-being (Díaz et al. 2015).

As mentioned earlier, campos de altitude in Brazil are found mainly in the Atlantic forest biome and in the Amazon biome. Although projections and forecasts for species and ecosystem in high altitude in Brazil, two facts indicate, even if indirectly, the level of threat Brazilian campos de altitude are exposed to when faced by climate change: (1) the Atlantic forest has been recently classified as one of the three biodiversity hotspots most vulnerable to climate change (Béllard et al. 2014); and (2) deforestation of the Amazon continuously raises concerns with a potential future savannization of this biome (Nobre & Borma 2009) and there is recent evidence suggesting that savannization may be taking place also in locations at the Atlantic rain forest (Sansevero 2013; Scarano & Ceotto 2015). So, in both cases, the island-like campos that emerge at high altitudes are likely to be directly or indirectly affected by impacts on the surrounding forests. This problem had already been highlighted by Martinelli (1996) who argued that the forests surrounding the campos de altitude act as buffers to maintain local climate and to avoid invasive species.

INFORMATION AVAILABLE AND KNOWLEDGE GAPS

While there is nearly an absolute lack of biological data for Amazonian campos de altitude (but see Nadruz et al. 2016), more information is available for campos de altitude of the Atlantic forest, especially for the Itatiaia plateau in southeast Brazil. The data indicates expectedly high levels of endemism (Martinelli 1984, 1996; Barbara et al. 2007, 2009; Ribeiro et al. 2007; Fernandez et al. 2012) and a surprisingly high diversity of ecophysiological behavior for plants, even at intraspecific level (Scarano et al. 2001). Flexibility of photosynthetic mechanisms and nitrogen use were found on some of the key endemic species in Itatiaia´s rocky outcrop and indicate potential for plasticity and acclimation even for plants that are rare in nature (Scarano 2009). However, it remains to be tested how plastic such species are in relation to increasing temperatures and reduced humidity fostered by global warming.

The concerns expressed in the IPCC report about the effects of climate change on biotic interactions (Magrin et al. 2014) are very applicable to the campos de altitude of Itatiaia. Medina et al. (2006) described how plant diversity in these rock outcrops depends on a few “mat species”. These are plants that establish and spread on the rock surface as mats, and as consequence provide new colonization sites and contribute to microhabitat heterogeneity in such habitats, thus allowing successful entry of a higher number of species (Porembski et al. 1998). Mat species often behave as nurse plants and, through facilitation, they play a role in the modification and maintenance of habitats that cover the bare rock and create germination sites to a large number of species that otherwise would not establish (Medina et al. 2006). Therefore, it can be expected that if climate change affects distribution or survival of such mat species, it can have an impactful effect on campo de altitude biodiversity. The potential increase of fire frequency in this habitat will also likely affect species diversity and biotic interactions (Medina et al. 2016, in this issue).

Nearly a decade ago, on a review of studies on rocky outcrop vegetation in Brazil - most of which on mountain ecosystems - we concluded that there were many scientific gaps to be filled (Scarano 2007). Despite much progress since then (as this Special Issue of Oecologia Australis for campos de altitude exemplifies), there remains a significant gap on climate change studies for mountain ecosystems such as the campos de altitude. One recommendation from that review was that long term ecological monitoring sites should be established to trace the potential effects of climate change on campos de altitude ecosystems and species. For instance, Grabherr et al. (2001) suggested monitoring indicators for short-term (< 10 years; e.g. flowering phenology), mid-term (between 10 and 50 years; e.g. community structure and composition), and long-term effects (> 50 years; e.g. landscape pattern close to the treeline) on biodiversity by climate change. Such an approach would definitely fit into the existing Brazilian network of Long Term Ecological Research Projects (Tabarelli et al. 2014), would much enhance the knowledge on the relationships between climate change and biodiversity, and would therefore increase potential application of results to policy.

Another important knowledge gap refers to studies on climate change and land use change impacts on ecosystem services derived from mountain ecosystems such as the campos de altitude. At Serra da Mantiqueira, the mountain chain to which the Itatiaia massif belongs, Simas et al. (2005) found carbon stocks in highland peat of 1,500 Mg ha^{-1} that is nearly five times more than what is found in mature Atlantic forest. High altitude ecosystems can be efficient carbon sinks as well of sources of water provision. The Paraíba do Sul river, which connects the megacities of São Paulo and Rio de Janeiro now undergoing a major water crisis, has the Itatiaia massif as a key water supplier of its watershed (Marengo & Alves 2005). Recent advances regarding the development of rapid assessments of ecosystem services (e.g., Meyer et al. 2015) could also be applied for long term monitoring of such areas.

FINAL REMARKS: POLICY ACTION

Perhaps the most significant step forward in promoting conservation and science on mountain ecosystems in Brazil has been the approval by the CONABIO (National Commission on Biodiversity) in 2011 (http://aplicacoes.jbrj.gov.br/materias/11_03_2011%281%29.html) of the national program of research and conservation of mountain ecosystems (Programa Nacional de Pesquisa e Conservação de Ecossistemas de Montanhas). This is in itself a sign that some of the usual obstacles between science output and decision-making at policy level (see Scarano & Martinelli 2010) have been overcome. However, this program still requires implementation, funding and visibility. Since 2011, no specific actions were undertaken or incentivized. We hope that this Special Issue on high altitude vegetation in Brazil can help highlight the importance and urgency of implementing this public policy.

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