THE DESICCATION-TOLERANT VASCULAR PLANTS' PARADOX:

THE ROLE OF ENVIRONMENTAL CONSTRAINTS ON THE DIVERSITY AND DISTRIBUTION OF PLANTS ABLE TO RESURRECT FROM DRYNESS

Luiz Fernando Bondi de Macedo

Gutachter:
Prof. Dr. Stefan Porembski, Universität Rostock, Abt. Allgemeine u. Spezielle Botanik
Prof. Dr. Bruno H.P. Rosado, State University of Rio de Janeiro (UERJ), Department of Ecology
Prof. Dr. Suzana Alcantara, Federal University of Santa Catarina (UFSC), Department of Botany

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submitted by

Luiz Fernando Bondi de Macedo

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Der Universität Rostock

Rostock, Februar 2023

Supervisors:

Prof. Dr. Stefan Porembski

Universität Rostock
Mathematisch-Naturwissenschaftlichen Fakultät
Institut für Biowissenschaften
Allgemeine und Spezielle Botanik
Germany

Prof. Dr. Bruno Henrique Pimentel Rosado

Universidade do Estado do Rio de Janeiro (UERJ)
Instituto de Biologia Roberto Alcântara Gomes
Departamento de Ecologia
Brazil

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When I started my Biology course I was completely certain that nothing related to Botany would fit for me. Then everything quickly changed in my second semester at the university, in which I had Botany classes with Laura Jane Santiago, which turned out to become a wonderful mentor with who I had the unique opportunity to learn about the inselbergs vegetation inselbergs. I am extremelly grateful for her pushing me towards the direction in which I find myself today. Then, I came to Germany to elaborate a doctorate project, and who would guess that (even in Germany) I would again have learned so much from another wonderful Brazilian female scientist? It has been around 6 years since I decided to study DT plants, but still today, everytime I write down “the DT plants” I hear in my head Luiza’s voice saying “as tolerantes” in her distinctive accent from Tchotcho. I am deeply thankful to Luiza de Paula for every kind of support she gave me along all these years.

At this point my doctorate started and, despite the cliché, I could never express enough my sincere gratitude to my supervisors Stefan Porembski and Bruno Rosado guidance thought-provoking discussion over the last years. I will always be thankful to Stefan for his attention and patience, as my admiration for him goes beyond his vast scientific experience and capacity to motivate into science every human being that cross his path. Thank you for always encouraging me to always do my best. Of course, my admiration and gratitude is extended to Bruno, which has always been an exceptional advisor and a model scientist to me. Thank you for being on my side even in the worst moments of my journey.

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Stäuber, Kibru Zeleke, Juliane Rexroth, Markus Eichel, Mirko Dreßler, Tabea Giese, Thomas Hübener, Zaïnabou Dabre for let me learning so much with you from scientific to cultural perspectives. Their companionship always helped me to sometimes forget what the cold of Rostock was sometimes trying to remember me: I am a bit too far from home. I also would like to thank Julius Köhler for all the encouragement and collaboration, besides Konrad Schultz for providing many scientific and philosophical incursions that significantly helped me during my doctorate (in the last 4 fears I spent more time with him than with anyone else, and going to the lab sitting by his side always was a pleasure for me). Most of all, I would like to thank Petra Kiehl for being so helpful and attentive during my stay. For much less she would have granted a place in heart, in that corner that only mothers could claim their right to be.

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To Jade, Cristal, and Marie

“Science progresses best when observations

force us to alter our preconceptions.”

Vera Rubin

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The desiccation-tolerant vascular plants (DT plants) stand out among tracheophytes due to their ability to tolerate the desiccation of their vegetative tissues. Because of this remarkable capacity, DT plants are often perceived as plants able to deal with the most distinct environmental constraints and paradigms concerning ecological aspects of desiccation tolerance have been developed. However, contradictions between theoretical premises and empirical findings are found in the literature. For example, previous studies have shown that the DT plants capacity to cope with desiccation is affected by the environmental constraints. This leads to a paradox where. On the one hand, these plants are able to resurrect after desiccation, while, on the other hand, environmental conditions significantly influence the diversity and distribution of these plants. Here, we discuss in three parts the ecology of DT plants, testing untested paradigms and fulfilling knowledge gaps regarding their ecology and conservation. In the first study, it was tested the paradigms of a convergent ecological specialization of DT plants for water deficit conditions and of the perception of these species in the extreme end of stress tolerance. In the second study, it was tested the paradigm that DT plants are strongly correlated with water deficit condition. In the third study, we investigate the impact of climate change on DT plants, which are largely neglected for conservation. For that, we combined biogeographical and functional approaches from a taxonomic, phylogenetic, and conservation perspective. We found that despite converging in desiccation tolerance, DT plants differ in relation to the water deficit conditions they occur and in their ecological strategies to deal with water deficit. In this sense, DT plants form a heterogeneous group of plants in how they deal with drought. We also found that DT plants are neither related, restricted, nor have their highest diversity linked to arid and highly seasonal precipitation conditions. Climate changes can affect the diversity and distribution of DT plants. We showed that species from wetter locations and ecologically more restricted will be more vulnerable when the worst future scenario is considered. Besides, twe suggest the geographical range as a good starting point to target species with a higher need for conservation attention. It is likely that the multiplicity of evolutionary processes that drove DT plants' diversity might be hindering the role of phylogeny in the understanding of species' ecological aspects and vulnerability to climate change. In this way, there is no significant difference between DT plants phylogenetic groups in their response to water deficit. At last, we identified conservation priority areas for DT plants in continents, except in Antarctica. In those areas, a low historical climatic variability was found, suggesting that the species’ vulnerability could be due to a higher sensitivity and lower adaptive capacity to climate change.

Die austrocknungstoleranten Gefäßpflanzen (AT-Pflanzen) zeichnen sich unter den Tracheophyten durch ihre Fähigkeit aus, die Austrocknung ihres vegetativen Gewebes zu tolerieren. Aufgrund dieser bemerkenswerten Fähigkeit werden AT-Pflanzen oft als Pflanzen angesehen, die mit den unterschiedlichsten Umweltbedingungen zurechtkommen und in der wissenschaftlichen Gemeinschaft entstanden Paradigmen zu ökologischen Aspekten der Austrocknungstoleranz. In der Literatur finden sich jedoch Widersprüche zwischen theoretischen Prämissen und empirischen Befunden, dies verdeutlicht es die Notwendigkeit einer Überprüfung der Paradigmen. So haben frühere Studien gezeigt, dass die Fähigkeit der AT-Pflanzen, mit der Austrocknung fertig zu werden, von den Umweltbedingungen beeinflusst wird. Dies führt zu einem Paradoxon, bei dem auf der einen Seite deise Pflanzen es vermögen nach der Ausrocknung wieder aufzuerstehen, während auf der anderen Seite Umweltbedingungen die Vielfalt und Verbreitung dieser Pflanzen maßgeblich beeinflussen. Hier wird in drei Teilen die Ökologie der AT-Pflanzen erörtert, wobei ungeprüfte Paradigmen getestet und Wissenslücken hinsichtlich ihrer Ökologie und Erhaltung geschlossen werden. In der ersten Studie wurden die zwei Paradigmen einer konvergenten ökologischen Spezialisierung von AT-Pflanzen auf Wasserdefizitbedingungen und der Wahrnehmung dieser Arten im extremen Bereich der Stresstoleranz getestet. In der zweiten Studie wurde das Paradigma getestet, dass AT-Pflanzen stark mit Wasserdefizitbedingungen korreliert sind. In der dritten Studie wurden die Auswirkungen des Klimawandels auf AT-Pflanzen untersucht, die bei der Erhaltung der Arten weitgehend vernachlässigt werden. Dazu wurden biogeographische und funktionale Ansätze aus taxonomischer, phylogenetischer und naturschutzfachlicher Sicht kombiniert. Als Ergebnis zeigte sich, dass sich AT-Pflanzen trotz ihrer gemeinsamen Austrocknungstoleranz in Bezug auf

die auftretenden Wasserdefizitbedingungen und in ihren ökologischen Strategien zur Bewältigung des Wasserdefizits unterscheiden. In diesem Sinne bilden die AT-Pflanzen eine, in Bezug auf ihre Fähigkeit mit Trockenheit umzugehen, heterogene Gruppe von Pflanzen. Es zeigte sich, dass AT-Pflanzen weder verwandt noch ökologische eingeschränkt sind und ihre höchste Vielfalt nicht mit ariden und stark saisonalen Niederschlagsbedingungen zusammenhängt. Klimaveränderungen können sich auf die Vielfalt und die Verbreitung von AT-Pflanzen auswirken. Im schlechtesten Zukunftsszenario werden Arten aus feuchteren und ökologisch eingeschränkteren Gebieten stärker gefährdet sein. Außerdem wurde festgestellt, dass die Größe des geografischen Verbreitungsgebietes der AT-Pflanzen ein guter Indikator ist, um die Anfälligkeit der Arten gegenüber dem Klimawandel zu beschreiben. Es ist wahrscheinlich, dass die Vielzahl der evolutionären Prozesse, die zur Vielfalt der AT-Pflanzen geführt haben, beeinträchtigend auf die Rolle der Phylogenie für das Verständnis der ökologischen Aspekte der Arten und ihrer Anfälligkeit für den Klimawandel wirken könnten. So gibt es keine signifikanten Unterschiede zwischen den phylogenetischen Gruppen der AT-Pflanzen hinsichtlich ihrer Reaktion auf Wasserdefizite. Schließlich wurden in allen Kontinenten, mit Ausnahme der Antarktis, prioritäre Schutzgebiete für AT-Pflanzen identifiziert. In diesen Gebieten wurde eine geringe historische Klimavariabilität festgestellt, was darauf schließen lässt, dass die Verletzlichkeit der Arten auf eine höhere Empfindlichkeit und geringere Anpassungsfähigkeit an den Klimawandel zurückzuführen sein könnte.

ABBREVIATIONS

AI – Thornthwaite’s aridity index
ANCOVA – Analyses of Covariance
ANOVA – Analyses of variance
AUC – Area under the receiver operating characteristic
BIO15 – Coefficient of variation in precipitation seasonality
Ca$_{50}$ – Circular Area with a radius of 50 km
CSR – competitiveness, ruderalism, and stress-tolerance
CWD – Climate water deficit
DRF – Drought frequency
DRI – Drought intensity
DRL – Drought length
DS plants – Desiccation-sensitive vascular plants
DT plants – Desiccation-tolerant vascular plants
EIV$_{M}$ – Ellenberg Indicator values for moisture
EXP – Exposure to climate changes
H – Plant height
HS$_{EIVM}$ – Ellenberg Indicator values for moisture in which species exhibited the highest score
IDW – Inverse-distance weighted model
LA – Leaf area
LDMC – Leaf dry matter content
LHS – leaf, height, and seed
MAT – Mean annual temperature
MaxEnt – Maximum entropy
MI – Marginality index
NB – Niche breadth
NP – Niche position along the environmental gradients
OV – Overlapping index
PCA – Principal component analysis
PK – Pearson’s measure of Kurtosis
SDM – Species distribution model
SEN – Sensitivity to climate changes
SI – Walsh and Lawler's rainfall seasonality index
SLA – Specific leaf area
SM – Seed mass
SPEI – Standardized Precipitation Evapotranspiration Index
Srad – Solar radiation
Tukey HSD – Tukey honestly significant difference
VPD – Vapor pressure deficit
VUL – Vulnerability to climate changes
WDA – Water deficit affiliation
WDNB – Niche breadth along a water deficit gradient
ΔDRF – Variability in drought frequency
ΔDRI – Variability in drought intensity
ΔDRL – Variability in drought length
ΔMAT – Variability in mean annual temperature
ΔSrad – Variability in solar radiation
ΔVPD – Variability in vapor pressure deficit

This thesis makes use of qr code to access color information on the distribution, ecology, and conservation of desiccation-tolerant vascular species.

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THE ECOLOGY OF DESICCATION-TOLERANT VASCULAR PLANTS

DT plants in the steepness Sugarloaf Mt. Picture by L. Bondi

CHAPTER 1

THE ECOLOGY OF DESICCATION-TOLERANT VASCULAR PLANTS

In plants, the desiccation tolerance is the capacity of an organism (or its tissues and organs) to tolerate almost complete loss of protoplasmic water, reaching equilibrium with the atmospheric dryness (Bewley, 1979; Oliver et al., 2000; Gaff and Oliver, 2013). Desiccation-tolerant organisms suspend their cellular metabolism in the air-dry state, resuming their metabolic activities when moisture conditions are favorable (Bewley, 1979; Oliver et al., 2000). The capacity to tolerate desiccation is commonly found in algae, lichens, and bryophytes, although among vascular plants, this response seems to be mostly related to reproductive structures (i.e., pollen, spores, and seeds; Bewley, 1979; Oliver and Bewley, 1997; Vicre et al., 2004; Toldi et al., 2010; Farrant and Moore, 2011; Farrant et al., 2020). The desiccation tolerance of vegetative tissues in vascular plants is considered a rare feature which has independently evolved multiple times within Tracheophytes phylogeny (Oliver et al. 2000; Gaff and Oliver, 2013; Marks et al., 2021; Porembski, 2021). It makes the desiccation-tolerant vascular plants (DT plants) a particular group of species able to overcome less than 13-20% of protoplasmic water without losing the viability of photosynthetic tissues (Oliver et al., 2000; Gaff and Oliver, 2013; Porembski, 2021).

After the first publications about DT plants in the first half of the XX century (e.g., Dinter, 1918; Heil, 1924; Porembski 2021) the scientists' interest on this subject increased, and with that, the expected diversity of DT plants also raised. The species number estimations increased from 60-70 species (Bewley, 1979) to around 1500 species (Porembski 2021). The scientific advances in this aspect were possible due to the many studies on single or few species (e.g., Hambler, 1961; Owoseye and Sanford, 1972; Gaff and Churchill, 1976; Eickmeier, 1979;

Barthlott and Porembski, 1996; Sherwin and Farrant, 1996; Tuba et al., 1998; Farrant, 2000; Bartels, 2005; Vieira et al., 2017; do Nascimento et al., 2020) and studies that revealed more extensive lists of DT plants (e.g., Gaff, 1977; Gaff and Latz, 1978; Gaff and Bole, 1986; Gaff, 1987; Gaff et al., 1990; Meirelles et al., 1997; Iturriaga et al., 2000; Hemp, 2002; Kessler and Siorak, 2007; Kirkpatrick 2008; Proctor, 2009; Hietz, 2010; Mkhize 2018; Péli and Nagy-Déri, 2018; López-Pozo et al., 2019). Marks et al. (2021) catalogued 360 DT plants which can be found in all continents, excluding Antarctic, and are distributed into 10 fern and fern ally, and 10 angiosperm families.

Alongside with the species descriptions, the species' responses to the environment were inherently assessed. At certain extent, the DT plants responses to water deficit has been largely investigated either or both at the morpho-anatomical (e.g., Gaff et al., 1976; Tuba et al., 1993; Barthlott and Porembski, 1996; Moore et al., 2007; Korte and Porembski, 2012), ecophysiological (e.g., Eickmeier, 1979; Schwab et al., 1989; Lebkuecher and Eickmeier, 1991; Tuba et al., 1998; Willigen et al., 2001; Georgieva et al., 2020), and "omics" (e.g., Harten and Eickmeier, 1986; Piatkowski et al., 1990; Iturriaga et al., 1992; Gaff and Bartels, 1997; Blomstedt et al., 1998; Farrant et al., 2003; Liu et al., 2009; Giarola and Bartel, 2015; Juszczak and Bartels, 2017) levels. Due these scientific efforts, it is possible to us discuss common plants responses associated with desiccation tolerance in many species. For example, the role of leaf folding (e.g., Lebkuecher and Eickmeier, 1991; Oliver and Bewley, 1997; Farrant et al., 2003; Kampowski et al., 2018), sugars accumulation (e.g., Kaiser et al., 1985; Roser 1991; Muller et al., 1995; Iturraga et al., 2000; de Moraes et al., 2014; Williams et al., 2015; Zhang et al., 2018), and LEA proteins production (e.g., Piatkowski et al., 1990; Blomstedt et al., 1998; Bartels and

Mattar, 2002; Smith-Espinoza et al., 2007; Liu et al., 2009; Giarola and Bartel, 2015; Juszczak and Bartels, 2017).

Those above-mentioned responses are often viewed as mechanisms of DT plants to overcome desiccation (e.g., Oliver et al., 2020; Marks et al., 2021; Porembski et al., 2021). However, the ecological implications of the different ways to cope with desiccation among DT plants are still unexploited (Marks et al., 2021). That is because, due to desiccation tolerance capacity, DT plants are often perceived as plants able to deal with the most distinct environmental constraints (e.g. remaining alive for even more than 50 years in the dry state; Roser 1991; Alpert, 2000; Scott, 2000; Griffiths et al., 2014). This assumption is reinforced by the fact that most DT plants occur in ecosystems distinguished by lack of soil, prone to quick water depletion, and high solar radiation. Porembski and Barthlott (2000) claimed inselbergs (i.e., rock outcrops that abruptly emerge from the surroundings) as centers of diversity for DT plants, while Marks et al. (2021) estimated that 90% of DT plants grow in rock outcrops. Because of that, DT plants have aroused the interest of scientist due to the possible use of desiccation tolerant genes on economically important plants in face to climate change (Vicre et al., 2004; Toldi et al., 2010; Farrant and Moore, 2011; Griffiths et al., 2014; Farrant et al., 2020). However, we first need to improve our understanding on the DT plants response to climate changes to more effectively conduct biotechnological investigations with DT plants in order to enhance global food and water secutiy. To the best of our knowledge, the response of DT plants to an increasing drought promoted by climate change is still unknown.

The lack of studies in this sense is related to the DT plants expectancy of "unbeatableness" by drought. However, previous studies (e.g., Farrant et al., 1999; Farrant & Kruger, 2001; Farrant et al., 2003; Georgieva et al., 2008) showed that this assumption is not true because DT plants capacity to cope with desiccation depends on environmental constraints. From that contradiction emerges a paradox in which plants able to resurrect from the almost complete dryness are in fact affected by changes in the environmental constraints. This paradox challenges our understanding on the desiccation tolerance of these plants and rise questions about existing paradigms which can be found in the literature. For instance, until what extent can we expected the drought tolerance of drought-tolerant plant if its survival is affected by an increase in drought conditions? It is necessary to disentangle this paradox in order to promote consistent scientific advances in the DT plants context.

Marks et al. (2021) summarized the environmental constraints to DT plants diversity and identified the desiccation rate, light incidence, temperature conditions, besides the frequency, intensity, and length of drought events as the main factors that affect their desiccation capacities (Figure 1.1). They also highlighted that the influence of these six factors vary among species and more studies are needed to better comprehend the many dimensions of variability in desiccation tolerance among DT plants. Ultimately, the above-mentioned constraints determines the diversity and distribution patterns of DT plants across the globe, implying in conservation issues for species due to climate change. Still, not much further information is found in the literature to explain the diversity of DT plants in their ecology.

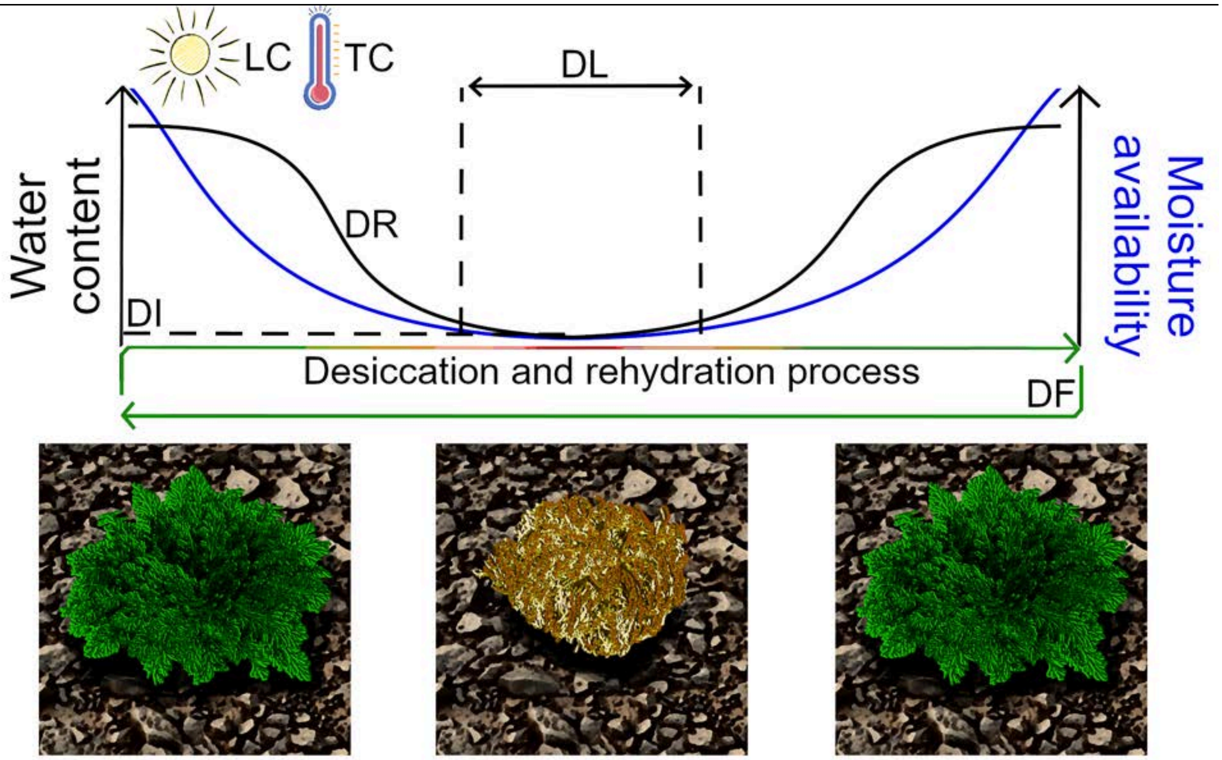

Figure 1.1. The desiccation-tolerant vascular plants' response (black line) to moisture availability (blue line) along time in which desiccation and rehydration processes occur**.** DR – desiccation rate; LC – light incidence; TC – temperature conditions; DF – drought frequency; DI – drought intensity (dashed line); DL – drought length. Adapted from Marks et al. (2021).

The ecological differences among the DT plants are usually attributed to the two main mechanisms of desiccation tolerance could be identified among DT plants. Plants can overcome desiccation by keeping chlorophyll when desiccating (i.e., homoiochlorophyllous plants) or dismantling the photosynthetic apparatus (i.e., poikilochlorophyllous plants; Bewley, 1979; Oliver et al., 2000; Tuba, 2008; Marks et al., 2021; Porembski, 2021). Such mechanisms are supposed to promote different affinities of species for conditions and resources where they grow (Gaff and Latz, 1978; Meirelles et al., 1997; Oliver et al., 2020; Marks et al., 2021). Homoiochlorophyllous plants, mostly found among ferns and ferns allies, and eudicots families, would better tolerate quicker and repeated desiccation events. Conversely, the poikilochlorophyllous response, exclusively found among monocots families, is expected to confer advantages to the plants growth under higher solar radiation, prolonged and more intensive drought periods (Meirelles et al 1997; Alpert 2000; Oliver et al., 2000; Marks et al., 2021). Still, exceptions can be found. For instance, Selaginellaceae and Myrothamnaceae species are homoiochlorophyllous and inhabit locations exposed to longer droughts where poikilochlorophyllous plants are also recorded (Porembski, 2021).

It highlights the need for more studies that aim to discuss the role of environmental constraints to the diversity of DT plants. That is even more crucial in a climate change scenario. Future droughts events are expected to become more unpredictable, more intensive, set in quicker, and last longer, depending on the location (Broennimann et al. 2006; Sheffield et al. 2012; Trenberth et al. 2014; Mukherjee et al. 2018). Overall, DT plants occur in drought prone habitats (e.g., rock outcrops and canopy; Marks et al., 2021). In this sense, it is possible that climate change exceeds DT plants tolerances to environmental constraints. Therefore, studies that improve our understanding about the ecological aspects of DT plants and evaluate critical species and locations for conservation become essential for scientific advances in this subject.

In this thesis, it is intended to discuss how environmental constraints influence the diversity and distribution of DT plants, and its impact on their conservation. For that, we combined biogeographical and functional approaches, structuring the thesis in five chapters and two appendix sections:

(1) A general introduction, in which we bring the state of the art and contextualization of the existing knowledge gaps to be addressed in this thesis;

(2) study on the selective factors that influence the DT plants' diversity and distribution. Here, we combined biogeographical and functional approaches to discuss the paradigms

of DT plants’ convergent ecological specialization for water deficit conditions and their placement at the extreme end of stress tolerance;

(3) A study on the correlation of DT plants with drought. In this chapter we used all known information about DT plants to correlate their distribution and diversity with climate variables related to drought, based on historical and future conditions;

(4) A study on the vulnerability of DT plants to climate change. Here, we model the species distribution to describe how climate change will affect DT plants' diversity and distribution from a taxonomic, phylogenetic, and biogeographic perspective;

(5) Conclusions and perspectives, in which we highlight the most remarkable findings and suggest remaining knowledge gaps that could be better explored by future studies.

(6) In the first appendix (Appendix I) we bring additional tables and figures that support the information presented in the thesis’ chapters.

(7) In the second appendix (Appendix II) we bring the project “DT plants of the world”, which consists in providing a global database with updated species checklist and in which general aspects of their distribution, ecology, and conservation can be found.

CHAPTER 2

SELECTIVE FACTORS THAT INFLUENCE THE DIVERSITY AND DISTRIBUTION OF DESICCATION-TOLERANT VASCULAR PLANTS

Coexisting on the different angles of drought (*Selaginella sellowii* and *Trilepis lhotzkiana*). Picture by L. Bondi

CHAPTER 2

SELECTIVE FACTORS THAT INFLUENCE THE DIVERSITY AND DISTRIBUTION OF DESICCATION-TOLERANT VASCULAR PLANTS

INTRODUCTION

The differential performance of organisms across resources and conditions promotes patterns correlating species and environment (Chase and Leibold, 2003). Based on this notion, biologists have historically attempted to understand ecological processes by approaching the species' responses to the environment (Lavorel and Garnier, 2002; Funk et al., 2017). However, oversimplifying the understanding of species-environment relationships based on single responses can entail misleading assumptions. For instance, species classifications based on one trait hinder the importance of multiple trade-offs that arise from an array of traits that influence the performance of organisms (Shipley et al., 2016; Funk et al., 2017; Dias et al., 2000). That is because traits can interact and produce alternative functional designs in which species exhibit equivalent fitness for similar resources and conditions, loosening an individualized trait selection (Marks and Lechowicz, 2006; Pistón et al., 2019; Dias et al., 2000). In other words, a trait alone may not necessarily indicate the action of a selective force for species occurrence in a given habitat. Thus, inferences must be carefully drawn when correlating the species' response to the ecological processes shaping the distribution of species across environments.

Because DT plants can tolerate desiccation, they are claimed as convergent specialists for water deficit conditions (e.g. Gaff, 1977; Alpert, 2000; Porembski and Barthlott, 2000; Alpert, 2005; Marks et al., 2021). In other words, DT plants find their optimal conditions (i.e., those under which individuals are fittest; Begon et al., 2006) in water deficit conditions (Figure 2.1).

This paradigm is reinforced by the notion that most DT plants, from different phylogenetic lineages (i.e. convergence when less related entities seem more related than they phylogenetically are; Doolittle, 1994), have their occurrence strongly linked to ecosystems distinguished by periods of water deficit (i.e. many of those species are considered rock outcrop specialists; Porembski and Barthlott, 2000; Marks et al., 2021).

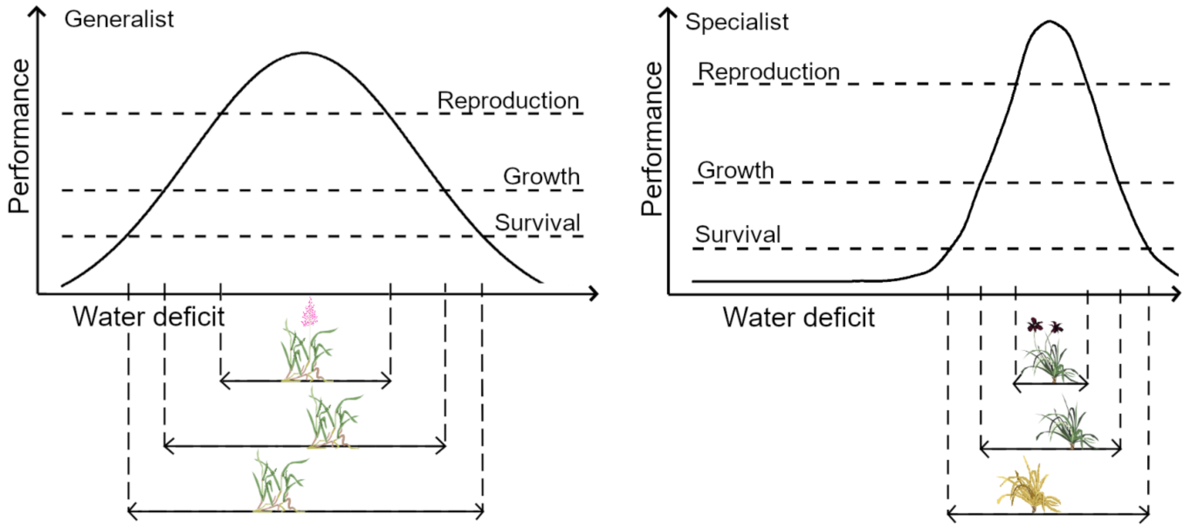

Figure 2.1. Expected ecological specialization for water deficit conditions of desiccation-tolerant vascular plants. Adapted from Begon et al. (2006) and Devictor et al. (2010).

Because desiccation tolerance is understood as such (Volaire, 2018), a second and derived paradigm suggests that all DT plants are placed at the extreme end of stress tolerance, with the most conservative resource-use to guarantee survival at the cost of faster growth (e.g. Alpert and Oliver, 2002; Bartels, 2005; Teodoro et al., 2021; Figure 2.2). That is due to the existence of a growth vs. survival trade-off in which the conservative use of resources to overcome environmental stress (*sensu* Grime, 1977; Box 2.1) precludes a quick allocation of resources that would enhance the plants' growth (Grime, 1977; Reich, 2014; Volaire, 2018). That implies that DT plants lack advantageous traits for rapid growth in productive conditions or compensate for biomass loss. In other words, because DT plants ensure their survival in drought, they would fail to compete for resources or to occur when drought exceeds leaves' capacity to tolerate desiccation. Those paradigms have never been tested and lead to the assumption that all DT plants are exclusively selected by water deficit playing a selective role as a stressful factor (*sensu* Grime, 1977). Consequently, the impact of competition and disturbance on DT plants might be overestimated (e.g., Gaff and Bole, 1986; Porembski, 2000; Alpert and Oliver, 2002).

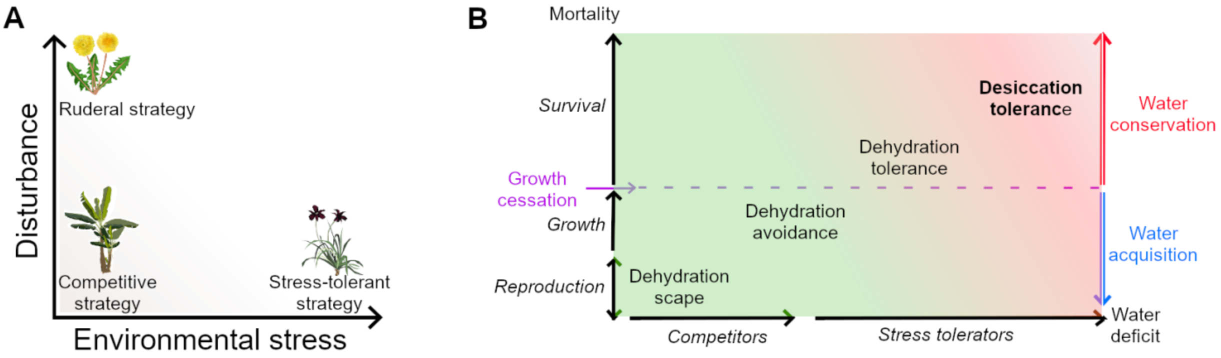

Figure 2.2. Expected position of desiccation-tolerant vascular plants at the extreme end of stress tolerance, conservative resource-use, and survival. A – the trade-offs in species responses to low environmental-stress and disturbance (favoring the competitive strategy), high environmental-stress and low disturbance (favoring the stress-tolerant strategy), and high disturbance and low environmental-stress (favoring the ruderal strategy); B – species strategies to cope with water deficit in relation to the fitness components (i.e, Survival, growth, and reproduction) and water conservation-acquisition trade-off. Adapted from Grime (1977) and Volaire (2018), respectively.

However, specialist plants are expected to exhibit responses in which costs and benefits are supposedly more advantageous in a narrower range of resources and conditions. In other words, specialists have traits only suitable to specific ecological conditions (Box 2.1). The ecological specialization can reflect limited plasticity or low intraspecific variability (MacArthur and Levins, 1964; Levins, 1962; Devictor et al., 2010). But DT plants respond to the water variability with morpho-anatomical and physiological plasticity (e.g., leaf folding and sugars accumulation during drying; Oliver et al., 2000; Porembski and Barthlott, 2000; do Nascimento et al., 2020; Porembski, 2021; Marks et al., 2021). Besides, they are likely to exhibit high genetic diversity due to their occurrence in terrestrial island ecosystems (de Paula et al., 2017; Rexroth et al., 2019; Porembski et al., 2021).

Box 2.1 Glossary

Disturbance, any external factor that promotes loss of biomass (Grime, 1977).

Ecological convergence, the extent in which less related entities seem more related than they phylogenetically are (Doolittle, 1994).

Ecological specialization, the extent in which a species finds its optimal related to a particular set of resources and conditions (MacArthur & Levins, 1964).

Ecological strategy, a grouping of similar or analogous characteristics which describes how species sustains populations and causes them to exhibit similarities in ecology (Westoby, 1998; Grime et al., 2014).

Environmental stress, any external factor that reduces biomass acquisition (Grime, 1977).

Water deficit, a hydrological imbalance in which the evaporative demand exceeds the water supply (Volaire, 2018).

Furthermore, it has been widely reported that DT plants differ in their traits, how they cope with desiccation, and the drought conditions in which they occur (e.g., Gaff and Latz, 1978; Gaff, 1986; Gaff and Bole, 1986; Meirelles et al., 1997; Marks et al., 2021). That could mean DT plants do not necessarily overlap their ecological niche when water deficit is considered, despite their convergent desiccation tolerance response. In this sense, other selective processes rather than environmental stress might shape DT plants' occurrence across habitats. De Paula et al. (2015) reported that some DT plants show competitive capacities in productive conditions, likewise coexisting species that cannot tolerate desiccation (i.e., desiccation-sensitive vascular plants; DS plants). Similarly, Alcântara et al. (2015) showed that DT plants are as productive as phylogenetically related DS plants when moisture conditions are favorable for their growth.

These two findings agree with theoretical expectations that DT plants grow and reproduce before coexisting species do so when water is available (Scott, 2000; Bartels, 2005). Still, that might not necessarily be true for all DT plants. For example, Teodoro et al. (2021) found that a DT plant exhibited lower growth when compared to a phylogenetically related DS plant, even under high moisture conditions.

The contradictions and lack of agreement across theoretical and empirical studies highlight the need for a deeper understanding of ecological aspects that shape DT plants' diversity and distribution. Here, erroneous assumptions could negatively affect efforts for their conservation and potential use for biotechnological purposes. In this study, we aimed to evaluate paradigms of DT plants' convergent ecological specialization for water deficit conditions and their placement at the extreme end of stress tolerance, attempting to test the hypothesis that (i) DT plants are convergent regarding their ecological specialization to water deficit conditions when compared to DS plants, and that (ii) DT plants exhibit ecological strategies more related to stress-tolerance, conservative resource-use, and survival when compared to DS plants. We combined biogeographical and functional approaches to address the raised questions.

MATERIALS AND METHODS

Species selection

Assuming a higher variability between species than within them, we selected DT and DS plants based on the functional traits information available for the analyses. First, we selected 27 DT plants whose desiccation tolerance was identified by previous studies (Table 2.1). For the DT plants, we used individuals cultivated in the greenhouses from the Botanical Garden of the University of Rostock (Germany) and the Plant Ecology Lab of the University of the State of Rio de Janeiro (Brazil). Complementarily, we included DT plants whose leaf traits information was available in de Paula et al. (2015) or in the TRY database (Kattge et al., 2020).

To promote a balanced contrast, we selected 27 DS plants considering their maximum phylogenetic relatedness with the selected DT plants, whenever possible. We also took into account the availability of leaf trait information in the abovementioned sources (i.e., de Paula et al., 2015 and TRY database) for DS plants selection. We selected species with the highest geographical and ecological variability possible to bring together a very heterogeneous group of DS plants concerning water deficit conditions (i.e., generalist and specialist plants in relation to this constraint). For example, species with different distribution ranges (e.g., the widespread *Juncus inflexus* and the Southeastern Brazil endemic *Pitcairnia azouryi*; POWO, 2022), divergent habitat distribution (e.g., *Pseudolaelia vellozicola*, an epiphyte on Velloziaceae, and *Echinochloa crus-galli*, which occurrence is extended from forests to wetlands; Porembski, 2003; POWO, 2022), and displaying different strategies to cope with drought (e.g. the succulent *Prescottia montana* and the annual *Melinis repens*; POWO, 2022).

Table 2.1. Desiccation-tolerant vascular plants and phylogenetically related desiccation-sensitive plants used as model species in this study, with their respective phylogenetic information, and response to desiccation. RD – response to desiccation; DT – desiccation tolerance; DS – desiccation sensitive.

Species	Botanical family	Phylogenetic group	RD
Anemia ferruginea Kunth	Anemiaceae	Pteridophytes	DT
Asplenium ceterach L.	Aspleniaceae	Pteridophytes	DT
Asplenium scolopendrium L.	Aspleniaceae	Pteridophytes	DS
Asplenium trichomanes L.	Aspleniaceae	Pteridophytes	DT
Asplenium viride Huds.	Aspleniaceae	Pteridophytes	DS
Blechnum occidentale L.	Blechnaceae	Pteridophytes	DS
Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	Pteridophytes	DS
Dicranopteris ampla Ching & P.S. Chiu	Gleicheniaceae	Pteridophytes	DS
Lindsaea lancea (L.) Bedd.	Lindsaeaceae	Pteridophytes	DS
Polypodium interjectum Shivas	Polypodiaceae	Pteridophytes	DT
Polypodium vulgare L.	Polypodiaceae	Pteridophytes	DT
Adiantum latifolium Lam.	Pteridaceae	Pteridophytes	DT
Adiantum obliquum Willd.	Pteridaceae	Pteridophytes	DS
Adiantum pedatum L.	Pteridaceae	Pteridophytes	DS
Doryopteris collina (Raddi) J. Sm.	Pteridaceae	Pteridophytes	DT
Doryopteris varians (Raddi) Sm.	Pteridaceae	Pteridophytes	DT
Polygonatum odoratum (Mill.) Druce	Asparagaceae	Monocots	DS
Encholirium gracile L.B. Sm.	Bromeliaceae	Monocots	DS
Pitcairnia azouryi Martinelli & Forzza	Bromeliaceae	Monocots	DS
Tillandsia stricta Sol. ex Sims	Bromeliaceae	Monocots	DS
Afrotrilepis pilosa (Boeckeler) J. Raynal	Cyperaceae	Monocots	DT
Bulbostylis lagoensis (Boeckeler) A. Prata & M.G. López	Cyperaceae	Monocots	DS
Carex arenaria L.	Cyperaceae	Monocots	DS
Coleochloa setifera (Ridl.) Gilly	Cyperaceae	Monocots	DT
Cyperus coriifolius Boeckeler	Cyperaceae	Monocots	DS
Microdracoides squamosus Hua	Cyperaceae	Monocots	DT
Trilepis lhotzkiana Nees ex Arn.	Cyperaceae	Monocots	DT
Juncus inflexus L.	Juncaceae	Monocots	DS
Erythronium grandiflorum Pursh	Liliaceae	Monocots	DS
Cyrtopodium glutiniferum Raddi	Orchidaceae	Monocots	DS
Prescottia montana Barb. Rodr.	Orchidaceae	Monocots	DS
Pseudolaelia vellozicola (Hoehne) Porto & Brade	Orchidaceae	Monocots	DS

Table 2.1. (continued)

Species	**Botanical family**	**Phylogenetic group**	**RD**
Aira caryophyllea L.	Poaceae	Monocots	DS
Echinochloa crus-galli (L.) P. Beauv.	Poaceae	Monocots	DS
Melinis repens (Willd.) Zizka	Poaceae	Monocots	DS
Microchloa kunthii Desv.	Poaceae	Monocots	DT
Oropetium aristatum (Stapf) Pilg.	Poaceae	Monocots	DT
Oropetium thomaeum (L. f.) Trin.	Poaceae	Monocots	DT
Phragmites communis Trin.	Poaceae	Monocots	DS
Poa annua L.	Poaceae	Monocots	DS
Sporobolus festivus Hochst. ex A. Rich.	Poaceae	Monocots	DT
Styppeiochloa hitchcockii (A. Camus) Cope	Poaceae	Monocots	DT
Barbacenia gounelleana Beauverd	Velloziaceae	Monocots	DT
Barbacenia purpurea Hook.	Velloziaceae	Monocots	DT
Barbacenia tomentosa Mart.	Velloziaceae	Monocots	DT
Vellozia candida J.C. Mikan	Velloziaceae	Monocots	DT
Vellozia plicata Mart.	Velloziaceae	Monocots	DT
Vellozia pulchra L.B. Sm.	Velloziaceae	Monocots	DT
Xerophyta dasylirioides Baker	Velloziaceae	Monocots	DT
Xerophyta elegans (Balf.) Baker	Velloziaceae	Monocots	DT
Haberlea rhodopensis Friv.	Gesneriaceae	Eudicots	DT
Ramonda myconi (L.) Rchb.	Gesneriaceae	Eudicots	DT
Sinningia brasiliensis (Regel & E. Schmidt) Wiehler	Gesneriaceae	Eudicots	DS
Lamium purpureum L.	Lamiaceae	Eudicots	DS

The paradigm of DT plants' convergent ecological specialization for water deficit

For the biogeographical approach, we performed the Outlying Mean Index analysis (Dolédec et al., 2000) to identify DT and DS plants' habitat affinities across drought-related climatic variables. This method uses the climatic information from where species occur to construct an ordination which describes species' climatic niches. This analysis gives a marginality index (MI) and niche breadth value (NB) as descriptors of species ecological specialization. Additionally, we obtained the species' mean niche position along the environmental gradients (NP), which describes the species' affinity for water deficit.

We obtained the species occurrence records from the databases "Tropicos" (http://tropicos.org), Global Biodiversity Information Facility (GBIF; https://www.gbif.org/), and "Species Link" (http://splink.cria.org.br/). We excluded duplicated, erroneous, and uncertain data according to the database Plants of the World Online (POWO, 2022). Then, a presence-absence matrix for all used species was generated, identifying geographical locations, referred to as sampling units, which could contain one or more species. For every sampling unit, we assessed the environmental information regarding the following five climatic variables related to water deficit: (i) Thornthwaite's aridity index, (ii) climatic water deficit, (iii) drought intensity, (iv) drought frequency, and (v) drought length. Higher values of Thornthwaite's aridity index and climatic water deficit describe higher water deficit for a given location. Higher values of drought intensity, frequency, and length describe more intense, frequent, and extensive drought events, respectively.

To obtain the Thornthwaite's aridity index, we divided the cumulative monthly difference between precipitation and Thornthwaite's potential evapotranspiration along the year by the modulus of the cumulative potential evapotranspiration along the same period (Thornthwaite, 1948). We calculated the climatic water deficit using the absolute values of the cumulative monthly difference between precipitation and Thornthwaite's potential evapotranspiration throughout the year (Esquivel-Muelbert et al., 2017). For the drought intensity, frequency, and length, a drought event was defined by a given set of consecutive dry months according to the Standardized Precipitation Evapotranspiration Index on a time scale of one month and within the period from January 1901 to December 2018. We estimated the drought intensity as the whole-period average of cumulative Standardized Precipitation Evapotranspiration Index scores within the drought events. We assessed the drought frequency by counting drought events within the period. Finally, we calculated the drought length as the whole-period average of the number of months within a drought event. We derived all the climatic variables from climatic datasets obtained from the Worldclim (https://worldclim.org/) and Standardized Precipitation Evapotranspiration Index (https://spei.csic.es) databases.

For the functional approach, we applied the method proposed by Shipley et al. (2017) to predict species Ellenberg Indicator values for moisture (EIV_M) throughout functional traits. We assessed the species' EIV_M by calculating their habitat affinities for the nine first ordinal Ellenberg classes for soil moisture (aquatic habitats were excluded from moisture level gradient). We described habitat affinities by the probability of a species being classified in a given EIV_M, in which higher probabilities would describe higher affinities. Then, we generated EIV_M habitat affinity curves for each species. To calculate species' EIV_M, the specific leaf area (SLA), leaf dry matter content (LDMC), leaf area (LA) and seed mass (SM) were either (i) measured for DT and DS plants following the proceedings proposed by Pérez-Harguindeguy et al. (2013), (ii) obtained from the TRY database (i.e., traits numbers 3109, 3115, 47, 26, respectively) or (iii) collected from de Paula et al. (2015; Table S2.1). We used at least two leaf replicates from five different individuals for the traits measurements whenever possible. We assessed the functional traits using an oven (T12, Heraeus Instruments, Hanau, Germany), analytical scale (SBC33, Scaltec, HeilingenstaDT plants, Germany), and image scanner (CanoScan LiDE 220, Canon, Amstelveen, The Netherlands). Then, we processed leaf areas in ImageJ software (Schneider et al., 2012). We considered species with trait values from at least three individuals for the species from the TRY database. Pteridophytes were not used in this analysis once they do not produce seed for SM assessment.

Ecological convergence

We used the overlapping index (OV) as a proxy for species convergence to similar ecological conditions in relation to the Outlying Mean Index analysis' ordination axes and EIV_M. A higher ecological overlap (i.e., higher OV values) informs a higher convergence between species. We performed multiple pairwise comparisons to estimate the OV, as described by Pastore and Calcagnì (2019). For the Outlying Mean Index analysis' ordination axes, we performed Kernel density estimations using species' individuals, while for EIV_M, we used the habitat affinity curves. Considering that the desiccation-tolerance response can describe ecological convergence for species, DT plants were expected to exhibit higher ecological overlap with each other than when compared to DS plants.

Ecological specialization

For the Outlying Mean Index analysis results, we used the MI, NB, and the Pearson's measure of Kurtosis (PK) over Kernel density estimations for species individuals' distribution along the two first axes of the ordination. Complementarily, we calculated the PK for the species' EIV_M curves (Table S2.3). Species ecologically more distant from the average conditions (i.e., higher MI) or with narrower niche breadth along the environmental gradients (i.e., lower NB) are expected to display higher ecological specialization. The PK describes the sharpness of the peak for species' optimal conditions. Thus, species whose optimal conditions are more restricted to certain scores of the ordination axes or EIV_M (i.e., higher PK values) were regarded as more specialists in relation to moisture conditions. In this framework, it was expected that DT plants exhibit a higher MI, lower NB, and a higher PK when compared to DS plants.

Affinity for water deficit conditions

We used the NP along the two first axes of the Outlying Mean Index analysis' ordination and by the EIV_M in which species exhibited the highest score (HS_{EIVM}) to describe species' affinity for water deficit conditions. The positive correlation between NP and the environmental variables related to water deficit describes a higher affinity of species for such conditions, as the HS_{EIVM} for lower EIV_M reflects a higher affinity for lower soil moisture levels. Therefore, DT plants were expected to differ from DS plants by exhibiting a stronger positive correlation with the water deficit variables and higher scores for lower EIV_M.

The paradigm of DT plants in the extreme end of stress tolerance

First, we conducted the globally calibrated method presented by Pierce et al. (2016) for the estimation of species ecological strategies according to the Grime's CSR scheme (C-selection – competitiveness, R-selection – ruderalism, and S-selection – stress-tolerance). In this scheme, C-selection refers to the ability of plants to compete for resources in productive habitats, R-selection denotes plants' capacity to cope with external constraints that lead individuals to a biomass loss, and S-selection describes plants' ability to deal with external constraints that restrict individuals' growth. For that, we assessed the functional traits LA, SLA and LDMC as described above and used the stratefy tool to calculate species affinities for C-selection, S-selection, and R-selection of the CSR scheme (Table S2.3).

Then, we applied the procedure proposed by Westoby (1998) for the species ecological strategies estimation within LHS scheme (L – leaf, H – height, and S – seed). The SLA, plant height at maturity, and SM describe the L, H, and S components, respectively. We measured both SLA and SM as informed previously. In addition, we estimated the canopy height at maturity by (i) measuring the plant height according to the procedure proposed by Pérez-

Harguindeguy et al. (2013), (ii) obtained from the TRY database, (iii) collected from de Paula et al. (2015), or (iv) using species' voucher information. We log-transformed all the three functional traits obtained for the LHS scheme estimation. We did not use pteridophytes in the LHS estimations due to their lack of seeds for SM assessments.

Trade-offs between resource acquisition enhancing growth and resource conservation ensuring survival reflect the species' ability to cope with environmental factors and their position within CSR and LHS schemes (Pierce et al., 2016; Reich, 2014; Westoby, 1998). A higher score for S-selection strategy corresponds to stress-tolerance, conservative resource-use and survival. For the LHS scheme, plans with low SLA, low H, and higher SM can be related to stress-tolerance, conservative resource-use and survival strategies (Westoby, 1998; Niinemets, 2001; Lavergne et al., 2003; Koch et al., 2004; Moles et al., 2005; Poorter and Rozendaal, 2008; Bolmgren and Eriksson 2010). While the CSR scheme assumes that the trade-offs at the leaf level scale to whole-plant and reproductive trade-offs (Pierce et al 2016), the LHS scheme includes direct measurement of plant reproductive strategies (Westoby, 1998). All functional traits were measured as described above.

Data Analyses

First, we split the DT and DS plants into three main phylogenetic groups: pteridophytes, monocots, and eudicots (Marks et al., 2021). Then, we performed Analyses of Covariance (ANCOVAs) to evaluate the differences between DT and DS plants. For the ANCOVA's first covariate regarding species' ecological convergence (i.e., OV), we grouped pairwise comparisons between two DT plants as "desiccation-tolerance x desiccation-tolerance" and comparisons between a DT and a DS plants as "desiccation-tolerance x desiccation-sensitive".

For the second covariate, we grouped pairwise comparisons within one of the three main phylogenetic groups as "*same phylogenetic groups*" (e.g., pteridophytes x pteridophytes) and across phylogenetic groups as "*different phylogenetic groups*" (e.g., pteridophytes x monocots). To find significant differences in PK, MI, NB, NP, C-selection, S-selection, R-selection, L, H, and S between DT and DS plants; we used the species' response to desiccation as a first covariate (i.e., desiccation-tolerant and desiccation-sensitive), and the phylogenetic groups as the second covariate (i.e., pteridophytes, monocots, and eudicots). We chose this analysis to evaluate the differences between DT and DS plants, while controlling for the effect of phylogenetic inertia on species scores. Whenever the assumptions for parametric analysis were not fulfilled, we performed Box-Cox transformations (Box and Cox, 1964) before conducting the ANCOVAs. To minimize the chance of inflating the type I error rate (Jafari and Ansari-Pour, 2019), we conducted the Bonferroni correction method was applied to the ANCOVAs' *p*-values always the comparisons use a different response variable as alternative proxies to investigate the same ecological question.

To analyze the HS_{EIVM} for DT and DS plants, we conducted a χ^2 test to verify if the species' highest probability of being classified to a given EIV_M is independent of their response to desiccation. We chose the χ^2 test because it informs if the distribution of species along EIV_M is statistically related to desiccation-tolerance or does not differ from what is expected by chance.

The assessment of species' geographical distribution and obtaining climate data, besides calculations of indices, probabilities, and analyses, were performed with R software (R Core Team 2021).

RESULTS

The paradigm of DT plants' convergent ecological specialization for water deficit

In general, we did not observe differences between DT and DS plants in the conducted analyses. The two first axes of the PCA performed in the Outlying Mean Index analysis explained 49.6 and 29.8% (Table S2.2). The Outlying Mean Index analysis' PCA1 axis was positively correlated with more extensive and intensive drought events, although less frequent. The PCA2 axis was negatively correlated with higher water deficit (Figure 2.3; Table S2.2). Almost all species distribution was significantly explained by this analysis, except by *B. tomentosa* and *H. rhodopensis* (Table S2.3). Regarding species EIV_M, it was not possible to observe delimitation between DT and DS plants. Species from both functional groups were more related to soil moisture between the Ellenberg ordinal classes 3 and 5 (Table S2.4).

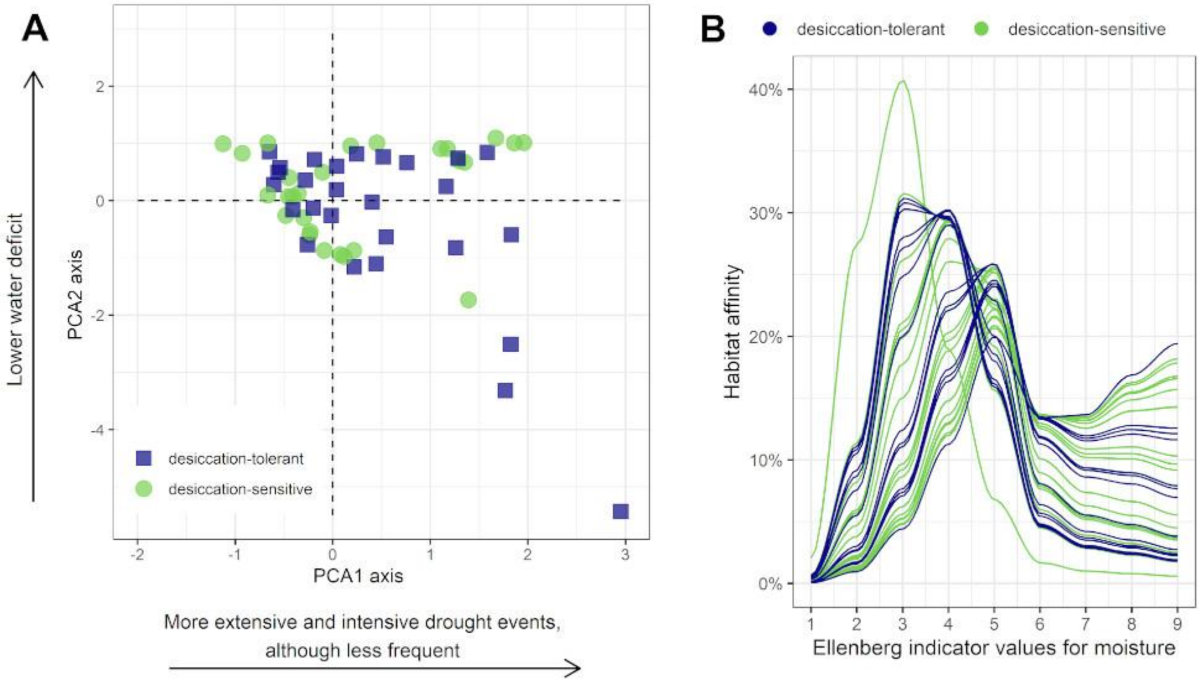

Figure 2.3. Species' correlation to water deficit, by their response to desiccation. A - species distribution in relation to the two first axes of the outlying mean index analysis; B - species' habitat affinities in relation to Ellenberg indicator values for moisture.

In relation to the convergence in the occurrence of species' individuals along the first axis of the Outlying Mean Index analysis' ordination, we found a significantly higher ecological overlapping (OV_{PCA1}: F = 14.9631, adjusted *p*-value = 0.0003; Figure 2.4; Table S2.6) in desiccation-tolerance x desiccation-sensitive comparisons (OV_{PCA1} $\mu = 0.4124 \pm 0.0127$) than in desiccation-tolerance x desiccation-tolerance comparisons (OV_{PCA1} $\mu = 0.3616 \pm 0.0101$). However, it was not found a significant difference when the axis PCA2 was considered (OV_{PCA2}: F = 5.5153, adjusted *p*-value = 0.057). Similarly, the ecological overlap between DT plants was not significantly different from the ecological overlap between DT and DS plants regarding their EIV_M (OV_{EIVM}: F = 0.5014, adjusted *p*-value = 1).

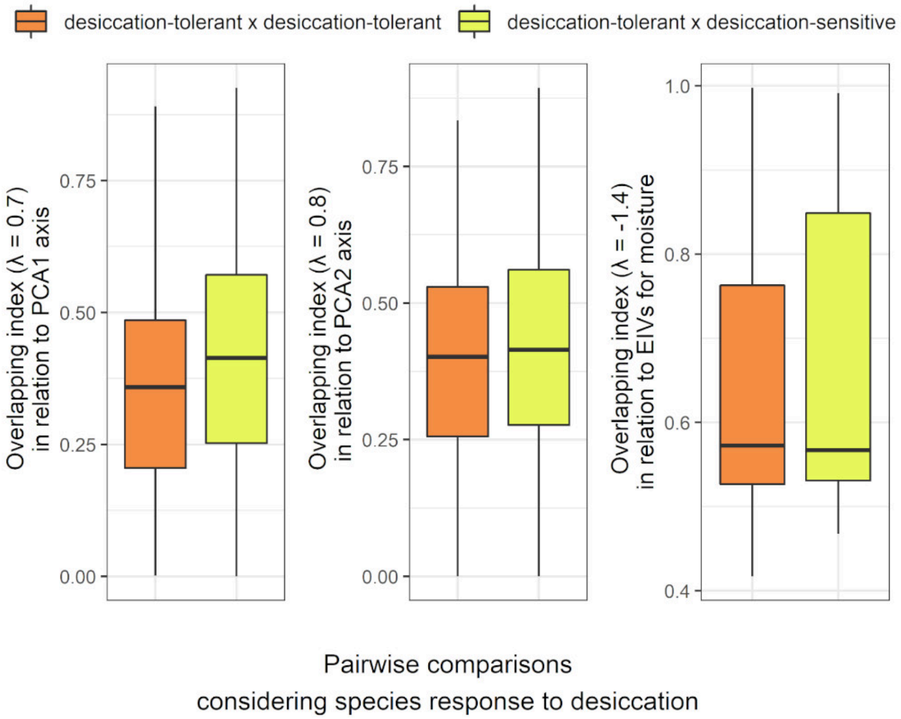

Figure 2.4. Species' convergence in relation to water deficit, according to the outlying mean index analysis and Ellenberg indicator values for moisture (EIV_M), in which the pairwise overlapping index between desiccation-tolerant and desiccation-sensitive vascular plants are compared to the pairwise overlapping index between desiccation-tolerant species.

We did not find significant effect of species response to desiccation on the overall variability in species distribution shape along the two first Outlying Mean Index analysis' axes (PK_{PCA1}: F = 0.1516, adjusted *p*-value = 1; PK_{PCA2}: F = 0.9352, adjusted *p*-value = 1), species ecological distance from the average conditions (MI: F = 1.4029, adjusted *p*-value = 1), and species niche breadth along the environmental gradients (NB: F = 0.0093, adjusted *p*-value = 1; Figure 2.5; Table S2.7). In addition, we did not find a significant difference in the habitat affinities between DT and DS plants along a soil moisture gradient (PK_{EIVM}: F = 0.0513, df = 31, adjusted *p*-value = 1).

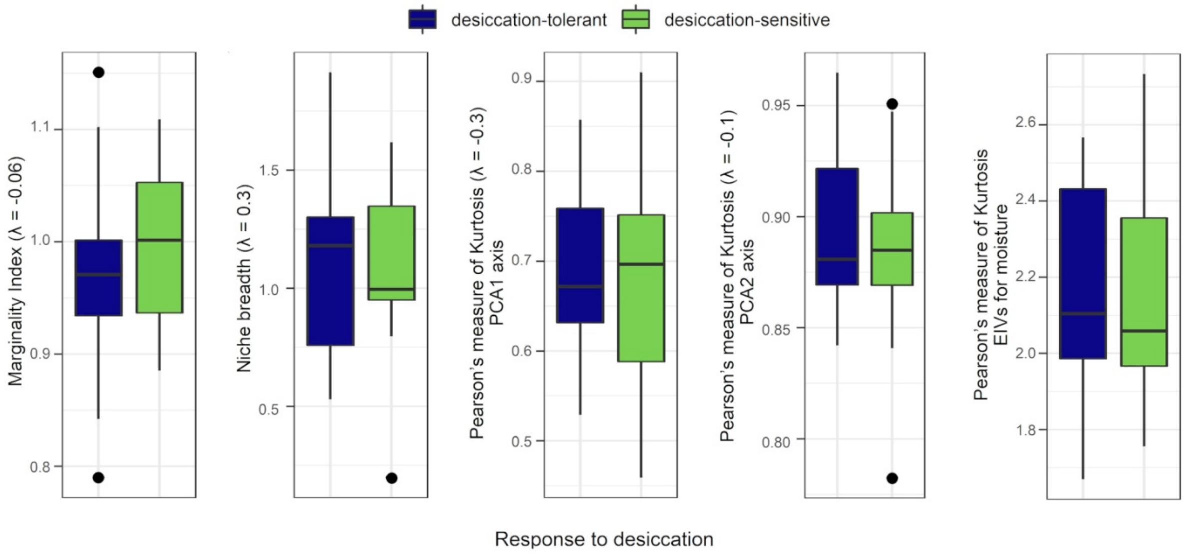

Figure 2.5. Comparisons of species' ecological specialisation along water deficit gradients according to outlying mean index analysis and Ellenberg indicator values for moisture (EIV_M), in relation to their response to desiccation.

The niche position along the two first Outlying Mean Index analysis' axes between DT and DS plants was not significantly different (NP_{PCA1}: F = 1.4899, adjusted *p*-value = 0.4560; NP_{PCA2}: F = 2.7050, adjusted *p*-value = 0.2126; Figure 2.6). Besides, the species' HS_{EIVM} is independent of the species strategies to cope with desiccation (HS_{EIVM}: χ^2 = 0.7485, *p*-value = 0.7866).

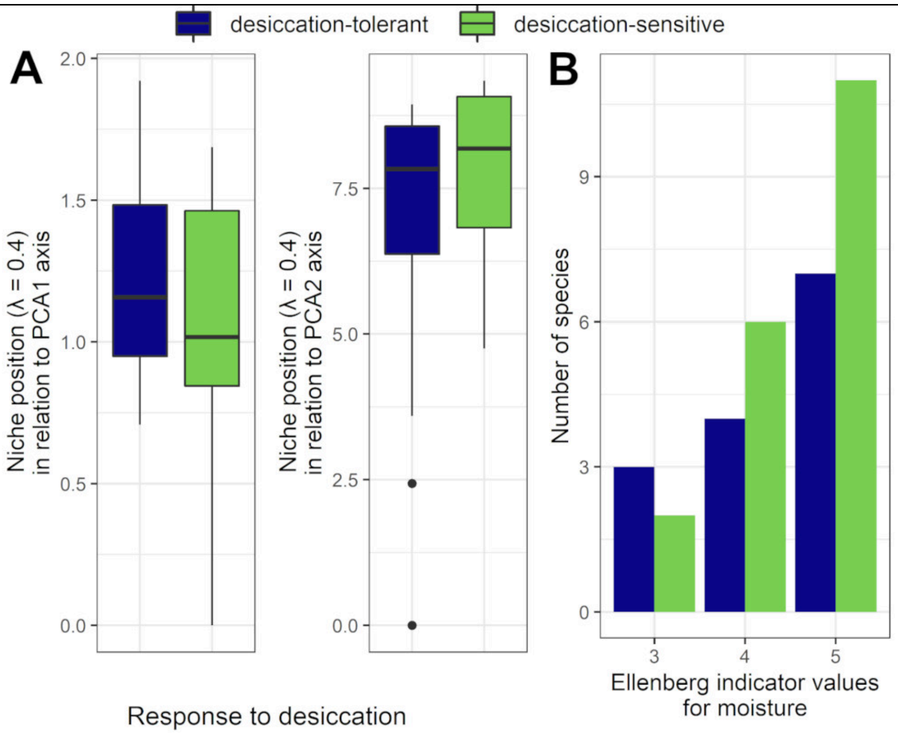

Figure 2.6. Comparisons of species' affinity for water deficit according to outlying mean index analysis and Ellenberg indicator values for moisture, in relation to their response to desiccation. A – species' niche position in relation to the outlying mean index analysis' two first axes; B – number of species by the Ellenberg indicator value in which their higher habitat affinity was registered.

The paradigm of DT plants in the extreme end of stress tolerance

It was not possible to observe a distinction between DT and DS plants neither in the CSR scheme nor the LHS scheme (Figure 2.7; Table S2.5; Table S2.8). No significant effect of species response to desiccation was found on the variability of their relative proportion of C-selection (F = 0.3771, adjusted *p*-value = 1), S-selection (F = 2.31, adjusted *p*-value = 0.4044), and R-selection (F = 1.3553, adjusted *p*-value = 0.7497). The species' SLA did not differ between DT and DS plants (L: F = 0.9837, adjusted *p*-value = 0.9783), as well as plants' H (H: F = 0.018, adjusted *p*-value = 1), and SM (S: F = 0.156, adjusted p-value = 1).

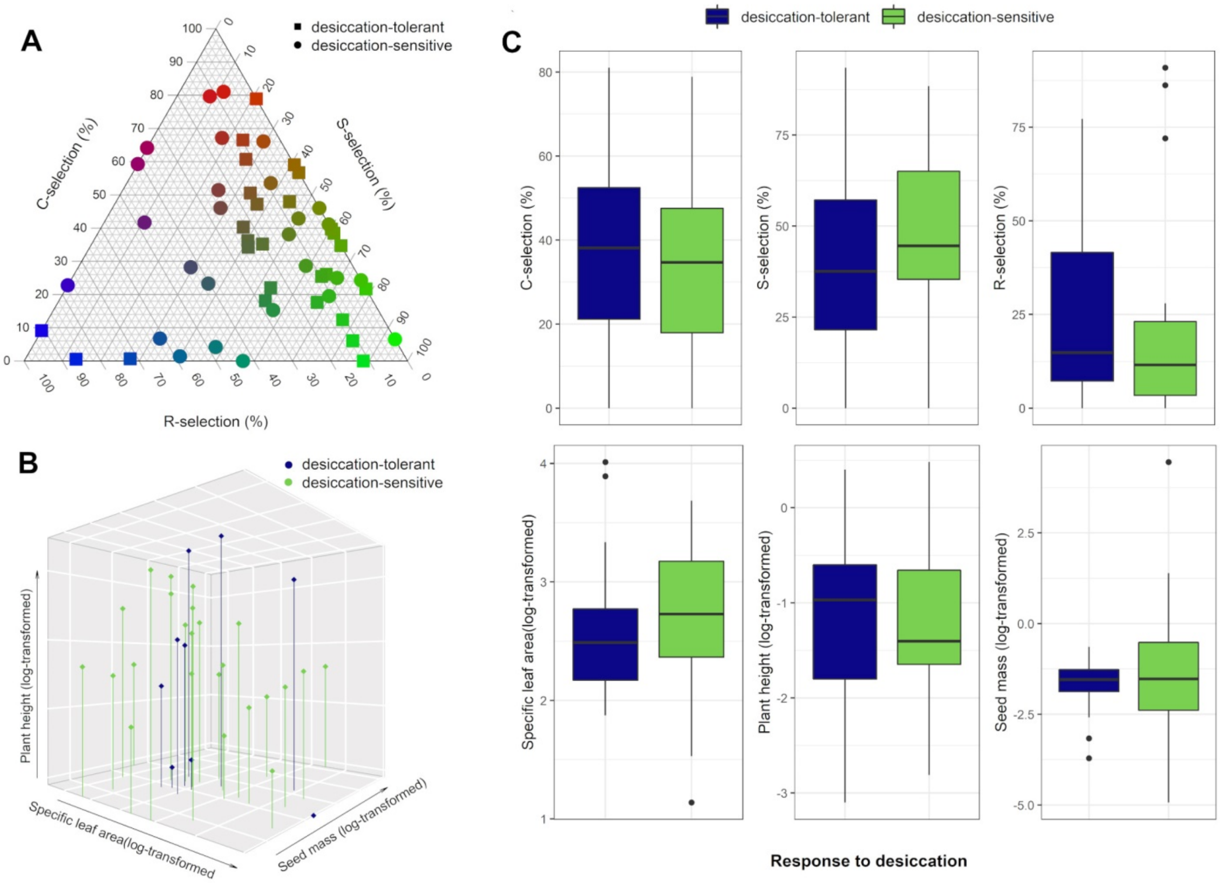

Figure 2.7. Ecological strategies of desiccation-tolerant and desiccation-sensitive vascular plants according to Grime's CSR and Westoby's LHS schemes. A – Species mean position in the CSR scheme; B – species mean position in the LHS scheme; C – comparisons of the species' relative proportion of C-selection, S-selection, R-selection, specific leaf area, plant height, and seed mass in relation to species response to desiccation.

DISCUSSION

We did not find a convergent ecological specialization to water deficit conditions for the DT plants. They also did not exhibit ecological strategies more related to stress-tolerance, conservative resource-use and survival than DS plants. We advocate that species are far more complex to have their ecological niches defined only by one response to the environment, as ecosystems do not have only one prominent process exclusively explaining species occupancy.

DT plants were not a homogeneous group in any aspects covered by this study. The DT plants' convergence in their response to desiccation should be carefully used to underpin assumptions of species convergence in other aspects (Figure 2.8). Convergence depends on the specific response or aspect of the environment in question (Winemiller et al., 2015; Funk et al., 2017; Pistón et al., 2019). For example, because of their ability to tolerate desiccation, all desiccation tolerant plants can cope with drought as a stresfull factor (i.e., water deficit restricting DTPs' growth). However, it does not mean that all DT plants have the same fitness when drought acts as a stressful constraint (i.e., water deficit promoting biomass loss, such as when leaves cannot rehydrate or completely re-green).

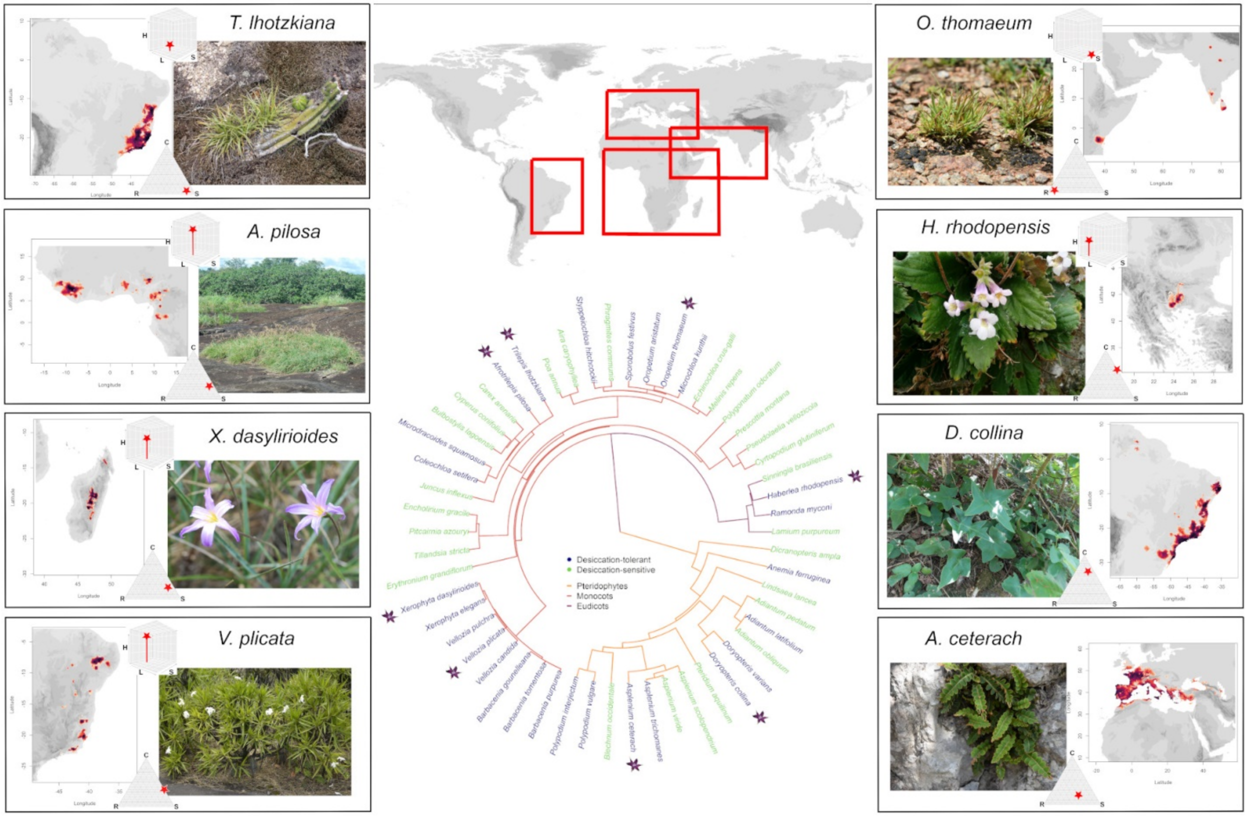

Figure 2.8. The diversity of desiccation-tolerant vascular plants, in relation to their phylogenetic and geographical distribution, morphology, and ecological strategies.

That is because we should not neglect the statistical improbability of different evolutive events generating the same complex genic outcome (Gould, 1970). Some DT plants construct small, expensive, and long-lived leaves with slow returns on biomass investment (e.g., the higher S-selection in most monocots). Others invest in long-lived leaves with a higher light interception, which is advantageous in productive conditions (e.g., higher C-selection in many pteridophytes and eudicots). Adding more heterogeneity, it is also possible to find DT plants with cheap photosynthetic tissues in which the carbon returns on biomass investment are higher, favoring short productive opportunities (e.g., the higher R-selection in some Poaceae lineages).

That DT plants' different way to perceive and cope with drought can be reflected in the environmental conditions they occur. For instance, the poikilochlorophyllous *Afrotrilepis pilosa* and *Vellozia plicata* grow in fully exposed habitats on granite outcrops (Porembski 2021), while the homoiochlorophyllous *Doryopteris collina* and *Ramonda myconi* inhabit more shaded and sheltered habitats on the same type of outcrops (Meirelles et al., 1997; Fernández-Marín et al., 2020). Our results showed that *A. pilosa* and *V. plicata* have a higher relative proportion of stress-tolerance (66 and 65%, respectively) than *D. collina* and *R. myconi* (24 and 21%, respectively). Thus, despite converging in their desiccation tolerance, these species do not converge in water deficit conditions they are found and in how they deal with water availability. Such differences can also be observed within the same phylogenetic lineages in which species share the same mechanism to tolerate desiccation. For example, contrasting with *V. plicata*, *Barbacenia gounelleana* exhibited an acquisitive resource-use (e.g., SLA = 27), a CS/CSR strategy (C:S:R = 34:41:24 %), and had its occurrence related to the most humid sites among all DT plants. Similarly, five DT pteridophytes registered a higher relative proportion for C-selection (*Adiantum latifolium, D. collina, D. varians, Polypodium interjectum, P. vulgare*), while three showed higher scores for S-selection (*Anemia ferruginea, Asplenium ceterach, A. trichomanes*).

We observed that the moisture conditions in which the DT plants had their HS_{EIVM} varied from fresh soils of average dampness (e.g., *Microchloa kunthii* and *Trilepis lhotzkiana*) to dry ground rather than moist (e.g., *Oropetium aristatum* and *V. plicata*). Those findings can be linked to the fact that some DT plants exhibit advantageous responses for higher growth and resource acquisition (e.g., higher LA and SLA; Reich et al., 1998; Niinemets, 2001; Poorter and Rozendaal, 2008). Such responses would reflect suitable ecological strategies to also cope with more productive conditions or with higher disturbance (e.g., higher relative percentage of C and R strategies, higher H, and smaller SM; Westoby, 1998; Pierce et al., 2016). It displaces DT plants from the extreme end of stress tolerance and reveals the relevance of other ecological processes shaping DT plants' distribution.

The higher capacity to deal with productive and disturbance conditions can increase DT plants' vulnerability to the negative effects of drought (Reich, 2014). However, their ability to tolerate desiccation could compensate for the drought vulnerability promoted by higher investment in growth. The perception of trait interaction to mitigate the negative effects of drought can be found in former studies. For instance, DT plants display folded leaves while drying, reducing photooxidative damages promoted by light incidence over desiccated tissues (Porembski and Barthlott, 2000; Porembski, 2021). It means that DT plants exhibit a greater leaf area for light capture when water is available, conferring them higher competitive abilities for resources. Although, they decrease their exposed surface area when water is unavailable, increasing stress-tolerance capacity. Other traits support this response. For example, the leaf folding correlates with a venation structure that allows the avoidance of irreversible damages in their hydraulic system during leaf folding (i.e., parallel nervature in monocots or netlike venation pattern in Gesneriaceae; Kampowski et al., 2018; Porembski 2021). Besides leaf folding during desiccation and its appropriate venation structure, many DT monocot species also develop a velamen radicum (e.g., in Velloziaceae species). The velamen radicum increases water capture and storage (Porembski and Barthlott, 2000; Oliveira et al., 2005; Zotz et al., 2017; Porembski 2021), reducing DT plants' exposure to water deficit conditions and improving their competitive abilities (Oliveira et al., 2005).

Alternatively, some DT plants might not have their occurrence restricted to the existence of drought as an external constraint that limits productivity (i.e. environmental stress). To those species, the drought would act as a disturbance factor, leading individuals to biomass loss caused by irreversible damages (i.e., disturbance), or being perceived by species as a secondary selective agent (Grime, 1977; Wilson and Lee, 2000; Pierce et al., 2017). That can be the case for the two annual plants *O. aristatum* and *O. thomaeum* (Porembski 2021), which scored high relative proportions of ruderalism (72 and 86.2%, respectively). Drought as a disturbance factor for these species is corroborated by their high values of SLA, besides low H and SM (*O. aristatum*: SLA = 49, H = 83, and SM = 0.042; *O. thomaeum*: SLA = 55.2, H = 45, and SM = 0.225). The desiccation tolerance would allow their leaves to survive quick water shortages, when drought acts as a stressful factor. However, their leaf traits favor quicker returns on biomass investment and shorter life cycles, reaching reproduction before long-term droughts play a disturbance role. This is compatible with the fact that these species have their geographic occurrence related to regions with more extensive and intensive drought events in the dry season and short dry periods in the wet season (Figure S2.1). Therefore, the alternative functional designs within DT plants could promote the diversity of ecological strategies found among them and suggest that their occurrence is not driven by a common selective force, such as water deficit as a stressful constraint. If the alternative functional designs reflects ecological differences between species is up to be investigated (Figure S2.2; Figure S2.3; Figure S2.4).

Rather than solely water deficit, we suggest that the desiccation tolerance could bring advantages to dealing with the quick and pronounced water availability variation. That can be supported by DT plants' almost absence in deserts (Fahmy et al., 2006; Porembski, 2021) and their strong correlation with habitats characterized by marked moisture fluctuations (i.e., rock outcrops; Porembski and Barthlott, 2000; Gaff and Oliver, 2013). Our results are in agreement with these expectations. Although we did not assess the moisture fluctuations in this study, we found a low average probability of DT plants occurrence in extreme dryness (0.32% according to species EIV_M).

The higher temporal variation in the availability of a given resource is expected to benefit species with a more generalist response to different levels of this resource (Lynch and Gabriel, 1987; Sexton et al., 2017). That happens because species from highly variable environments are expected to mitigate the selective pressures promoted by the circumstances that they are subjected (Wilson and Yoshimura, 1994; Callaway et al., 2003). For example, a habitat in which organisms experience enough water to grow, but cannot avoid the negative effects of drought periods, is supposed to gather species that can cope with water abundance and deficiency. In this case, DT plants exhibit traits that allow compatible growth and reproduction when water is available, plus the survival of photosynthetic tissues when water is unavailable (Oliver and Bewley, 1996; Zhang et al., 2018; do Nascimento et al., 2020). That is coherent with the plastic responses of DT plants to water availability (do Nascimento et al., 2020) and their need to hold a positive carbon balance under repeated desiccation-rehydration cycles (Alpert, 2005). Therefore, the occurrence of DT plants in such habitats could imply ecological strategies that fit both contrasting environmental situations they experience instead of an exclusive adaptation for only one facet of the environment.

Our results showed that the view of DT plants as a homogeneous group of plants in how they deal with drought and the simple correlation of desiccation tolerance with water deficit might be a mistaken generalization. A lot of knowledge about DT plants has been gathered, and paradigms have been consolidated. However, we need new studies that challenge the accepted paradigms that might be constraining the scientific progress regarding the ecological aspects of DT plants. For that, we argue that alternative functional designs should be considered when the

DT plants' responses to water deficit conditions are investigated. Also, we encourage new studies that seek for a better understanding on how our results might vary within the most diverse phylogenetic lineages. Besides drought promoting an environmental stress, we suggest that the low water availability intensifying competition between plants or long droughts leading to biomass loss might have also played an important evolutionary role for some DT species. Since among vascular plants the desiccation tolerance has independently re-evolved multiple times, it is plausible that the importance of those evolutionary processes change according to the distinct phylogenetic lineages in which DT plants are found. A better comprehension of DT plants' responses to the ecological processes that shape their occurrences across environments would substantially aid the development of more robust ecological assumptions for these species.

DESICCATION-TOLERANT VASCULAR PLANTS AND DROUGHT:

SYMPATHY FOR THE DEVIL?

Tolerant, but drying first (*Barbacenia purpurea*). Picture by L. Bondi

CHAPTER 3

DESICCATION-TOLERANT VASCULAR PLANTS AND DROUGHT: SYMPATHY FOR THE DEVIL?

INTRODUCTION

In plant ecology, drought is usually referred to as a water deficit resulting from a hydrological imbalance in which the evaporative demand exceeds the water supply, and may be considered one of the main drivers of plant mortality (Volaire, 2018; McDowell et al., 2018). Due to climate change, in some locations more than in others (Broennimann et al., 2006), future droughts events will become more unpredictable, more intensive, set in quicker, and last longer (Sheffield et al., 2012; Trenberth et al., 2014; Mukherjee et al., 2018). Hence, the global changes affecting rainfall-evapotranspiration dynamics are supposed to alter the species diversity and distribution patterns (Engelbrecht et al., 2007; Esquivel-Muelbert et al., 2017). However, which species are potentially more or less vulnerable to changes in drought regimes and how it might impact plants' biodiversity depends on extrinsic (e.g. exposition to changes in drought) and intrinsic factors for species (e.g. species sensitivity and capacity to mitigate the effects of future droughts; Dawson et al., 2011).

Box 3.1 Glossary

Exposure to climate changes, the extent of climate change to be experienced by a species (Dawson et al., 2011).

Sensitivity to climate changes, the degree to which the species individuals' fitness is influenced by climate change (Dawson et al., 2011).

Vulnerability to climate changes, the extent to which a species is threatened with extinction due to climate change (Dawson et al., 2011).

Water deficit, a hydrological imbalance in which the evaporative demand exceeds the water supply (Volaire, 2018).

Desiccation-tolerant vascular plants (DT plants) stand out among vascular plants due to their ability to avoid drought mortality by tolerating desiccation (i.e. losing up to 13-20% of their protoplasmic water; Scott, 2000; Oliver et al., 2000; Porembski and Barthlott, 2000). Because of this remarkable response, these species are expected to have their distribution strongly and exclusively related to drought conditions (e.g., Scott, 2000; Alpert, 2000; Oliver et al., 2000; Alpert, 2005). That means DT plants exhibit a high water deficit affiliation (WDA) and a narrow niche breadth along a water deficit gradient (WDNB; Figure 3.1). The DT plants' occurrence in ecosystems where drought is expected to be the strongest selective factor reinforces this notion. For example, Porembski and Barthlott (2000) claimed inselbergs as centers of diversity for DT plants, while Marks et al. (2021) estimated that 90% of DT plants grow in rock outcrops.

However, the variability among the DT plants can hamper generalizations concerning their ecological aspects. For example, two different mechanisms to cope with desiccation have emerged within the multiple times desiccation tolerance re-evolved (Oliver et al., 2000; Marks et al., 2021). While all desiccation-tolerant pteridophytes and eudicots keep their chlorophyll when desiccating (i.e. homoiochlorophyllous species), the majority of desiccation-tolerant monocots dismantles and reconstructs their photosynthetic apparatus (i.e. poikilochlorophyllous species; Oliver et al., 2000; Porembski, 2021). Those mechanisms are expected to promote ecological differences between species (Gaff, 1971; Gaff and Latz, 1978; Meirelles et al., 1997; Oliver et al., 2020; Marks et al., 2021). Pteridophytes and eudicots can be found in a broader range of habitats (e.g. also occurring in the forest canopy or inselberg rock pools), entailing a broader WDNB (Porembski and Barthlott, 2000; Porembski, 2021). Conversely, monocots are expected to be found in drier sites and thus exhibit higher WDA than homoiochlorophyllous species (Meirelles et al., 1997; Alpert, 2000; Oliver et al., 2000; Tuba, 2008; Marks et al., 2021; Figure 3.1).

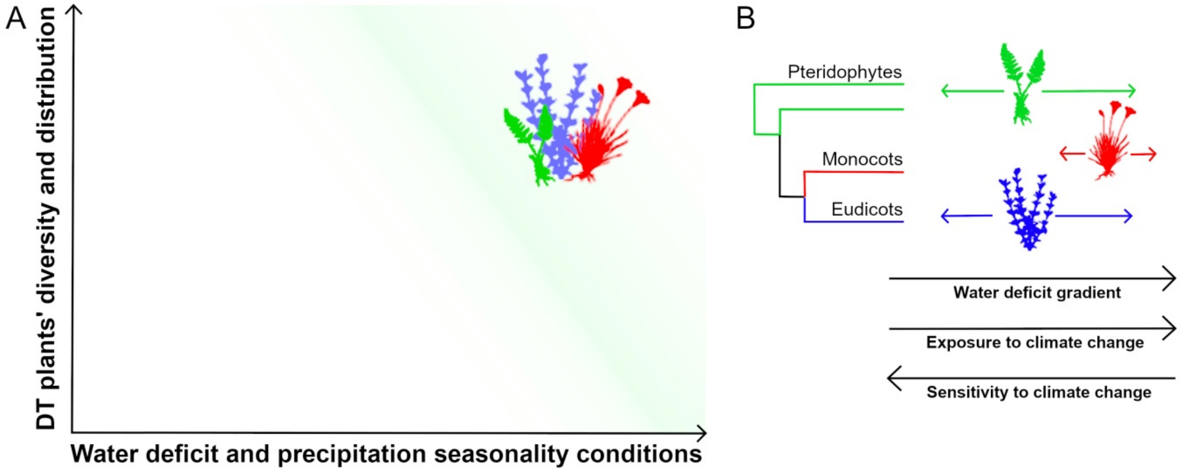

Figure 3.1. The expected correlation of desiccation-tolerant vascular plants (DT plants) with drought. A – The diversity and distribution of DT plants along water deficit and precipitation seasonality gradients; B – The DT plants' niche position and breadth along water deficit gradient and the expected impact of climate changes on the diversity and distribution of DT plants.

Still, there are exceptions to the assumptions mentioned above (e.g., homoiochlorophyllous Selaginellaceae and Myrothamnaceae species grow in locations where poikilochlorophyllous plants occur). Moreover, those assumptions have never been tested and are mostly based on the study of particular lineages (Marks et al., 2021). Consequently, contradictions are found linking the DT plants' diversity and drought conditions. While some authors relate their diversity to arid habitats (Scott, 2000; Oliver et al., 2000; Alpert, 2005; Bartels, 2005), others associate their diversity with seasonally wet locations (Porembski and Barthlott, 2000; Porembski et al., 2021). To improve the general knowledge about DT plants is essential to understand general trends for their distribution and diversity.

Nevertheless, since DT plants are supposed to withstand unpredictable drought periods (Porembski and Barthlott, 2000; Porembski et al., 2021), the possible impact of future drought events on DT plants' diversity has not been receiving much attention. In fact, the DT plants' ability to tolerate desiccation is affected by changes in the environmental factors related to drought (Marks et al., 2021). Although, it is not clear how changes, and in which environmental factors, could differentially impact DT plants' diversity and distribution. Also, on the one hand, DT plants from wetter climates are expected to be more sensitive to drought (Marks et al., 2021). That can make them more vulnerable to climate change. However, DT plants from drier climates should show narrower niche breadths (Tuba, 2008; Porembski, 2021), increasing their extinction risks (Broennimann et al., 2006; Saupe et al., 2015). Besides, plants from drier climates are the ones predicted to be more exposed to changes (Trenberth et al., 2014; Mukherjee et al., 2018; Figure 3.1). Those uncertainties evidence the urge for studies to help elucidate those questions and support consistent strategies for the DT plants' conservation in a climate-changing world.

The main aim of this study was to understand DT plants' correlation to drought, how drought influences their diversity, and if their relationship with drought explains their potential vulnerability to climate change. For that, we tested the following hypothesis: (i) DT plants have a high WDA and narrow WDNB; (ii) DT plants' diversity increases with higher drought and precipitation seasonality conditions; (iii) DT plants with higher WDA and narrower WDNB are potentially more vulnerable to climate change; (iv) pteridophytes and eudicots display a lower WDA and broader WDNB, show the highest diversity under lower drought and precipitation seasonality conditions, and are potentially less vulnerable to climate change despite being more sensitive to changes in climate. On the contrary, monocots exhibit a higher WDA, narrower WDNB, have the highest diversity found under higher drought and precipitation seasonality conditions, and have a higher potential vulnerability to climate change due to their higher exposure to shifts in climate. For that, we used all DT plants described in the literature and their known worldwide occurrences to correlate their distribution and diversity with climate variables related to drought, based on historical and future climate information.

MATERIALS AND METHODS

Desiccation-tolerant vascular plants and their geographical distribution

In this study, we considered all DT plants reported by scientific studies. For that, we performed a bibliographic search in January of 2021 using the Web of Science search engine (apps.webofknowledge.com) with the key-words combination (*'desiccation tolerant' OR 'resurrection') AND (angiosperm* OR pteridophyte* OR lycophyte* OR vascular OR plant**), and included additional studies this bibliographic search (please see the Appendix II for more detailed information species assembly). We only used taxa in which the "species" taxonomic level and the scientific names are currently recognized by international databases, using the Tropicos database (https://www.tropicos.org/) as priority. Based on the species' currently accepted taxonomic nomenclature, we classified species among the three main phylogenetic groups: Pteridophytes, Monocots, and Eudicots. In total, 337 DT plants (80 genera and 21 families) reported in 1145 scientific studies (1115 from the keywords search and 30 additional studies) were used (Appendix II).

Then, we obtained the occurrence records of all DT plants from international databases in which herbarium vouchers are available (e.g., Global Biodiversity Information Facility - GBIF, Tropicos, and Species Link, please see the Appendix II for more detailed information species geographical distribution). We only used records of herbarium vouchers and available geographic information (i.e., global positioning system – GPS – information or precise description of the locality or municipality). From those records, we removed duplicated, erroneous and uncertain data according to appropriate literature and the databases (e.g., Plants of the World Online - POWO, Tropicos, Flora do Brasil 2020, and World Plants). We used one km-radius from each species' occurrence to rarefy occurrence records in order to avoid the effects of sampling bias. We used the resulting occurrence points for further analysis, except for one species (*Tripogon polyanthus*) which did not present any valid occurrences.

Desiccation-tolerant vascular plants' distribution along water deficit gradients

The drought is here referred to as the degree to which the evaporative demand (i.e. potential evapotranspiration) urges the water supply via precipitation. To estimate drought, we calculated the Thornthwaite's aridity index (AI) and climate water deficit (CWD) for the areas in which DT plants were observed. First, the CWD was obtained by the sum of monthly water deficit over a year was used in absolute values, while the AI was obtained by dividing the CWD by the modulus of the cumulative Thornthwaite's potential evapotranspiration for the same period (Thornthwaite, 1948; Esquivel-Muelbert et al., 2017; please see Appendix II for detailed information concerning the environmental factors assessment). We used climate datasets from the Worldclim v2.1 database (https://www.worldclim.org/) to calculate both indices.

To investigate DT plants' distribution along water deficit gradients, WDA was defined as the drought condition in which a species was mostly associated according to their distribution information. To examine the water deficit range in which DT plants tolerate, the WDNB was here defined as the maximum variation along a drought gradient in which a species can occur. To assess species' WDA and WDNB, we use both drought indices (i.e., AI and CWD). .

Desiccation-tolerant vascular plants' diversity in relation to drought and precipitation seasonality

Assuming that there is a gradient of drought and precipitation seasonality conditions across habitats, the species richness and phylogenetic diversity were used as two alternative metrics to estimate DT plants' diversity. We assessed the species richness by simple species counting, while we calculated the phylogenetic diversity using the Rao diversity index. For drought, the above-mentioned indices were used (i.e. AI and CWD). Precipitation seasonality was referred to as the temporal patterns of rainfall incidence across the year, considering this main water supply path to the vegetation (Walsh and Lawler, 1981). We used two indices to assess DT plants' diversity in relation to precipitation seasonality: the Walsh and Lawler's rainfall seasonality index (SI) and the coefficient of variation in precipitation seasonality (BIO15). We calculated the SI as the cumulative difference between the month and mean monthly rainfall, divided by the mean annual rainfall (Walsh and Lawler 1981; Appendix II). The BIO15 refers to the *bio15* dataset obtained from the Worldclim v2.1 database. Despite using the same parameters, the two indices diverge in relation to the weight given to more seasonal conditions. The SI generates regular differences along the whole seasonality spectrum, while BIO15 amplifies differences among locations as the seasonality increases. For this reason and based on the capacity of both indices to indicate variability in rainfall unevenness across the year, both metrics were considered adequate to the estimation of precipitation seasonality. We used climate datasets from the Worldclim v2.1 database to calculate the SI.

The potential vulnerability of desiccation-tolerant vascular plants to changes in drought conditions

To evaluate DT plants' potential vulnerability to climate change in relation to water conditions, we performed the climate-niche factor analysis (Rinnan and Lawler, 2019; (please see Appendix II for detailed information concerning the conservation aspects of DT plants). To assess the distribution area for species, we generated distribution models as the consensus areas between the two modelling approaches, always it was possible (please see Appendix II, Table I for detailed information concerning the species geographical distribution). First, we conducted the niche-based modelling maximum entropy (MaxEnt, Phillips et al., 2004) to predict every species distribution based on a climatic niche perspective. Then, we performed the inverse-distance weighted model (IDW) approach to predict every species distribution by a presence-absence interpolation model. We set the resolution of 2°30'' for all species in this study (i.e., 4 x 4 km resolution). We chose those techniques as alternative distribution hypotheses encompassing abiotic suitability and habitat accessibility (Diniz-Filho et al., 2003; Pearson and Dawson, 2003; Soberón and Peterson, 2005; Bahn and Mcgill, 2007). We evaluated the predictive power of models from both techniques by the area under the receiver operating characteristic after cross-validation of the original data using the method of k-means (k=5), in which 10000 random background points were generated for each model (Barbet-Massin et al., 2012). We considered at least 50% of the consensus between five different random cross-validation routines for the same approach. Then, we used individual model thresholds (i.e. best sensitivity and specificity) to produce final binary occurrence maps for each technique. At last, we used the consensus areas between both techniques to conduct the climate-niche factor analysis. We did not perform the above-mentioned models for species with less than five observation points after the rarefying method. To get around this problem, we assessed those species' distribution maps using the circular area (50 km radius) method proposed by Hijmans and Spooner (2001).

We calibrated all MaxEnt models with the same variables to describe the six environmental constraints listed by Marks et al. (2021) that impact the outcome of desiccation tolerance. First, we used the (i) vapor pressure deficit, (ii) solar radiation, and (iii) annual mean temperature as a proxy for (a) desiccation rate, (b) light and (c) temperature during species desiccation and rehydration. We calculated those variables from the Worldclim v2.1 database historical datasets; please see the Appendix II for detailed information concerning the environmental factors assessment). As a proxy for the (d) intensity, (e) duration, and (f) frequency of drought events where DT plants occur, we used the Standardized Precipitation Evapotranspiration Index to produce the variables (iv) drought intensity, (v) drought length, and (vi) drought frequency. We derived those variables from the dataset available in the Standardized Precipitation Evapotranspiration Index database (https://spei.csic.es/) using a time-scale of one month.

Then, we used drought-related datasets *bio1*, *bio4*, *bio12*, and *bio15* obtained from the Worldclim database to describe the influence and the amount of change in temperature and precipitation where DT plants are distributed. For the current climatic conditions, we used historical datasets, while we employed predictions available by the Coupled Model Intercomparison Project v.6 to assess future climate conditions. For that, we used shared socioeconomic pathways that reflect the more optimistic (i.e. SSP1 – 2.6W·m^{-2}) and pessimistic predictions (i.e. SSP5 – 8.5 W·m^{-2}) for the closer (i.e. 2021-2040) and more remote (i.e. 2081-2100) time-frames available. Besides, attempting to encompass models with distinct climate sensitivities, we considered predictions made by the Global climate models MIROC6 (equilibrium climate sensitivity = 2.3) and CanESM5 (equilibrium climate sensitivity = 5.6; Smith et al., 2020). In total, for each species, we performed four future scenarios (i.e. four near-future scenarios and four far-future scenarios combining more optimistic/pessimistic predictions with climatically more/less sensitive models). We used the overall climate sensitivity (SEN) for each species to evaulate the amount of specialization in each climate dimension (i.e. variables) species exhibit by examining their present distribution in the geographical space. Also, we used the overall climate exposure (EXP) to assess the departure from historical conditions in each climate dimension species will be subjected within their distribution areas. At last, we estimated the species potential vulnerability to change in drought by the overall climate vulnerability (VUL; Rinnan and Lawler, 2019). Species with higher SEN, EXP, and VUL are expected to be potentially more vulnerable to climate change in parts of relation to drought conditions if they remain in place.

Data analyses

To identify general trends of DT plants and phylogenetic groups in relation to the drought gradients, we performed a principal component analysis. In parallel, to compare DT plants' phylogenetic groups in relation to their species' WDA and WDNB, we performed Welsh's ANOVAs. Then, we conducted *post-hoc* Tukey honestly significant difference (HSD) tests in cases of significant differences highlighted by the Welsh's ANOVAs. We chose the Welsh's ANOVA due to the unbalanced distribution of DT plants among the three phylogenetic groups. We opted for the Tukey HSD test for comparing pairwise differences while avoiding Type I errors. In order to minimize the effects of the non-normal distribution of the WDA/WDNB values to parametric analyses (i.e. Welch's ANOVA and Tukey HSD test), all the measurements were transformed using the Box-Cox technique (Box and Cox, 1964). We chose this method due to its transformation power and optimization towards normality by an exponential value given by λ. We conducted the Bonferroni correction method to minimize the chance of inflating the type I error rate (Jafari and Ansari-Pour, 2019) when more than one Welch's ANOVAs were performed to investigate the same ecological question.

To assess the diversity of DT plants along drought and precipitation seasonality gradients, the AI, CWD, SI, and BIO15 indices were divided into class intervals in which the class size was 2.13, 20.62, 0.02, 2.61, respectively. We chose those class sizes based on the Silverman's rule of thumb for bandwidth selection, which assumes a Gaussian distribution of species to attenuate the effects of the uneven individuals' sampling efforts across the space (Cowell and Flachaire, 2015). Then, we performed local polynomial regressions to estimate DT plants' diversity along the drought and precipitation seasonality gradients. We predicted the DT plants' highest diversity using regression's resulting function. We repeated the same routine for the three main phylogenetic groups.

To evaluate the correlation between DT plants' distribution along the drought gradients (i.e. WDA and WDNB) and species VUL (including its components, i.e. SEN and EXP), we performed linear models for each future scenario. We considered this approach the best way to examine such relationships, or their absence, by providing simple linear equations to understand the increase/decrease of species vulnerability in relation to DT plants' relationship with drought. We log-transformed all variables for the linear models. At last, as explained above, we performed Welch's ANOVAs with Bonferroni correction and Tukey HSD tests to compare the VUL, SEN, and EXP as described above.

We conducted all geographic information system routines, descriptive and statistical analyses, and all graphical representations in R software 4.2.0 (R Core Team 2021).

Desiccation-tolerant vascular plants' distribution along water deficit gradients

We could identify that DT plants exhibited a WDA of 32 ± 1.1 for AI and of 341 ± 15 for CWD (Figure 3.2; Table S3.1). Comparing phylogenetic groups, we could not identify significant differences between pteridophytes (WDA_{AI} = 33 ± 1.5; WDA_{CWD} = 339 ± 19.1), monocots (WDA_{AI} = 30 ± 1.58; WDA_{CWD} = 364 ± 28.3), and eudicots (WDA_{AI} = 31 ± 3; WDA_{CWD} = 251 ± 29.8) concerning species WDA (WDA_{AI}: Welch's ANOVA F-value = 0.3663, adjusted *p*-value = 1; WDA_{CWD}: Welch's ANOVA F-value = 1.7268, adjusted *p*-value = 0.3706, Table S3.2). However, DT plants showed a WDNB of 52 ± 1.5 concerning the AI and 817.1 ± 30.5 regarding the CWD, in which pteridophytes ($WDNB_{AI}$ = 65 ± 1.6; $WDNB_{CWD}$ = 1011 ± 36.5) showed significantly broader WDNB than monocot ($WDNB_{AI}$ = 36 ± 2.2; $WDNB_{CWD}$ = 599 ± 50.5) and eudicot ($WDNB_{AI}$ = 35 ± 3.9; $WDNB_{CWD}$ = 335 ± 49.1) plants ($WDNB_{AI}$: Welch's ANOVA F-value = 60.7068, adjusted *p*-value < 0.0001; $WDNB_{CWD}$: Welch's ANOVA F-value = 47.8713, adjusted *p*-value < 0.0001; Table S3.3). These differences could be depicted by the positive correlation between WDNB and pteridophytes, besides the negative association of WDNB with monocots and eudicots in the principal component analysis' ordination, which explained 93% of the total variance (60% and 33% for PCA1 and PCA2 respectively; Table S3.4).

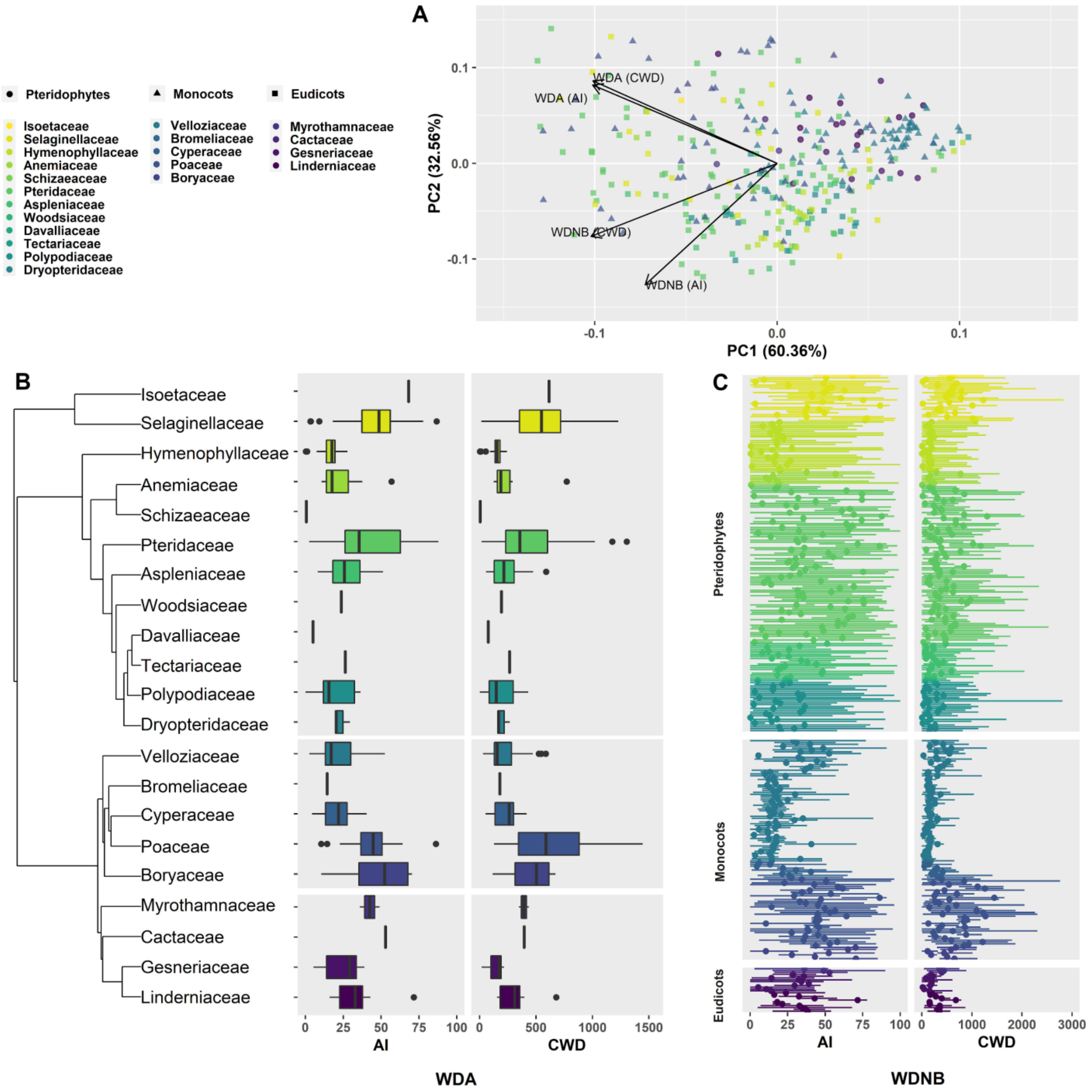

Figure 3.2. Desiccation-tolerant vascular plants' (DT plants) distribution along the water deficit gradients, grouped by their three main phylogenetic groups and botanical families, which was ordered by their position along the tracheophytes phylogenetic tree. The water deficit affinity (WDA) and niche breadth along water deficit conditions (WDNB) were assessed by the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD) were considered. A – DT plants' position along the two first axes of the principal component analysis (i.e. PCA1 and PCA2); B – DT plants' WDA; C – DT plants' WDNB.

Desiccation-tolerant vascular plants' diversity in relation to water deficit and precipitation seasonality

The DT plants' diversity decreases with drought conditions. The highest DT plants' species richness was found in locations with AI scores between 23.4 - 25.6 and CWD values between 0 - 20.6, while their highest phylogenetic diversity was found between 21.3 - 23.4 for AI and 0 - 20.6 for CWD (Table 3.1; Table S3.5). Considering both drought indices, monocots' highest species richness were registered to the wetter locations (species richness: AI = 21.3 - 23.4 and CWD = 0 - 20.6) when compared pteridophytes (species richness: AI = 29.8 - 31.9 and CWD = 0 - 20.6) and eudicots (species richness: AI = 25.6 - 27.7 and CWD = 206.2 - 226.8). On the other hand, eudicots stood out as the phylogenetic group which the highest phylogenetic diversity was encountered in the wetter areas (eudicots' phylogenetic diversity: AI = 10.6 - 12.8 and CWD = 41.2 - 61.9; pteridophytes' phylogenetic diversity: AI = 38.3 - 40.5 and CWD = 948.5 - 969.2; monocots' phylogenetic diversity: AI = 63.9 - 66 and CWD = 721.7 - 742.3).

Table 3.1. Drought conditions in which the greater diversity of desiccation-tolerant vascular plants (DT plants) is found. DT plants diversity was estimated by species richness and phylogenetic diversity. Drought conditions were assessed by Thornthwaite's aridity index (AI) and climate water deficit (CWD). bw = bandwidth according to Silverman's rule of thumb, used to determine class intervals' size along the drought gradients.

	AI (bw = 2.13)		**CWD (bw = 20.62)**	
	Species richness	**Phylogenetic diversity**	**Species richness**	**Phylogenetic diversity**
DT plants	23.4 - 25.6	21.3 - 23.4	0 - 20.6	0 - 20.6
Pteridophytes	29.8 - 31.9	38.3 - 40.5	0 - 20.6	948.5 - 969.2
Monocots	21.3 - 23.4	63.9 - 66	0 - 20.6	721.7 - 742.3
Eudicots	25.6 - 27.7	10.6 - 12.8	206.2 - 226.8	41.2 - 61.9

Regarding the precipitation seasonality, DT plants' diversity was higher under intermediary conditions (Table 3.2). Here, the highest diversity values were registered to locations with seasonal precipitation regimes (species richness: SI = 0.6 - 0.62 and BIO15 =65.4 - 68; phylogenetic diversity: SI = 0.83 - 0.85 and BIO15 = 99.4 - 102). Although the highest species richness of Pteridophytes was linked to less seasonal sites when compared to monocots and eudicots (pteridophytes' species richness: SI = 0.51 - 0.53 and BIO15 = 60.2 - 62.8; monocots' species richness: SI = 0.67 - 0.69 and BIO15 = 78.5 - 81.1; eudicots' species richness: SI = 0.78 - 0.81 and BIO15 = 78.5 - 81.1), eudicots registered their highest phylogenetic diversity to locations with the most equitable distribution in precipitation (eudicots' phylogenetic diversity: SI = 0.09 - 0.12 and BIO15 = 10.5 - 13.1; pteridophytes' phylogenetic diversity: SI = 0.78 - 0.81 and BIO15 = 94.2 - 96.8; monocots' phylogenetic diversity: SI = 0.85 - 0.88 and BIO15 = 102 - 104.6).

Table 3.2. Precipitation seasonality conditions in which the greater diversity of desiccation-tolerant vascular plants (DT plants) is found. DT plants diversity was estimated by species richness and phylogenetic diversity. Precipitation seasonality was assessed by Walsh and Lawler's rainfall seasonality index (SI) and coefficient of variation in precipitation seasonality (BIO15). bw = bandwidth according to Silverman's rule of thumb, used to determine class intervals' size along the precipitation seasonality gradients.

	SI (bw = 0.02)		**BIO15 (bw = 2.61)**	
	Species richness	**Phylogenetic diversity**	**Species richness**	**Phylogenetic diversity**
DT plants	0.6 - 0.62	0.83 - 0.85	65.4 - 68	99.4 - 102
Pteridophytes	0.51 - 0.53	0.78 - 0.81	60.2 - 62.8	94.2 - 96.8
Monocots	0.67 - 0.69	0.85 - 0.88	78.5 - 81.1	102 - 104.6
Eudicots	0.78 - 0.81	0.09 - 0.12	78.5 - 81.1	10.5 - 13.1

The potential vulnerability of desiccation-tolerant vascular plants to changes in drought conditions

In overall terms, the DT plants' SEN to changes in drought conditions is more prominent than their EXP in most of the evaluated scenarios (SEN = 1.42 ± 0.02; EXP: 2021-2040 | SSP1 = 0.68 ± 0.03, 2021-2040 | SSP5 = 0.81 ± 0.04, 2081-2100 | SSP1 = 0.86 ± 0.04; Table S3.6; Table

S3.7). The exception was noticed for the most pessimistic scenario in the farthest future, in which the DT plants' EXP was noticeably higher (EXP: 2081-2100 | SSP5 = 2.67 ± 0.11) and increased the species VUL when compared to all the other scenarios (VUL: 2021-2040 | SSP1 = 1.24 ± 0.01, 2021-2040 | SSP5 = 1.25 ± 0.01, 2081-2100 | SSP1 = 1.25 ± 0.01, 2081-2100 | SSP5 = 1.36 ± 0.01).

In general, WDA could not describe species VUL to changes in drought conditions (Figure 3.3; Table S3.8). The only exception could be observed for WDA_{CWD} in the most pessimistic scenario of the farthest time frame, in which a negative relationship was registered (slope = -0.96, *p*-value = 0.0284). For most scenarios in which the relationship between WDNB and VUL was evaluated, the correlation was not significant (Table S3.9). Again, an exception could be observed for the most pessimistic scenario in the farthest decades, in which a negative relationship was observed when both indices were considered (AI: slope = -2.25, *p*-value = 0.0113; CWD: slope = -2.81, *p*-value = 0.0074).

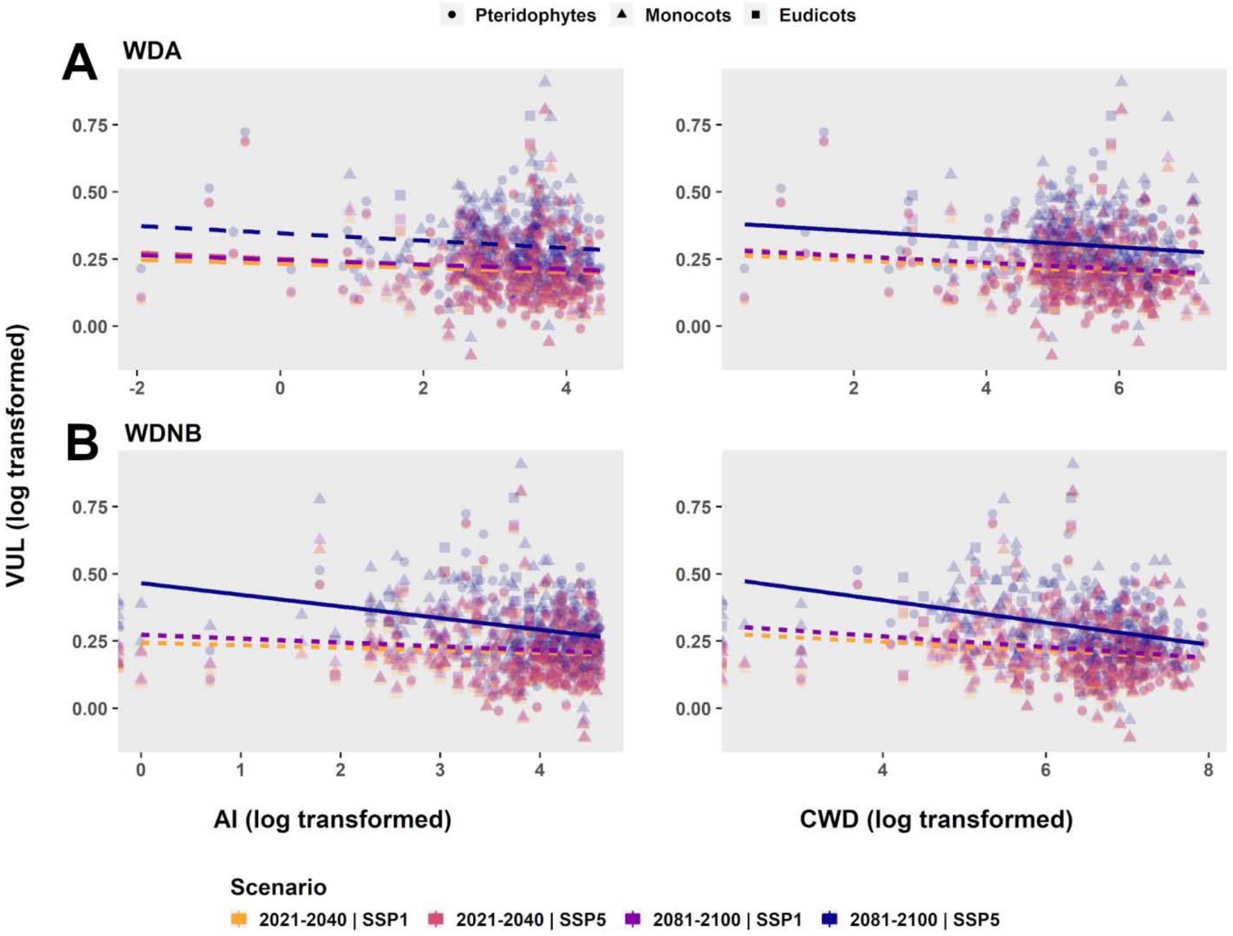

Figure 3.3. Correlations between desiccation-tolerant vascular plants' (DT plants) distribution along the water deficit gradients and their potential vulnerability (VUL) to changes in drought conditions, identifying DT plants' three main phylogenetic groups. The water deficit affinity (WDA) and niche breadth along water deficit conditions (WDNB) were assessed by the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD) were used. The species VUL to changes in drought conditions considered four different future scenarios combining the closer (i.e. 2021-2040) and more remote (i.e. 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e. SSP5 – 8.5 W·m-2) shared socioeconomic pathways. All variables were log-transformed and full lines describe significant relationship between them, while dashed lines indicate non-significant relationships. A – Correlations between DT plants' WDA and VUL; B – Correlations between DT plants' WDNB and VUL.

When the climate-niche factor analysis' results were compared between the three main phylogenetic groups, significant differences could be found for species' SEN (F-value = 7.0403, *p*-value = 0.0018), EXP in all scenarios (EXP: F-values = 81.3822, 89.2667, 89.1582, and

91.3397 for 2021-2040 | SSP1 – SSP5 and 2081-2100 | SSP1 – SSP5, respectively; and adjusted *p*-value < 0.0001 for comparisons), and VUL only for the most pessimistic scenario in the farthest future (2081-2100 | SSP5 | VUL: F-value = 61.9187, adjusted *p*-value = 0.002; Figure 3.4; Table S3.10; Table S3.11). Concerning species' SEN, monocots showed significantly lower SEN than pteridophytes and eudicots ($SEN_{monocots} = 1.35 \pm 0.03$; $SEN_{pteridophytes} = 1.45 \pm 0.24$; $SEN_{eudicots} = 1.56 \pm 0.06$). Regarding species' EXP, pteridophytes exhibited significantly lower EXP than monocots and eudicots in all examined scenarios ($EXP_{pteridophytes} = 0.46 \pm 0.24$, 0.52 ± 0.23, 0.57 ± 0.24, and 1.78 ± 0.76; $EXP_{monocots} = 1 \pm 0.03$, 1.24 ± 0.04, 1.25 ± 0.04, and 3.95 ± 0.13; $EXP_{eudicots} = 0.93 \pm 0.06$, 1 ± 0.07, 1.22 ± 0.08, and 3.6 ± 0.25; for 2021-2040 | SSP1 – SSP5 and 2081-2100 | SSP1 – SSP5, respectively). At last, in the only scenario in which significant differences in VUL were reported between the phylogenetic groups, pteridophytes will be less VUL than monocots and eudicots ($VUL_{pteridophytes} = 1.33 \pm 0.05$; $VUL_{monocots} = 1.4 \pm 0.04$; $VUL_{eudicots} = 1.47 \pm 0.07$).

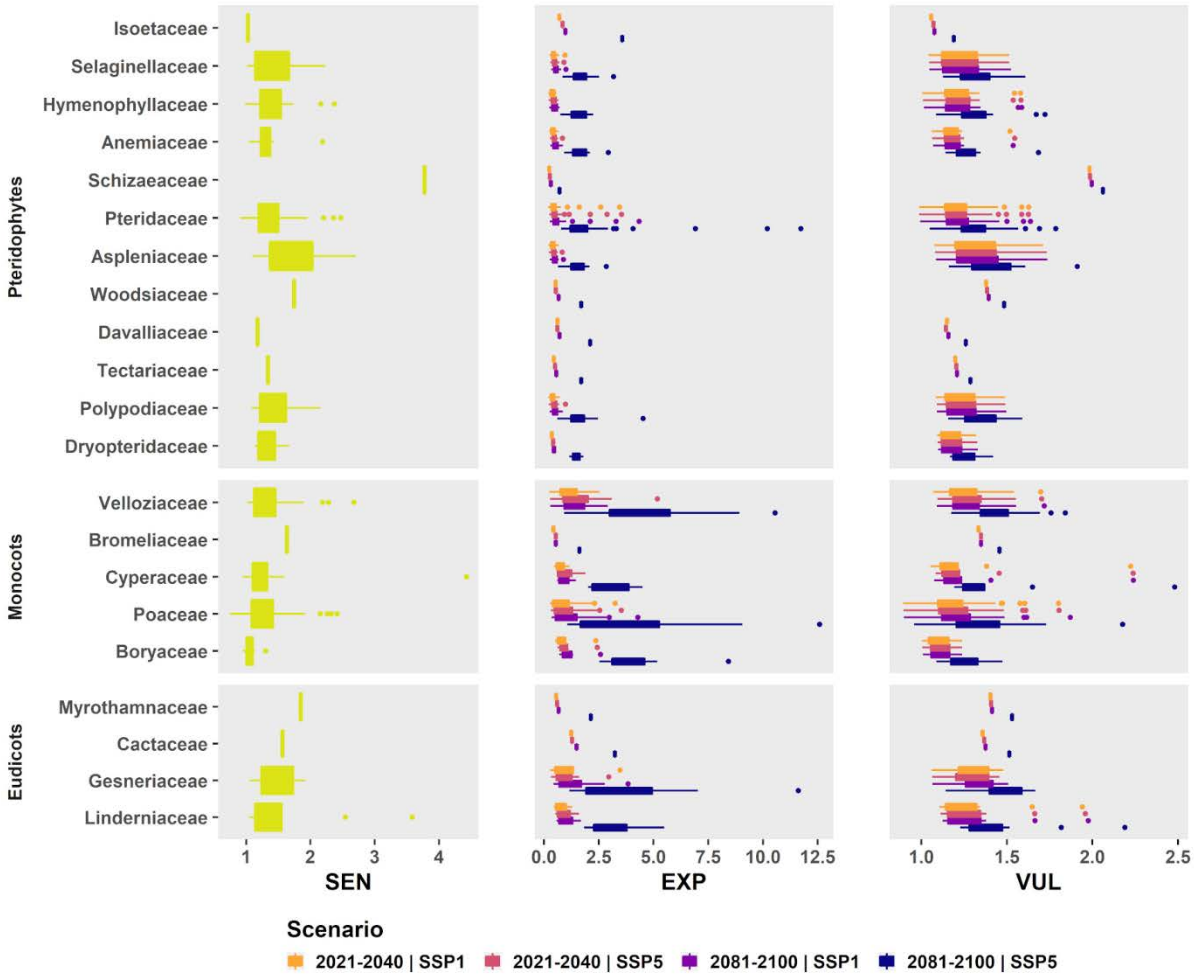

Figure 3.4. Differences between desiccation-tolerant vascular plants' botanical families in respect to their sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to changes in drought conditions. Four different future scenarios were used, combining the closer (i.e. 2021-2040) and more remote (i.e. 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e. SSP5 – 8.5 W·m-2) shared socioeconomic pathways.

The DT plants neither had a high WDA nor a narrow WDNB; consequently, their higher diversity did not increase with higher drought and precipitation seasonality conditions (Figure 3.5). Pteridophytes and eudicots did not jointly differ from monocots in most assessed aspects, except for species SEN to changes in drought conditions. That implies that solely the strategy regarding the photosynthetic apparatus maintenance cannot explain differences between DT plants concerning their relationship with drought. In general, only in the long-term and under a fossil-fueled development the DT plants' relationship with drought could explain species' potential vulnerability to changes in drought conditions. In this case, species from the most humid habitats and ecologically more restricted can be considered more extinction-prone.

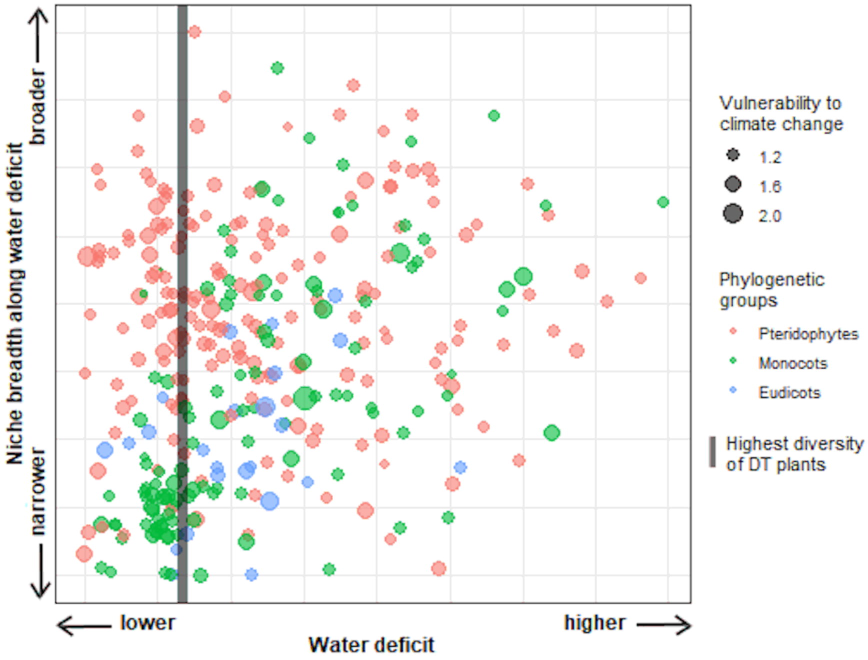

Figure 3.5. The desiccation-tolerant vascular plants' (DT plants) distribution along the water deficit in relation to their niche breadth, given by their vulnerability to changes in drought conditions and phylogenetic groups. The water deficit condition in which the highest diversity of DT plants is found is indicated by the vertical line.

Our results suggest the relevance of rainfall to DT plants' distribution and diversity when we bring together the negative correlation of DT plants with water deficit and the low diversity of DT plants in arid and highly seasonal conditions. Even when DT plants’ species richness is higher in moderate and seasonal conditions, our results indicate that wet and precipitation-equitable conditions gather species with the most distinct evolutionary histories (Figure 3.6). The topo-edaphic conditions of the locations where DT plants grow would also reinforce the rainfall importance for most DT plants. That is because rock outcrops and canopies offer a substrate with low water storage capacity, in which water deficit periods set in quicker (Porembski and Barthlott, 2000; Proctor and Tuba, 2002; Alcantara et al., 2015). In this sense, the water supply events must be either frequent or consistent enough to allow species to recoup respiratory losses of carbon during dry and recovering periods (Alpert, 2005). That agrees with the notion that DT plants are less likely to occur in locations with insufficient rainfall to abbreviate long dry spells, as pointed out by Fahmy et al. (2006). As aridity and precipitation seasonality increase, the diversity of DT plants decreases. Fewer species can cope with arid and seasonal conditions, and the evolutionary solutions to deal with such conditions seem to be related to a few phylogenetic lineages. Aguirre-Gutiérres et al. (2022) reported a decrease in functional redundancy as water deficit increased in tropical rainforests. Our results suggest that the same pattern can be expected for DT plants too, although more investigations in this direction must be conducted in the future.

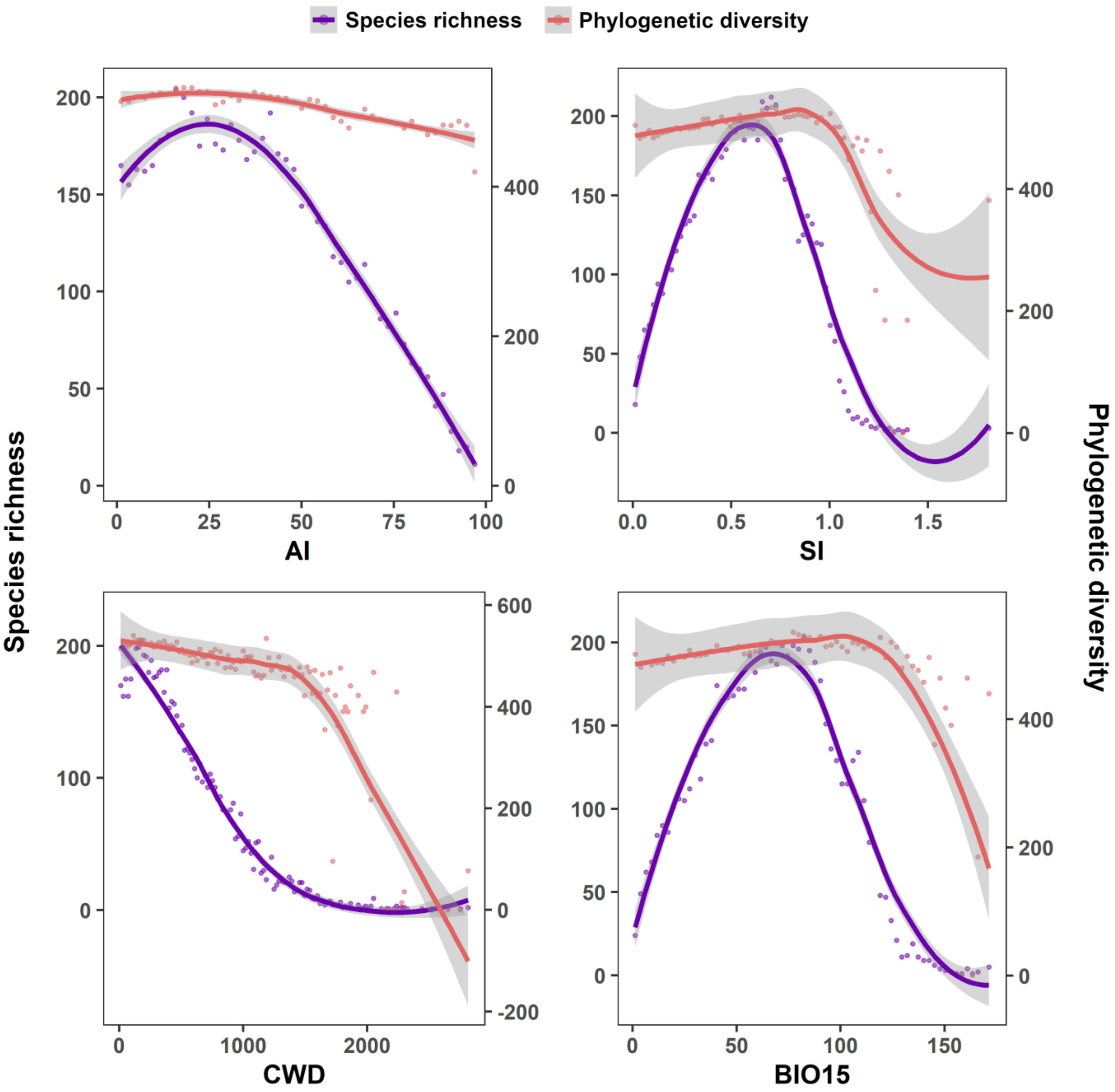

Figure 3.6. Diversity of desiccation-tolerant vascular plants along drought and precipitation seasonality gradients. DT plants' diversity was estimated by species richness and phylogenetic diversity. The Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD) were used to estimate drought conditions, while the Walsh and Lawler's rainfall seasonality index (SI) and the coefficient of variation in precipitation seasonality (BIO15) were used to calculate the precipitation seasonality.

Still, our results showed that DT plants form a very heterogeneous group of plants concerning their relationship with drought. We could not cluster phylogenetic lineages or main functional groups according to water deficit conditions. It suggests that the mechanisms to tolerate desiccation do not explain alone how drought influences DT plants diversity and distribution. We advocate the existence of different trait combinations to explain why DT plants with the same mechanism to cope with desiccation diverged in their ecological aspects related to drought. These different trait combinations would create alternative functional designs in which species individuals exhibit similar fitness under a given set of resources and conditions (Marks and Lechowicz, 2006; Dias et al., 2020). Although, it reduces the environmental selective forces over single traits (Dias et al. 2020), such as the photosynthetic apparatus maintenance. For instance, de Paula et al. (2019) showed that three co-existing poikilochlorophyllous Velloziaceae species (i.e., *Barbacenia tomentosa*, *Vellozia plicata*, and *Vellozia pulchra*) exhibit different anatomical traits combination. However, even though alternative functional designs promote similar fitness for the conditions found in the inselberg those species coexist, they may perform distinctively in different environments. Analyzing those species' relationship with water deficit, we observe that *Vellozia plicata* have a higher WDA (30 ± 3.26) and broader WDNB (370.00 ± 43.14) when compared to *Vellozia pulchra* (WDA = 18.00 ± 1.41 and WDNB = 204.00 ± 16.82) and *Barbacenia tomentosa* (WDA = 12.00 ± 1.05 and WDNB = 109.00 ± 12.83). Therefore, it would be interesting to understand the different alternative functional designs related to desiccation tolerance and how they could explain observed ecological patterns.

Interestingly, despite expectancy for homoiochlorophyllous plants with lower WDA (e.g., Tuba, 2008; Oliver et al., 2020; Marks et al., 2021), it was the homoiochlorophyllous species from different phylogenetic lineages that scored the highest values for WDA. As mentioned before, the alternative functional designs might be important to explain those patterns, such as anti-oxidants accumulation in *Myrothamnus flabellifolius* reducing the photooxidation effects

(Farrant and Kruger, 2001) or mechanisms to survive desiccation and rehydration events spending very little energy in *Selaginella lepidophylla* (Eickmeier, 1979).

However, we should not neglect that many homoiochlorophyllous species tend to be found in more shady habitats, such as rock crevices or within monocot mats (Gaff, 1977; Porembski, 2021). That is supposed to reduce pteridophytes' dependency on climate since the lower exposure implies they experience less intense droughts, in a lower frequency, and of shorter duration (Parmentier et al., 2006; Porembski, 2021). Our methods could not detect microhabitat differences or verify the tolerance spectrum of DT plants mechanically. Although it does not overrule the influence of climate on homoiochlorophyllous species distribution nor invalidate the fact that the highest species richness of pteridophytes is found in drier locations (Figure S3.1). It reinforces the need for more studies at finer spatial scales to elucidate more specific questions. That can be assessed either by presenting measurements of water availability or by performing temporal monitoring of plants' water status. For example, Teodoro et al. (2021) followed environmental conditions and plants' responses in field and greenhouse experiments. Through these approaches, they could identify that two co-existing Velloziaceae species with distinct strategies regarding desiccation experience a similar mild drought in their natural habitats, but show different sensitivities to drought.

Regardless the microhabitat, the life over rock (or phorophyte) offers a great amount of within-generation water variability (Porembski and Barthlott, 2000). The temporal variability of a given resource is supposed to favour generalist species in relation to this resource availability (Lynch and Gabriel, 1987; Broennimann et al., 2006; Sexton et al., 2017). DT plants must grow and reproduce when water is available and ensure the survival of photosynthetic tissues during drought (Oliver and Bewley, 1997; Zhang et al., 2018; do Nascimento et al., 2020). Thus, the ability to cope with selective pressures promoted by both dry and wet conditions would explain why DT plants did not show a narrow WDNB. Former studies support this understanding. For instance, Alcantara et al., (2015) showed that DT Velloziaceae do not differ in their ecophysiology from phylogenetically related desiccation-sensitive species. Similarly, do Nascimento et al. (2020) reported that the desiccation-tolerant *Barbacenia graminifolia* (Velloziaceae) acts as a homoiohydric plant under higher soil moisture conditions and poikilohydric when water is not available.

A broader niche breadth can reduce the species' extinction risks (Levins, 1962; Broennimann et al., 2006; Saupe et al., 2015; Carscadden et al., 2020). That was also true for DT plants once DT plants with narrower WDNB are potentially more vulnerable to changes in drought conditions. DT plants from the most humid habitats are also potentially more vulnerable in the worst possible scenario. Thus, they should be carefully monitored alongside ecologically more restricted species. Curiously, the link between species VUL and SEN or EXP is not obvious (Figure 3.7). For example, DT plants with narrower WDNB are not more sensitive to changes. Similarly, DT plants from most humid locations are neither more sensitive nor will become more exposed to changes. That means that the combination between SEN and EXP would better explain the DT plants' VUL rather than those components alone. This might imply that some expectations, such as that DT plants from wetter climates may have reduced desiccation tolerance capacities (Marks et al., 2021) or that drier locations will experience a greater magnitude of changes (Mukherjee et al., 2018), should be considered in an integrative way to enhance the prediction power of general assumptions for DT plants' VUL.

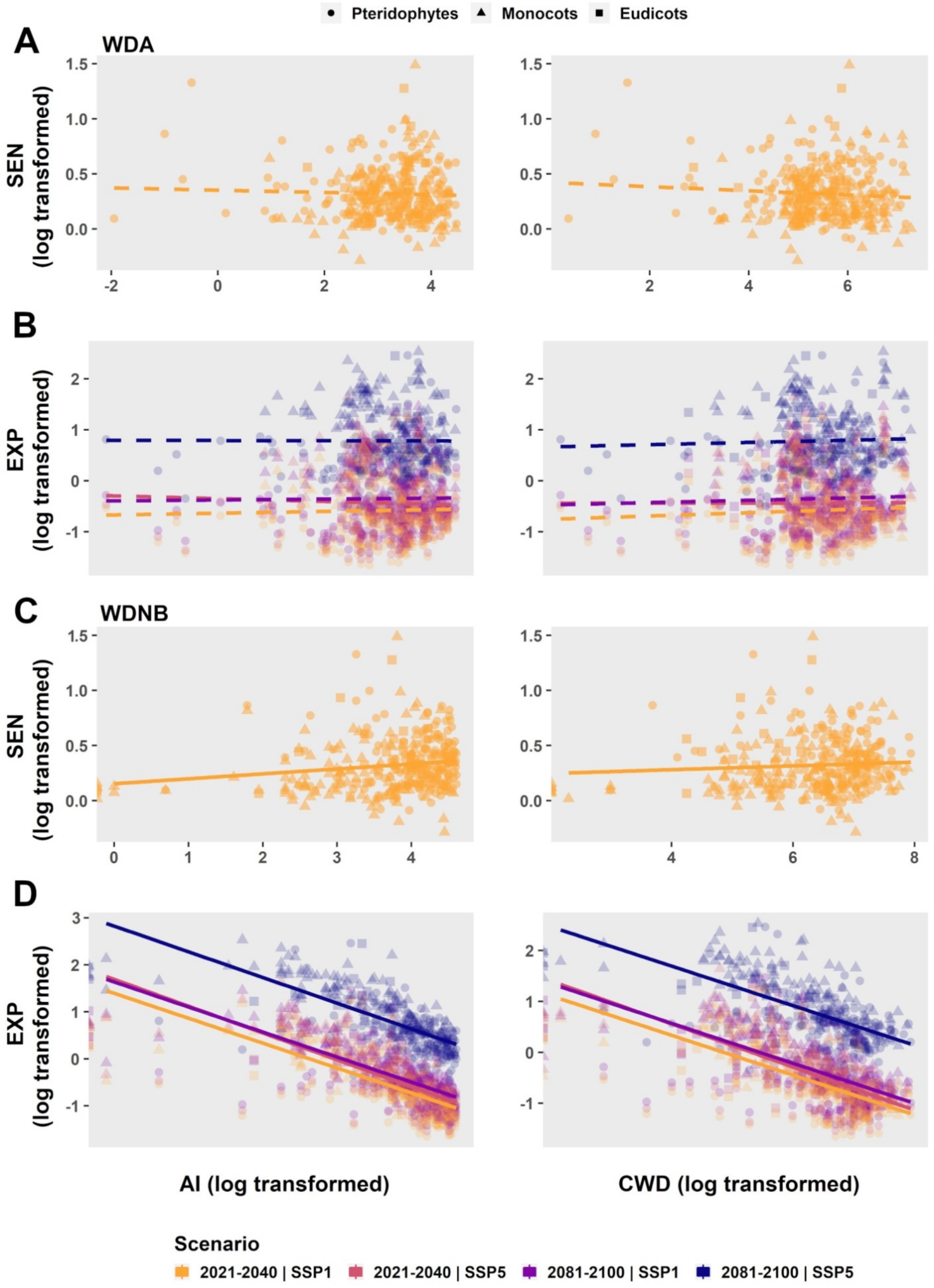
● Pteridophytes ▲ Monocots ■ Eudicots
A
WDA
SEN (log transformed)
1.5
1.0
0.5
0.0
-2
0
2
4
2
4
6
B
EXP (log transformed)
2
1
0
-1
C
WDNB
SEN (log transformed)
1.5
1.0
0.5
0.0
0
1
2
3
4
4
6
8
D
EXP (log transformed)
3
2
1
0
-1
AI (log transformed)
CWD (log transformed)
Scenario
2021-2040 | SSP1
2021-2040 | SSP5
2081-2100 | SSP1
2081-2100 | SSP5

Figure S3.7. Correlations between desiccation-tolerant vascular plants' (DT plants) distribution along the water deficit gradients and sensitivity (SEN) and exposure (EXP) to changes in drought conditions, identifying DT plants' three main phylogenetic groups. The water deficit affinity (WDA) and niche breadth along water deficit conditions (WDNB) were assessed by the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD). The species VUL to changes in drought conditions considered four different future scenarios combining the closer (i.e., 2021-2040) and more remote (i.e., 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m^{-2}) and more pessimistic (i.e., SSP5 – 8.5 W·m^{-2}) shared socioeconomic pathways. All variables were log transformed and full lines describe significant relationship between them, while dashed lines indicate non-significant relationships. A – Correlations between DT plants' WDA and SEN; B – Correlations between DT plants' WDA and EXP; C – Correlations between DT plants' WDB and SEN; D – Correlations between DT plants' WDB and EXP.

The DT angiosperms should also be carefully observed. That is because they exhibited narrower WDNB, have their diversity related to the most humid conditions, will be more exposed to changes, and are potentially more vulnerable if we keep the historical increasing rates of greenhouse gas emissions and a fossil-fueled development. Also, DT angiosperms are mainly confined to rock habitats and should be followed more closely to avoid potential extinction. Besides climate changes, additional threats such as inselbergs destruction or species invasion could alter their abundance patterns in their native habitats and drive them to local extinctions (Porembski, 2000; McKinney, 1997; Slatyer et al., 2014; Porembski et al., 2016; Carscaden et al., 2020). It reinforces other claims for the conservation of inselbergs' vegetation (Corlett and Tomlinson, 2000; Burke, 2003; Fonty et al., 2009; de Paula et al., 2016; Porembski et al., 2016; Rabarimanarivo et al., 2019). Thus we argue that inselbergs conservation might be crucial to increase DT angiosperms' chance to mitigate the effects of changes via seeds dispersion.

Nevertheless, it does not mean that pteridophytes and species occurring in other ecosystems should be ignored. For example, *Schizaea pusilla* is a fern species that do not occur on rock outcrops (Kiss and Swatzell, 1996). It is among the DT plants predicted to become more vulnerable to changes in drought conditions. It confirms the notion that, as for the conservation of species in general (Dawson et al., 2011), one-size-fits-all conservation strategies are probably fated to fail for DT plants. Therefore, conservation efforts should consider how DT plants are complex and different from each other concerning their distribution, correlation to drought, and vulnerability aspects.

CHAPTER 4

THE VULNERABILITY OF DESICCATION-TOLERANT VASCULAR PLANTS TO CLIMATE CHANGE

And what if it gets drier? (*Vellozia plicata*). Picture by L. Bondi

CHAPTER 4

THE VULNERABILITY OF DESICCATION-TOLERANT VASCULAR PLANTS TO CLIMATE CHANGE

INTRODUCTION

Climate change is considered one of the main threats to global biodiversity (Thomas et al., 2004; Pimm, 2008; Pecl et al. 2017). That is because abiotic factors affect organisms' fitness and the long-term shifts in climate mean states might exceed species' tolerances (Brown et al., 1996; Pearson and Dawson, 2003; Soberón and Peterson, 2005; Dawson et al., 2011; Anderson, 2016; Aguirre-Gutiérrez et al., 2022). As a consequence, declines in species diversity are expected to occur worldwide (Thomas et al., 2004; Aguirre-Gutiérrez, et al., 2022). Since the impact of changes varies across species and the magnitude of changes varies throughout locations (Dawson et al., 2011; Trenberth et al., 2014; Mukherjee et al., 2018), it is not a simple task to understand the effects of climate change to biodiversity and draw conservation strategies to minimize them.

In this context, desiccation-tolerant vascular plants (DT plants) form a polyphyletic group of plants that can overcome the desiccation of their photosynthetic tissues without losing biomass (i.e., less than 13-20% of protoplasmic water; Oliver et al., 2000; Porembski & Barthlott, 2000). Because of their ability to tolerate droughts, the impacts of climate change on these species have been largely neglected. However, empirical studies have shown that DT plants are affected by changes in environmental constraints. For example, they are particularly influenced by changes in the desiccation rate, light and temperature during their desiccation and rehydration processes, besides the frequency, intensity, and duration of drought events (Farrant et al., 1999; Farrant & Kruger, 2001; Farrant et al., 2003; Georgieva et al., 2008; Marks et al., 2021). In this sense, changes in climate affecting the capacity of DT plants to cope with drought (e.g., rising temperature and anomalies in rainfall-evapotranspiration dynamics) might threaten these species with extinction. To the best of our knowledge, no further details are known concerning how the shifts in those factors can influence DT plants' distribution and diversity patterns. Improving our understanding of how different DT plants vary in their vulnerability to climate change is of paramount importance to their conservation.

The influence of environmental constraints on DT plants is supposed to vary across species. Much of this variation is often explained by the fact that the desiccation tolerance independently re-evolved multiple times within the vascular plants' phylogeny (e.g., Oliver et al., 2000; Porembski & Barthlott, 2000; Marks et al., 2021). In other words, this assumption agrees with the expectancy that phylogenetically closely related species tend to share similar requirements and tolerances for environmental conditions (Webb et al., 2002; Wiens, 2004; Cavender-Bares et al., 2009; Cadotte et al., 2017). It makes phylogeny a good proxy for our understanding of how climate change could impact different species. However, that is not necessarily true for all DT plants. For instance, DT plants from different phylogenetic lineages coexist under similar ecological conditions, and this pattern is repeated in different regions of the world and under different climates (Gaff, 1977; Gaff and Latz, 1978; Gaff, 1987; Meirelles et al., 1997; Porembski, 2021).

Alternatively, the species' biogeographic patterns can be used to describe how they are influenced by changes in environmental constraints. For example, endemic species are expected to be more sensitive to climatic variability than widespread species (Gaston, 1996; Broennimann et al., 2006; Slatyer et al., 2013; Saupe et al., 2015; Carscadden et al., 2020). However, DT plants are strongly related to inselbergs, which are isolated rock outcrops characterized by marked fluctuations in water availability (Barthlott et al., 1993; Porembski and Barthlott, 2000 Marks et al., 2021). From this perspective, an inselberg-endemic DT plant might be considered less sensitive to climate change when compared to most desiccation-sensitive species. Then, the observed biogeographic patterns for DT plants might be more related to stochastic factors than to their vulnerability to climate change. Thus, despite the usefulness of phylogenetic and biogeographical patterns to identify general trends of species response to climate change, their predictive power for DT plants remains to be tested.

Ultimately, the extent to which climate change will impact species diversity depends if the magnitude of shifts in climate correlates with their diversity patterns (Dawson et al., 2011). For DT plants, inselbergs from eastern South America, south/southeastern Africa, Madagascar, and western Australia are expected to be centers of diversity (Alpert, 2000; Porembski & Barthlott, 2000). This expectancy neglects phylogenetic and endemism aspects of DT plants' diversity, and includes locations in the most distinct climates in which climate change might differ (e.g., dry areas are predicted to become even drier; Trenberth et al. 2014; Mukherjee et al. 2018). In general, areas of lower climatic variability are expected to gather higher diversity and endemism of species (Pianka, 1966; Stenseth, 1984; Willig et al., 2003; Fine, 2015; Harrison and Noss, 2017). For DT plants, it is not known whether areas of higher diversity are prone to climate change or not. Besides, it is very important to include the phylogenetic and endemism information in these assessments. Regions of higher phylogenetic diversity are supposed to gather species with the most diverse and unique ecosystem functions which evolved along with phylogenetic clades (Mace et al., 2003; Purvis et al., 2005; Rosauer et al., 2009; Vellend et al., 2010; Winter et al., 2013; Gerhold et al., 2015). Similarly, the preservation of areas with higher endemism would not only aid the conservation of species with higher extinction risks but would also prevent the loss of species that do not occur anywhere else (Kier et al., 2009; Rosauer et al., 2009; Harrison and Noss, 2017). In this way, such information is crucial in order to identify global conservation priority areas and support conservation efforts, which is very much desired in a climate-changing world (Mace et al., 2003; Harrison and Noss, 2017; Allan et al., 2022).

In this study, we first aimed to examine the role of species' phylogenetic and biogeographic patterns on the understanding of DT plants' vulnerability to climate change, in order to identify species with more need for conservation. Then, we aimed to correlate the diversity and endemism of DT plants with climatic variability across the geographical space, in order to identify global conservation priority areas for those species. We expected that (i) DT plants phylogenetically more related have their distribution more similarly influenced by climatic conditions, (ii) DT plants geographically more restricted have their distribution more affected by changes in climate, and (iii) locations with higher diversity and endemism of DT plants are less prone to climate change. For that, we model the species distribution using global climate data and used historical climate data to describe how climate change will affect DT plants' diversity and distribution from a taxonomic, phylogenetic, and biogeographic perspective.

MATERIALS AND METHODS

Species data

In order to obtain a list of DT plants, we first conducted a bibliographic search using the Web of Science search engine (apps.webofknowledge.com) and the key-words combination (*"desiccation tolerant" OR "resurrection") AND (angiosperm* OR pteridophyte* OR lycophyte* OR vascular OR plant**), including additional studies which could not be depicted in the bibliographic search. All DT plants reported at the “species” taxonomic level by those scientific studies we considered, standardizing the scientific names according to the Tropicos database (please see the Appendix II for more detailed information species assembly). We found 337 DT plants (80 genera and 21 families) reported in 1145 scientific studies (Appendix II).

Then, we obtained the occurrence records for every DT plant using database records in which herbarium vouchers were available (e.g., Global Biodiversity Information Facility – GBIF, Tropicos, and Species Link) with geographic information from the databases (i.e., global positioning system – GPS – information or precise description of the locality or municipality; please see the Appendix II for more detailed information species geographical distribution). We removed duplicated, erroneous and uncertain data according to specific literature and international databases (e.g., Plants of the World Online – POWO, Tropicos, Flora do Brasil 2020, and World Plants). Finally, to avoid the effects of the uneven sampling bias, we reduced multiple records for the species within an area of 1 km-radius to only one occurrence.

Climate data

We used the (i) vapor pressure deficit (VPD), (ii) solar radiation (SRad), (iii) mean annual temperature (MAT), (iv) drought frequency (DRF), (v) drought intensity (DRI), and (vi) drought length (DRL) as a proxy for the six constraints listed by Marks et al. (2021; i.e., desiccation rate, light and temperature during species desiccation and rehydration, besides the frequency, intensity, and duration of drought events, respectively). Here, higher values of VPD, SRad, MAT, DRI, DRL, and DRF describe climates in which the desiccation rate of DT plants is greater, light and temperature is higher during desiccation-rehydration processes, and droughts are more intense, extensive, and frequent.

To estimate the present climatic conditions in which DT plants might occur, we first calculated the VPD, SRad, and MAT using historical datasets from the Worldclim v2.1 database (https://www.worldclim.org/; please see Appendix II for detailed information concerning the environmental factors assessment). We estimated the VPD as the annual mean value of the monthly differences between saturated vapor pressure and actual vapor pressure (Grossiord et al., 2020). For the actual vapor pressure we used the *vapr* dataset, while the saturated vapor pressure was estimated using the *tmin* and *tmax* datasets and the equation provided by Fick & Hijmans (2017). The SRad and MAT were set by the annual mean of the *srad* and *bio1* datasets, respectively. Then, we calculated the DRF, DRI, and DRL using the one-month dataset from the Standardized Precipitation Evapotranspiration Index (SPEI) database (https://spei.csic.es/). Here, a drought event is composed of a given set of consecutive dry months (i.e., SPEI < 0). We estimated the DRF as the mean count of drought events per year. We estimated the DRI as the average of drought event intensity, given by the cumulative SPEI for each month within a drought event. At last, we estimated the DRL as the whole-period average of the number of consecutive dry months within a drought event. For all climate data, we used raster grids of 4 km x 4 km resolution.

To evaluate the historical climatic variability, we used at least a 30-year period to estimate average climatic conditions as recommended by World Meteorological Organization (https://public.wmo.int/). First, we used the individual-years datasets *vpd, srad, tmin*, and *tmax* from the Terra Climate project (https://www.climatologylab.org/terraclimate.html) to estimate the VPD, SRad, and MAT. The MAT for each year was calculated by the mean value between the maximum and minimum temperature (i.e., *tmax* - *tmin*). To estimate the variability in VPD (**Δ**VPD), SRad (**Δ**SRad), and MAT (**Δ**MAT), we subtracted the average climatic conditions registered for the period between 1958 and 1989 from the averaged records for the period between 1990 and 2021. Then, we used the SPEI datasets as described above to measure the variability in DRF (**Δ**DRF), DRI (**Δ**DRI), and DRL (**Δ**DRL), subtracting the average climatic conditions registered for the period between 1958 and 1988 from the averaged records for the period between 1990 and 2020. We used the same raster grid resolution detailed above.

Species distribution models

For all analyses in this study, we generated distribution maps for each species as the consensus area for the species distribution between the two modeling approaches, always it was possible to assess (please see Appendix II for detailed information concerning the species geographical distribution). First, we used the Maximum Entropy technique (MaxEnt; Phillips et al., 2004), to estimate the species distribution on a climatic niche perspective, using VPD, SRad, MAT, DRF, DRI, and DRL for model calibration. Then, we conducted the Inverse-distance weighted model approach (IDW) to predict every species distribution by a presence-absence interpolation model. Both models were evaluated by the area under the receiver operating characteristic (AUC) after cross-validation using the method of k-means (k=5), in which 10000 random background points were generated (Barbet-Massin et al., 2012). Each MaxEnt and IDW models was produced by at least 50% of consensus between five different random cross-validation routines for the same approach. At last, we generated binary distribution maps for each species, in which individual model thresholds were estimated using the minimum omission rates for true positives and true negatives (i.e., best sensitivity and specificity). For every species, we used a 4 x 4 km spatial unit.

Unfortunately, the modeling techniques could not be performed for species with less than five observation points after rarefying occurrences. To get around this problem, we estimated the species distribution by applying the method of the Circular Area with a radius of 50 km (Ca_{50}), as proposed by Hijmans & Spooner (2001). The species distribution models were performed for 316 species, and 20 species had less than 5 valid occurrences, so only the Ca_{50} was used to assess their distribution maps.

Phylogeny describing the impact of climate change on DT plants

First, we generate a matrix of phylogenetic distance using the cophenetic distance between species to describe the phylogenetic relatedness between DT plants. For that, we considered the phylogenetic hypothesis provided by Jin and Qian (2019) as *Scenario 3*. Lower phylogenetic distance describes higher shared evolutionary history between a pair of species. Simultaneously, we evaluated the relative importance of VPD, SRad, MAT, DRF, DRI, and DRL for species distribution by randomly permuting one variable at a time in the MaxEnt model to calculate the decrease in the models' training AUC. The higher relative importance of a given environmental constraint describes a higher sensitivity of the species to changes in this factor. Then, we generated a matrix of dissimilarity using the Euclidean distance in relation to the relative importance of the six above-mentioned environmental constraints. Lower dissimilarity describes the higher ecological similarity between a pair of species regarding the importance of the given environmental constraint to their distribution. Then, we conducted linear models using phylogenetic distance and dissimilarity matrices to investigate the correlation between these two aspects. The phylogenetic distance and dissimilarity index were log-transformed before conducting the linear model and the Bonferroni correction method was applied to the linear models' *p*-values.

Biogeographical patterns describing the impact of climate change on DT plants

First, we calculated the geographical range for each species as the area within their distribution maps, generated by the species distribution models above-described. Lower geographical range denotes species geographically more restricted. Then, we estimate the species' tolerance to climate change by calculating the difference between the maximum and minimum values for VPD, SRad, MAT, DRF, DRI, and DRL in which the species is expected to occur. Higher values of tolerance to changes in a given environmental constraint depict a higher tolerance of species for the variability of this environmental constraint. For that, we used the species' distribution maps and the six above-mentioned environmental constraints individually. At last, we conducted linear models using the species' geographical range and species' tolerance to climate change, using the number of valid occurrences per species as covariate in order to control the effect of different sampling efforts in the correlation. Here, all values were also log-transformed and the Bonferroni correction method was also applied to the linear models' *p*-values.

Climatic variability in the global centers of diversity and endemism for DT plants

Four different approaches were used to determine the global centers of diversity and endemism for DT plants. While (i) species richness (SR) and (ii) phylogenetic diversity (PD) were used to identify centers of diversity, (iii) endemism richness (ER) and (iv) phylogenetic endemism (PE) were applied to highlight the centers of endemism. Firstly, to calculate the DT plants' species richness on a global scale, we overlapped the distribution maps of every DT plant and measured the cumulative species count in each spatial unit, as Förderer et al. (2018). Locations with higher species richness encountered a greater number of DT plants. Secondly, to assess the DT plants' phylogenetic diversity across the globe, we calculated the Rao index for α-diversity (Rao, 1982) of the phylogenetic trees constructed for the species that share their occurrence in the same spatial unit. Here, we used the phylogenetic hypothesis provided by Jin and Qian (2019) as *Scenario 3* to calculate the cophenetic distance matrix between co-occurring species. Areas with higher phylogenetic diversity have gathered DT plants with the most distinct evolutionary histories. Thirdly, we estimated the DT plants' endemism richness by giving each species the same value that is equally distributed across every grid cell in which the species occur, following Kier et al. (2009). Then, we summed the range fractions of every species that co-occur in the same spatial unit. Locations with higher endemism richness accumulated a higher number of species with restricted geographical ranges. Lastly, for the DT plants' phylogenetic endemism, it was considered the species' endemism, the species phylogenetic distance to the closely related taxa, and the range of the specie's closely related taxa (Rosauer et al., 2009). For that, similar calculations to endemism richness and phylogenetic diversity were employed. Regions with higher phylogenetic endemism gathered more DT plants in which they and their evolutive history are spatially restricted. Those approaches were chosen because they provide alternative biodiversity metrics from a taxonomic, phylogenetic, and biogeographic standpoint. Then, we correlated the diversity and endemism values in each spatial unit with the ΔVPD, ΔSRad, ΔMAT, ΔDRF, ΔDRI, and ΔDRL for the same grid cell. All geographic information system routines, descriptive, and statistical analyses, besides all graphical representations, were conducted in R software 4.2.0 (R Core Team, 2022).

RESULTS

Phylogeny describing the impact of climate change on DT plants

The DT plants can be phylogenetically very distinct. Opposing the many congeneric species, such as *Xerophyta retinervis* and *Xerophyta villosa* (0.97), ferns allies were phylogenetically very distant from ferns and angiosperms (801.57). The MAT was the environmental factor more important in explaining the distribution of 137 species (43%; Table S4.1). In contrast, DRI was more relevant to the distribution of only 4 species (1%). On average, MAT (33.2% ± 1.3), VPD (24.5% ± 1.3), and SRad (19.1% ± 1) were the variables with the highest relative importance for the species distribution, while DRI (6.2% ± 0.5), DRF (8.7% ± 0.7), and DRL (8% ± 0.6) were the factors less relevant to explain species distribution. The species dissimilarity ranged from 1 (between *Eragrostiella brachyphylla* and *Boea hygroscopica*) to 134 (between *Doryopteris kitchingii* and *Barbacenia gounelleana*). We found a significantly positive correlation between species' phylogenetic distance and dissimilarity regarding the importance of environmental constraints to their distribution (intercept = 3.77, slope = 0.0016, $R^2 = 0.0025$, p-value < 0.0001; Figure 4.1; Table S4.2).

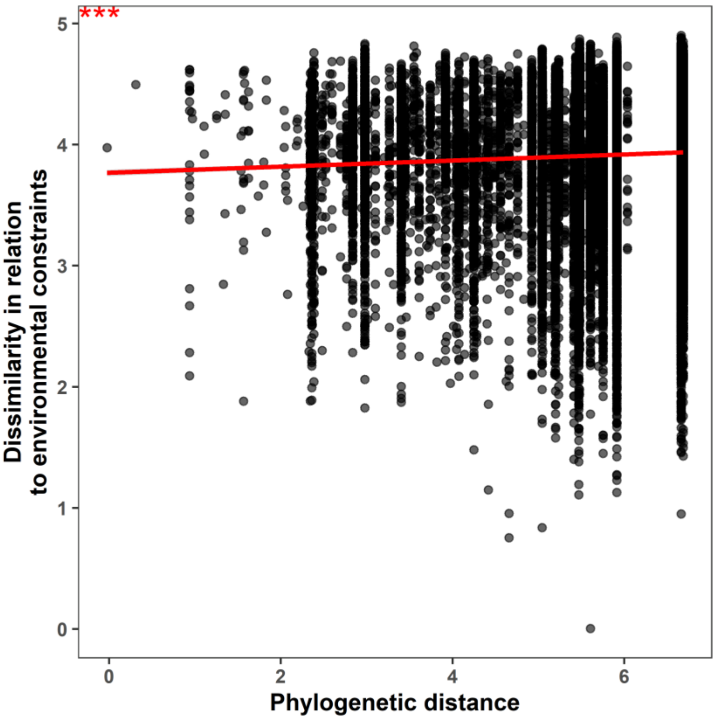

Figure 4.1. Correlation between desiccation-tolerant vascular plants' phylogenetic distance and dissimilarity regarding the importance of environmental constraints to their distribution. *** *p*-value < 0.0001.

Biogeographical patterns describing the impact of climate change on DT plants

The DT plants varied greatly in their geographic ranges (Appendix S1), with *Xerophyta splendens* (391 km²) contrasting with *Asplenium trichomanes* (7620502 km²). Similarly, the tolerance ranges to changes in the environmental variables were also divergent (Appendix S1). For the VPD, species varied from 0.07 kPa (*Barbacenia spectabilis*) to 3.31 kPa (*Selaginella bryopteris*), while the SRad varied from 112 kJ m^{-2} day^{-1} (*Allosorus pteridioides*) to 15184 kJ m^{-2} day^{-1} (*Asplenium septentrionale*) and MAT varied from 0.8 °C (*Barbacenia spectabilis*) to 41.5 °C (*Asplenium dalhousiae*). For the DRF, DRI, and DRL *Blossfeldia liliputana* and *Xerophyta splendens* showed no variation, while the species with the broader tolerance to these environmental constraints were *Adiantum hispidulum* (1.12 drought events per year), *Melpomene* *flabelliformis* (1.47 SPEI units), and *Tripogonella spicata* (1.22 months), respectively. We found significantly positive correlations between species' geographical range and tolerance to climate change, regarding all environmental variables (VPD: intercept = -3.06, slope = 0.25, $R^2 = 0.58$, p-value < 0.0001; SRad: intercept = 4.8, slope = 0.29, $R^2 = 0.68$, p-value < 0.0001; MAT: intercept = -0.23, slope = 0.23, $R^2 = 0.52$, p-value < 0.0001; DRF: intercept = -5.86, slope = 0.33, $R^2 = 0.44$, p-value < 0.0001; DRI: intercept = -5.71, slope = 0.36, $R^2 = 0.58$, p-value < 0.0001; DRL: intercept = -5.93, slope = 0.36, $R^2 = 0.66$, p-value < 0.0001; p-value < 0.0001; Figure 4.2; Table S4.2).

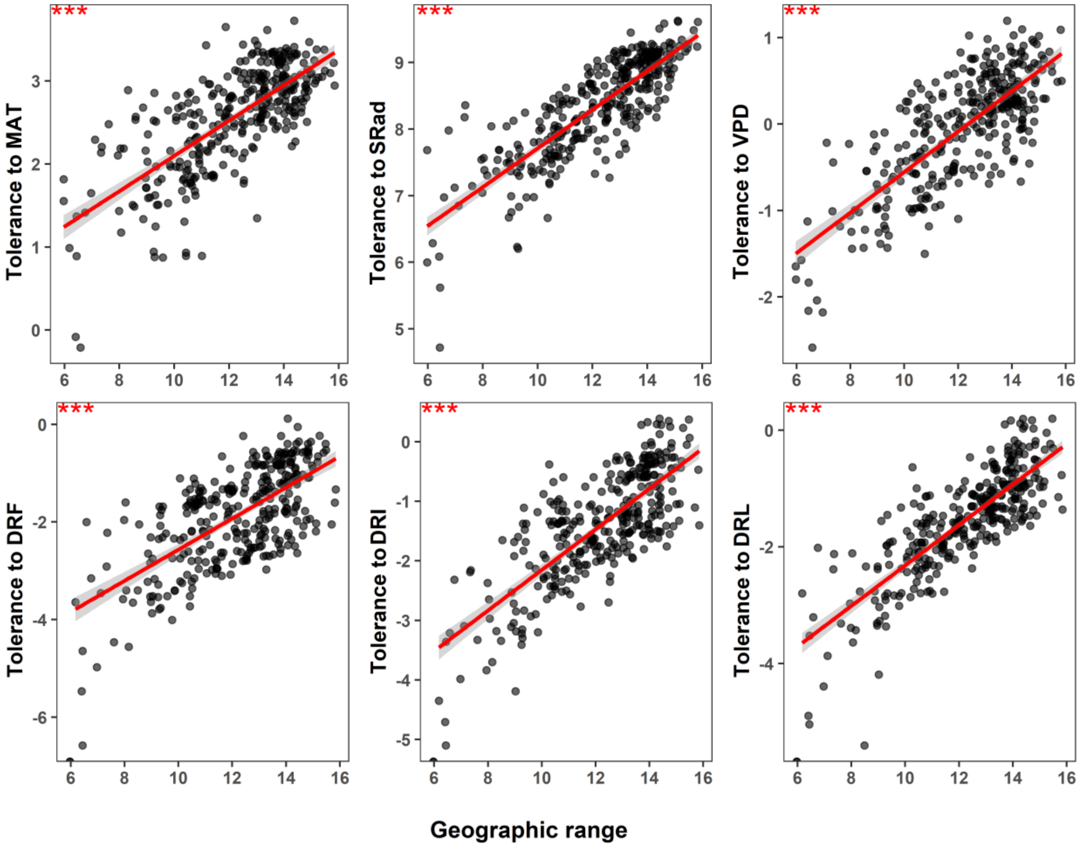

Figure 4.2. Correlation between desiccation-tolerant vascular plants' geographical range and tolerance to changes in the environmental constraints. VPD – vapor pressure deficit; SRad – solar radiation; MAT – mean annual temperature; DRF – drought frequency; DRI – drought intensity; DRL – drought length; *** p-value < 0.0001.

Climatic variability in the global centers of diversity and endemism for DT plants

With regards to centers of diversity for DT plants, we could point out areas in (1) the Central American Cordillera, (2) Brazilian Sugarloaf Land, (3) East African Rift-Eastern Highlands-Drakensberg, and (4) Malagasy Central High Plateau. In Mesoamerica, we found a high diversity in locations the Central American Cordillera, ranging from Guatemalan Sierras Madre and de los Cuchumatanes to the Costa Rican Cordilleras Central and de Talamanca. In South America, we found a high diversity in southeastern Brazil, more particularly in a region called Sugarloaf Land (de Paula et al. 2020). In eastern Africa, we highlight locations within the East African Rift-Eastern Highlands-Drakensberg. More precisely in the Albertine Rift from Rwanda to Burundi and in the Gregory Rift from Kenya to Malawi. In Africa, we also encountered a high diversity in the Zimbabwe-Mozambique's Eastern Highlands and the Limpopo-Mpumalanga section of the Great Escarpment in South Africa. At last, a high diversity of DT plants was also recorded in the Malagasy Central High Plateau (Figure 4.3; Figure S4.2; Figure S4.3).

As centers of endemism for DT plants we outline locations in the (i) Mexican-Central American Cordilleras, (ii) Caribbean Islands, (iii) Bolivia's Cordillera Oriental-Quebrada de Humahuaca, (iv) Brazilian Sugarloaf Land, (v) Provence-Ionian-Belasica Range, (vi) Ogo and Bale Mountains, (vii) East African Rift-Eastern Highlands-Drakensberg, (viii) Khomas Hochland, (ix) Madagascar-Mascarene Islands, (x) Center-southern Arabian Mountains, (xi) Western Ghats, (xii) Yunnan province, (xiii) Northern Territory-Wet Tropics, and (xiv) Richmond Range. We include (i) locations in the Mexican Sierras Madre Occidental, Madre Oriental, Madre del Sur, and Mixteca, in Mexico, to the existing centers of diversity in Mesoamerica, which was extended to the Sierra Madre from Chiapas to Nicaragua. In Costa

Rica, the high-endemism areas differed from the centers of diversity, ranging from Cordilleras Central, Tilarán, and Guanacaste. The (ii) Caribbean islands of Cuba, Jamaica, and Hispaniola (i.e., Haiti and the Dominican Republic) could also be highlighted. Two new regions were identified in South America, (iii) the Tucumán-Bolivian province of Bolivia's Cordillera Oriental and the Jujuy province in Northwestern Argentina. They were added to the (iv) Sugarloaf Land to this continent, which has been mentioned above. In Europe, (v) the Provence region in Southeastern France, continental areas of the Ionian Region in Northeastern Greece, and the Belasica Range region in Greece-Bulgaria stood out as centers of endemism here. In Africa centers of endemism were, new areas were observed more to the North of the East African Rift, such as in (vi) the Somalian Ogo Mountains and Bale Mountains region in the Ethiopian Highlands. In southern Africa, southern and western areas of the Great Escarpment could be emphasized, such as in (vii) Lesotho's Drakensberg which was included in the East African Rift-Eastern Highlands-Drakensberg center and (viii) Namibian Khomas Hochland. In the non-continental parts of Africa (ix), relevant areas for the endemism of DT plants could be extended from the Central High Plateau to the Anozy region in Madagascar and in the two Mascarene Islands, Mauritius and Réunion. In Asia, we raise awareness of (x) the center-southern Arabian Mountains in the Dhofar Governorate of Oman and Mahra Governorate of Yemen. Also, we highlight (xi) the Nilgiri Hills in the Indian Western Ghats and (xii) the Yunnan province in China. At last, we bring attention to two regions of Australia (xiii), in the North of the Northern Territory and the Wet Tropics of Queensland, besides (xiv) the Northeast of the Richmond Range in New Zeeland as the centers of endemism for DT plants in Oceania (Figure 4.4; Figure S4.4; Figure S4.5).

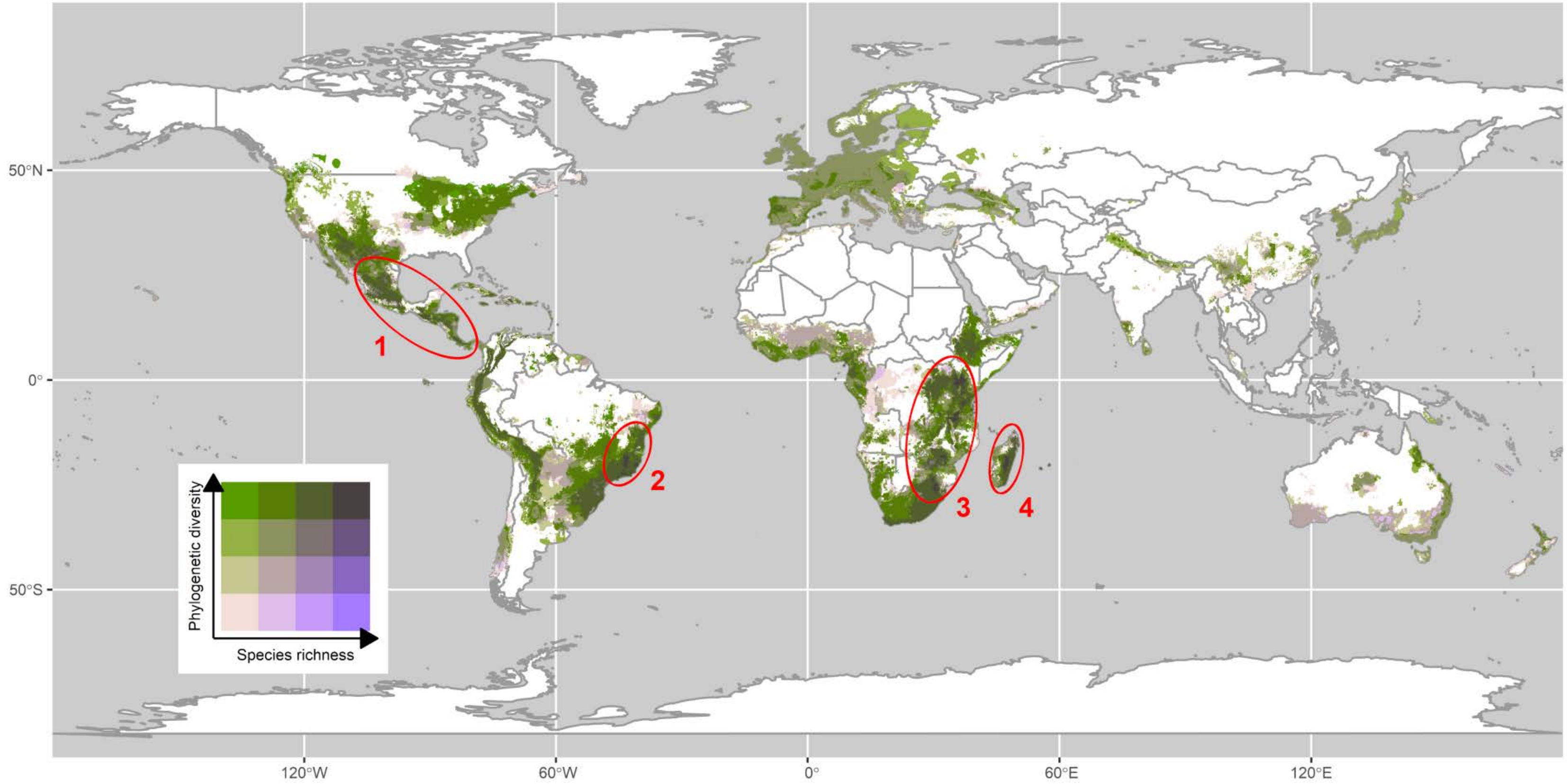

Figure 4.3. Centers of diversity for DT plants according to species richness and phylogenetic diversity. (1) the Central American Cordillera; (2) Brazilian Sugarloaf Land; (3) East African Rift-Eastern Highlands-Drakensberg; (4) Malagasy Central High Plateau.

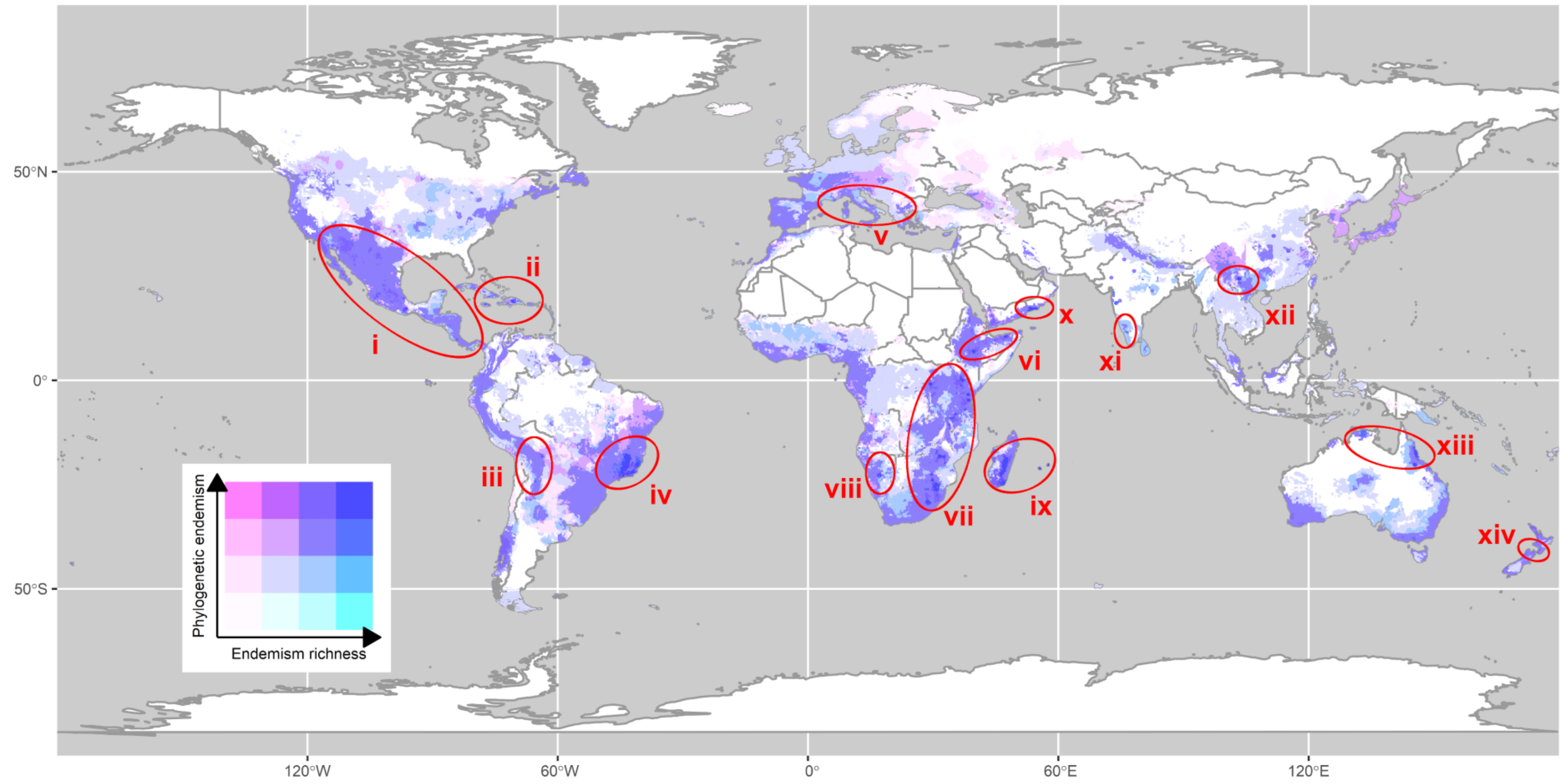

Figure 4.4. Centers of endemism for DT plants according to endemism richness and phylogenetic endemism. (i) Mexican-Central American Cordilleras; (ii) Caribbean Islands; (iii) Bolivia's Cordillera Oriental-Quebrada de Humahuaca; (iv) Brazilian Sugarloaf Land; (v) Provence-Ionian-Belasica Range; (vi) Ogo and Bale Mountains; (vii) East African Rift-Eastern Highlands-Drakensberg; (viii) Khomas Hochland; (ix) Madagascar-Mascarene Islands; (x) Center-southern Arabian Mountains; (xi) Western Ghats; (xii) Yunnan province; (xiii) Northern Territory-Wet Tropics; (xiv) Richmond Range.

Trends in DT plants' diversity and endemism in relation to the historical climatic variability varied according to the metric of diversity or endemism and the environmental constraint in question (Figure 4.5). We could observe that areas more prone to climate change, especially in relation to the variables VPD, DRF, DRI, and DRL, are the ones in which species and endemism richness tend to decrease. However, we could not identify increases or decreases when phylogeny was taken into account when comparing diversity and endemism with locations' historical climatic variability.

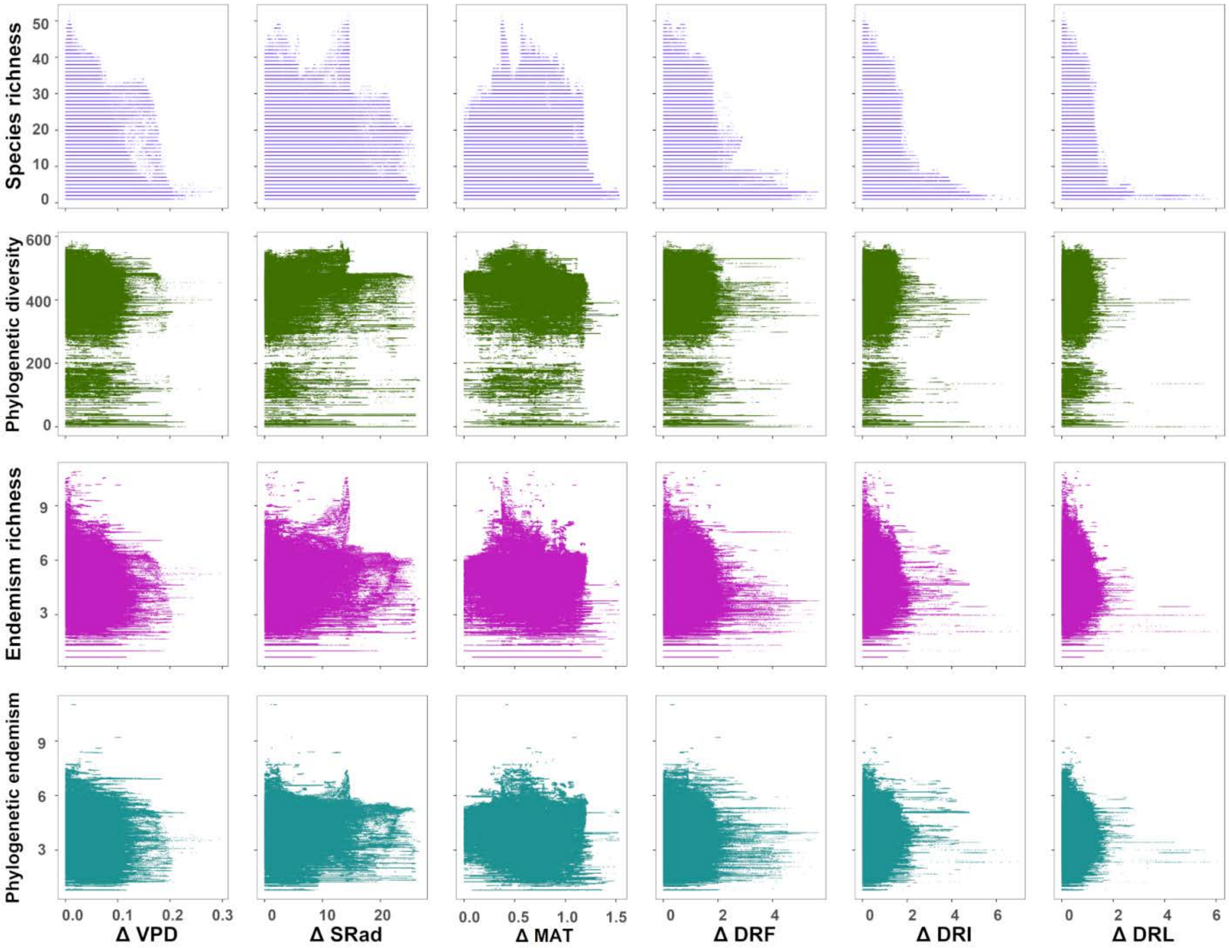

Figure 4.5. Trends in desiccation-tolerant vascular plants' (DT plants) diversity and endemism in relation to the historical climatic variability, under species richness, phylogenetic diversity, endemism richness, and phylogenetic endemism perspectives. VPD – vapor pressure deficit; SRad – solar radiation; MAT – mean annual temperature; DRF – drought frequency; DRI – drought intensity; DRL – drought length.

DISCUSSION

Desiccation-tolerant vascular plants with more need for conservation

We could confirm the hypotheses that DT plants phylogenetically more related have their distribution more similarly influenced by climatic conditions, However, the correlation between phylogeny and species' ecological similarities was very weak. We also could confirm that DT plants geographically more restricted have their distribution more affected by climate change. From this perspective, DT plants with a higher level of endemism should be prioritized for conservation.

Low similarities in ecology among phylogenetically related species have been discussed by former studies (Cavender-Bares et al., 2009; de Bello et al., 2015; Cadotte et al., 2017). The ecological divergence of closely related taxa can be either explained by a limiting similarity required for species in sympatry or distinct selective processes acting over species in allopatry (Abrams, 1983; Cavender-Bares et al., 2009; HilleRisLambers et al., 2012; Cadotte et al., 2017). In the opposite direction, the ecological convergence of species that share little evolutionary history might be promoted by strong environmental filters shaping advantageous plant responses to cope with common constraints (Weiher and Keddy, 1995; Kraft et al., 2015). Our data do not permit us to discuss the importance of those processes for DT plants' diversity. Still, we observed that some closely related species exhibited ecological dissimilarities, with both overlapping (e.g., *Micraira viscidula* and *M. subulifolia*) and disjunct (e.g., *Cheilanthes eckloniana* and *Cardiomanes reniforme*) distribution. Ecological dissimilarities among closely related species could also be depicted by the distinctive influence of climatic variables on *Barbacenia gounelleana* when compared to othere Velloziaceae species (Figure S4.1). Some less related taxa presented ecological similarities (e.g., *Pleurosorus rutifolius* and *Paraboea crassifolia*). It could suggest that different evolutionary processes might vary among DT plants and depends on the phylogenetic level, geographical scale, and ecological aspects in question. That means we might find species vulnerable to climate changes within the most diverse lineages, in which conservation actions should not rely on one-size-fits-all strategies.

However, the role of evolutionary processes in explaining the ecological similarities between species is not obvious. That is because the processes involved above-mentioned might also result in different outcomes (e.g., competition leading to species convergence or environmental filters driving the divergence of closely related species; Cavender-Bares et al., 2009; Kraft et al., 2015). Besides, the extent to which evolutionary processes can explain species' vulnerability to climate change is still unclear. Key evolutionary processes which determined the ecological patterns of DT plants can also explain the species' occurrence across habitats (Pearson and Dawson, 2003; Soberón & Peterson, 2005; Peterson, 2009; Vellend, 2010). However, the time scale in which climate change operates is different, and it might imply that different key ecological processes will shape species diversity and distribution (de Bello et al., 2015; Anderson, 2016; Van Dyke et al., 2022). Thus, although the relevance of phylogeny to describe the species’ vulnerability to climate change is promising (Mace et al., 2003; Purvis et al., 2005), we need studies to increase its prediction power. We advocate for studies that correlate relevant evolutionary processes with important ecological processes from a climate change angle, and that take into account the different scales (e.g., phylogenetic and geographic) in which they would differentially operate.

We also support studies that assess the three components of species vulnerability for DT plants (i.e., sensitivity, exposure, and adaptive capacity to climate change; Dawson et al., 2011). For instance, in relation to species sensitivity, our results showed an existing knowledge gap concerning how DT plants respond to environmental variables. It is expected that Hymenophyllaceae species can survive even when subjected to quick water shortages (Porembski 2021), while Velloziaceae species would only survive if the desiccation rate is slower (Oliver et al., 2000). However, we found contradictory results. The variation in VPD is more relevant to explain the distribution of Hymenophyllaceae species (57 % ± 4.1) than Velloziaceae species (12.9 % ± 2.2). Enhancing the complexity of the species-environment relationships among DT plants, we found that species differ within those lineages. The relative importance of VPD ranged between 21% (*Trichomanes bucinatum*) and 92% (*Cardiomanes reniforme*) for Hymenophyllaceae, and from values close to 0% (*B. riedeliana*, *Vellozia caput-ardeae*, *V. ciliata*, *Xerophyta eglandulosa*, *X. scabrida*) to 69% (*V. variegata*) in Velloziaceae. As a general trend, we found that DT plants that are geographically more restricted also exhibit a narrower niche breadth, what can be understood as a higher sensitivity to changes of small range species (Broennimann et al., 2006; Saupe et al., 2015; Carscadden et al., 2020).

The higher sensitivity to changes is not the only factor that could endanger small-range species under climate change scenarios. The smaller geographical range can also be related to limited dispersal capacity (Gaston, 1996; Slatyer et al., 2013; Carscadden et al., 2020). It means that tracking suitable conditions is more challenging for them, which is problematic if changes exceed their tolerance or capacity to mitigate the negative effects of changes remaining *in situ* (Dawson et al., 2011). It reinforces the need to improve our understanding of the magnitude of predicted shifts in the environmental variables where species occur and their adaptive capacity. It is noteworthy to say that it is true for all species, not only endemic ones. Still, we suggest the species' geographical range as a good starting point to target species with a higher need for conservation attention.

Global conservation priority areas for DT plants

The centers of diversity for DT plants do not completely coincide with global regions where the highest diversity of vascular plants, in general, is encountered (Barthlott et al. 2005; Cai et al., 2022). For example, while areas between Costa Rica and Ecuador showed higher diversity of vascular plants (Barthlott et al. 2005; Cai et al., 2022), a higher diversity of DT plants was encountered ranging from Costa Rica to the southern locations in Mexico, bordering Guatemala. Still, areas with a great diversity of vascular plants also gathered a relevant diversity of DT plants or were included as their centers of endemism. For instance, the Albertine Rift, Mpumalanga-Pondoland, and Madagascar centers identified by Barthlott et al. (2005) and Cai et al. (2022) encompass locations in which high diversity of DT plants was also found. Those regions, alongside southeastern Brazil, have already been indicated by former studies as promising areas for DT plants diversity (Alpert 2000; Porembski and Barthlott 2000; Scott 2000; Porembski 2021). Barthlott et al. (2005) and Cai et al. (2022) also highlighted the vascular plant diversity in the Mesoamerica, Caribbean, Mediterranean, Indochina-China, Western Ghats, and northeastern Australia centers, whose locations overlap with centers of endemism for DT plants.

Curiously, widely recognized areas by their high species diversity (e.g. Borneo and Papua New Guinea, Barthlott et al. 2005; Kier et al. 2005; Kreft et al. 2008) showed very little diversity of DT plants. Among the studies compiled by our literature search, no study was conducted in those regions. Some centers of DT endemism are located in regions either or both less species-rich and with data deficiency (Kier et al. 2005; Meyer et al. 2015). For DT plants, the geographic bias in scientific surveys has also been recently emphasized in other studies (Porembski 2011; Porembski 2021; Tebele et al. 2021). Moreover, some locations within the priority conservation areas that we identified are not included in global centers of diversity (Barthlott et al. 2005; Kier et al. 2005; Cai et al., 2022), for example the Somalian Ogo Mountains and Ethiopian Highlands. The same happens for centers of endemism for vascular plants (Kier et al. 2009; Harrisson and Noss 2017), which do not include the Namibian Khomas Hochland and North of Australian Northern Territory, and for the hotspots for biodiversity conservation (Myers et al. 2000; Mittermeier et al. 2011), that do not include the Zimbabwe-Mozambique's Eastern Highlands.

We could not entirely confirm the hypothesis that locations with higher diversity and endemism of DT plants are less prone to climatic variability. This hypothesis was true when species richness was accounted for. That might indicate that the magnitude of changes might not be high where most species occur. However, it also could tell us that the evolutionary processes that drove the diversity of DT plants are related to long-term climatic evenness. Either due to lower extinction or higher diversification rates, species have been accumulated in regions with low climatic variability (Pianka 1966; Stenseth 1984; Willig et al. 2003; Fine 2015; Harrison and Noss 2017). Species that evolved from low historical climatic variability are expected to be less tolerant to environmental changes when compared to species from regions in which historical climatic variability was higher (Willig et al. 2003; Fine 2015). It means that despite being less exposed to climate change, species found in the centers of diversity and endemism for DT plants might be more sensitive to changes and exhibit a lower adaptive capacity to changes.

The magnitude of changes might be a factor more critical in some of the locations with the highest diversity and endemism of DT plants from a phylogenetic standpoint. Changes will not be homogeneous throughout the globe (Dawson et al. 2011; Trenberth et al. 2014; Mukherjee et al. 2018), and we can find high phylogenetic diversity and endemism of DT plants in the most varied climates. For instance, considering the Köppen-Geiger climate classification (Kottek et al. 2006), centers of diversity and endemism for DT plants are found in Equatorial (e.g. in southeastern Brazil), Arid (e.g. Mexican Sierra Madre Occidental), and Warm Temperate climates (e.g. Limpopo-Mpumalanga section of the Great Escarpment). Moreover, regions that concentrate species with the most distinct evolutionary histories are not necessarily the ones with the most species numbers. In this sense, we should not neglect important regions in which unique responses and ecosystem functions might be found and were left out from our main findings. For example, southwestern Australia assembles Boryaceae species, a monocot family in which the desiccation tolerance has evolved. In this family, it is possible to observe DT monocots with secondary growth or a facultative desiccation tolerance (Porembski and Barthlott 2000; Gaff and Oliver 2013). Besides, functional redundancy is expected to decrease in less species-rich locations, and the lower functional redundancy might reduce the ecological stability of plant communities (Biggs et al. 2020). For example, the local extinction of one species might represent the loss of its function if not properly compensated by functionally redundant species (Suding et al. 2008). We highlight that diversity-area approaches tend to fail to recognize other important aspects of plant communities (e.g. functional redundancy) and consequently overlook the relevance of biodiversity “coldspots” for conservation (Kareiva and Marvier 2003; Allan et al. 2022). That reinforces the need to include such locations in future surveys and conservation debates. We thus advocate for studies that improve our understanding of key evolutionary processes that can explain the different components of species' vulnerability to climate change from a global perspective. Such studies must not neglect less fashionable geographical areas and phylogenetic groups and embrace the many nuances within the diversity of DT plants.

CONCLUSIONS AND PERSPECTIVES

(re)Hydrated *Selaginella sellowii*. Picture by L. Bondi

CHAPTER 5

CONCLUSIONS AND FUTURE DIRECTIONS

In this thesis, we could test some paradigms and deepen our understanding of the ecology and conservation of desiccation-tolerant vascular plants (DT plants). However, the generalities pointed out in this thesis claim for further investigations that could challenge the existing assumptions by evaluating ecological aspects of DT plants in the field and bring more precise assessments from narrower phylogenetic and geographic scales.

Here, we found that DT plants are not only selected by drought as an environmental constraint. For example, to some species, drought could act as a disturbance factor, leading individuals to biomass loss caused by irreversible damages (i.e., disturbance; sensu Grime, 1977) or being perceived by species as a secondary selective agent (e.g., competition for resources could act as a stronger selective factor where some species occur). Consequently, they differ in relation to the water deficit conditions they occur and in their ecological strategies to deal with water deficit. Therefore, we could affirm that DT plants form a heterogeneous group of plants in how they deal with drought, despite their desiccation tolerance ability. It highlights a need for studies that could encompass the complex diversity of species' response to the environment among DT plants. For that, we advocate for future studies that take into account the alternative functional designs that could promote the diversity of ecological strategies and preclude their convergence to the same resources and conditions. Moreover, rather than solely water deficit, we suggest that the desiccation tolerance could bring advantages to coping with the quick and pronounced water availability variation. In this sense, we need studies that assess the moisture fluctuation in the locations where DT plants occur and, under such conditions, measure fitness and fitness differences among individuals and species. For example, Teodoro et al. (2021)

evaluated the species' response to water variability by combining field assessments and greenhouse experiments. We believe that studies like this would promote the needed scientific progress concerning desiccation tolerance.

We also found that DT plants are neither related, restricted, nor have their higher diversity linked to arid and highly seasonal precipitation conditions. Instead, our results suggest the relevance of rainfall to DT plants' distribution and diversity. We found a negative correlation of DT plants with water deficit and the low diversity of DT plants in arid and highly seasonal conditions. Our results indicate that the evolutionary role of drought for DT species must be carefully reframed. We believe that the short alternation of wet and dry periods might better explain the distribution and diversity of DT plants. It corroborates with the fact that most DT plants occur in rock outcrops or canopies, in which the substrate with low water storage capacity causes water deficit periods to set in quicker (Porembski and Barthlott, 2000). Among species, the DT plants' correlation with drought remains unclear. We first need a better characterization of drought. Slette et al. (2019) showed how ecologists ignore the importance of drought characterization, which is even more critical when we consider that there is a lack of agreement on the definition of what this process is and what it means for living organisms. Moreover, although at different levels, fluctuations in water availability occur in every terrestrial ecosystem on earth, and the species' responses to such variability determine the observed biodiversity patterns. It means that the existence of a water deficit in a habitat and its selective power can not necessarily be described by species' responses to it (Slette et al., 2019). For instance, is not uncommon to find DT plants and succulent species coexisting in the same inselberg vegetation island. Still, the judgment only based on these species' responses might lead us to contrasting conclusions about drought conditions because they perceive water deficit in different ways.

Then, it is also important to consider the "post-drought period", termed by Vilonen et al. (2022) to ecosystem responses but which can be applied at the species' individuals level. Here drought events can potentially alter the species' responses to the next drought events. As an example of a positive legacy of a drought event to some DT plants, plants 'record' a stress memory that improves their response to future environmental stresses (Galviz et al., 2022), and it has already been proposed to M. flabellifolius (Bentley and Farrant, 2020). Significant advances in the understanding of DT plants' correlation with drought if those topics begin to be considered when describing the drought conditions they are found and long-term responses to drought.

The strategy regarding the photosynthetic apparatus maintenance cannot solely explain differences between DT plants concerning their relationship with drought. We need more studies that identify both mechanisms in DT plants and deepen our knowledge concerning the diversity of species' response within them. For example, Marks et al. (2021) listed 210 DT plants, in which the mechanism concerning chlorophyll maintenance during desiccation is still unknown for 44 species (21%). However, the study carried out by Marks et al. (2021) took into account many species in which desiccation-tolerance or taxonomic nomenclature was not used in our study (e.g., Cyperus spp.). When the species list used in the present study is considered, the number of DT plants in which the desiccation tolerance mechanism is unknown increases to 191 species (56%). Among homoiochlorophytes, some species are annuals (e.g., *Oropetium aristatum*), while others are perennials (e.g., *Styppeiochloa hitchcockii*). However, what are the mechanisms behind such responses that reflect ecological differences among species? Are lithophytes and epiphytes ecologically different from each other? Which species are lithophytes, and which ones are epiphytes? Future studies could help to elucidate such questions.

We showed that climate change could affect the diversity and distribution of DT plants. This is special when the worst future scenario was considered. Species from wetter locations and ecologically more restricted will be more vulnerable. However, DT plants from most humid locations are neither more sensitive nor will become more exposed to changes. It means that we need studies that evaluate the three components of species vulnerability: species sensitivity to changes, exposure to changes, and adaptive capacity to mitigate the negative effects of climate change. Although we could identify a general pattern of species vulnerability, a more holistic approach is still necessary to improve the current predictions of the impact of climate change on these species.

Our results also depicted the low predictive power of species' phylogenetic relatedness to explain the differential influence of climate changes on DT plants. Here, the multiplicity of evolutionary processes that might be involved in the DT plants' diversity could hinder the role of phylogeny in the understanding of species vulnerability to climate change. In this sense, the importance of evolutionary processes might vary among DT plants depending on the phylogenetic level, geographical scale, and ecological aspects in question. It reinforces the need for conservation actions that do not rely on one-size-fits-all strategies. On the other hand, our results suggest that we should have an attentive look at DT plants with small geographical ranges when evaluating which species might be more vulnerable to climate change.

When we consider the species number and the diversity of evolutionary histories, our results suggest that conservation efforts should mainly target regions in Mesoamerica, southeastern South America, eastern Africa, and Madagascar. When we also consider species' biogeographic aspects and the rarity of phylogenetic lineages across space, we extended our conservation concerns to locations beyond the tropics and encompass all continents. Those areas can be considered less prone to climate change when taxonomy is taken into account, giving hints of the importance of low climatic variability to the population maintenance of many DT plants. This pattern is not necessarily true when phylogeny is considered. It suggests that climate change can significantly impact locations in which the most distinct responses and functions to the ecosystem are found. Thus, we plead for conservation planning in locations in which the highest diversity and endemism of DT plants are encountered.

It is noteworthy to say that the number of known DT plants and the relative importance of some regions is likely to increase with more studies on overlooked phylogenetic groups and locations. Tebele et al. (2021) reported the strong bias of studies on particular DT plants and from specific world regions. We strongly support new studies on poorly investigated taxa and areas under the desiccation tolerance perspective. For example, Porembski (2021) cited the occurrence of desiccation tolerance response in the genus *Streptocarpus* (Gesneriaceae), although we could not find any study identifying species from this genus as a DT plant. The establishment of common criteria can also contribute to improving our knowledge on the diversity of DT plants. For instance, only considering vegetative organs, the desiccation tolerance ability is expected to vary among species (Marks et al., 2021). In some species, the desiccation tolerance ability is restricted to basal portions of leaves (e.g., *Cyperus alatus*, *C. bellus*, *Eragrostis invalida*, *Fimbristylis dichotoma*, *Kyllinga nervosa*, *Poa bulbosa*, *Sporobolus blakei*; Gaff 1977; Gaff & Latz, 1978; Gaff and Bole, 1986; Gaff, 1987), while in others it is exclusive to immature leaves (e.g., *Carex pachystylis*, *C. physodes*, *Conandron ramondioides*, *Cyperus capensis*, *Eragrostis hispida*, *Oreocharis primuloides*, *Sporobolus nervosus*; Gaff 1977; Blomstedt et al., 2018; Marks et al., 2021). Similarly, Montenegro et al. (1979) detected the desiccation tolerance capacity on *Clinopodium chilense* (Lamiaceae), although this response is particular to brachyblast leaves. Is it due to the differential exposure of leaves influencing factors such as their desiccation rate? It is still unclear the ecological implications for the variety of responses among DT plants and their individual leaves.

In some cases, different authors point out contrasting species' responses to desiccation (e.g., *Dicranopteris linearis*, *Hemionitis acrostica*, *Reaumuria songarica*; Russel et al., 1998; Liu et al., 2007; Anthelme et al., 2011; Liu et al., 2014; Kavitha & Murugan, 2016; Mkhize, 2018; Shah et al., 2019). In a first step, a better consensus among studies on the desiccation tolerance thresholds and the use of standardized methodologies might not only help to elucidate these problems, as also favor comparisons between species. For instance, López-Pozo et al. (2020) developed a field-portable semi-quantitative method to identify the desiccation tolerance response among species. The use of this technique can be very useful to enhance our current knowledge in neglected regions (e.g., Tropical Asia or Papua New Guinea). However, this method failed to identify widely known DT plants as such (e.g., *Barbacenia purpurea*), evidencing the need for a better comprehension of the desiccation tolerance response. In a second step, we advocate for studies that use multiple measurements of the species' response to desiccation in order to deepen our knowledge of the diversity of mechanisms found among species to achieve desiccation tolerance (i.e., alternative functional designs).

Climate change is not the only threat to DT plants' diversity promoted by anthropic activities. Marks et al. (2021) estimate that 90% of all DT plants occur on rock outcrops, where biodiversity is threatened by alarming rates of quarrying, water harvesting, tourism, and urbanization (Porembski et al., 2016). In these ecosystems, the biological invasion has also been pointed out as a threat to rock outcrops' biodiversity (Porembski, 2000; de Paula et al., 2015). Fire could also be included as a threat to rock outcrops' biodiversity conservation (Aximoff et al., 2016). We were not able to find studies that evaluated the relevance of such threats for DT plants, hampering appropriated conservation strategies for them. We support studies that assess the impact of anthropic activities, either individualized or combined, for DT plants. We believe that such studies are crucial to enhance our understanding of the ecological aspects of DT plants and improve our conservation efforts for these species.

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Not alone *Doryopteris*, *Trilepis*, and *Barbacenia*. Picture by Luiz Bondi

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APPENDIX I

ADDITIONAL TABLES AND FIGURES SUPPORTING THE INFORMATION PRESENTED IN THE THESIS' CHAPTERS

Barbacenias bouquet. Picture by L. Bondi

APPENDIX I

CHAPTER 2 – SELECTIVE FACTORS THAT INFLUENCE THE DIVERSITY AND DISTRIBUTION OF DESICCATION-TOLERANT VASCULAR PLANTS

Table S2.1. Desiccation-tolerant vascular plants and phylogenetically related desiccation-sensitive plants, with their respective functional trait values. RD – response to desiccation; GF – Growth form; G – Graminoid; H – Herb; LA – leaf area (mm^2); SLA – specific leaf area (mm^2mg^{-1}); LDMC – leaf dry matter content (gg^{-1}); SM – seed mass (mg); H – Plant height (mm).

Species	RD	GF	LA	SLA	LDMC	SM	H
A. latifolium[1,3]	DT	H	12157.6	20.5	0.35	-	-
A. obliquum[1,3]	DS	H	11749.2	14.3	0.36	-	-
A. pedatum[1,3]	DS	H	50.0	70.4	0.31	-	-
A. pilosa[1]	DT	G	1174.1	12.0	0.37	0.20	-
A. caryophyllea[1,3]	DS	G	14.2	21.1	0.27	0.14	-
A. ferruginea[1]	DT	H	2931.4	20.1	0.30	-	-
A. ceterach[1,3]	DT	H	496.0	17.8	0.29	-	-
A. scolopendrium[1,3]	DS	H	15385.0	17.6	0.23	-	-
A. trichomanes[1,3]	DT	H	1042.0	19.4	0.34	-	-
A. viride[1,3]	DS	H	510.0	19.9	0.34	-	-
B. gounelleana[1]	DT	G	4601.7	27.0	0.37	-	-
B. purpurea[1,2]	DT	G	2522.4	12.1	0.31	0.29	462
B. tomentosa[1,2]	DT	G	878.0	18.8	0.31	0.29	255
B. occidentale[1,3]	DS	H	7022.8	26.5	0.28	-	-
B. lagoensis[1,2]	DS	G	87.3	9.2	0.33	0.09	189
C. arenaria[1,3]	DS	G	536.0	12.2	0.33	0.88	-
C. setifera[1]	DT	G	151.0	11.2	0.27	0.38	-
C. coriifolius[1,2]	DS	G	6667.0	11.0	0.24	0.18	338
C. glutiniferum[1,2]	DS	H	41965.0	18.9	0.21	0.01	754
D. ampla[1,3]	DS	H	7389.7	13.1	0.45	-	-
D. collina[1]	DT	H	2172.2	11.2	0.19	-	-
D. varians[1]	DT	H	2602.5	11.9	0.21	-	-
E. crus-galli[1,3]	DS	G	1544.2	31.5	0.24	1.54	-
E. gracile[1,2]	DS	H	3322.3	3.1	0.22	0.44	254
E. grandiflorum[1,3]	DS	H	1962.1	17.9	0.16	4.02	-
H. rhodopensis[1]	DT	H	2893.3	6.5	0.24	0.02	-
J. inflexus[1,3]	DS	G	1954.5	4.6	0.30	0.09	-
L. purpureum[1,3]	DS	H	537.5	39.9	0.14	0.80	-
L. lancea[1,3]	DS	H	15778.9	34.4	0.31	-	-
M. repens[1,2]	DS	G	726.1	23.1	0.24	0.22	442

Table S2.1. (continued)

M. kunthii[1]	DT	G	93.6	28.1	0.12	0.16	-
M. squamosus[1]	DT	H	16.0	18.8	0.05	-	-
O. aristatum[1]	DT	G	31.8	49.0	0.22	0.04	-
O. thomaeum[1]	DT	G	29.7	55.2	0.19	0.23	-
P. communis[1,3]	DS	G	4795.5	15.3	0.41	0.42	-
P. azouryi[1,2]	DS	H	4721.5	11.1	0.18	0.25	224
P. annua[1,3]	DS	G	138.3	39.5	0.23	0.26	-
P. odoratum[1,3]	DS	H	1667.5	24.7	0.18	85.93	-
P. interjectum[1,3]	DT	H	5436.7	16.3	0.30	-	-
P. vulgare[1,3]	DT	H	6246.0	12.4	0.35	-	-
P. montana[1,2]	DS	H	5976.4	14.3	0.09	0.01	124
P. vellozicola[1,2]	DS	H	3225.0	6.4	0.32	0.01	250
P. aquilinum[1,3]	DS	H	83.4	28.6	0.28	-	-
R. myconi[1]	DT	H	3053.1	8.7	0.19	-	-
S. brasiliensis[1,2]	DS	H	6526.3	25.5	0.12	0.02	625
S. festivus[1]	DT	G	376.1	12.8	0.30	0.08	-
S. hitchcockii[1]	DT	G	973.2	7.3	0.45	-	-
T. stricta[1,2]	DS	H	120.5	10.3	0.19	0.11	60
T. lhotzkiana[1,2]	DT	G	208.7	13.7	0.49	0.15	68
V. candida[1,2]	DT	H	792.6	9.2	0.37	0.23	965
V. plicata[1,2]	DT	H	1181.2	9.9	0.39	0.25	748
V. pulchra[1]	DT	H	2749.4	8.5	0.36	0.53	1494
X. dasylirioides[1]	DT	H	908.3	12.1	0.33	0.19	400
X. elegans[1]	DT	H	1430.3	14.8	0.23	-	-

[1]Personal observation; [2]de Paula et al. 2015; [3]Kattge et al. 2020.

Table S2.2. Outlying Mean Index analysis' (OMI) results with scores for climatic variables. PCA1 – first axis of the OMI's ordination; PCA2 – second axis of the OMI's ordination.

	PCA1	**PCA2**
Eigenvalues	2.4832	1.4901
Variance explained	49.66%	29.80%
Normed scores for climatic variables		
Thornthwaite's aridity index	0.443	-0.532
Climatic water deficit	0.495	-0.433
Drought frequency	-0.137	-0.500
Drought intensity	0.519	0.437
Drought length	0.519	0.297

Table S2.3. Outlying Mean Index analysis' (OMI) results with scores for species. RD – response to desiccation; PCA1 – mean position along the first axis of the OMI's ordination; PCA2 – mean position along the second axis of the OMI's ordination; MI – marginality index, NB – niche breadth along the environmental gradients.

Species	**RD**	**PCA1**	**PCA2**	***p*-value**	**MI**	**NB**
A. latifolium	DT	1.5844	0.8443	0.001	3.3144	4.1045
A. obliquum	DS	1.9576	1.0125	0.001	4.8878	4.8934
A. pedatum	DS	-1.1254	0.9929	0.001	2.3056	0.4950
A. pilosa	DT	0.4429	-1.1005	0.001	2.3650	1.8509
A. caryophyllea	DS	-0.0869	-0.8696	0.001	0.7726	0.8903
A. ferruginea	DT	1.1610	0.2460	0.001	1.6283	4.1722
A. ceterach	DT	0.2190	-1.1589	0.001	1.4149	1.8370
A. scolopendrium	DS	-0.3546	0.1286	0.001	0.1877	0.9361
A. trichomanes	DT	-0.6036	0.2840	0.001	0.4527	1.0736
A. viride	DS	-0.4476	0.4042	0.001	0.4142	0.8801
B. gounelleana	DT	-0.6499	0.8536	0.001	2.3437	0.1227
B. purpurea	DT	-0.5612	0.4977	0.012	0.9133	0.4145
B. tomentosa	DT	-0.5390	0.5745	0.059	1.1227	0.1981
B. occidentale	DS	1.2932	0.6983	0.001	2.1675	3.4100
B. lagoensis	DS	1.1067	0.9089	0.001	3.5440	3.0815
C. arenaria	DS	-0.4807	-0.2570	0.001	0.3551	0.7183
C. setifera	DT	0.4026	-0.0252	0.001	0.3710	1.7264
C. coriifolius	DS	-0.1048	0.4981	0.004	0.7378	0.9454
C. glutiniferum	DS	0.4513	1.0100	0.001	2.5449	2.5371
D. ampla	DS	-0.9276	0.8287	0.001	1.7707	1.0486
D. collina	DT	0.7597	0.6648	0.001	1.0426	1.7505
D. varians	DT	-0.1872	0.7202	0.001	0.5958	0.9249
E. crus-galli	DS	0.2144	-0.8682	0.001	0.8029	3.1670
E. gracile	DS	1.8611	1.0088	0.001	7.4791	2.8207
E. grandiflorum	DS	0.1148	-0.9735	0.001	1.1680	0.9871
H. rhodopensis	DT	0.5464	-0.6316	0.155	1.1138	0.2024
J. inflexus	DS	0.0784	-0.9408	0.001	0.9031	1.5612
L. purpureum	DS	-0.2371	-0.5980	0.001	0.4410	0.6465
L. lancea	DS	1.6696	1.0927	0.001	3.9912	4.3521
M. repens	DS	1.3893	-1.7340	0.001	5.1602	3.8667
M. kunthii	DT	1.8267	-0.5960	0.001	4.2236	3.4827
M. squamosus	DT	-0.2592	-0.7685	0.01	1.6392	0.2889
O. aristatum	DT	2.9512	-5.4298	0.001	48.9644	2.5973
O. thomaeum	DT	1.7681	-3.3191	0.001	17.0000	6.8981

Table S2.3. (continued)

P. communis	DS	-0.4529	0.0703	0.001	0.2216	1.5976
P. azouryi	DS	-0.6659	0.0962	0.028	0.8980	0.0048
P. annua	DS	-0.2995	-0.3007	0.001	0.1835	0.4725
P. odoratum	DS	-0.4116	0.0709	0.001	0.1814	0.9246
P. interjectum	DT	-0.0166	-0.2568	0.001	0.0983	0.3105
P. vulgare	DT	-0.4095	-0.1579	0.001	0.2004	0.4047
P. montana	DS	-0.6658	1.0105	0.001	1.6334	0.5402
P. vellozicola	DS	1.3505	0.6714	0.001	3.5017	2.3613
P. aquilinum	DS	-0.2312	-0.5423	0.001	0.3543	0.8117
R. myconi	DT	0.0378	0.1927	0.023	0.4323	0.3982
S. brasiliensis	DS	1.1741	0.9085	0.001	3.4102	2.2347
S. festivus	DT	1.8243	-2.5070	0.001	11.5482	8.5180
S. hitchcockii	DT	-0.2833	0.3560	0.001	3.3470	0.6291
T. stricta	DS	0.1824	0.9560	0.001	0.9742	0.9812
T. lhotzkiana	DT	0.5155	0.7665	0.001	1.1240	2.1844
V. candida	DT	0.2445	0.8184	0.001	1.3384	2.0944
V. plicata	DT	1.2607	-0.8222	0.001	2.4754	3.5605
V. pulchra	DT	1.2820	0.7446	0.001	3.6134	1.4282
X. dasylirioides	DT	-0.2008	-0.1289	0.001	2.8613	1.7362
X. elegans	DT	0.0397	0.6020	0.002	1.9293	0.1599

Table S2.4. Desiccation-tolerant vascular plants and phylogenetically related desiccation-sensitive plants, with their respective scores for Ellenberg indicator values for moisture (EIV_M). The lower is the Ellenberg ordinal classes the higher is water deficit conditions. Thus, higher scores for lower EOCs reflect a higher affinity for low soil moisture levels. RD – response to desiccation; HS_{EIVM} – the EIV_M in which species exhibited the highest score.

Species	RD	Ellenberg ordinal classes									HS_{EIVM}
		1	2	3	4	5	6	7	8	9	
A. pilosa	DT	0.00	0.02	0.08	0.17	0.25	0.13	0.12	0.12	0.12	5
A. caryophyllea	DS	0.00	0.05	0.18	0.28	0.24	0.09	0.06	0.06	0.04	4
B. purpurea	DT	0.00	0.01	0.04	0.11	0.20	0.13	0.14	0.17	0.19	5
B. tomentosa	DT	0.00	0.02	0.07	0.16	0.24	0.13	0.12	0.13	0.13	5
B. lagoensis	DS	0.00	0.03	0.11	0.22	0.26	0.12	0.09	0.09	0.08	5
C. arenaria	DS	0.00	0.01	0.06	0.14	0.22	0.14	0.13	0.15	0.16	5
C. setifera	DT	0.00	0.02	0.07	0.17	0.24	0.13	0.12	0.12	0.12	5
C. coriifolius	DS	0.00	0.01	0.05	0.12	0.21	0.14	0.13	0.16	0.18	5
C. glutiniferum	DS	0.00	0.01	0.05	0.13	0.22	0.14	0.13	0.15	0.17	5
E. crus-galli	DS	0.00	0.01	0.06	0.15	0.23	0.14	0.13	0.14	0.14	5
E. gracile	DS	0.02	0.27	0.41	0.19	0.07	0.02	0.01	0.01	0.01	3
E. grandiflorum	DS	0.00	0.05	0.20	0.29	0.23	0.08	0.06	0.05	0.04	4
H. rhodopensis	DT	0.01	0.09	0.28	0.30	0.18	0.05	0.04	0.03	0.02	4
J. inflexus	DS	0.00	0.01	0.05	0.12	0.21	0.14	0.13	0.16	0.18	5
L. purpureum	DS	0.00	0.02	0.09	0.19	0.25	0.13	0.11	0.11	0.10	5
M. repens	DS	0.00	0.02	0.10	0.20	0.26	0.13	0.10	0.10	0.09	5
M. kunthii	DT	0.00	0.03	0.11	0.22	0.26	0.12	0.09	0.09	0.08	5
O. aristatum	DT	0.01	0.09	0.27	0.30	0.19	0.06	0.04	0.03	0.02	4
O. thomaeum	DT	0.00	0.06	0.20	0.29	0.23	0.08	0.06	0.05	0.04	4
P. communis	DS	0.00	0.01	0.06	0.15	0.23	0.14	0.13	0.14	0.14	5
P. azouryi	DS	0.00	0.06	0.21	0.29	0.23	0.08	0.05	0.05	0.04	4
P. annua	DS	0.00	0.04	0.15	0.26	0.25	0.10	0.07	0.07	0.06	4
P. odoratum	DS	0.00	0.06	0.21	0.29	0.22	0.08	0.05	0.04	0.04	4
P. montana	DS	0.00	0.02	0.09	0.20	0.25	0.13	0.10	0.11	0.10	5
P. vellozicola	DS	0.00	0.08	0.26	0.30	0.19	0.06	0.04	0.03	0.03	4
S. brasiliensis	DS	0.00	0.01	0.05	0.13	0.22	0.14	0.13	0.15	0.17	5
S. festivus	DT	0.00	0.03	0.11	0.22	0.26	0.12	0.09	0.09	0.08	5
T. stricta	DS	0.01	0.11	0.32	0.29	0.16	0.04	0.03	0.02	0.02	3
T. lhotzkiana	DT	0.00	0.03	0.12	0.24	0.26	0.11	0.09	0.08	0.07	5
V. candida	DT	0.01	0.11	0.30	0.30	0.17	0.05	0.03	0.02	0.02	3
V. plicata	DT	0.01	0.11	0.31	0.29	0.16	0.05	0.03	0.02	0.02	3
V. pulchra	DT	0.01	0.11	0.31	0.30	0.16	0.05	0.03	0.02	0.02	3
X. dasylirioides	DT	0.00	0.08	0.25	0.30	0.20	0.06	0.04	0.04	0.03	4

Table S2.5. Ecological strategies of desiccation-tolerant and desiccation-sensitive species according to the Grime's CSR scheme (C-selection – competitiveness, R-selection – ruderalism, and S-selection – stress-tolerance). RD – response to desiccation.

Species	RD	C-selection (%)	S-selection (%)	R-selection (%)	Strategy class
A. latifolium	DT	50.5	33.7	15.8	CS/CSR
A. obliquum	DS	53.6	37.6	8.8	CS
A. pedatum	DS	1.4	39.9	58.7	SR
A. pilosa	DT	26.1	65.8	8.2	S/CS
A. caryophyllea	DS	0	57.1	42.9	SR
A. ferruginea	DT	36.2	40.3	23.5	CS/CSR
A. ceterach	DT	18.2	53.8	28	S/CSR
A. scolopendrium	DS	67.2	18.1	14.8	C/CS
A. trichomanes	DT	22.1	53.3	24.6	S/CSR
A. viride	DS	15.3	57.3	27.4	S/CSR
B. gounelleana	DT	34.2	41.3	24.4	CS/CSR
B. purpurea	DT	39.7	51.8	8.5	CS
B. tomentosa	DT	21.8	52.4	25.8	S/CSR
B. lagoensis	DS	6.5	93.5	0	S
B. occidentale	DS	46	28.2	25.7	C/CSR
C. arenaria	DS	19.5	69.8	10.7	S/CS
C. setifera	DT	12.4	76.9	10.7	S/CS
C. coriifolius	DS	66.1	29.3	4.6	C/CS
C. glutiniferum	DS	79.7	8.6	11.7	C
D. ampla	DS	42.9	50.2	7	CS
D. collina	DT	66.5	23.8	9.7	C/CS
D. varians	DT	60.7	27.5	11.8	C/CSR
E. crus-galli	DS	28.2	29.4	42.4	CSR
E. gracile	DS	24.3	75.7	0	S/CS
E. grandiflorum	DS	59.3	0	40.7	CR
H. rhodopensis	DT	59	41	0	CS
J. inflexus	DS	41.1	58.9	0	CS
L. purpureum	DS	22.8	0	77.2	R/CR
L. lancea	DS	51.4	25	23.6	C/CSR
M. repens	DS	23.3	36.4	40.3	SR/CSR
M. kunthii	DT	9.1	0	90.9	R
M. squamosus	DT	0	88.5	11.5	S
O. aristatum	DT	0.7	27.3	72	R/SR
O. thomaeum	DT	0.5	13.3	86.2	R
P. communis	DS	38.1	50	11.9	CS/CSR

Table S2.5. (continued)

P. azouryi	DS	80.9	11.7	7.3	C
P. annua	DS	6.8	32	61.2	R/SR
P. odoratum	DS	41.7	10.6	47.8	CR
P. interjectum	DT	47.2	37.1	15.7	CS/CSR
P. vulgare	DT	47.9	45.2	6.9	CS
P. montana	DS	25	69.1	5.9	S/CS
P. vellozicola	DS	46	54	0	CS
P. aquilinum	DS	4.2	47.9	47.9	SR
R. myconi	DT	78.9	21.1	0	C/CS
S. brasiliensis	DS	64.1	0	35.9	C/CR
S. festivus	DT	17.7	67.6	14.7	S/CS
S. hitchcockii	DT	21.7	78.3	0	S/CS
T. stricta	DS	29	59.2	11.8	S/CSR
T. lhotzkiana	DT	7.5	80.6	11.9	S
V. candida	DT	23.6	76.4	0	S/CS
V. plicata	DT	26.7	72.9	0.4	S/CS
V. pulchra	DT	39.7	60.3	0	CS
X. dasylirioides	DT	25.5	64.8	9.7	S/CS
X. elegans	DT	40.3	37	22.7	CS/CSR

Table S2.6. Analysis of Covariance (ANCOVA) summary table for determining significant differences between pairwise correlations between *desiccation-tolerant vs. desiccation-tolerant plants* and *desiccation-tolerant vs. desiccation-sensitive plants* in relation to metrics for ecological convergence, when controlling for pairwise correlations within a given phylogenetic group or between different phylogenetic groups. OV (PCA1) – overlapping value of the species' distribution along the first outlying mean index analysis (OMI)'s PCA axis; OV (PCA2) – overlapping value of the species' distribution along the second OMI's PCA axis; OV (EIV) – overlapping value of the species' habitat affinities curves along the Ellenberg indicator values for moisture. Bonferroni correction method was applied to the ANCOVAs' p-values.

	F	**adj *p*-value**
Ecological convergence		
OV (PCA1)	14.9631	0.0003**
OV (PCA2)	5.5153	0.057
OV (EIV)	0.5014	1

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05*

Table S2.7. Analysis of Covariance (ANCOVA) summary table for determining significant differences between desiccation-tolerant and desiccation-sensitive plants in relation to metrics for ecological specialization and correlation with water deficit, when controlling for their phylogenetic groups. PK (PCA1) – Pearson's measure of Kurtosis for the species' distribution density along the first outlying mean index analysis (OMI)'s PCA axis; PK (PCA2) – Pearson's measure of Kurtosis for the species' distribution density along the second OMI's PCA axis; MI – OMI's marginality index; NB – OMI's niche breadth value; PK (EIV) – Pearson's measure of Kurtosis for the species' habitat affinities curves along the Ellenberg indicator values (EIVs) for moisture; NP (PCA1) – species' mean position along the first OMI's PCA axis; NP (PCA2) – species' mean position along the second OMI's PCA axis. Bonferroni correction method was applied to the ANCOVAs' *p*-values.

	F	**adj *p*-value**
Ecological specialization		
PK (PCA1)	0.1516	1
PK (PCA2)	0.9352	1
MI	1.4029	1
NB	0.0093	1
PK (EIV)	0.0513	1
Correlation with water deficit		
NP (PCA1)	1.4899	0.456
NP (PCA2)	2.705	0.2126

Table S2.8. Analysis of Covariance (ANCOVA) summary table for determining significant differences between desiccation-tolerant and desiccation-sensitive plants in relation to their ecological strategies, when controlling for their phylogenetic groups. The CSR scheme (C-selection – competitiveness; S-selection – stress-tolerance; R-selection – ruderalism) and the LHS (L – leaf; H – height; S – seed) scheme were used. Bonferroni correction method was applied to the ANCOVAs' *p*-values.

	F	**adj *p*-value**
CSR scheme		
C-selection	0.3771	1
S-selection	2.31	0.4044
R-selection	1.3553	0.7497
LHS scheme		
L	0.9837	0.9783
H	0.018	1
S	0.156	1

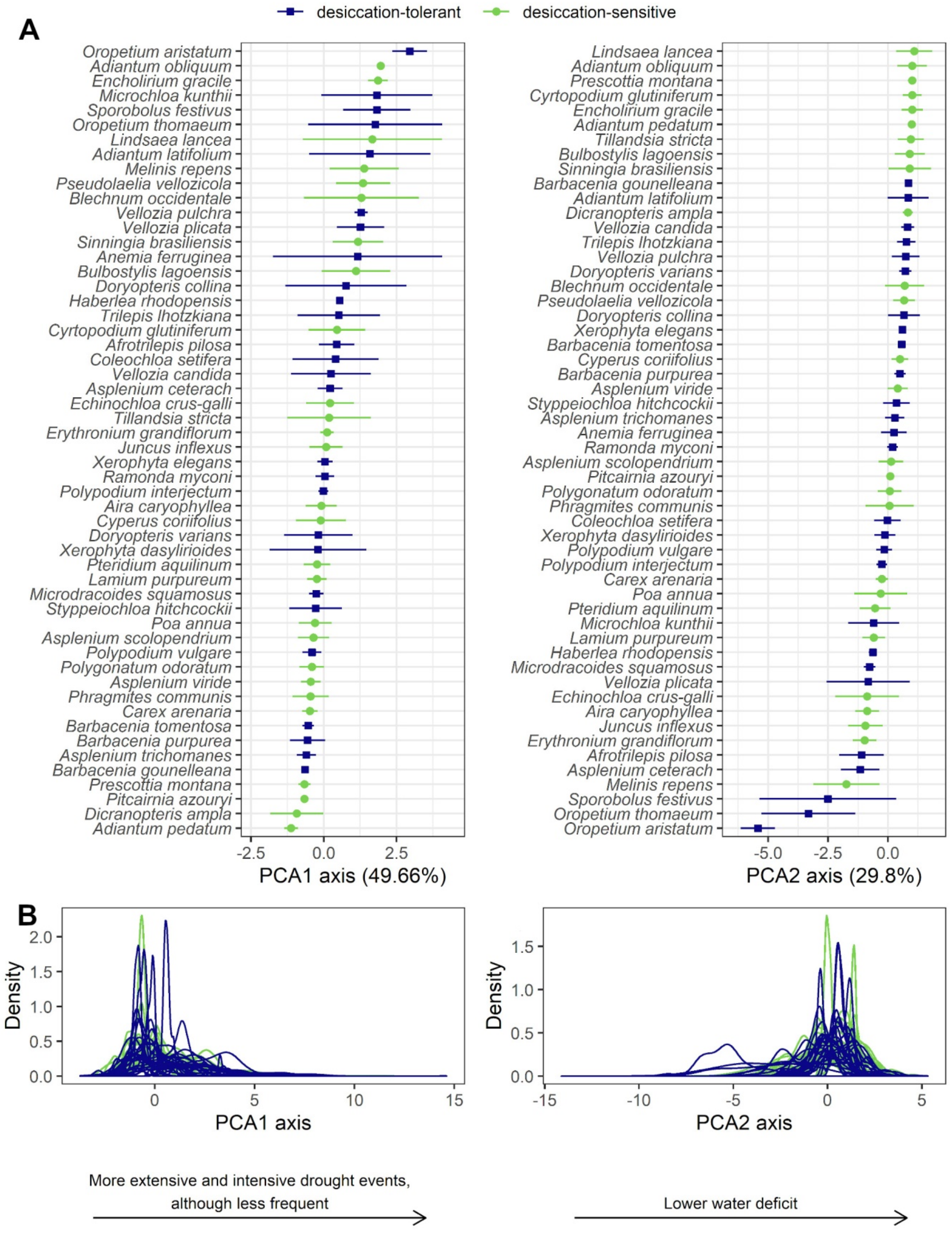


Figure S2.1. Desiccation-tolerant and desiccation-sensitive vascular plants distribution across the two first PCA axes of the Outlying Mean Index analysis. A – species mean position and individuals' occurrence breadth along each axis; B – Kernel density plots of species distributions along each axis.

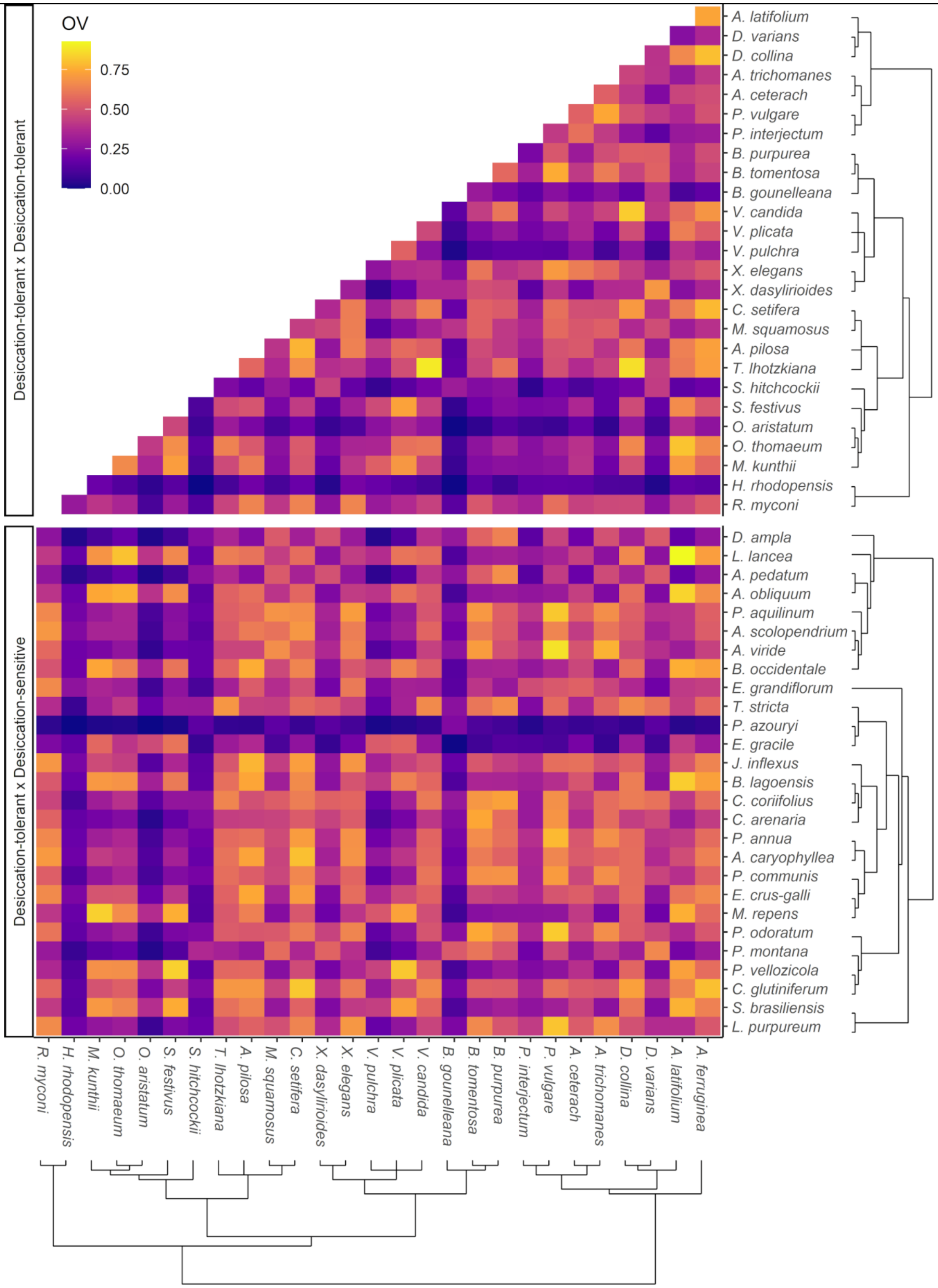


Figure S2.2. Species' convergence to similar ecological conditions in relation to the Outlying Mean Index analysis' ordination axis 1. OV – overlapping index.

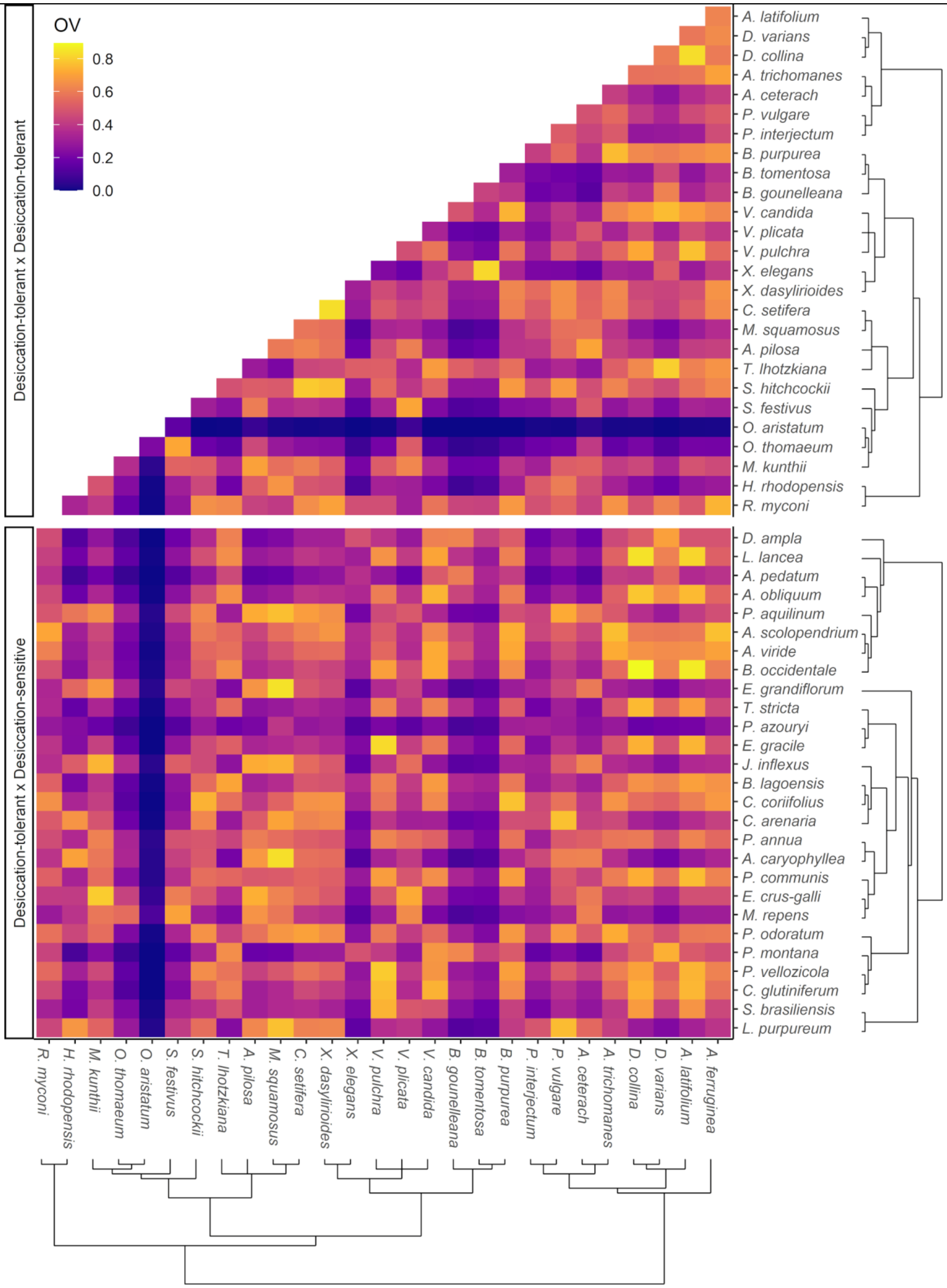


Figure S2.3. Species' convergence to similar ecological conditions in relation to the Outlying Mean Index analysis' ordination axis 2. OV – overlapping index.

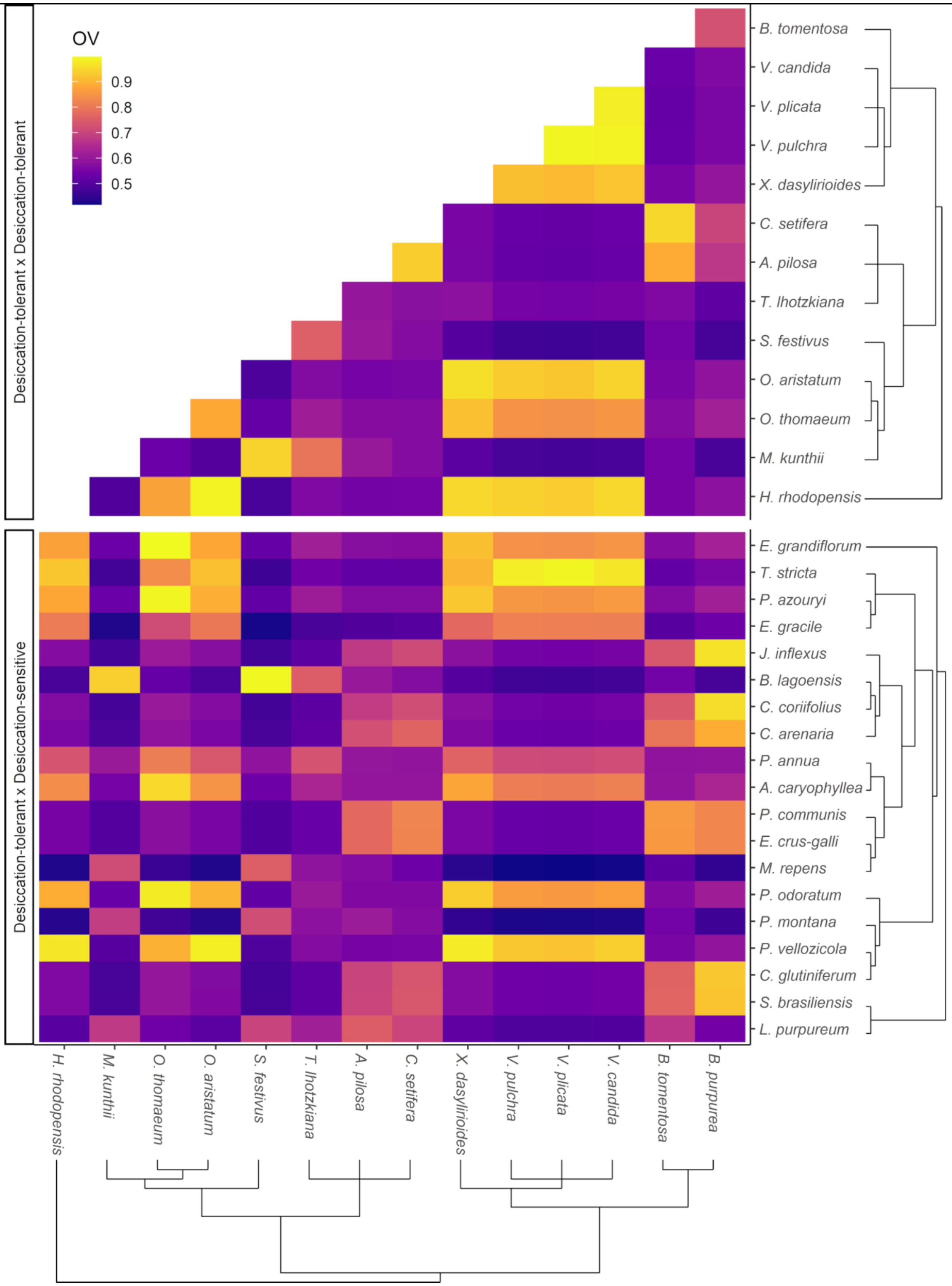


Figure S2.4. Species' convergence to similar ecological conditions in relation to the Ellenberg indicator values for moisture. OV – overlapping index.

APPENDIX I

CHAPTER 3 – DESICCATION-TOLERANT VASCULAR PLANTS AND DROUGHT: SYMPATHY FOR THE DEVIL?

Table S3.1. Desiccation-tolerant vascular plants' (DT plants) distribution along the water deficit gradients using the mean values for their three main phylogenetic groups and botanical families. The water deficit affinity (WDA) and niche breadth along water deficit conditions (WDNB) were calculated using the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD). PCA1 – mean position along the first axes of the outlying mean index (OMI)'s ordination; PCA2 – mean position along the second axis of the OMI's ordination

	WDA		**WDNB**			
	AI	**CWD**	**AI**	**CWD**	**PCA1**	**PCA2**
DT plants	32 ± 1.1	341 ± 15	52 ± 1.5	817 ± 30	-	-
Pteridophytes	33 ± 1.5	339 ± 19	65 ± 1.6	1011 ± 36	-0.39 ± 0.4	-0.1 ± 0.1
Anemiaceae	24 ± 6.4	392 ± 44	72 ± 7.4	750 ± 40	-0.4 ± 0.4	-1.03 ± 0.2
Aspleniaceae	27 ± 3.1	232 ± 44	70 ± 4.9	582 ± 125	0.03 ± 0.2	-0.75 ± 0.2
Davalliaceae	5 ± 0	208 ± 15	32 ± 0	338 ± 34	1.76 ± 0	-0.34 ± 0
Dryopteridaceae	23 ± 3.2	265 ± 0	75 ± 9	1030 ± 0	-0.06 ± 0.3	-1.17 ± 0.2
Hymenophyllaceae	16 ± 1.4	394 ± 0	64 ± 4.7	360 ± 0	0.68 ± 0.1	-0.93 ± 0.1
Isoetaceae	68 ± 0	309 ± 46	45 ± 0	312 ± 72	-1.51 ± 0	1.35 ± 0
Polypodiaceae	19 ± 2.5	179 ± 27	67 ± 5	961 ± 115	-0.61 ± 0.2	-0.07 ± 0.2
Pteridaceae	42 ± 2.4	659 ± 60	65 ± 2.5	1080 ± 110	-0.72 ± 0.2	-0.03 ± 0.1
Schizaeaceae	1 ± 0	450 ± 83	26 ± 0	499 ± 121	-3.4 ± 0	1.4 ± 0
Selaginellaceae	46 ± 4.6	143 ± 22	60 ± 4.7	276 ± 64	-0.91 ± 0.4	0.2 ± 0.2
Tectariaceae	26 ± 0	197 ± 35	54 ± 0	1097 ± 151	0.07 ± 0	-0.43 ± 0
Woodsiaceae	24 ± 0	178 ± 0	68 ± 0	650 ± 0	0.6 ± 0	-0.57 ± 0
Monocots	30 ± 1.6	364 ± 28	36 ± 2.2	599 ± 50	0.45 ± -0.5	-0.15 ± 0.1
Boryaceae	49 ± 8.6	5 ± 0	31 ± 5.6	210 ± 0	-0.05 ± 0.5	1.3 ± 0.3
Bromeliaceae	14 ± 0	193 ± 0	48 ± 0	490 ± 0	1.01 ± 0	-0.42 ± 0
Cyperaceae	21 ± 3.9	238 ± 34	37 ± 6.1	969 ± 99	0.93 ± 0.3	0.27 ± 0.2
Poaceae	44 ± 2.3	422 ± 29	52 ± 4.5	1100 ± 58	-0.95 ± 0.2	-0.29 ± 0.2
Velloziaceae	22 ± 1.5	75 ± 0	27 ± 2.3	570 ± 0	1.35 ± 0.1	0.53 ± 0.1

Table S3.1. (continued)

Eudicots	31 ± 3	251 ± 30	35 ± 3.9	335 ± 49	0.89 ± -0.6	-0.19 ± 0.1
Cactaceae	53 ± 0	144 ± 12	49 ± 0	786 ± 69	-0.08 ± 0	-0.13 ± 0
Gesneriaceae	24 ± 3.8	554 ± 67	38 ± 5.5	1098 ± 121	1.31 ± 0.2	0.26 ± 0.2
Linderniaceae	34 ± 4.6	615 ± 0	27 ± 5.3	930 ± 0	0.85 ± 0.3	0.97 ± 0.2
Myrothamnaceae	42 ± 6.5	276 ± 85	62 ± 13	1017 ± 116	-0.46 ± 0.5	0.14 ± 0.1

Table S3.2. Significant differences between the three main phylogenetic groups of desiccation-tolerant vascular plants' (i.e., pteridophytes, monocots, and eudicots) distribution along the water deficit gradients, according to Welch's analysis of variance (ANOVA) for non-balanced sample sizes. The water deficit affinity (WDA) and niche breadth along water deficit conditions (WDNB) were calculated using the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD). F-value – F statistic; num df – numerator degrees of freedom; denom df – denominator degrees of freedom; λ – optimal value to normalize the data according to Box-Cox transformation technique. Bonferroni correction method was applied to the Welch's ANOVA *p*-values always multiple comparisons were performed.

	F-value	**num df**	**denom df**	**adj *p*-value**
WDA_{AI} ($\lambda = 0.51$)	0.3663	2	69.9284	1.0000
WDA_{CWD} ($\lambda = 0.3$)	1.7268	2	70.5795	0.3706
$WDNB_{AI}$ ($\lambda = 0.67$)	60.7086	2	62.1461	< 0.0001
$WDNB_{CWD}$ ($\lambda = 0.42$)	47.8713	2	63.0569	< 0.0001

Table S3.3. Significance of differences between pairs of group means according to Tukey's honestly significant difference (HSD) test for whenever the Welch's analysis of variance for non-balanced sample sizes comparing the species distribution along the water deficit gradients between the three main phylogenetic groups of desiccation-tolerant vascular plants (i.e., pteridophytes, monocots, and eudicots) scored a p-value < 0.05. Significant differences were only found for species niche breadth along water deficit conditions (WDNB) using the drought indices Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD). diff – differences in the observed means between groups; lwr – lower end point of the 95% confidence interval of observed difference; upr – upper end point of the 95% confidence interval of observed difference; λ – optimal value to normalize the data according to Box-Cox transformation technique. Bonferroni correction method was applied to the Tukey's HSD *p*-values always multiple comparisons were performed.

	diff	**lwr**	**upr**	**adj *p*-value**
WDB_{AI} ($\lambda = 0.67$)				
pteridophytes - monocots	-4.59	-5.94	-3.23	< 0.0001
pteridophytes - eudicots	-7.47	-9.99	-4.95	< 0.0001
monocots - eudicots	-2.88	-5.48	-0.28	0.0260
WDNB_{CWD} ($\lambda = 0.42$)				
pteridophytes - monocots	-4.59	-5.94	-3.23	< 0.0001
pteridophytes - eudicots	-7.47	-9.99	-4.95	< 0.0001
monocots - eudicots	-2.88	-5.48	-0.28	0.0260

Table S3.4. Variance explained and variable scores for the two first axes of the principal component analysis (i.e., PCA1 and PCA2). The variables used were the species water deficit affinity (WDA) and niche breadth along water deficit conditions (WDNB), assessed by the two drought indices Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD).

	PCA1	PCA2
Summary		
Standard deviation	1.55	1.14
Proportion of Variance	0.6	0.33
Variables		
WDA_{AI}	-0.53	0.43
WDA_{CWD}	-0.53	0.45
$WDNB_{AI}$	-0.38	-0.67
$WDNB_{CWD}$	-0.54	-0.4

Table S3.5. The water deficit and precipitation seasonality conditions with highest species diversity of desiccation-tolerant vascular plants, assessed by Kernel's density functions using the Silverman's rule of thumb for bandwidth selection. The Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD) were used to estimate water deficit conditions, while the Walsh & Lawler's rainfall seasonality index (SI) and the coefficient of variation in precipitation seasonality (BIO15) were used to calculate the precipitation seasonality where desiccation-tolerant vascular plants are found.

	AI	**CWD**	**SI**	**BIO15**
DTPs	17.39	164.46	0.71	79.6
Pteridophytes	29.37	187.44	0.56	64.54
Anemiaceae	20.68	185.67	0.58	73.67
Aspleniaceae	23.46	161.13	0.46	48.73
Dryopteridaceae	27.86	180.77	0.64	78.01
Hymenophyllaceae	8.81	122.33	0.54	66.28
Polypodiaceae	14.2	147.95	0.53	60.08
Pteridaceae	41.19	351.54	0.57	68.11
Selaginellaceae	39.37	577.1	0.59	64.44
Monocots	16.91	169.32	0.73	85.03
Boryaceae	66.31	544	0.69	79.5
Cyperaceae	21.52	212.97	0.58	74.3
Poaceae	43.42	277.33	0.93	107.87
Velloziaceae	16.21	143.04	0.73	86.37
Eudicots	24.9	153.92	0.85	74.69
Myrothamnaceae	43.46	394.37	0.93	111.16
Gesneriaceae	24.07	95	0.66	71.18
Linderniaceae	25.57	192.31	0.67	73.38

Table S3.6. Desiccation-tolerant vascular plants' (DT plants) sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to climate changes, combining to two different future scenarios within the closer time-frame (i.e., 2021-2040): the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e., SSP5 – 8.5 W·m-2) shared socioeconomic pathways.

	SEN	2021-2040			
		SSP1		SSP5	
		EXP	VUL	EXP	VUL
DT plants	1.42 ± 0.02	0.68 ± 0.03	1.24 ± 0.01	0.81 ± 0.04	1.25 ± 0.01
Pteridophytes	1.45 ± 0.24	0.46 ± 0.24	1.23 ± 0.04	0.52 ± 0.23	1.24 ± 0.03
Anemiaceae	1.4 ± 0.06	0.41 ± 0.06	1.21 ± 0.06	0.49 ± 0.07	1.22 ± 0.06
Aspleniaceae	1.69 ± 0.03	0.41 ± 0.03	1.32 ± 0.04	0.46 ± 0.04	1.32 ± 0.04
Davalliaceae	1.18 ± 0	0.61 ± 0	1.15 ± 0	0.61 ± 0	1.14 ± 0
Dryopteridaceae	1.35 ± 0.05	0.36 ± 0.05	1.18 ± 0.07	0.42 ± 0.06	1.19 ± 0.07
Hymenophyllaceae	1.43 ± 0.02	0.39 ± 0.02	1.22 ± 0.02	0.45 ± 0.02	1.23 ± 0.02
Isoetaceae	1.02 ± 0	0.69 ± 0	1.06 ± 0	0.84 ± 0	1.07 ± 0
Polypodiaceae	1.45 ± 0.03	0.41 ± 0.03	1.23 ± 0.02	0.47 ± 0.04	1.24 ± 0.02
Pteridaceae	1.39 ± 0.05	0.51 ± 0.05	1.22 ± 0.01	0.57 ± 0.05	1.22 ± 0.01
Schizaeaceae	3.77 ± 0	0.24 ± 0	1.98 ± 0	0.26 ± 0	1.98 ± 0
Selaginellaceae	1.45 ± 0.03	0.46 ± 0.03	1.23 ± 0.03	0.5 ± 0.03	1.24 ± 0.03
Tectariaceae	1.34 ± 0	0.44 ± 0	1.2 ± 0	0.5 ± 0	1.2 ± 0
Woodsiaceae	1.75 ± 0	0.52 ± 0	1.38 ± 0	0.54 ± 0	1.38 ± 0
Monocots	1.35 ± 0.03	1 ± 0.03	1.24 ± 0.04	1.24 ± 0.04	1.26 ± 0.04
Boryaceae	1.07 ± 0.24	0.98 ± 0.24	1.1 ± 0.04	1.08 ± 0.23	1.11 ± 0.03
Bromeliaceae	1.63 ± 0	0.42 ± 0	1.33 ± 0	0.54 ± 0	1.35 ± 0
Cyperaceae	1.58 ± 0.08	0.8 ± 0.08	1.29 ± 0.12	1.06 ± 0.15	1.31 ± 0.12
Poaceae	1.36 ± 0.11	0.86 ± 0.11	1.22 ± 0.03	0.95 ± 0.13	1.22 ± 0.03
Velloziaceae	1.34 ± 0.07	1.12 ± 0.07	1.26 ± 0.02	1.47 ± 0.1	1.28 ± 0.02
Eudicots	1.56 ± 0.06	0.93 ± 0.06	1.31 ± 0.06	1 ± 0.07	1.31 ± 0.06
Cactaceae	1.56 ± 0	1.24 ± 0	1.36 ± 0	1.28 ± 0	1.37 ± 0
Gesneriaceae	1.48 ± 0.29	1.14 ± 0.29	1.3 ± 0.04	1.11 ± 0.25	1.29 ± 0.04
Linderniaceae	1.58 ± 0.1	0.79 ± 0.1	1.3 ± 0.08	0.95 ± 0.12	1.31 ± 0.08
Myrothamnaceae	1.85 ± 0.01	0.55 ± 0.01	1.4 ± 0.01	0.59 ± 0.02	1.41 ± 0.01

Table S3.7. Desiccation-tolerant vascular plants' (DT plants) sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to climate changes, combning to two different future scenarios within the more remote time-frame (i.e., 2081-2100): the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e., SSP5 – 8.5 W·m-2) shared socioeconomic pathways.

		2081-2100			
	SEN	**SSP1**		**SSP5**	
		EXP	**VUL**	**EXP**	**VUL**
DT plants	1.42 ± 0.02	0.86 ± 0.04	1.25 ± 0.01	2.67 ± 0.11	1.36 ± 0.01
Pteridophytes	1.45 ± 0.24	0.57 ± 0.24	1.24 ± 0.03	1.78 ± 0.76	1.33 ± 0.05
Anemiaceae	1.4 ± 0.06	0.53 ± 0.08	1.22 ± 0.06	1.69 ± 0.25	1.3 ± 0.07
Aspleniaceae	1.69 ± 0.03	0.51 ± 0.04	1.33 ± 0.04	1.56 ± 0.13	1.42 ± 0.04
Davalliaceae	1.18 ± 0	0.71 ± 0	1.16 ± 0	2.1 ± 0	1.26 ± 0
Dryopteridaceae	1.35 ± 0.05	0.45 ± 0.06	1.19 ± 0.07	1.48 ± 0.19	1.26 ± 0.08
Hymenophyllaceae	1.43 ± 0.02	0.48 ± 0.03	1.23 ± 0.02	1.59 ± 0.08	1.32 ± 0.03
Isoetaceae	1.02 ± 0	0.97 ± 0	1.08 ± 0	3.56 ± 0	1.19 ± 0
Polypodiaceae	1.45 ± 0.03	0.52 ± 0.04	1.24 ± 0.02	1.7 ± 0.16	1.34 ± 0.02
Pteridaceae	1.39 ± 0.05	0.64 ± 0.06	1.23 ± 0.01	1.93 ± 0.18	1.31 ± 0.01
Schizaeaceae	3.77 ± 0	0.31 ± 0	1.99 ± 0	0.71 ± 0	2.06 ± 0
Selaginellaceae	1.45 ± 0.03	0.56 ± 0.03	1.24 ± 0.03	1.69 ± 0.11	1.32 ± 0.03
Tectariaceae	1.34 ± 0	0.55 ± 0	1.21 ± 0	1.69 ± 0	1.29 ± 0
Woodsiaceae	1.75 ± 0	0.66 ± 0	1.39 ± 0	1.7 ± 0	1.48 ± 0
Monocots	1.35 ± 0.03	1.25 ± 0.04	1.26 ± 0.04	3.95 ± 0.13	1.4 ± 0.04
Boryaceae	1.07 ± 0.24	1.23 ± 0.24	1.11 ± 0.03	4.28 ± 0.76	1.25 ± 0.05
Bromeliaceae	1.63 ± 0	0.54 ± 0	1.35 ± 0	1.61 ± 0	1.46 ± 0
Cyperaceae	1.58 ± 0.08	1.01 ± 0.1	1.3 ± 0.12	3.23 ± 0.31	1.45 ± 0.14
Poaceae	1.36 ± 0.11	1.12 ± 0.15	1.24 ± 0.03	3.43 ± 0.45	1.35 ± 0.04
Velloziaceae	1.34 ± 0.07	1.37 ± 0.07	1.28 ± 0.02	4.36 ± 0.24	1.43 ± 0.02
Eudicots	1.56 ± 0.06	1.22 ± 0.08	1.33 ± 0.06	3.6 ± 0.25	1.47 ± 0.07
Cactaceae	1.56 ± 0	1.48 ± 0	1.37 ± 0	3.23 ± 0	1.51 ± 0
Gesneriaceae	1.48 ± 0.29	1.55 ± 0.34	1.33 ± 0.04	4.25 ± 1.01	1.47 ± 0.05
Linderniaceae	1.58 ± 0.1	1.01 ± 0.12	1.32 ± 0.08	3.31 ± 0.38	1.45 ± 0.09
Myrothamnaceae	1.85 ± 0.01	0.66 ± 0.02	1.41 ± 0.01	2.13 ± 0.03	1.53 ± 0.01

Table S3.8. Linear models evaluating the correlation between desiccation-tolerant vascular plants' water deficit affinity (WDA) and species' sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to climate changes. The WDA was calculated using the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD). To assessment of species' SEN, EXP, and VUL, four different future scenarios were considered from the combination between the closer (i.e., 2021-2040) and more remote (i.e., 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e., SSP5 – 8.5 W·m-2) shared socioeconomic pathways. All values were log-transformed before performing the linear models. Bonferroni correction method was applied to the linear models *p*-values always multiple comparisons were performed.

	WDA					
	AI			**CWD**		
	Slope	**R²**	**(adj) *p*-value**	**Slope**	**R²**	**(adj) *p*-value**
SEN	-0.13	< 0.01	0.5053	-0.30	0.01	0.1718
2021-2040 | SSP1 | EXP	0.04	< 0.01	0.6327	0.09	< 0.01	0.3217
2021-2040 | SSP5 | EXP	-0.05	< 0.01	0.4784	0.07	< 0.01	0.4747
2081-2100 | SSP1 | EXP	0.02	< 0.01	0.8104	0.07	< 0.01	0.4747
2081-2100 | SSP5 | EXP	0.00	< 0.01	0.9558	0.06	< 0.01	0.5013
2021-2040 | SSP1 | VUL	-0.41	< 0.01	0.3124	-0.74	0.01	0.1062
2021-2040 | SSP5 | VUL	-0.60	0.01	0.1394	-0.81	0.01	0.0765
2081-2100 | SSP1 | VUL	-0.47	< 0.01	0.2420	-0.81	0.01	0.0765
2081-2100 | SSP5 | VUL	-0.69	0.01	0.0777	-0.96	0.01	0.0284

Table S3.9. Linear models evaluating the correlation between desiccation-tolerant vascular plants' niche breadth along water deficit conditions (WDNB) and species' sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to climate changes. The WDNB was calculated using the Thornthwaite's aridity index (AI) and Cumulative water deficit (CWD). To assessment of species' SEN, EXP, and VUL, four different future scenarios were considered from the combination between the closer (i.e., 2021-2040) and more remote (i.e., 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e., SSP5 – 8.5 W·m-2) shared socioeconomic pathways. All values were log-transformed before performing the linear models. Bonferroni correction method was applied to the linear models *p*-values always multiple comparisons were performed.

	WDNB					
	AI			**CWD**		
	Slope	**R²**	**(adj) *p*-value**	**Slope**	**R²**	**(adj) *p*-value**
SEN	1.23	0.02	0.0042	1.19	0.02	0.0240
2021-2040 | SSP1 | EXP	-1.55	0.21	< 0.0001	-1.57	0.16	< 0.0001
2021-2040 | SSP5 | EXP	-1.45	0.20	< 0.0001	-1.66	0.17	< 0.0001
2081-2100 | SSP1 | EXP	-1.58	0.22	< 0.0001	-1.66	0.17	< 0.0001
2081-2100 | SSP5 | EXP	-1.52	0.21	< 0.0001	-1.63	0.17	< 0.0001
2021-2040 | SSP1 | VUL	0.23	< 0.01	0.8089	-0.01	< 0.01	0.9946
2021-2040 | SSP5 | VUL	-0.12	< 0.01	0.9006	-0.59	< 0.01	0.5883
2081-2100 | SSP1 | VUL	-0.27	< 0.01	0.7690	-0.59	< 0.01	0.5883
2081-2100 | SSP5 | VUL	-2.25	0.02	0.0113	-2.81	0.02	0.0074

Table S3.10. Significant differences between the three main phylogenetic groups of desiccation-tolerant vascular plants' (i.e., pteridophytes, monocots, and eudicots) in relation to their sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to climate changes. Differences are depicted by the Welch's analysis of variance (ANOVA) for non-balanced sample sizes, and considers four different future scenarios combining the closer (i.e., 2021-2040) and more remote (i.e., 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e., SSP5 – 8.5 W·m-2) shared socioeconomic pathways. F-value – F statistic; num df – numerator degrees of freedom; denom df – denominator degrees of freedom; λ – optimal value to normalize the data according to Box-Cox transformation technique. Bonferroni correction method was applied to the Welch's ANOVA *p*-values always multiple comparisons were performed.

	F-value	**num df**	**denom df**	**(adj) *p*-value**
SEN (λ = -1.27)	7.0403	2	60.8782	0.0018
2021-2040 | SSP1 | EXP (λ = -0.42)	81.3822	2	61.4083	< 0.0001
2021-2040 | SSP5 | EXP (λ = -0.46)	89.2667	2	61.8072	< 0.0001
2081-2100 | SSP1 | EXP (λ = -0.46)	89.1582	2	62.6367	< 0.0001
2081-2100 | SSP5 | EXP (λ = -0.38)	91.3397	2	62.1766	< 0.0001
2021-2040 | SSP1 | VUL (λ = -2)	2.0372	2	61.7023	0.5564
2021-2040 | SSP5 | VUL (λ = -2)	2.0083	2	61.8367	0.5716
2081-2100 | SSP1 | VUL (λ = -2)	2.82	2	61.8083	0.2692
2081-2100 | SSP5 | VUL (λ = -1.8)	8.5745	2	61.9187	0.0020

Table S3.11. Significance of differences between pairs of group means according to Tukey's honestly significant difference (HSD) test between the three main phylogenetic groups of desiccation-tolerant vascular plants (i.e., pteridophytes, monocots, and eudicots) whenever the Welch's analysis of variance scored a p-value < 0.05 comparing the species' sensitivity (SEN), exposure (EXP), and potential vulnerability (VUL) to climate changes. The assessment of species SEN, EXP, and VUL was conducted considering four different future scenarios combining the closer (i.e., 2021-2040) and more remote (i.e., 2081-2100) time-frames with the more optimistic (SSP1 – 2.6W·m-2) and more pessimistic (i.e., SSP5 – 8.5 W·m-2) shared socioeconomic pathways. diff – differences in the observed means between groups; lwr – lower end point of the 95% confidence interval of observed difference; upr – upper end point of the 95% confidence interval of observed difference; λ – optimal value to normalize the data according to Box-Cox transformation technique. Bonferroni correction method was applied to the Tukey's HSD *p*-values always multiple comparisons were performed.

	diff	**lwr**	**upr**	**adj *p*-value**
SEN (λ = -1.27)				
pteridophytes - monocots	-0.08	-0.14	-0.03	0.0006
pteridophytes - eudicots	0.03	-0.07	0.12	0.8132
monocots - eudicots	0.11	0.01	0.21	0.0290
2021-2040 | SSP1 | EXP (λ = -0.42)				
pteridophytes - monocots	0.37	0.30	0.44	< 0.0001
pteridophytes - eudicots	0.33	0.21	0.46	< 0.0001
monocots - eudicots	-0.04	-0.17	0.10	0.7985
2021-2040 | SSP5 | EXP (λ = -0.42)				
pteridophytes - monocots	0.42	0.35	0.49	< 0.0001
pteridophytes - eudicots	0.35	0.21	0.48	< 0.0001
monocots - eudicots	-0.07	-0.21	0.07	0.4462
2081-2100 | SSP1 | EXP (λ = -0.46)				
pteridophytes - monocots	0.37	0.30	0.44	< 0.0001
pteridophytes - eudicots	0.37	0.24	0.49	< 0.0001
monocots - eudicots	-0.01	-0.13	0.12	0.9944

Table S3.11. (continued)

2081-2100 | SSP5 | EXP (λ = -0.46)				
pteridophytes - monocots	0.20	0.17	0.24	< 0.0001
pteridophytes - eudicots	0.18	0.12	0.25	< 0.0001
monocots - eudicots	-0.02	-0.09	0.05	0.7432
2081-2100 | SSP5 | VUL (λ = -0.38)				
pteridophytes - monocots	0.04	0.01	0.07	0.0099
pteridophytes - eudicots	0.09	0.03	0.15	0.0016
monocots - eudicots	0.05	-0.01	0.11	0.1590

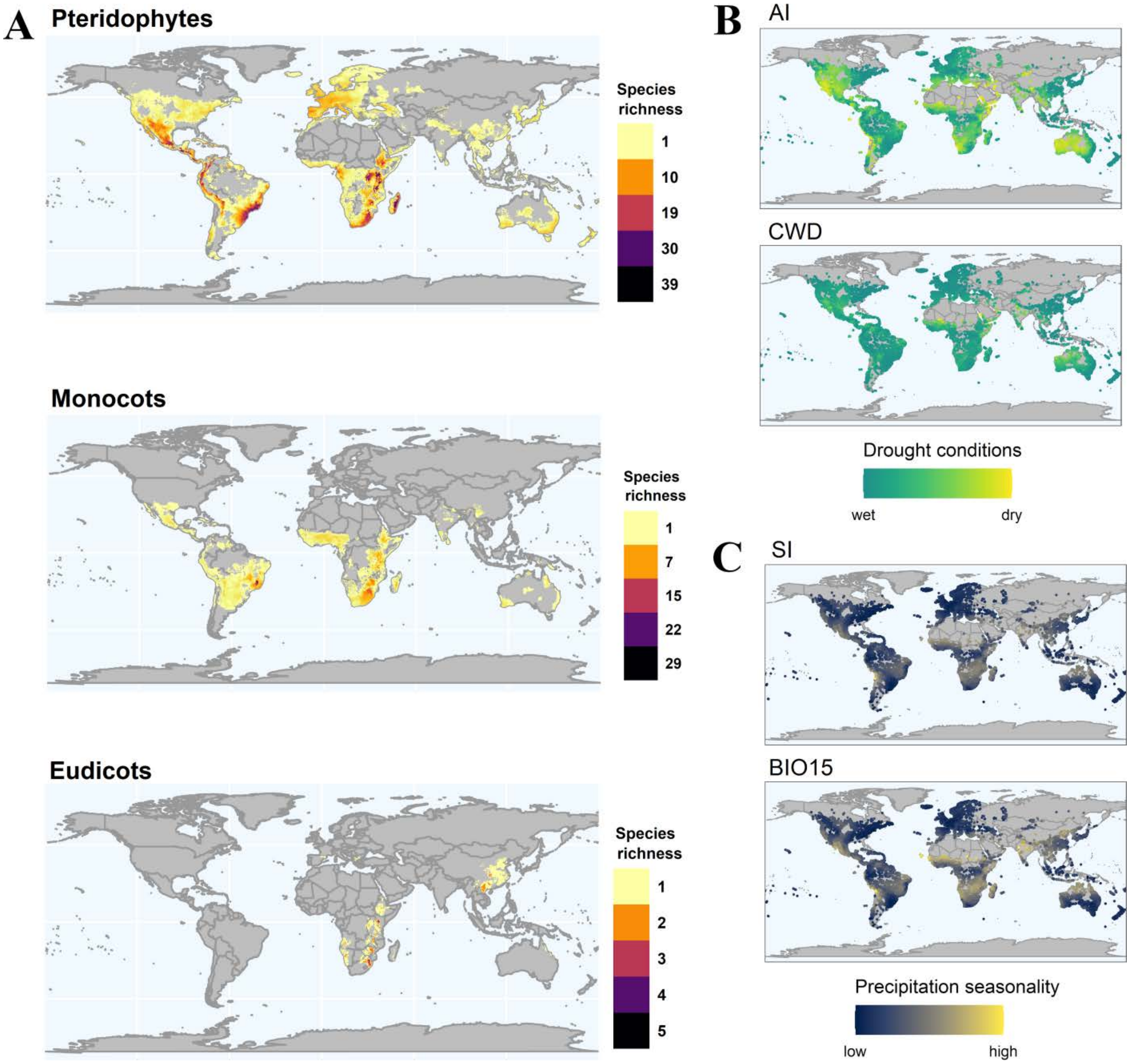


Figure S3.1. The global distribution of desiccation-tolerant vascular plants (DT plants) according to A – the three main phylogenetic groups' species richness; B – water deficit conditions in locations DT plants are found; C – precipitation seasonality in locations DT plants are found. AI – Thornthwaite's aridity index; CWD – Cumulative water deficit; SI – Walsh and Lawler's rainfall seasonality index; BIO15 – coefficient of variation in precipitation seasonality.

APPENDIX I

CHAPTER 4 – THE VULNERABILITY OF DESICCATION-TOLERANT VASCULAR PLANTS TO CLIMATE CHANGE

Table S4.1. The relative importance of environmental variables for the desiccation-tolerant vascular plants distribution. VPD – vapor pressure deficit; SRad – solar radiation; MAT – mean annual temperature; DRF – drought frequency; DRI – drought intensity; DRL – drought length.

Species	**VPD**	**SRAD**	**AMT**	**DRF**	**DRI**	**DRL**
A. aethiopicum	57.28	4.74	34.26	1.39	1.74	0.60
A. adiantum-nigrum	36.36	2.58	52.62	1.70	3.86	2.88
A. cordatum	0.41	13.86	80.58	0.84	0.78	3.52
A. dalhousiae	4.40	8.16	36.51	18.98	5.58	26.37
A. ferruginea	6.64	13.68	63.97	5.53	4.63	5.56
A. flexuosa	12.23	20.30	62.08	0.36	3.87	1.16
A. friesiorum	61.95	1.25	27.61	0.43	4.76	4.00
A. megalura	19.69	31.81	17.17	23.05	2.49	5.79
A. monanthes	47.84	11.17	30.63	2.52	1.96	5.87
A. obovatum	45.12	19.17	32.45	1.60	0.68	0.97
A. pringlei	2.03	21.48	2.93	49.10	3.85	0.61
A. praegracile	38.56	12.40	1.01	4.27	43.76	0.00
A. ruta-muraria	19.16	6.51	63.75	4.44	1.59	4.55
A. rutifolium	51.24	1.08	32.26	4.24	3.64	7.54
A. rotundifolia	53.29	7.79	29.49	2.54	0.14	6.75
A. sandersonii	69.06	3.98	11.74	0.29	8.52	6.42
A. septentrionale	13.57	9.19	50.05	14.58	0.86	11.75
A. tomentosa	8.34	4.00	76.74	3.87	0.57	6.49
A. trichomanes	23.48	6.74	55.79	1.80	1.14	11.05
A. theciferum	26.51	21.52	37.84	2.26	1.42	10.46
A. uhligii	1.68	16.27	60.50	18.69	1.11	1.75
A. villosa	29.04	6.02	34.20	2.03	12.98	15.72
A. mexicana	8.08	9.37	38.99	6.63	19.80	17.13
A. ceterach	64.40	7.58	18.33	3.43	2.74	3.52
M. caffrorum	6.43	2.50	78.08	0.13	0.20	12.66
P. rutifolius	4.05	7.40	83.53	1.19	1.64	2.19
B. constricta	2.80	3.85	58.63	1.95	28.53	4.23
B. mirabilis	36.85	0.10	1.23	10.87	47.14	3.81
B. nitida	31.93	25.69	0.49	0.00	0.00	41.89
B. septentrionalis	90.36	0.38	0.87	1.22	0.98	6.20

Table S4.1. (continued)

B. scirpoidea	36.14	3.52	0.45	0.46	2.04	57.39
B. sphaerocephala	5.57	36.76	8.64	2.29	10.06	36.68
P. lanuginosa	15.38	20.19	26.33	6.27	13.81	18.02
A. pilosa	6.29	23.54	32.82	0.35	7.13	29.88
B. liliputana	1.62	0.48	61.09	9.52	27.28	0.00
C. abyssinica	0.00	5.65	49.34	23.01	0.21	21.79
C. microcephala	0.00	62.19	7.01	9.51	0.35	20.94
C. pallidior	34.49	22.53	14.83	0.08	28.07	0.00
C. setifera	49.12	33.10	12.18	3.13	1.51	0.95
M. squamosus	6.16	25.72	5.42	42.65	20.06	0.00
T. ciliatifolia	31.27	26.06	15.41	11.80	12.80	2.66
T. lhotzkiana	32.51	5.38	50.22	1.04	4.32	6.54
T. microstachya	4.65	70.85	4.25	10.74	3.51	6.01
D. angustata	37.44	15.86	20.00	8.95	13.29	4.46
E. acrostichoides	67.82	2.26	22.48	0.68	2.21	4.55
E. petiolatum	15.32	14.14	62.67	1.10	2.54	4.22
E. piloselloides	8.15	5.12	81.75	1.23	2.78	0.96
B. hygroscopica	89.65	1.98	0.03	7.86	0.04	0.44
B. hygrometrica	12.30	15.78	31.55	0.22	27.01	13.15
D. clarkeana	28.62	51.60	3.65	0.12	0.00	16.01
H. rhodopensis	9.06	12.93	40.83	7.62	29.52	0.04
P. crassifolia	5.49	6.31	80.17	0.09	3.87	4.06
P. rufescens	8.84	28.81	51.04	9.54	1.05	0.73
R. myconi	3.70	65.55	12.36	0.59	11.42	6.38
R. nathaliae	0.00	62.17	7.56	5.27	0.00	25.00
R. serbica	0.00	51.29	3.41	0.00	3.19	2.12
C. frappieri	78.01	1.45	11.31	7.75	0.33	1.14
C. inopinatum	41.30	11.37	44.91	1.90	0.11	0.41
H. caudiculatum	44.23	22.92	31.99	0.44	0.09	0.33
H. cruentum	71.44	7.08	20.33	0.36	0.19	0.60
H. capillare	75.80	2.53	9.41	3.28	4.48	4.49
H. dentatum	89.66	1.76	5.40	1.03	0.13	2.02
H. fucoides	52.41	15.52	22.53	0.20	5.58	3.76
H. hirsutum	82.73	3.73	6.40	0.64	3.74	2.75
H. kuhnii	72.39	8.36	4.49	6.65	4.03	4.09
C. reniforme	92.21	2.47	1.31	1.14	2.86	0.01
H. peltatum	51.76	5.16	32.51	1.76	4.45	4.36
H. polyanthos	68.64	7.05	19.33	0.38	1.64	2.96
H. plicatum	74.90	13.83	8.64	0.62	2.00	0.01

Table S4.1. (continued)

H. sanguinolentum	29.98	11.35	35.82	11.06	4.56	7.22
H. splendidum	28.30	30.34	16.57	12.94	6.18	5.68
H. tunbrigense	58.46	2.29	35.35	0.27	0.26	3.36
P. borbonicum	74.33	4.67	16.77	1.23	1.18	1.83
T. bucinatum	20.76	34.59	17.31	14.84	12.50	0.00
C. chevalieri	33.88	1.23	28.17	32.14	4.38	0.20
T. capillaceum	26.68	17.55	44.38	0.44	1.39	9.56
T. diaphanum	63.99	10.46	21.22	2.62	0.85	0.85
D. erosum	82.02	7.71	2.40	0.22	0.13	7.51
C. melanotrichum	64.39	1.19	18.57	4.61	4.91	6.33
T. pyxidiferum	35.76	6.54	54.50	0.83	1.47	0.89
T. polypodioides	42.05	6.92	34.01	1.85	2.57	12.61
T. rigidum	48.67	12.23	31.82	1.15	2.33	3.80
T. radicans	33.63	24.99	33.69	0.84	0.91	5.94
I. australis	3.87	1.29	65.36	2.93	23.56	2.99
C. hirsutum	0.00	2.79	65.43	0.00	31.78	0.00
C. lanceolatum	75.59	0.46	10.29	13.57	0.03	0.07
C. plantagineum	45.73	6.78	32.21	4.93	9.78	0.58
C. pumilum	18.67	0.02	58.19	0.00	21.28	1.84
C. wilmsii	18.46	0.00	61.43	3.18	16.92	0.00
L. pulchella	14.29	30.71	33.49	3.07	18.44	0.00
L. wilmsii	10.95	35.20	34.43	5.84	0.00	13.59
M. flabellifolius	4.44	42.02	42.62	2.43	2.18	6.32
M. moschatus	35.68	28.16	10.19	6.02	0.44	19.51
M. multinervia	21.10	48.67	0.74	0.00	25.40	4.09
A. dimorpha	42.88	21.14	6.22	2.44	12.36	14.96
A. fendleri	25.83	40.57	5.67	1.89	7.38	18.65
A. hispidulum	40.15	9.54	5.44	15.72	13.53	15.61
A. incisum	43.38	6.59	12.09	7.96	17.48	12.50
A. latifolium	31.34	23.46	30.41	1.08	1.99	11.72
A. radiata	32.51	5.49	13.19	10.18	25.12	13.51
A. raddianum	6.88	14.47	76.87	1.07	0.30	0.41
A. semiflabellata	57.22	14.32	6.15	2.34	3.14	16.84
A. sinuata	4.75	35.72	52.44	1.51	2.44	3.13
B. hispida	9.23	55.55	30.28	0.82	0.60	3.51
P. cambricum	48.18	15.12	30.60	4.97	0.44	0.69
C. capensis	0.71	30.30	5.00	3.98	2.68	57.34
C. distans	70.91	2.53	22.12	2.54	0.31	1.58
C. depauperata	0.00	70.96	5.03	1.95	0.00	22.06

Table S4.1. (continued)

C. dinteri	36.09	16.67	5.86	5.33	13.44	22.61
C. buchtienii	24.12	7.60	57.66	0.00	8.78	1.85
C. eckloniana	0.67	4.93	83.14	8.63	2.42	0.20
A. farinosa	36.26	3.09	57.37	1.55	0.00	1.72
C. glauca	18.18	11.52	16.78	41.89	0.99	10.64
C. gracillima	24.66	31.02	15.66	20.83	4.27	3.56
C. hirta	7.87	33.21	44.03	6.63	7.88	0.38
A. cochisensis	10.67	38.70	34.90	6.82	1.15	7.76
C. heterophylla	0.00	40.49	25.11	0.71	9.48	24.22
A. integerrima	24.72	27.63	31.06	3.64	3.83	9.12
C. lasiophylla	17.80	13.73	34.56	9.85	4.92	19.15
C. multifida	24.45	12.92	60.37	0.00	1.46	0.80
C. marginata	12.65	5.98	74.49	0.82	5.62	0.44
C. parviloba	0.21	9.00	63.22	11.47	16.11	0.00
C. sieberi	7.99	16.88	67.54	1.77	0.64	5.18
C. tenuifolia	33.52	1.39	40.68	2.22	2.19	20.00
C. vellea	45.74	23.30	16.01	12.23	2.01	0.72
C. catanensis	68.02	13.47	9.26	8.42	0.83	0.00
D. collina	43.09	1.19	52.25	0.44	0.63	2.41
D. concolor	1.00	13.82	80.64	2.59	0.82	1.13
C. notholaenoides	9.45	21.75	64.51	0.74	2.35	1.19
D. varians	64.96	4.61	13.45	2.90	2.18	11.90
E. bifaria	18.14	50.52	10.57	20.73	0.04	0.00
E. brachyphylla	89.57	1.65	0.00	7.90	0.87	0.00
E. nardoides	18.30	6.76	67.08	7.86	0.00	0.00
E. nindensis	0.05	55.75	39.98	0.71	1.41	2.10
E. paradoxa	0.01	0.15	83.56	0.00	7.77	8.51
C. quadripinnata	4.90	12.52	50.39	9.23	9.65	13.30
M. flabelliformis	72.47	6.19	8.71	4.08	0.52	8.04
A. albomarginata	9.47	20.62	54.75	13.93	1.04	0.20
P. atropurpurea	3.19	17.57	61.85	0.10	9.85	7.43
P. andromedifolia	7.65	17.12	47.59	6.03	2.41	19.20
C. bonariensis	9.06	12.69	64.18	2.25	3.75	8.07
P. sagittata	2.12	10.83	79.73	0.58	1.92	4.82
C. fragillima	21.23	41.60	1.17	10.30	0.42	25.29
P. glabella	23.26	29.09	40.21	0.99	4.37	2.08
C. inaequalis	0.68	12.07	80.66	3.36	0.84	2.39
D. kitchingii	0.22	0.44	96.73	2.17	0.00	0.44
C. lendigera	14.86	26.96	51.94	0.50	1.77	3.97

Table S4.1. (continued)						
C. marlothii	38.10	59.44	0.19	0.12	2.15	0.00
C. myriophylla	11.97	12.12	68.56	0.78	1.87	4.69
P. marantae	17.21	1.95	63.09	14.24	0.00	3.51
A. coriaceus	0.00	36.61	58.17	3.19	2.03	0.00
C. nitidula	0.00	20.50	52.42	0.00	0.12	26.96
P. ovata	6.71	3.62	53.58	8.73	8.45	18.91
C. parryi	24.76	60.02	1.45	1.05	6.07	6.65
C. pringlei	21.28	24.98	37.54	7.80	2.62	5.78
D. pedata	15.11	15.02	40.45	6.71	21.88	0.82
H. palmata	10.52	57.15	16.90	2.48	7.42	5.53
A. pteridioides	0.57	35.05	23.08	7.57	30.49	3.24
H. tomentosa	15.87	9.48	66.46	2.36	0.34	5.49
C. tomentosa	0.82	7.93	63.92	1.22	1.63	24.48
D. triphylla	2.97	48.89	35.42	6.95	0.34	5.43
P. ternifolia	6.79	10.50	43.16	10.75	10.44	18.36
P. triangularis	12.88	7.80	53.88	12.28	1.18	11.98
H. volkensii	62.55	6.51	15.43	15.02	0.49	0.00
C. wrightii	20.98	37.67	18.04	12.29	2.38	8.65
L. abyssinica	52.00	9.86	26.88	3.26	2.85	5.14
M. adamsii	12.53	36.47	31.00	9.47	8.54	2.00
M. caffra	24.81	25.20	23.10	21.20	3.37	2.31
M. indica	29.66	31.96	23.40	7.85	2.97	4.14
M. kunthii	38.90	9.44	40.44	1.37	0.91	8.94
M. lazaridis	80.00	14.06	0.81	1.65	2.29	1.19
M. piloselloides	14.26	24.82	38.10	8.17	3.10	11.55
M. patentiflora	10.45	50.36	28.26	10.35	0.59	0.00
M. peruviana	10.06	14.10	71.58	1.63	0.96	1.67
M. rufa	0.87	53.77	22.67	3.00	11.90	7.79
M. subulifolia	85.93	1.06	8.84	3.30	0.08	0.79
M. spinifera	8.67	65.72	4.99	11.61	0.10	8.92
M. tenuis	13.39	67.02	0.22	7.35	5.26	6.77
M. viscidula	13.29	70.76	0.04	8.77	7.13	0.00
N. lanuginosa	11.91	48.79	38.60	0.70	0.00	0.00
N. muelleri	68.06	16.70	7.39	1.19	3.91	2.75
N. scioana	15.44	19.37	42.62	8.80	13.25	0.52
O. aristatum	80.15	5.28	4.42	4.42	3.04	2.69
O. capense	6.86	3.86	59.80	18.06	6.44	4.97
O. divaricatum	34.72	15.81	16.06	0.00	19.93	13.47
O. thomaeum	64.25	1.77	6.50	24.98	0.00	2.50

Table S4.1. (continued)

P. angusta	21.90	2.55	25.93	22.12	17.17	10.34
P. boivinii	45.11	32.21	14.19	7.25	0.36	0.88
P. brachyptera	6.14	30.66	17.87	28.40	3.36	13.57
P. bridgesii	18.42	57.99	7.22	13.23	0.96	2.18
P. calomelanos	41.59	20.20	34.70	1.36	1.11	1.05
P. crassinervata	48.59	3.76	33.18	4.99	8.08	1.40
P. dura	62.76	13.37	19.90	2.44	1.50	0.04
P. eurybasis	3.52	6.51	87.89	0.67	0.73	0.67
P. falcata	80.76	3.88	11.07	0.35	1.01	2.94
G. furfuraceum	12.38	24.51	36.43	26.68	0.00	0.00
P. hirsutissima	8.75	44.88	45.73	0.23	0.08	0.33
P. interjectum	44.02	6.73	36.41	0.75	4.38	7.70
P. longipilosa	2.31	15.29	44.96	6.47	28.08	2.89
P. macrocarpa	69.67	1.88	21.90	0.77	0.64	5.15
P. mexicana	28.82	5.43	34.79	10.78	15.42	4.75
P. minima	3.72	26.62	60.62	3.41	3.47	2.16
P. mucronata	6.56	28.74	20.46	22.41	3.76	18.07
P. polypodioides	12.91	72.88	2.94	0.46	3.00	7.81
P. plebeia	28.70	3.61	45.66	2.07	14.23	5.72
P. pleopeltifolia	15.30	22.08	61.20	0.61	0.73	0.07
P. pectiniformis	51.07	19.76	18.61	0.78	8.03	1.76
P. rotundifolia	2.48	9.81	45.04	18.94	5.39	18.33
P. remotum	8.73	3.54	82.96	1.52	2.69	0.57
P. truncata	2.72	81.01	8.39	0.86	4.21	2.81
C. viridis	40.94	3.79	24.98	7.18	8.98	14.12
P. virginianum	14.40	14.17	56.94	0.31	8.48	5.70
P. vulgare	39.29	2.40	53.64	3.23	0.42	1.02
P. wrightiana	1.38	76.36	16.42	0.49	1.55	3.81
S. atrovirens	17.89	3.39	23.03	48.99	0.27	6.44
S. elongatus	45.53	31.20	17.26	1.47	1.84	2.70
S. festivus	29.34	2.54	10.40	16.15	12.61	28.96
S. fimbriatus	2.74	3.83	21.87	34.73	20.07	16.76
S. hitchcockii	5.24	3.72	73.16	2.51	1.15	14.22
S. pellucidus	30.92	12.74	3.14	16.54	5.16	31.50
S. ruspolianus	55.32	34.13	10.20	0.16	0.19	0.00
S. stapfianus	32.07	9.18	23.32	28.45	3.61	3.38
P. stemaria	72.66	4.25	15.76	0.57	2.72	4.03
T. curvatus	10.70	4.89	32.11	3.41	13.10	35.79
T. jacquemontii	34.26	0.00	15.73	10.20	26.88	12.92

Table S4.1. (continued)

T. major	5.04	28.99	44.32	15.61	5.80	0.24
T. minima	5.42	2.86	6.51	42.03	14.29	28.88
T. spicata	20.24	13.16	46.13	2.80	15.41	2.26
V. guineensis	58.51	27.17	0.89	6.78	3.99	2.65
V. isoetifolia	78.37	11.70	5.94	1.67	0.55	1.76
S. arizonica	27.41	26.00	15.21	9.85	3.65	17.89
S. bryopteris	22.89	29.07	9.81	11.26	7.14	19.82
S. convoluta	10.09	26.46	48.84	2.58	2.75	9.28
S. caffrorum	19.05	3.92	70.42	6.56	0.00	0.05
S. digitata	3.07	22.94	18.73	28.69	2.16	24.41
S. dregei	39.44	18.50	3.26	1.51	0.00	37.29
S. densa	9.01	16.72	38.92	6.93	10.32	18.10
S. echinata	8.48	31.00	13.83	13.50	9.37	23.82
S. eremophila	7.13	67.24	17.25	3.13	1.84	3.41
S. helvetica	3.32	24.50	35.02	8.50	14.81	13.85
S. helicoclada	17.17	31.33	11.06	6.01	0.54	33.89
S. imbricata	54.50	13.41	7.76	0.19	21.04	3.10
S. lepidophylla	19.55	12.58	11.04	1.54	17.67	37.62
S. nivea	6.77	8.16	1.72	81.78	0.00	1.57
S. njamnjamensis	13.65	50.76	11.80	22.97	0.45	0.37
S. peruviana	9.53	5.39	62.97	5.44	4.17	12.49
S. pilifera	9.22	19.71	11.62	48.21	2.42	8.82
S. pusilla	23.28	23.31	48.77	0.49	2.01	2.13
S. phillipsiana	0.84	15.90	68.14	7.27	6.51	1.35
S. rupincola	4.07	44.80	30.57	6.77	10.77	3.02
S. sellowii	12.66	23.05	52.58	2.06	8.09	1.57
S. sartorii	0.31	65.62	27.24	0.88	1.82	4.13
S. tamariscina	6.37	4.02	18.24	19.17	20.62	31.58
S. trisulcata	1.61	13.37	83.86	0.18	0.01	0.97
S. yemensis	15.90	12.49	58.01	0.07	0.32	13.21
A. orientalis	72.51	2.46	17.21	2.44	2.39	3.00
A. bracteata	5.99	24.14	52.45	0.90	16.52	0.00
B. blackii	6.14	5.99	56.46	17.09	4.24	10.09
B. flava	4.07	4.84	56.13	9.63	5.82	19.51
B. fragrans	42.83	0.06	32.74	22.68	1.09	0.60
B. longiflora	0.09	3.75	61.95	34.17	0.04	0.00
B. gentianoides	3.07	2.64	59.99	29.37	0.22	4.71
B. graminifolia	2.40	13.49	44.93	36.86	0.73	1.58
B. humahuaquensis	32.65	2.13	23.83	19.06	19.71	2.62

Table S4.1. (continued)

B. longiscapa	0.45	0.91	49.59	1.81	47.24	0.00
B. macrantha	8.36	2.79	43.95	34.00	1.95	8.94
B. purpurea	22.79	39.30	33.29	3.95	0.04	0.63
B. riedeliana	0.00	2.22	49.79	38.67	0.02	9.29
B. seubertiana	10.93	0.02	10.84	77.62	0.55	0.04
B. spectabilis	16.98	0.00	38.21	3.75	39.68	1.38
B. tomentosa	7.25	4.36	33.01	5.32	0.00	50.06
B. gounelleana	1.41	0.64	0.84	96.62	0.00	0.50
X. elegans	31.16	49.87	13.41	0.34	1.86	3.36
V. variabilis	2.78	22.27	54.66	5.69	3.01	11.58
V. albiflora	14.41	15.79	22.62	2.93	18.23	26.02
V. angustifolia	4.06	14.00	71.72	1.19	6.67	2.36
V. andina	1.11	6.06	82.03	9.77	0.77	0.26
B. boliviensis	14.94	23.03	58.15	0.26	3.62	0.00
V. candida	32.34	43.62	20.49	0.53	2.01	1.01
V. ciliata	0.00	16.81	20.35	46.85	16.00	0.00
V. caput-ardeae	0.00	0.00	56.31	42.89	0.00	0.81
V. caruncularis	6.33	2.99	34.92	7.89	13.32	34.54
V. compacta	5.19	6.11	24.49	7.93	8.70	47.57
V. declinans	1.43	4.36	48.90	40.00	2.75	2.56
V. epidendroides	2.26	4.60	41.29	41.81	3.73	6.31
V. glochidea	21.34	11.31	14.70	23.21	28.27	1.17
V. hatschbachii	13.84	52.09	10.90	2.47	11.38	9.32
V. hirsuta	3.87	2.57	52.01	11.86	21.50	8.18
V. nanuzae	0.64	1.28	43.39	41.27	8.56	4.86
V. nivea	1.35	0.81	53.57	29.00	2.76	12.52
V. plicata	12.04	7.43	31.28	2.17	31.26	15.82
V. pulchra	3.79	52.23	6.18	8.78	17.28	11.73
V. resinosa	1.84	4.63	51.43	34.54	1.17	6.40
V. flavicans	3.10	62.46	19.13	1.85	13.01	0.45
V. sellowii	3.29	5.38	42.47	12.28	5.62	30.95
V. squalida	5.51	1.81	77.76	0.23	11.05	3.63
V. subscabra	9.02	29.62	51.94	0.21	9.21	0.00
V. taxifolia	0.03	0.19	43.29	48.53	0.68	7.28
V. tubiflora	7.65	38.98	15.39	0.83	20.33	16.82
V. variegata	69.41	19.03	4.77	4.42	1.43	0.94
V. verruculosa	10.85	0.18	83.70	2.81	2.47	0.00
X. dasylirioides	53.05	18.19	18.36	2.39	3.30	4.71
X. eglandulosa	0.00	25.23	62.57	2.66	6.92	2.62

Table S4.1. (continued)

X. equisetoides	21.77	0.00	72.60	4.39	0.00	1.24
X. humilis	7.51	46.57	41.36	4.56	0.00	0.00
X. pinifolia	2.28	51.36	7.40	30.14	0.00	8.83
X. pectinata	10.20	30.42	31.30	0.76	6.72	20.59
X. retinervis	19.66	29.63	44.52	0.00	0.02	6.17
X. squarrosa	3.83	40.71	15.42	1.15	0.43	38.46
X. schlechteri	3.85	51.88	15.41	1.23	2.08	25.54
X. scabrida	0.00	70.46	5.31	9.65	0.00	14.58
X. schnizleinia	49.17	23.63	24.71	0.84	1.50	0.14
X. splendens	63.07	0.00	0.22	0.03	0.11	36.57
X. villosa	20.58	32.22	0.04	25.13	1.13	20.91
X. viscosa	54.26	20.00	25.74	0.00	0.00	0.00
W. ilvensis	14.21	53.69	18.46	0.93	9.77	2.93

Table S4.2. Linear models evaluating the correlation between species' phylogenetic distance and dissimilarity regarding the importance of environmental constraints to their distribution, and between species' geographical range and tolerance to climate change regarding the environmental variables: VPD – vapor pressure deficit; SRad – solar radiation; MAT – mean annual temperature; DRF – drought frequency; DRI – drought intensity; DRL – drought length. Bonferroni correction method was applied to the linear models' *p*-values always multiple comparisons were performed.

	Slope	**(adj) R^2**	**(adj) *p*-value**
Phylogenetic distance			
Environmental constraints	0.0002	0.0016	< 0.0001
Geographic range			
VPD	0.2520	0.5786	< 0.0001
SRad	0.2906	0.6802	< 0.0001
MAT	0.2320	0.5240	< 0.0001
DRF	0.3297	0.4417	< 0.0001
DRI	0.3557	0.5847	< 0.0001
DRL	0.3619	0.6641	< 0.0001

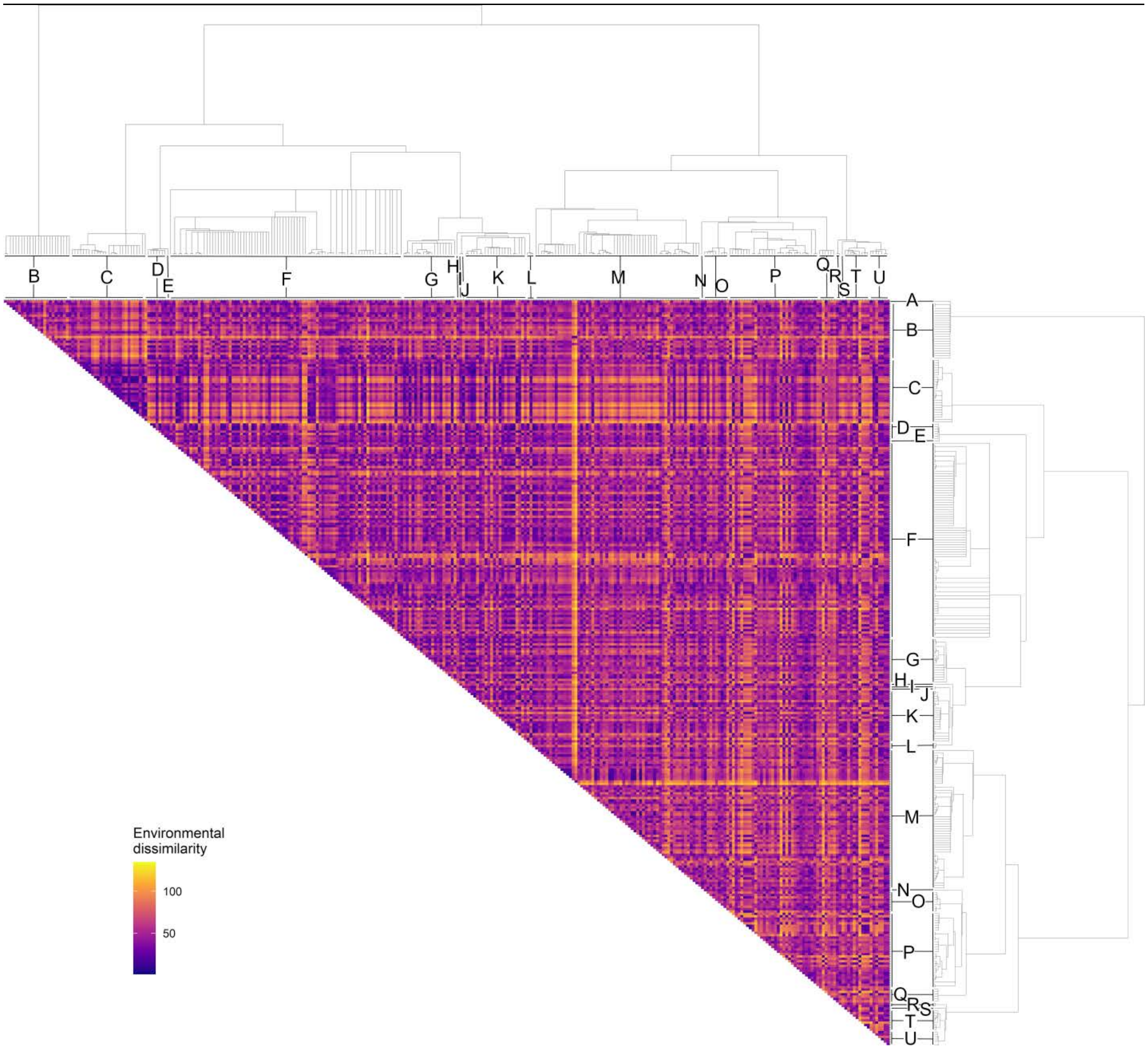


Figure S4.1. Species' ecological dissimilarity matrix in relation to the six main environmental constraints for desiccation tolerance: vapor pressure deficit, solar radiation, mean annual temperature, drought frequency, drought intensity, and drought length. A – Isoetaceae; B – Selaginellaceae; C – Hymenophyllaceae; D – Anemiaceae; E – Schizaeaceae; F – Pteridaceae; G – Aspleniaceae; H – Woodsiaceae; I – Davalliaceae; J – Tectariaceae; K – Polypodiaceae; L – Dryopteridaceae; M – Velloziaceae; N – Bromeliaceae; O – Cyperaceae; P – Poaceae; Q – Boryaceae; R – Myrothamnaceae; S – Cactaceae; T – Gesneriaceae; U – Linderniaceae.

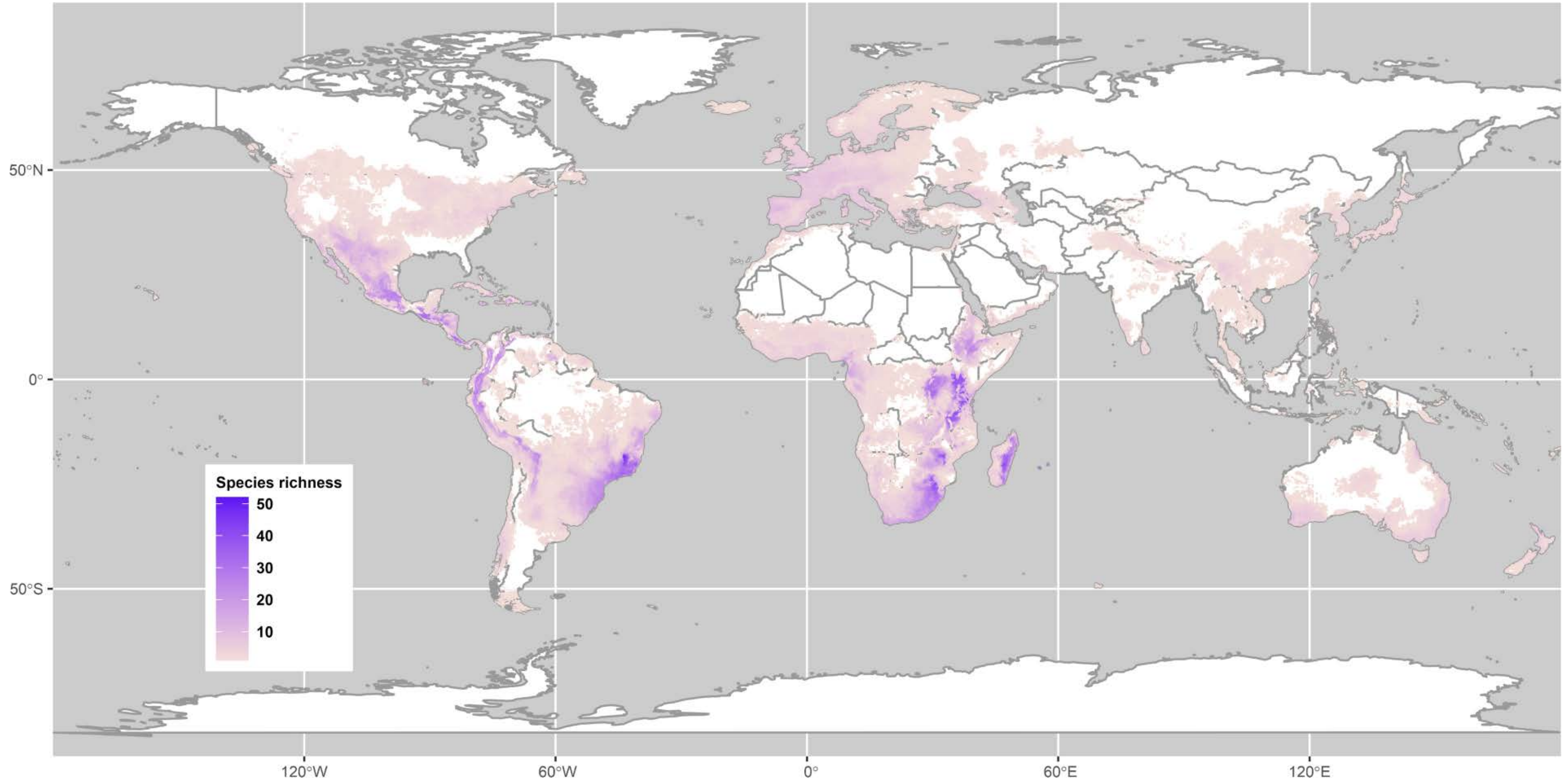


Figure S4.2. Centers of diversity for desiccation-tolerant vascular plants in relation to species richness.

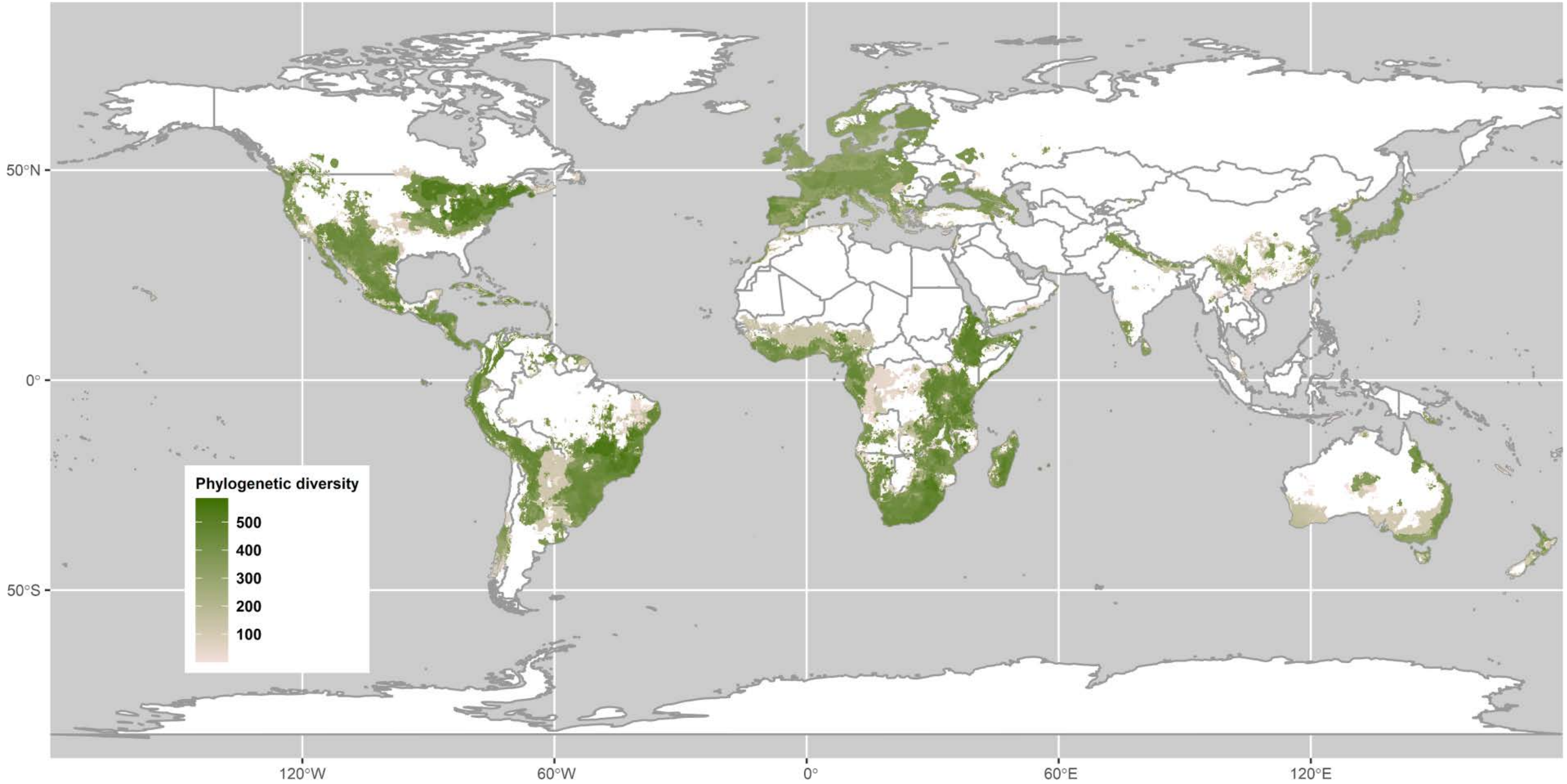


Figure S4.3. Centers of diversity for desiccation-tolerant vascular plants in relation to phylogenetic diversity.

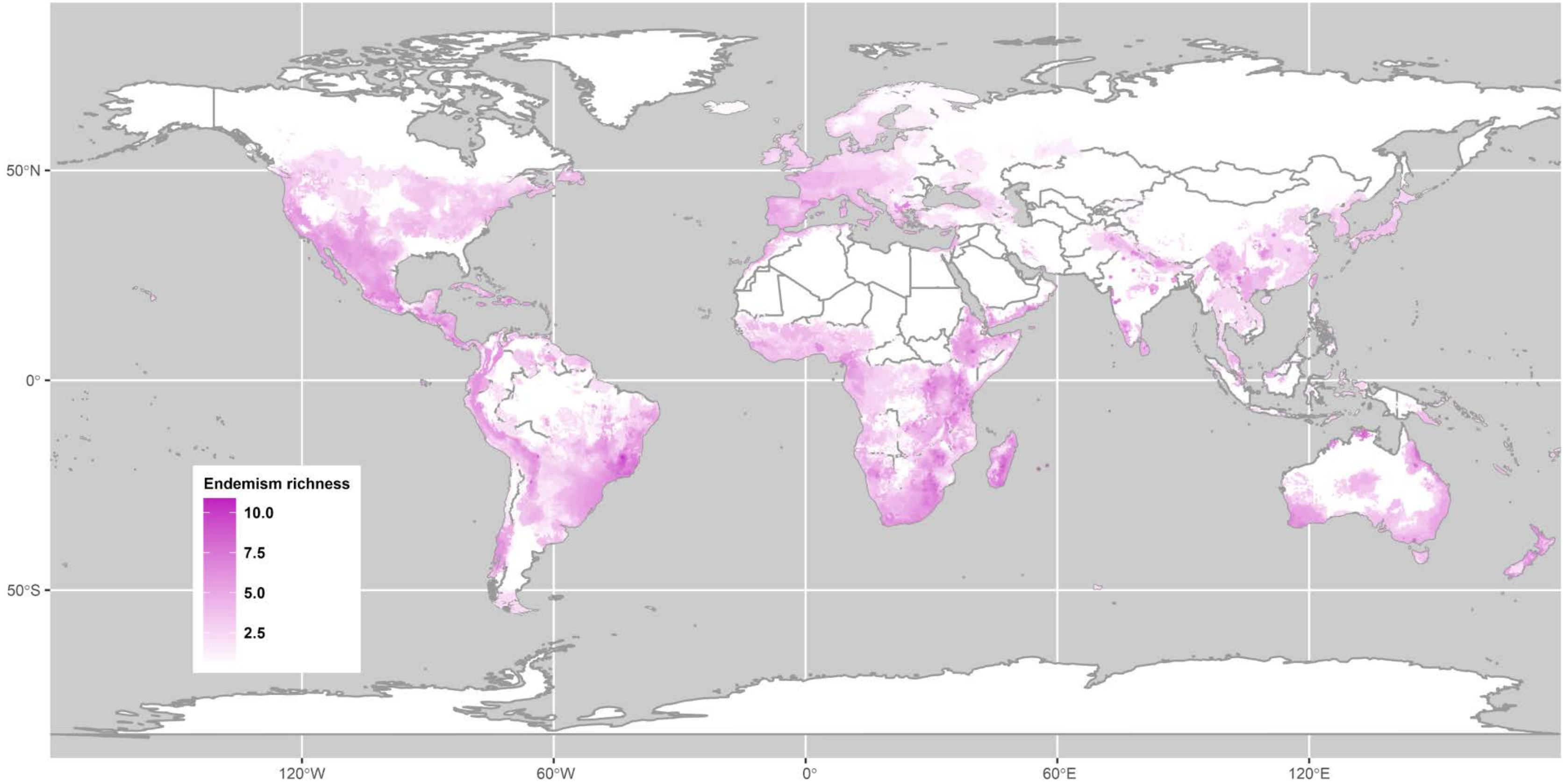


Figure S4.4. Centers of endemism for desiccation-tolerant vascular plants in relation to endemism richness.

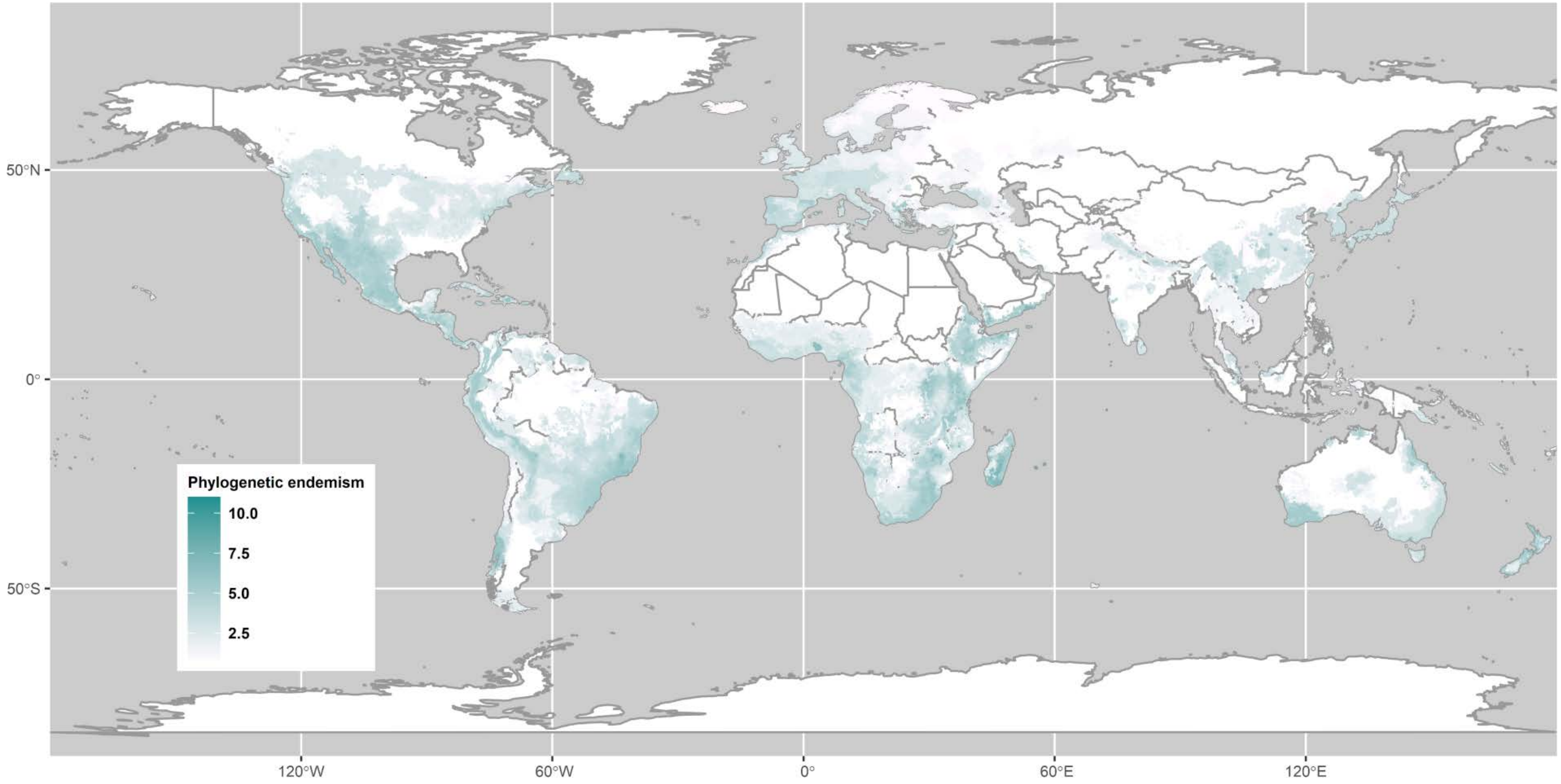


Figure S4.5. Centers of endemism for desiccation-tolerant vascular plants in relation to phylogenetic endemism.

APPENDIX II

DT PLANTS OF THE WORLD

Flower water uptake? from *Vellozia plicata*. Picture by L. Bondi

APPENDIX II

DT PLANTS OF THE WORLD

INTRODUCTION

Desiccation-tolerant vascular plants (DT plants) stand out among vascular plants due to their remarkable capacity to avoid drought mortality by tolerating desiccation of their vegetative tissues (i.e. losing up to 13-20% of their protoplasmic water; Scott, 2000; Oliver et al., 2000; Porembski and Barthlott, 2000). The desiccation tolerance re-evolved multiple times within the tracheophytes phylogeny (Oliver et al., 2000; Marks et al., 2021) and with that many ways to cope with desiccation (Oliver et al., 2000; Marks et al., 2021; Porembski, 2021). However, the diversity of DT plants and their diversity of responses to the environmental constraints is still spread throughtout many studies (e.g., Gaff, 1971; Gaff and Latz, 1978; Meirelles et al., 1997; Oliver et al., 2020; Marks et al., 2021).

Still, some generalizations can be found in the literature. For instance, 90% of DT plants are expected to grow in worldwide rock outcrops (Porembski and Barthlott, 2000; Marks et al., 2021), although some phylogenetic groups are mostly linked to certain areas (e.g., while Monocots are absent in North America and Europe, Eudicots are nearly absent in the Americas). The phylogenetic groups in which the desiccation-tolerance re-evolved also exhibit some patterns in relation to their ecological aspects. For example, while all desiccation-tolerant pteridophytes and eudicots keep their chlorophyll when desiccating (i.e. homoiochlorophyllous species), the majority of desiccation-tolerant monocots dismantles and reconstructs their photosynthetic apparatus (i.e. poikilochlorophyllous species; Oliver et al., 2000; Porembski, 2021). To the best of our knowledge, no individual or complete assessment on the diversity of DT plants from a biogeographic and ecological perspective has ever been conducted. In this way the geographical and ecological limits for the desiccation tolerance and DT plants remain unclear.

This existing knowledge gap can be even more critical in a climate change world, since it hampers effective conservation efforts for DT plants. This is special because DT plants have been widely overlooked for conservation aspects. This is conflicting with the Strategic Goal C (i.e., to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity) from the Aichi Biodiversity Targets (https://www.cbd.int/sp/targets/). Therefore, to improve our geographical, ecological, and conservation knowledge of such remarkable group of plants is highly desired.

OBJECTIVES

The aim of this project was to compile a global database with all described DT plants, providing an updated species checklist in which general aspects of their distribution, ecology, and conservation can be found. For that we conducted a systematic bibliographic search and estimated the species distribution, ecology, and conservation using different modelling approaches and global datasets from international databases.

MATERIAL AND METHODS

Species assembly

We considered all DT plants reported by scientific studies. In order to consistently assemble DT plants from the available literature, we performed a bibliographic search in January of 2021 using the Web of Science search engine (apps.webofknowledge.com) with the key-words combination (*'desiccation tolerant' OR 'resurrection') AND (angiosperm* OR pteridophyte**

OR lycophyte OR vascular OR plant**). We also included additional studies not present in the bibliographic search described above to improve the species list. We only used taxa reported within the "species" taxonomic level. We checked the validly recognized scientific names with the databases (i) Tropicos (https://www.tropicos.org/), (iii) TPL - The Plant List (http://theplantlist.org/), (ii) WCVP - World Checklist of Vascular Plants (https://wcvp.science.kew.org/), (iv) TNRS - Taxonomic Name Resolution Service v4.1 (http://tnrs.iplantcollaborative.org//TNRSapp.html), and (v) Flora do Brasil 2020 (http://floradobrasil.jbrj.gov.br/).

Environmental factors assessment

Constraints of DT plants distribution

We used climatic variables to assess the six constraints for DT plants distribution listed by Marks et al. (2021 i.e., desiccation rate, light and temperature during species desiccation and rehydration, besides the frequency, intensity, and duration of drought events, respectively). For all climate data, we used raster grids of 4 km x 4 km resolution.

First, the (i) vapor pressure deficit (VPD) was used as a proxy for desiccation rate. Higher values of VPD describe climatic conditions in which species experience higher desiccation rates, that is, desiccate faster. The VPD was estimated as the annual mean value of the monthly differences between saturated vapor pressure and actual vapor pressure (Eq. 1; Fick & Hijmans, 2017; Grossiord et al., 2020).

(Eq. 1)

$$VPD = 12^{-1} \cdot \sum_{i=1}^{i=12} es_i - ea_i$$

$$es_i = 2^{-1} \cdot \left(es_i^{max} - es_i^{min}\right)$$

$$es_i^{min} = 0.611 \cdot 10^{\frac{7.5 \cdot T_i^{min}}{(237.7 + T_i^{min})}}$$

$$es_i^{max} = 0.611 \cdot 10^{\frac{7.5 \cdot T_i^{max}}{(237.7 + T_i^{max})}}$$

In which *i* is a given month of the year varying from January (1) to Dezember (12); es is the saturated vapor pressure; ea_i is the actual vapor pressure; T^{min} and T^{max} are minimum and maximum temperatures. For the actual vapor pressure we used the *vapr* historical dataset from the Worldclim v2.1 database (https://www.worldclim.org/), while the saturated vapor pressure was estimated using the *tmin* and *tmax* datasets from the same database, in which the mean monthly values for the period from January 1970 to December 2000 were considered.

Then, the (ii) solar radiation (SRad) and (iii) mean annual temperature (MAT) were used to represent the light and temperature conditions during species desiccation and rehydration, respectively. Higher values of SRad and MAT portray locations in which light and temperature is higher during desiccation-rehydration processes. Here, the SRad and MAT were set by the annual mean of the *srad* and *bio1* historical datasets from the Worldclim v2.1 database (https://www.worldclim.org/), in which the mean monthly values for the period from January 1970 to December 2000 were considered.

At last, the (iv) drought frequency (DRF), (v) drought intensity (DRI), and (vi) drought length (DRL) were used to describe the frequency, intensity, and duration of drought events, respectively. Higher values of DRF, DRI, and DRL describes locations in which droughts are more frequent, intense, extensive. The standardized precipitation evapotranspiration index (SPEI) was used to estimate the DRF, DRI, and DRL. Those variables were derived from the dataset available in the SPEI database (https://spei.csic.es/) using a time-scale of one month to obtain monthly drought indices within the period from January 1901 to December 2018. Here, a drought event *j* is composed by a given set of consecutive dry months (i.e. SPEI < 0). The DRF was measured as the count of drought events within the whole period (Eq. 2). The DRI was estimated as the whole-period average of drought event intensity, given by the cumulative SPEI for each month within a drought event *j* (Eq. 3). The DRL was estimated as the whole-period average of the number of consecutive dry months within a drought event (Eq. 4).

(Eq. 2)

$$DRF = n$$

(Eq. 3).

$$DRI_j = \sum_{i=1}^{i=n} SPEI_i$$

$$DRI = n^{-1} \cdot \sum_{j=1}^{j=n} DRI_j$$

(Eq. 4)

$$DRL = n^{-1} \cdot \sum_{i=1}^{i=m} dm_i$$

In which *i* is a given month, *j* is a given drought event, *n* is the number of drought events within the whole-period, *m* is the number of consecutive dry months within a drought event, and *dm* is a dry month. The higher is DRI, DRL, and DRF scores, the more intense, extensive, and frequent is the drought events for a given location, respectively. The SPEI was considered the most appropriate approach to measure the intensity, length and frequency of drought events, because it considers anomalies in the balance between precipitation and PET rates in relation to average conditions within a broad historical climate records (Vicente-Serrano et al., 2010; Vicente-Serrano et al., 2012; Slette et al., 2019; Zang et al 2019; Slette et al., 2020). That means that by identifying abnormal dry periods as drought months or events, not only improves the temporal and spatial comparisons of drought for a given species, but also it takes into consideration the predictability of meteorological droughts for this species.

Drought and Precipitation seasonality

The drought is here referred to as the degree to which the evaporative demand (i.e. potential evapotranspiration) urges the water supply via precipitation, creating a water deficit circumstance in locations where DT plants occur. This water deficit was assessed by the Thornthwaite's aridity index (AI) index. Higher values of AI describe climatic conditions in which species experience higher water deficit. AI can be viewed as the percentage of water deficit imposed to plants in a location due to the evaporative demand, and was calculated by the Eq. 5.

(Eq. 5)

$$CWD = \left| \sum_{i=1}^{i=12} \begin{cases} P_i - PET_i & \text{if } P_i - PET_i \leq 0 \\ 0 & \text{if } else \end{cases} \right|$$

$$AI = 100 \cdot CWD \cdot \left(\sum_{i=1}^{i=12} PET_i\right)^{-1}$$

In which, *i* refers to a given month, P is monthly rainfall, PET is the potential evapotranspiration for a given month, and CWD is the climate water deficit. The AI was calculated using historical climatic information from the *prec*, *tavg*, *tmin*, and *tmax* datasets from Worldclim v2.1 database for each month of the year. AI scores close to 100 means that the water deficit is high, while values close to zero mean the nonexistence of months with water deficit over the year, according to the available data. This metric was selected because it simply measure the water balance in respect to climate in order to quantify the water deficit that externally act over species' individuals, regardless how species could perceive this water deficit (Thornthwaite, 1948).

Then, the precipitation seasonality was defined as the discrepancy on the monthly distribution of rainfall along the year (Walsh & Lawler, 1981). The precipitation seasonality was assessed by the Walsh & Lawler's seasonality index (SI), in which higher SI values describe locations in which precipitation is more unevenly distributed across the months of the year (Eq.3).

(Eq. 3)

$$SI = R^{-1} \cdot \sum_{i=1}^{i=12} \left| P_i - R \cdot 12^{-1} \right|$$

In which *i* refers to a particular month in the year, R is mean annual rainfall, and P is the monthly rainfall. The SI was chosen for providing a simple measure of the rainfall distribution over the year in relation to expected rainfall for each month if the precipitation is perfectly spread over the year.

Geographical distribution

Then, we obtained the occurrence records of all DT plants from the databases (i) GBIF - Global Biodiversity Information Facility (https://www.gbif.org/), (ii) Tropicos (https://www.tropicos.org), and (iii) Species Link (http://splink.cria.org.br/). From those occurrence records, we removed duplicated, erroneous and uncertain data according to appropriate literature and the databases (i) Plants of the World Online – POWO (https://powo.science.kew.org/), (ii) Flora do Brasil 2020, (iii) Tropicos, and (iv) World Plants (https://www.worldplants.de/). We only used records with the preserved specimen and available geographic information, accepting observations in which the respective geographic information could be obtained by a precise description of the locality or municipality. Avoiding the effects of sampling bias, we accepted only one occurrence per species within areas of one km-radius. We chose the one km-radius to rarefy occurrence records for considering the premise that most species occur in isolated rock outcrops in which gene flow among populations is expected to be low.

Then, using the occurrence records, we generated distribution maps for each species. . The distribution maps considered the consensus areas for the species distribution between the two species distribution model (SDM) approaches, always it was possible to assess. Ideally, the SDM for each species was conducted by combining techniques in which abiotic conditions and species movement were considered. Putting aside biotic interactions, the combination of such techniques is supposed to generate more realistic assessments of the species' actual distribution, once it depends on both abiotic suitability and habitat accessibility (Soberón & Peterson, 2005; Peterson, 2009).

Firtstly, we used the Maximum Entropy technique as the SDM approach (MaxEnt; Phillips et al., 2004) based on a climatic niche perspective. All MaxEnt models were calibrated with the same six variables mentioned above to describe the six main environmental constraints to DT plants (i.e., VPD, SRad, MAT, DRF, DRI, and DRL). The MaxEnt technique was chosen due to its ability to identify suitable areas of occurrence for species (Elith et al., 2011) with good predictive power, being little affected by the sample size effects and the sort of data which is required (Hernandez et al., 2006; Wisz et al., 2008; Elith et al., 2011; Gogol-Prokurat 2011; Yackulic et al., 2013; Feng et al., 2019).

Then, we conducted the Inverse-distance weighted model approach (IDW) to predict every species distribution by a presence-absence interpolation model. The IDW technique was chosen due to its capacity to predict species distribution under a strong spatial autocorrelation and because it provides an alternative hypothesis for the niche-based species distribution models, which can overestimate species distribution measures to areas beyond species dispersal capacity (Diniz-Filho et al., 2003; Pearson & Dawson 2003; Roberts et al. 2004; Bahn & Mcgill, 2007; Elith et al., 2011).

We evaluated the predictive power of SDMs from both techniques by the area under the receiver operating characteristic (AUC) after cross-validation using the method of k-means (k=5), in which 10000 random background points were generated (Barbet-Massin et al., 2012). Each MaxEnt and IDW models were produced by at least 50% of consensus between five different random cross-validation routines for the same approach. At last, we generated binary distribution maps for each species, in which individual model thresholds were estimated using the minimum omission rates for true positives and true negatives (i.e., best sensitivity and specificity). For every species, we used a 2°30'' x 2°30'' spatial unit (i.e., 4 x 4 km resolution), extending the spatial scale to 5° of latitude and longitude beyond the species' most external occurrence points.

Those SDM techniques could not be performed for species with less than five observation points after rarefying occurrences. To get around this problem, we estimated the species distribution by applying the method of the Circular Area with a radius of 50 km (Ca_{50}) for species with less than five observation points, as proposed by Hijmans & Spooner (2001). The circular area for the species occurrence points was considered the most adequate approach for species in which data points were not enough for any modelling technique because it provides an standardize estimation of the species distribution based on their dispersal limitations.

The species distribution was described by using the world geographical scheme for recording plant distributions as used by the Plants of the World Online database (available in https://web.archive.org/web/20160125135239/http:/www.nhm.ac.uk/hosted_sites/tdwg/TDWG_geo2.pdf). Additionally, we also evaluated the altitudinal range in which each DT plants occur. For that, we used occurrence points in which the species exact position was determined in field (i.e., GPS) and the elevation dataset from the Worldclim v2.1 database. Then, we assessed the minimum and maximum altitudinal values in relation to the sea level (in meters) the species occur and conducted Kernel density estimations to evaluate the species distribution along an altitudinal gradient.

Ecological aspects of DT plants distribution

DT were classified as homoiochlorophyllous or poikilochlorophyllous always information on this subject were found. For other ecological aspects of DT plants distribution we used only occurrence points in which the species exact position was determined in field.

We assessed the main climates in which each DT plant is found using the Köppen-Geiger climate classification. We used high global resolution Köppen-Geiger climate maps (available at http://koeppen-geiger.vu-wien.ac.at/present.htm) for the 25-year period 1986-2010 (9 x 9 km resolution), in which locations were split into five climate classes: (i) equatorial, (ii) arid, (iii) warm temperate, (iv) snow, (v) polar (Kottek et al., 2006; Rubel et al., 2017). Equatorial climates are distinguished by exhibiting minimum monthly temperature in the year is equal or higher than +18 ◦C. Locations are classified as warm temperate climates if the minimum monthly temperature in the year is higher than −3 ◦C and lower than +18 ◦C. Snow climates exhibit minimum monthly temperature in the year is lower than −3 ◦C. Polar climates exhibit maximum monthly temperature in the year is lower than +10 ◦C. Taking precipitation into account, arid climates show accumulated annual precipitations lower than 10 P_{th} (P_{th} is calculated as 2|MAT| + 0, if 2/3 of the annual precipitation occurs in winter, + 28, if 2/3 of the annual precipitation occurs in summer, + 14, if otherwise; Kottek et al., 2006). The Köppen-Geiger climate classification was chosen for providing a widely accepted and systematic evaluation of climate.

We also assessed the drought and precipitation seasonality in which DT plants were found. Here, we used the AI and SI indices. Locations with AI values below 16.7 indicates little or no water deficiency, while values between 16.7 and 33.3 point to a moderate summer/winter water deficiency, and higher than 33.3 denote a large summer/winter water deficiency (Thornthwaite, 1948). Complementarily, SI values lower than 0.39 suggest that precipitation is spread throughout the year (although from 0.20 it would indicate a definite wetter season), while between 0.40 – 1.19 denote a seasonal precipitation regime (although up to 0.59 the drier season is short, from 0.80 to 0.99 the dry season is long, and from 1 most precipitation occurs within 3 months in the year), and from 1.2 the precipitation is extremely seasonal (Walsh & Lawler, 1981).

Conservation aspects of DT plants

We assessed the DT plants' populations within their species distribution which are potentially more vulnerable to climate changes using the Climate Niche factorial Analysis (CNFA) for every species. This analysis estimates the degree of sensitivity and exposure to predicted changes within each species' distribution area. For that, we used the SDM generated by the 50% consensus between the two modelling techniques above mentioned (MaxEnt and IDW). Then, we compared the current climatic conditions in which DT plants occur with the predicted climatic conditions for the time-frame of 2081-2100 if the world share a socioeconomic pathway in which a fossil-fueled development is kept. We used datasets *bio1*, *bio4*, *bio12*, and *bio15* obtained from the Worldclim v2.1 database to describe the influence (i.e., sensitivity) and the amount of change (i.e., exposure) in temperature and precipitation where DT plants are distributed. For the current climatic conditions, we used historical datasets in which the mean monthly values for the period from January 1970 to December 2000 were considered. For the future climatic conditions we employed predictions available by the Coupled Model Intercomparison Project v.6. To assess the global effects of a fossil-fueled development (i.e. SSP5 – 8.5 $W \cdot m^{-2}$), we used two different global climate models in relation to their climatic sensitivity: MIROC6 (equilibrium climate sensitivity = 2.3) and CanESM5 (equilibrium climate sensitivity = 5.6; Smith et al., 2020). Finally, the mean future climatic condition was calculated by the average between the two global climate models.

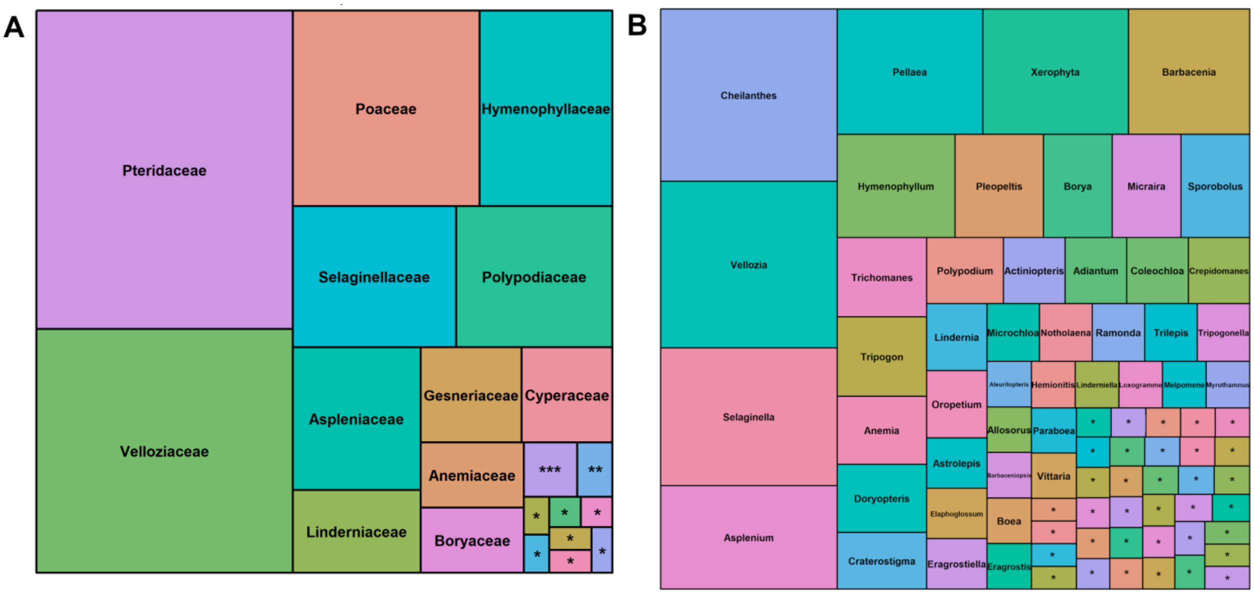
As an output of the climate-niche factor analysis, the overall climate sensitivity (SEN) for each species was generated, expressing the amount of specialization in each climate dimension (i.e. variables) species exhibit by examining their present distribution in the geographical space. Looking towards the future, we obtained the overall climate exposure (EXP) as the departure from historical conditions in each climate dimension species will be subjected within their present distribution areas. Taking those two aspects into account (i.e. SEN and EXP), the potential vulnerability to climate change was assessed through the overall climate vulnerability (VUL; Rinnan and Lawler, 2019). Species with higher SEN and EXP, and therefore higher VUL, are expected to be potentially more vulnerable to climate change if they remain in place. We chose the climate-niche factor analysis because it was considered a good approach for providing relevant evaluations of species sensitivity and exposure in the same order of magnitude and in a spatially-explicit framework (Rinnan and Lawler, 2019).

We also evaluated the DT plants conservation status using the database IUCN (International Union for Conservation of Nature) Red List of Threatened Species (https://www.iucnredlist.org/). In a scale of vulnerability from less to more threatened, species were categorized as (i) Least concern, (ii) Near Threatened, (iii) Conservation dependent, (iv) Vulnerable, (v) Endangered, (vi) Regionally extinct, (vii) Extinct in the Wild, (viii) Extinct. Species which were not found in the IUCN Redlist database were classified as not evaluated by IUCN. The IUCN Redlist categories were chosen because it takes into account information about species' range, population size, ecological aspects, use and trade, threats, and conservation actions for each species.

At last, we calculated the percentage of each DT plant distribution which is included found within protected areas. For that, we used the SDM generated by the two modelling techniques (MaxEnt and IDW), or CA_{50}, and datasets from World Database on Protected Areas (including other effective area-based conservation measures – OECMs). The World Database on Protected Areas was chosen for compiling a globally complete and updated source of data on protected areas and OECMs, which is monthly provided by governments, non-governmental organizations, landowners and communities (https://www.protectedplanet.net/en).

RESULTS

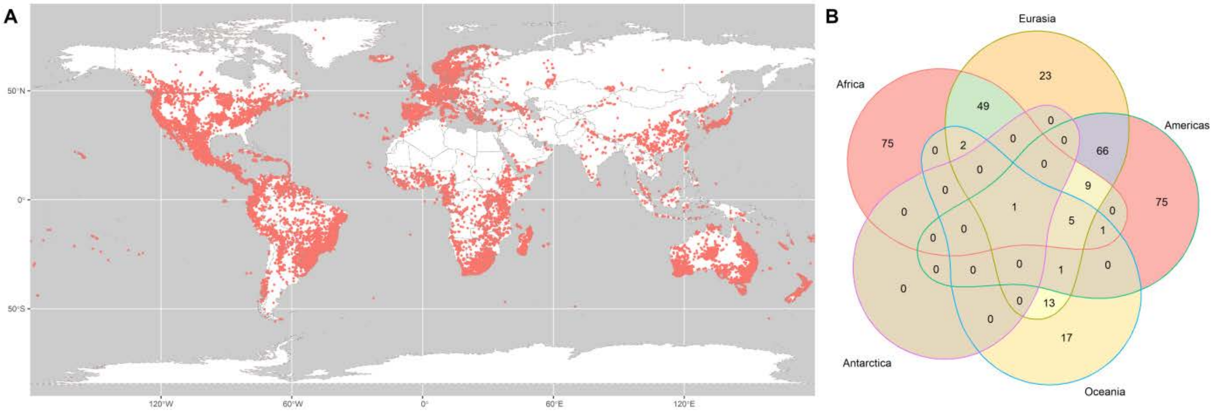
We found 1145 scientific studies (1115 from the keywords search and 30 additional studies), from which 337 DT plants (80 genera and 21 families) were reported. Pteridaceae was the most species-rich family (85 species) and exhibited the most species-rich genus (i.e., Cheilanthes, with 30 species). Conversely, we only found 1 species able to tolerate desiccation in 7 families and in 35 genera.



Appendix II, Figure 1. Species distribution among phylogenetic groups. A – species by botanical families - *Bromeliaceae, Cactaceae, Davalliaceae, Isoetaceae, Schizaeaceae, Tectariaceae, and Woodsiaceae, **Myrothamnaceae,***Dryopteridaceae; B – species by genera - *Acanthochlamys, Afrotrilepis, Argyrochosma, Arthropteris, Blossfeldia, Bommeria, Cardiomanes, Cosentinia, Ctenopteris, Damrongia, Davallia, Didymoglossum, Goniophlebium, Haberlea, Haplopteris, Hymenoglossum, Isoetes, Micrachne, Microdracoides, Microgramma, Mohria, Myriopteris, Negripteris, Onychium, Oreocharis, Paragymnopteris, Pecluma, Pentagramma, Pitcairnia, Platycerium, Pleurosorus, Polyphlebium, Schizaea, Styppeiochloa, Woodsia.

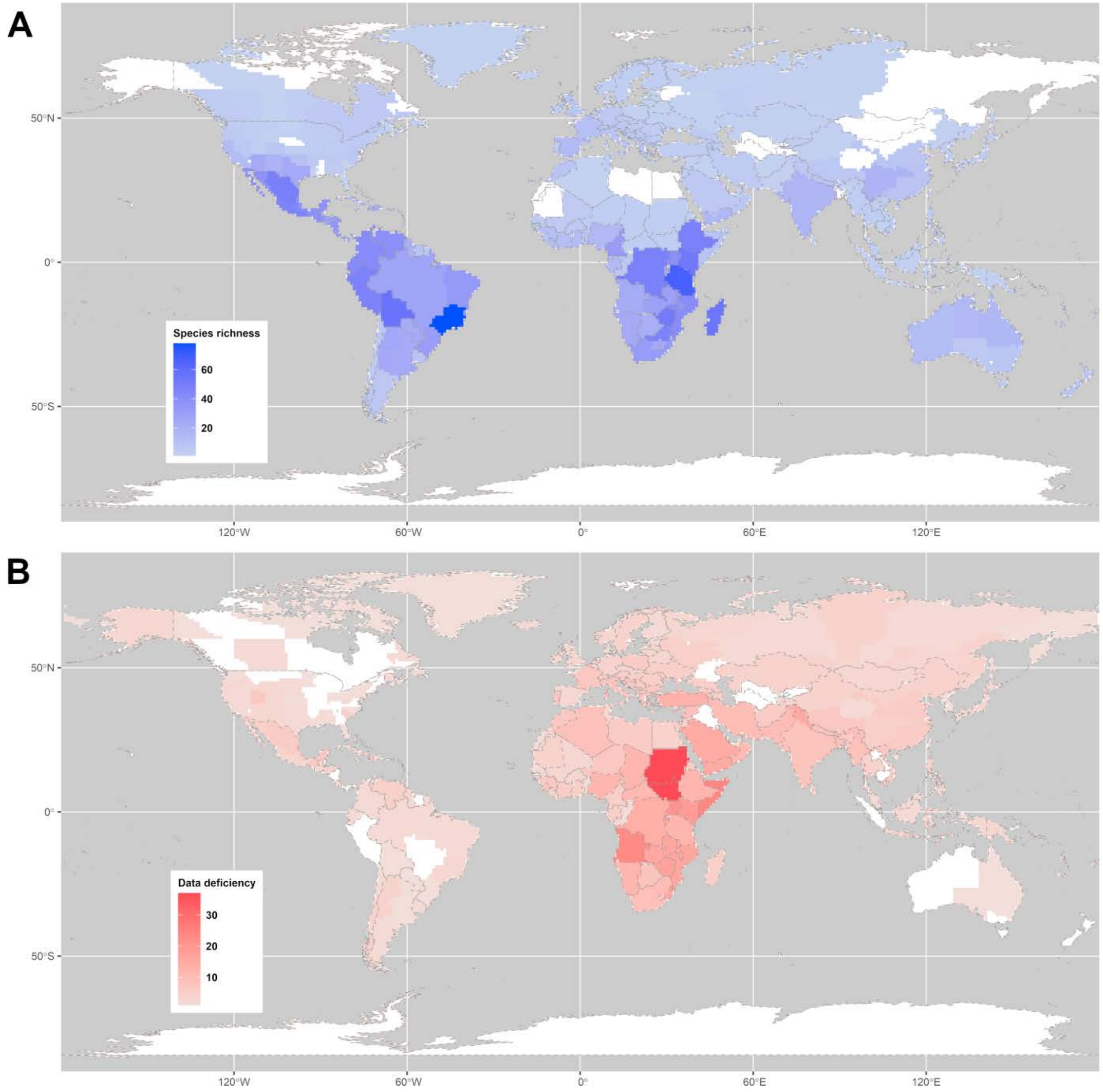
Geographical distribution

We assembled 97357 occurrence points for 336 DT plants, which were spread throughout all global continents. The Eurasia stood out as the continent in which the highest number of DT plants could be found (169 species) However, most of species found in Eurasia could also be found in the Americas and Africa, which gathered 158 and 142 species, respectively. Less rich species, Oceania counts with 40 species. Curiously, 1 species could be found in the Antarctica continent (i.e., *Hymenophyllum peltatum*, which can be found in the Kerguelen islands). No continent was completely isolated from others regarding the DT plants distribution, and only *Hymenophyllum peltatum* was found in all continents. A total of 190 species were found restricted to a single continent.



Appendix II, Figure 2. Desiccation-tolerant vascular plants distribution throughout the globe. A – occurrence points; B – species number by continents.

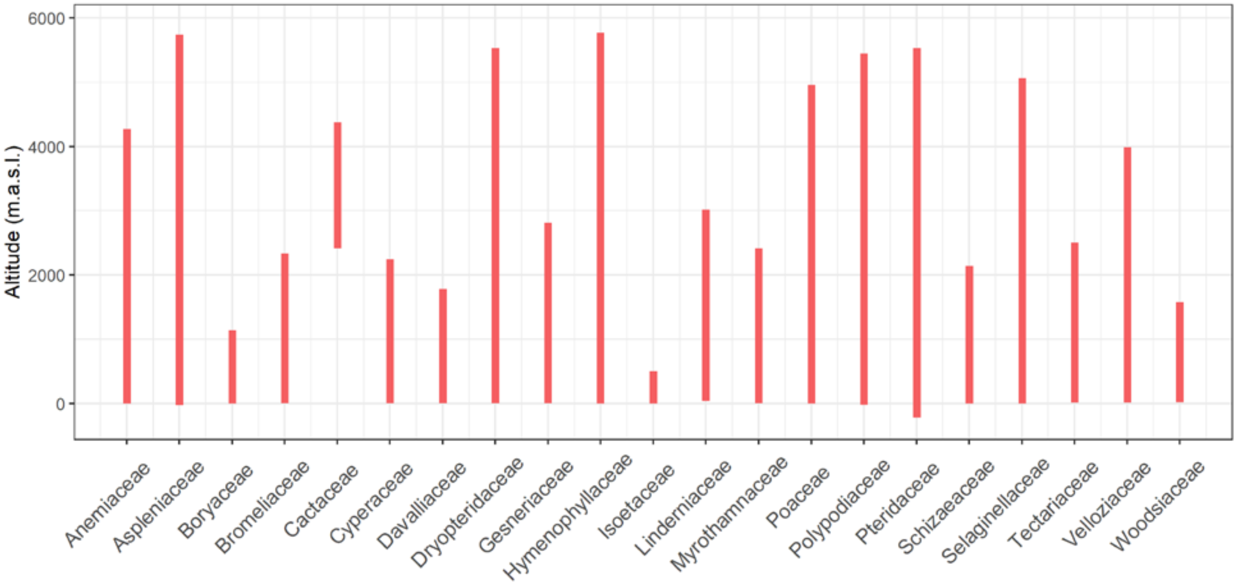
Locations in eastern regions of South America and Africa gathered the highest diversity of DT plants. The botanical families Velloziaceae and Poaceae were the botanical families that most contributed to make Southeast Brazil and Tanzania, respectively, as most species-rich world regions in relation to DTplants. The regions in the African continent were identified as with highest occurrence data deficiency. This was particularly special to Sudan and South Sudan, in which the occurrence data deficiency of species from the botanical families Pteridaceae and Poaceae most contributed to this pattern.



Appendix II, Figure 3. Desiccation-tolerant vascular plants distribution throughout the global regions. A – species number by global regions; B – occurrence data deficiency by global regions.

Regarding the DT plants distribution along an altitudinal gradient, we found species ranging from -216 m.a.s.l. (i.e., *Cheilanthes catanensis* and *Cosentinia vellea*) to 5761 m.a.s.l.

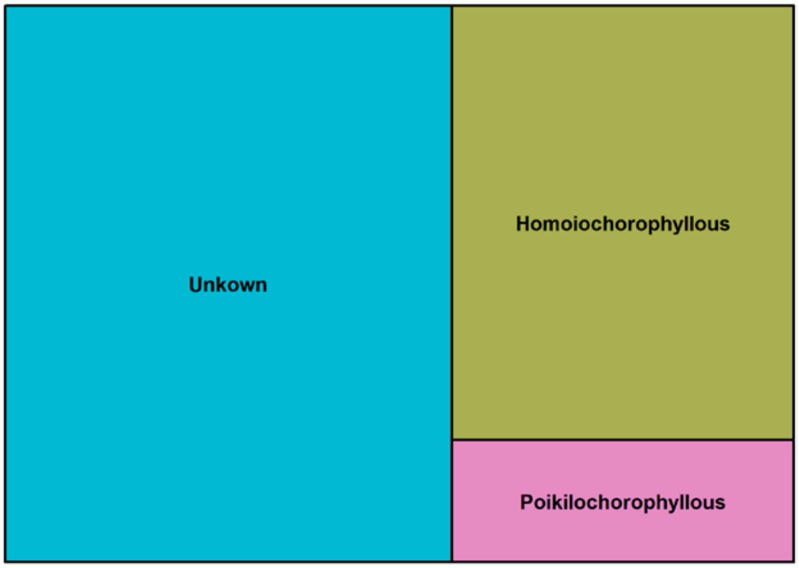
(*Hymenophyllum capillare*). In overall, families with many species seems to be represented in a broad altitudinal range. However, species of ferns and fern allies seem to be more wide distributed in elevation. Five families showed species occurring in altitudes above 5000 m.a.s.l., and they also were the families in which the broadest altitudinal range was registered among all families and all of them were ferns and Fern allies (i.e., Aspleniaceae, Dryopteridaceae, Hymenophyllaceae, Polypodiaceae, Selaginellaceae). However, the information gathered by GPS information must be confirmed, since in areas of great variability in altitude even the little accuracies might result in misleading inferences.



Appendix II, Figure 4. Desiccation-tolerant vascular plants distribution along an altitudinal gradient, grouped by botanical families.

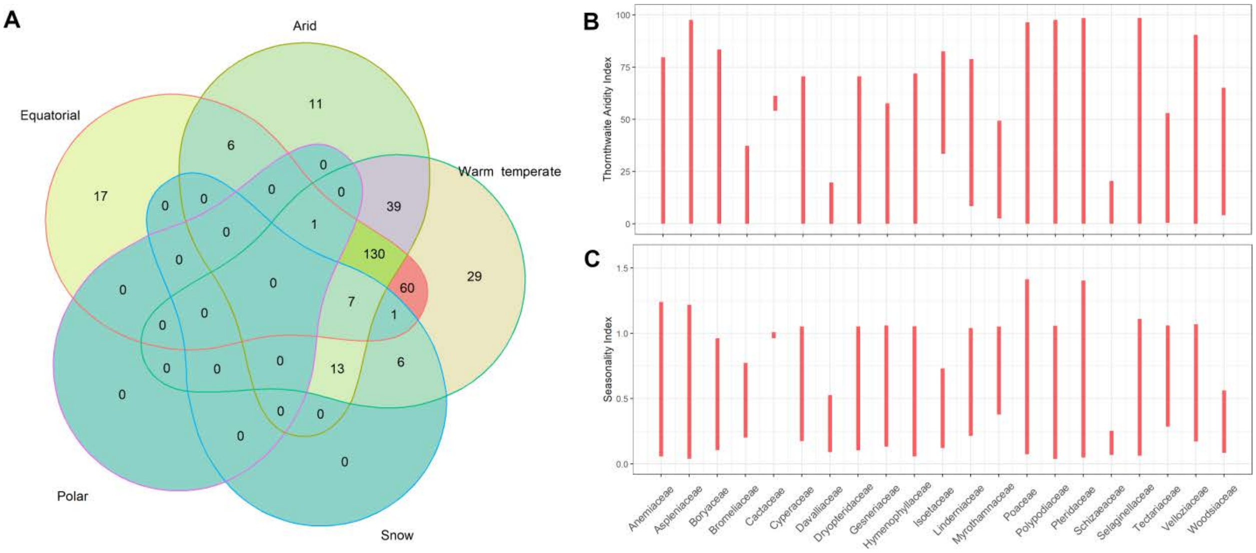
Ecological aspects of DT plants

Although many studies point out directions in relation to the distribution of the homoiochlorophyllous and poikilochlorophyllous responses among DT plants (Oliver et al., 2000; Marks et al., 2021; Porembski, 2021), most of DT plants still do not have their main desiccation tolerance mechanism described by scientific studies. This evidences the need for more studies that could test the desiccation tolerance mechanism of those species.



Appendix II, Figure 5. Desiccation-tolerant vascular plants distribution throughout the globe. A – occurrence points; B – species number

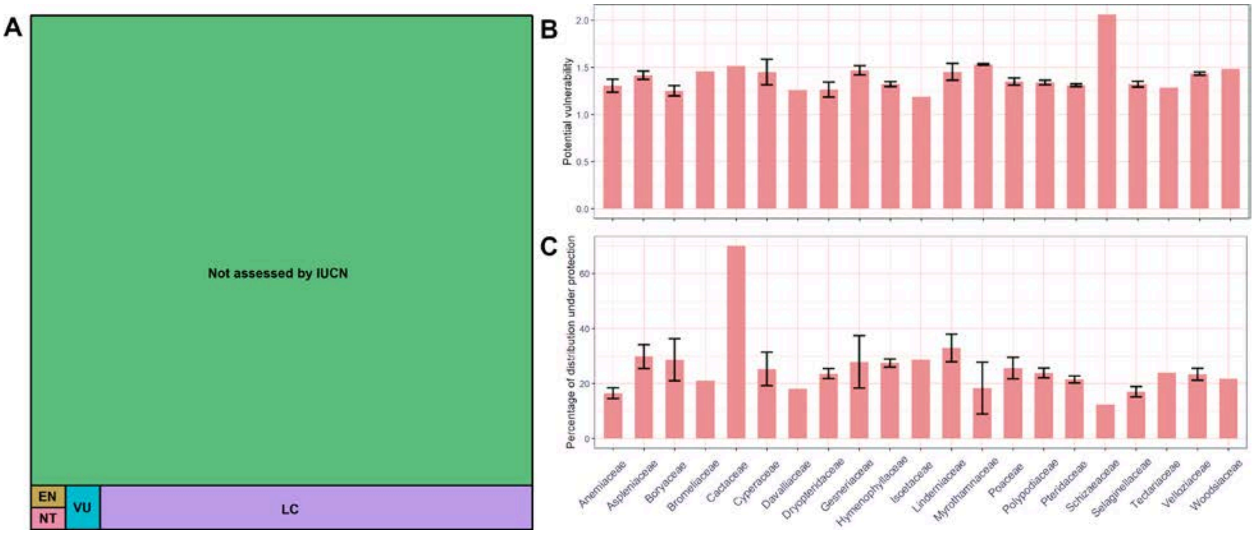
In relation to climate, the great majority of DT plants were found growing in more than one climate type. In special, many DT plants could either be found in equatorial, arid, and warm temperate climates, or both equatorial and warm temperate climates. The occurrence of DT plants is not common in snow and polar climates and no species was found restricted to those climate types. The fact that few DT plants were restricted to Arid climates is in concordance with the fact that many species have a broad distribution in relation to drought conditions and precipitation seasonality. This is special to Pteridaceae and Poaceae species, which can be found ranging from no or little to large water deficiency, besides occurring from locations in which precipitation is spread throughout the year to sites in which precipitation is extremely seasonal. That could be depicted by the DT plants Cheilanthes bonariensis (Pteridaceae) and Tripogonella spicata (Poaceae) which scored the highest ranges of AI and SI within their distribution, respectively.



Appendix II, Figure 6. Desiccation-tolerant vascular plants diversity in relation to climatic conditions. A – Species distribution in relation to Köppen-Geiger climate classification; B – species distribution along drought conditions, grouped by botanical families; C – species distribution along precipitation seasonality, grouped by botanical families.

Conservation aspects of DT plants

The SDMs were performed for 316 species, and 20 species had less than 5 valid occurrences, so the Ca_{50} was used to assess their distribution maps. Only one species was left out because no valid occurrence could be found (*Tripogon polyanthus*). For 336 species, we could no find specific phylogenetic group of plants that had a higher potential vulnerability among DT plants. For instance, *Coleochloa pallidior* (Cyperaceae), *Craterostigma pumilum* (Linderniaceae), *Micraira spinifera* (Poaceae), and *Schizaea pusilla* (Schizaeaceae) registered the highest potential vulnerability among DT plants. This is particularly critical, when considering that most of DT plants has not been yet assessed by conservation organizations such IUCN and have the most part of their distribution not protected by conservation efforts. At least 6 species have none of their distribution under protection (i.e., *Sporobolus ruspolianus*, *Tripogon capillatus*, *Tripogon jacquemontii*, *Tripogon lisboae*, *Allosorus coriaceus*, and *Notholaena dipinnata*), and none of them have been yet assessed by IUCN. This reinforce the need for conservation of DT plants.



Appendix II, Figure 7. Conservation aspects of desiccation-tolerant vascular plants. A – species classification in relation to IUCN Red list of threatened species; B – species potential vulnerability to climate change, grouped by botanical families; C – percentage of species distribution within protected areas, grouped by botanical families.

Appendix II, Table 1. Checklist of DT plants of the world

ANEMIACEAE

Anemia ferruginea Kunth
Anemia flexuosa (Savigny) Sw.
Anemia mexicana Klotzsch
Anemia rotundifolia Schrad.
Anemia tomentosa (Savigny) Sw.
Anemia villosa Humb. & Bonpl. ex Willd.
Mohria caffrorum (L.) Desv.

ASPLENIACEAE

Asplenium adiantum-nigrum L.
Asplenium aethiopicum (Burm. f.) Bech.
Asplenium ceterach L.
Asplenium cordatum (Thunb.) Sw.
Asplenium dalhousiae Hook.
Asplenium friesiorum C. Chr.
Asplenium megalura Hieron.
Asplenium monanthes L.
Asplenium obovatum Viv.
Asplenium praegracile Rosenst.
Asplenium pringlei Davenp.
Asplenium ruta-muraria L.
Asplenium rutifolium (P.J. Bergius) Kunze
Asplenium sandersonii Hook.
Asplenium septentrionale (L.) Hoffm.
Asplenium theciferum (Kunth) Mett.
Asplenium trichomanes L.
Asplenium uhligii Hieron.
Pleurosorus rutifolius Fée

BORYACEAE

Borya constricta Churchill
Borya inopinata P.I. Forst. & E.J. Thomps.
Borya mirabilis Churchill
Borya nitida Labill.
Borya scirpoidea Lindl.
Borya septentrionalis F. Muell.
Borya sphaerocephala R. Br.

BROMELIACEAE

Pitcairnia lanuginosa Ruiz & Pav.

CACTACEAE

Blossfeldia liliputana Werderm.

CYPERACEAE

Afrotrilepis pilosa (Boeckeler) J. Raynal
Coleochloa abyssinica (Hochst. ex A. Rich.) Gilly
Coleochloa microcephala Nelmes
Coleochloa pallidior Nelmes
Coleochloa setifera (Ridl.) Gilly
Microdracoides squamosus Hua

Appendix II, Table 1. (continued)

Trilepis ciliatifolia T. Koyama
Trilepis lhotzkiana Nees ex Arn.
Trilepis microstachya (C.B. Clarke) H. Pfeiff.
Davallia angustata Wall. ex Hook. & Grev.

DRYOPTERIDACEAE

Elaphoglossum acrostichoides (Hook. & Grev.) Schelpe
Elaphoglossum petiolatum (Sw.) Urb.
Elaphoglossum piloselloides (C. Presl) T. Moore

GESNERIACEAE

Boea hygrometrica (Bunge) R. Br.
Boea hygroscopica F. Muell.
Damrongia clarkeana (Hemsl.) C. Puglisi
Haberlea rhodopensis Friv.
Oreocharis mileensis (W.T. Wang) Mich. Möller & A. Weber
Paraboea crassifolia (Hemsl.) B.L. Burtt
Paraboea rufescens (Franch.) B.L. Burtt
Ramonda myconi (L.) Rchb.
Ramonda nathaliae Pančić & Petrovič
Ramonda serbica Pančić

HYMENOPHYLLACEAE

Cardiomanes reniforme (G. Forst.) C. Presl
Crepidomanes chevalieri (Christ) Ebihara & Dubuisson
Crepidomanes frappieri (Cordem.) J.P. Roux
Crepidomanes inopinatum (Pic. Serm.) J.P. Roux
Crepidomanes melanotrichum (Schltdl.) J.P. Roux
Didymoglossum erosum (Willd.) J.P. Roux
Hymenoglossum cruentum (Cav.) C. Presl
Hymenophyllum capillare Desv.
Hymenophyllum caudiculatum Mart.
Hymenophyllum dentatum Cav.
Hymenophyllum fucoides (Sw.) Sw.
Hymenophyllum hirsutum (L.) Sw.
Hymenophyllum kuhnii C. Chr.
Hymenophyllum peltatum (Poir.) Desv.
Hymenophyllum plicatum Kaulf.
Hymenophyllum polyanthos (Sw.) Sw.
Hymenophyllum sanguinolentum (G. Forst.) Sw.
Hymenophyllum splendidum Bosch
Hymenophyllum tunbrigense (L.) Sm.
Polyphlebium borbonicum (Bosch) Ebihara & Dubuisson
Trichomanes bucinatum Mickel & Beitel
Trichomanes capillaceum L.
Trichomanes diaphanum Kunth
Trichomanes polypodioides L.
Trichomanes pyxidiferum L.
Trichomanes radicans Sw.
Trichomanes rigidum Sw.

Appendix II, Table 1. (continued)

ISOETACEAE
Isoetes australis R.O. Williams
LINDERNIACEAE
Craterostigma hirsutum S. Moore
Craterostigma lanceolatum (Engl.) Skan
Craterostigma plantagineum Hochst.
Craterostigma pumilum Hochst.
Craterostigma wilmsii Engl. ex Diels
Lindernia brevidens Skan
Lindernia intrepidus (Dinter) Oberm.
Lindernia monroi (S. Moore) Eb. Fisch.
Lindernia purpurea (Lebrun & Touss.) R. Germ.
Linderniella pulchella (Skan) Eb. Fisch., Schäferh. & Kai Müll.
Linderniella wilmsii (Engl. ex Diels) Eb. Fisch., Schäferh. & Kai Müll.
MYROTHAMNACEAE
Myrothamnus flabellifolius Welw.
Myrothamnus moschatus (Baill.) Baill. ex Nied.
POACEAE
Eragrostiella bifaria (Vahl) Bor
Eragrostiella brachyphylla (Stapf) Bor
Eragrostiella nardoides (Trin.) Bor
Eragrostis nindensis Ficalho & Hiern
Eragrostis paradoxa Launert
Micrachne patentiflora (Stent & J.M. Rattray) P.M. Peterson
Micraira adamsii Lazarides
Micraira lazaridis L.G. Clark, Wendel & Craven
Micraira multinervia Lazarides
Micraira spinifera Lazarides
Micraira subulifolia F. Muell.
Micraira tenuis Lazarides
Micraira viscidula Lazarides
Microchloa caffra Nees
Microchloa indica (L. f.) P. Beauv.
Microchloa kunthii Desv.
Oropetium aristatum (Stapf) Pilg.
Oropetium capense Stapf
Oropetium roxburghianum S.M. Phillips
Oropetium thomaeum (L. f.) Trin.
Sporobolus atrovirens (Kunth) Kunth
Sporobolus elongatus R. Br.
Sporobolus festivus Hochst. ex A. Rich.
Sporobolus fimbriatus (Trin.) Nees
Sporobolus pellucidus Hochst.
Sporobolus ruspolianus Chiov.
Sporobolus stapfianus Gand.
Styppeiochloa hitchcockii (A. Camus) Cope
Tripogon capillatus Jaub. & Spach
Tripogon curvatus S.M. Phillips & Launert

Appendix II, Table 1. (continued)

- *Tripogon filiformis* Nees
- *Tripogon jacquemontii* Stapf
- *Tripogon lisboae* Stapf
- *Tripogon major* Hook. f.
- *Tripogon polyanthus* Naik & Patunkar
- *Tripogon curvatus* (F. Muell.) P.M. Peterson & Romasch.
- *Tripogonella minima* (A. Rich.) P.M. Peterson & Romasch.
- *Tripogonella spicata* (Nees) P.M. Peterson & Romasch.

POLYPODIACEAE

- *Ctenopteris heterophylla* Tindale
- *Goniophlebium furfuraceum* (Schltdl. & Cham.) T. Moore
- *Loxogramme abyssinica* (Baker) M.G. Price
- *Loxogramme lanceolata* (Sw.) C. Presl
- *Melpomene flabelliformis* (Poir.) A.R. Sm. & R.C. Moran
- *Melpomene peruviana* (Desv.) A.R. Sm. & R.C. Moran
- *Microgramma piloselloides* (L.) Copel.
- *Pecluma eurybasis* (C. Chr.) M.G. Price
- *Platycerium stemaria* (P. Beauv.) Desv.
- *Pleopeltis angusta* Humb. & Bonpl. ex Willd.
- *Pleopeltis crassinervata* (Fée) T. Moore
- *Pleopeltis hirsutissima* (Raddi) de la Sota
- *Pleopeltis macrocarpa* (Bory ex Willd.) Kaulf.
- *Pleopeltis mexicana* (Fée) Mickel & Beitel
- *Pleopeltis minima* (Bory) J. Prado & R.Y. Hirai
- *Pleopeltis plebeia* (Schltdl. & Cham.) A.R. Sm. & Tejero
- *Pleopeltis pleopeltifolia* (Raddi) Alston
- *Pleopeltis polypodioides* (L.) E.G. Andrews & Windham
- *Polypodium cambricum* L.
- *Polypodium interjectum* Shivas
- *Polypodium remotum* Desv.
- *Polypodium virginianum* L.
- *Polypodium vulgare* L.

PTERIDACEAE

- *Actiniopteris australis* (L. f.) Link
- *Actiniopteris dimorpha* Pic. Serm.
- *Actiniopteris radiata* (Sw.) Link
- *Actiniopteris semiflabellata* Pic. Serm.
- *Adiantum hispidulum* Sw.
- *Adiantum incisum* Forssk.
- *Adiantum latifolium* Lam.
- *Adiantum raddianum* C. Presl
- *Aleuritopteris albomarginata* (C.B. Clarke) Ching
- *Aleuritopteris farinosa* (Forssk.) Fée
- *Allosorus coriaceus* (Decne.) Christenh.
- *Allosorus pteridioides* (Reichard) Christenh.
- *Argyrochosma fendleri* (Kunze) Windham
- *Astrolepis cochisensis* (Goodd.) D.M. Benham & Windham
- *Astrolepis integerrima* (Hook.) D.M. Benham & Windham

Appendix II, Table 1. (continued)

Astrolepis sinuata (Lag. ex Sw.) D.M. Benham & Windham
Bommeria hispida (Mett. ex Kuhn) Underw.
Cheilanthes bonariensis (Willd.) Proctor
Cheilanthes buchtienii (Rosenst.) R.M. Tryon
Cheilanthes capensis (Thunb.) Sw.
Cheilanthes catanensis (Cosent.) H.P. Fuchs
Cheilanthes depauperata Baker
Cheilanthes dinteri Brause
Cheilanthes distans (R. Br.) Mett.
Cheilanthes eckloniana Mett.
Cheilanthes fragillima F. Muell.
Cheilanthes glauca (Cav.) Mett.
Cheilanthes gracillima D.C. Eaton
Cheilanthes hirta Sw.
Cheilanthes inaequalis (Kunze) Mett.
Cheilanthes lasiophylla Pic. Serm.
Cheilanthes lendigera (Cav.) Sw.
Cheilanthes marginata Kunth
Cheilanthes marlothii (Hieron.) Domin
Cheilanthes multifida (Sw.) Sw.
Cheilanthes myriophylla Desv.
Cheilanthes nitidula Wall. ex Hook.
Cheilanthes notholaenoides (Desv.) Maxon ex Weath.
Cheilanthes parryi (D.C. Eaton) Domin
Cheilanthes parviloba Sw.
Cheilanthes pringlei Davenp.
Cheilanthes quadripinnata (Forssk.) Kuhn
Cheilanthes sieberi Kunze
Cheilanthes tenuifolia (Burm. f.) Sw.
Cheilanthes tomentosa Link
Cheilanthes viridis (Forssk.) Sw.
Cheilanthes wrightii Hook.
Cosentinia vellea (Aiton) Tod.
Doryopteris collina (Raddi) J. Sm.
Doryopteris concolor (Langsd. & Fisch.) Kuhn
Doryopteris kitchingii (Baker) Bonap.
Doryopteris pedata (L.) Fée
Doryopteris triphylla (Lam.) Christ
Doryopteris varians (Raddi) Sm.
Haplopteris volkensii (Hieron.) E.H. Crane
Hemionitis palmata L.
Hemionitis tomentosa (Lam.) Raddi
Myriopteris rufa Fée
Negripteris scioana (Chiov.) Pic. Serm.
Notholaena dipinnata Fraser-Jenk.
Notholaena lanuginosa Desv. ex Poir.
Notholaena muelleri (Hook.) Fraser-Jenk.
Onychium divaricatum (Poir.) Alston

Appendix II, Table 1. (continued)

Paragymnopteris marantae (L.) K.H. Shing
Pellaea andromedifolia (Kaulf.) Fée
Pellaea atropurpurea (L.) Link
Pellaea boivinii Hook.
Pellaea brachyptera (T. Moore) Baker
Pellaea bridgesii Hook.
Pellaea calomelanos (Sw.) Link
Pellaea dura (Willd.) Hook.
Pellaea falcata Fée
Pellaea glabella Mett. ex Kuhn
Pellaea longipilosa Bonap.
Pellaea mucronata (D.C. Eaton) D.C. Eaton
Pellaea ovata (Desv.) Weath.
Pellaea pectiniformis Baker
Pellaea rotundifolia (G. Forst.) Hook.
Pellaea sagittata (Cav.) Link
Pellaea ternifolia (Cav.) Link
Pellaea truncata Goodd.
Pellaea wrightiana Hook.
Pentagramma triangularis (Kaulf.) Yatsk., Windham & E. Wollenw.
Vittaria guineensis Desv.
Vittaria isoetifolia Bory

SCHIZAEACEAE

Schizaea pusilla Pursh

SELAGINELLACEAE

Selaginella arizonica Maxon
Selaginella bryopteris Baker
Selaginella caffrorum (Milde) Hieron.
Selaginella convoluta (Arn.) Spring
Selaginella densa Rydb.
Selaginella digitata Spring
Selaginella dregei (C. Presl) Hieron.
Selaginella echinata Baker
Selaginella eremophila Maxon
Selaginella helicoclada Alston
Selaginella helvetica (L.) Spring
Selaginella imbricata (Forssk.) Spring ex Decne.
Selaginella lepidophylla (Hook. & Grev.) Spring
Selaginella nivea Alston
Selaginella njamnjamensis Hieron.
Selaginella peruviana (Milde) Hieron.
Selaginella phillipsiana (Hieron.) Alston
Selaginella pilifera A. Braun
Selaginella rupincola Underw.
Selaginella sartorii Hieron.
Selaginella sellowii Hieron.
Selaginella tamariscina (P. Beauv.) Spring
Selaginella trisulcata Aspl.

Appendix II, Table 1. (continued)

Selaginella yemensis (Sw.) Spring

TECTARIACEAE

Arthropteris orientalis (J.F. Gmel.) Posth.

VELLOZIACEAE

Acanthochlamys bracteata P.C. Kao
Barbacenia blackii L.B. Sm.
Barbacenia fanniae (N.L. Menezes) Mello-Silva
Barbacenia flava Mart. ex Schult. f.
Barbacenia fragrans Goethart & Henrard
Barbacenia gentianoides Goethart & Henrard
Barbacenia gounelleana Beauverd
Barbacenia graminifolia L.B. Sm.
Barbacenia longiflora Mart.
Barbacenia longiscapa Goethart & Henrard
Barbacenia macrantha Lem.
Barbacenia purpurea Hook.
Barbacenia riedeliana Goethart & Henrard
Barbacenia seubertiana Goethart & Henrard
Barbacenia spectabilis L.B. Sm. & Ayensu
Barbacenia tomentosa Mart.
Barbaceniopsis boliviensis (Baker) L.B. Sm.
Barbaceniopsis humahuaquensis Noher
Vellozia albiflora Pohl
Vellozia andina Ibisch, R. Vásquez & Nowicki
Vellozia angustifolia Goethart & Henrard
Vellozia candida J.C. Mikan
Vellozia caput-ardeae L.B. Sm. & Ayensu
Vellozia caruncularis Mart. ex Seub.
Vellozia ciliata L.B. Sm.
Vellozia compacta Mart. ex Schult. f.
Vellozia declinans Goethart & Henrard
Vellozia epidendroides Mart. ex Schult. f.
Vellozia flavicans Mart. ex Schult. f.
Vellozia glochidea Pohl
Vellozia hatschbachii L.B. Sm. & Ayensu
Vellozia hirsuta Goethart & Henrard
Vellozia nanuzae L.B. Sm. & Ayensu
Vellozia nivea L.B. Sm. & Ayensu
Vellozia plicata Mart.
Vellozia pulchra L.B. Sm.
Vellozia resinosa Mart. ex Schult. f.
Vellozia sellowii Seub.
Vellozia semirii Mello-Silva & N.L. Menezes
Vellozia squalida Mart. ex Schult. f.
Vellozia streptophylla L.B. Sm.
Vellozia subscabra J.C. Mikan
Vellozia taxifolia (Mart. ex Schult. f.) Mart. ex Seub.
Vellozia tubiflora (A. Rich.) Kunth

Appendix II, Table 1. (continued)

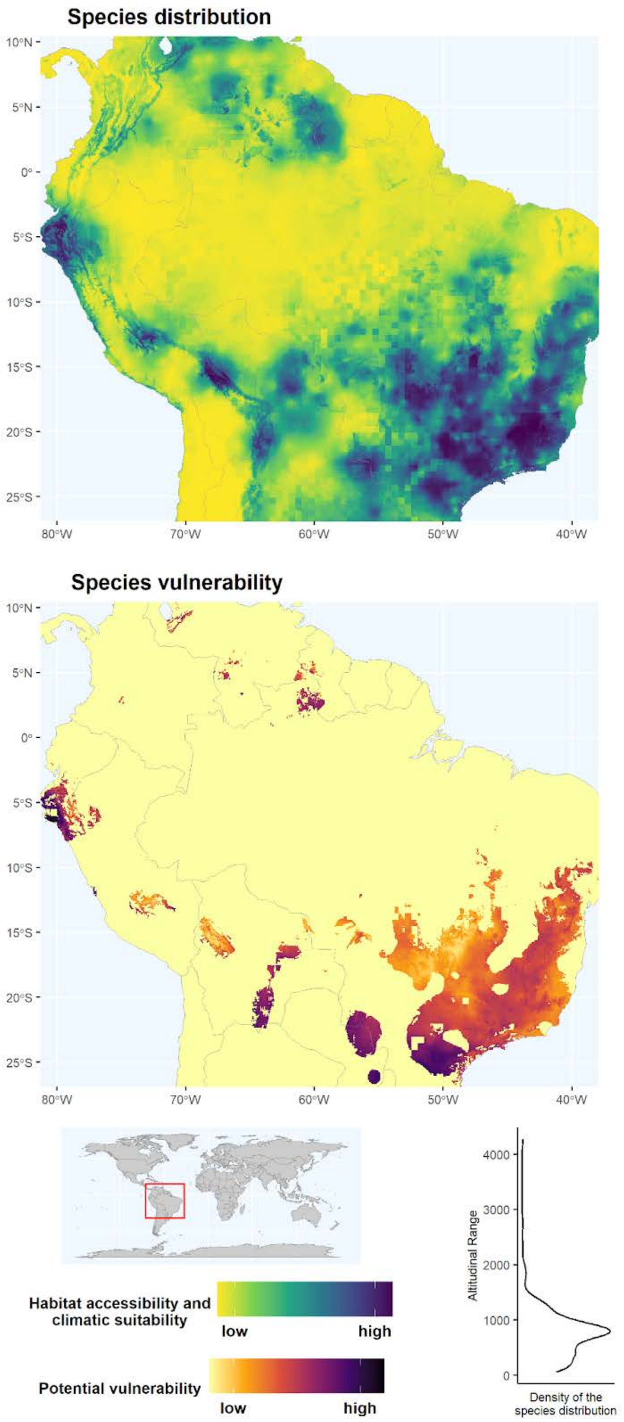
Vellozia variabilis Mart. ex Schult. f.
Vellozia variegata Goethart & Henrard
Vellozia verruculosa Mart. ex Schult. f.
Xerophyta dasylirioides Baker
Xerophyta eglandulosa H. Perrier
Xerophyta elegans (Balf.) Baker
Xerophyta equisetoides Baker
Xerophyta humilis (Baker) T. Durand & Schinz
Xerophyta nandrasanae Phillipson & Lowry
Xerophyta pectinata Baker
Xerophyta pinifolia Lam.
Xerophyta retinervis Baker
Xerophyta rippsteinii L.B. Sm., J.-P. Lebrun & Stork
Xerophyta scabrida (Pax) T. Durand & Schinz
Xerophyta schlechteri (Baker) N.L. Menezes
Xerophyta schnizleinia (L.B. Sm. & Ayensu) Baker
Xerophyta spekei Baker
Xerophyta splendens (Rendle) N.L. Menezes
Xerophyta squarrosa Baker
Xerophyta villosa (Baker) L.B. Sm. & Ayensu
Xerophyta viscosa Baker

WOODSIACEAE

Woodsia ilvensis (L.) R. Br.

Detailed information about DT plants of the world

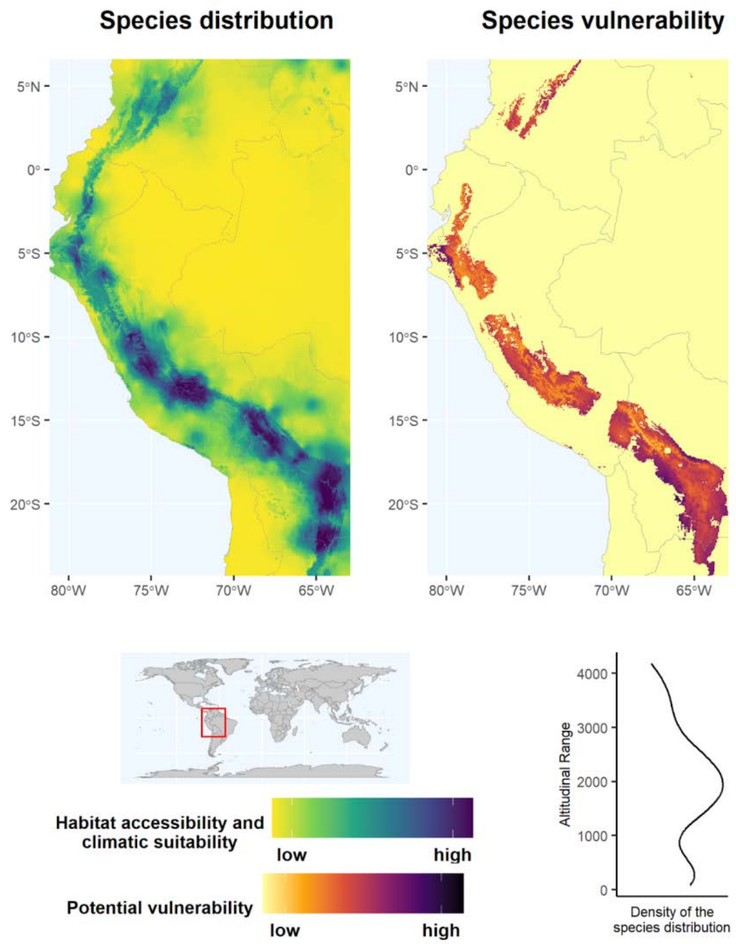
Anemiaceae



Anemia ferruginea Kunth

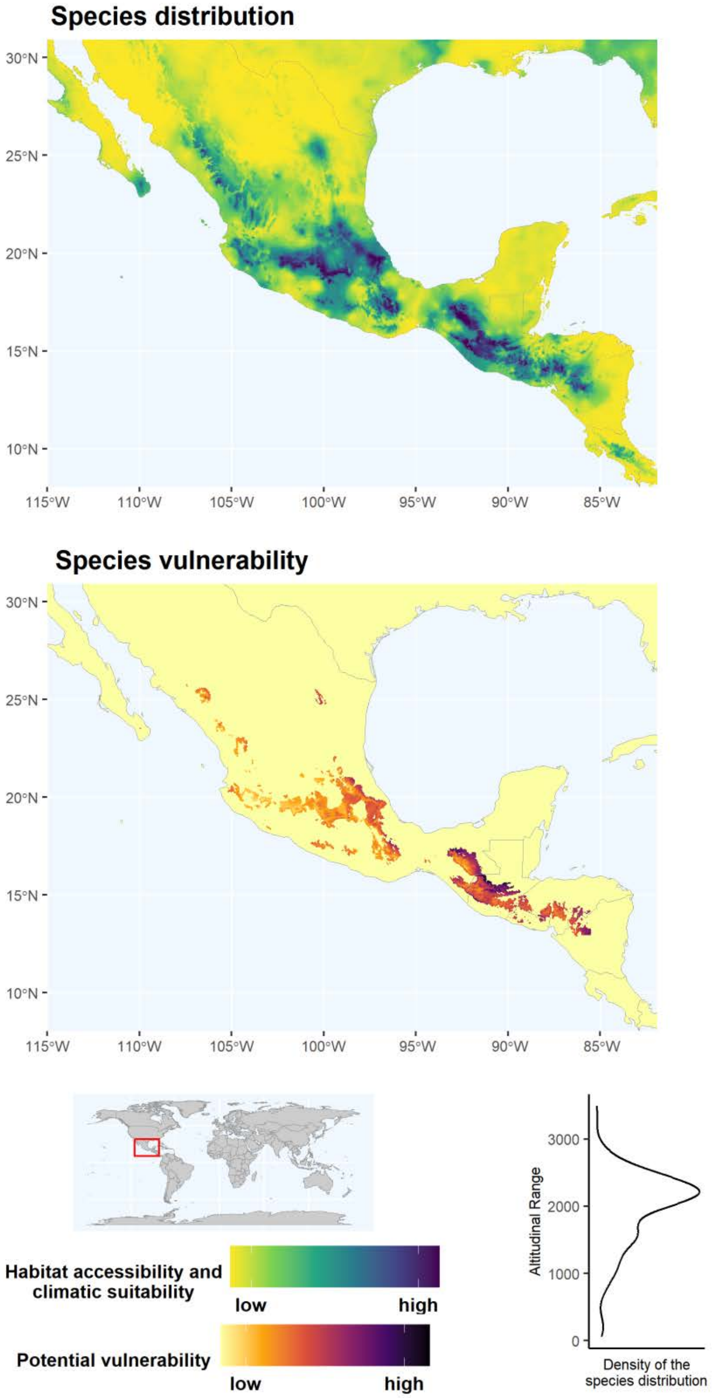
A. ferruginea is a homoiochlorophyllous plant whose distribution comprises Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Ecuador, Guyana, Honduras, Paraguay, Peru, Venezuela. *A. ferruginea* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 60 to 4273 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. ferruginea* populations are expected to be potentially more vulnerable to climate change in parts of North eastern parts of Bolivia, southern and central-western parts of Brazil, Ecuador, and Paraguay, besides locations in Argentina, Colombia, Peru, and Venezuela. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

Anemia flexuosa (Savigny) Sw.



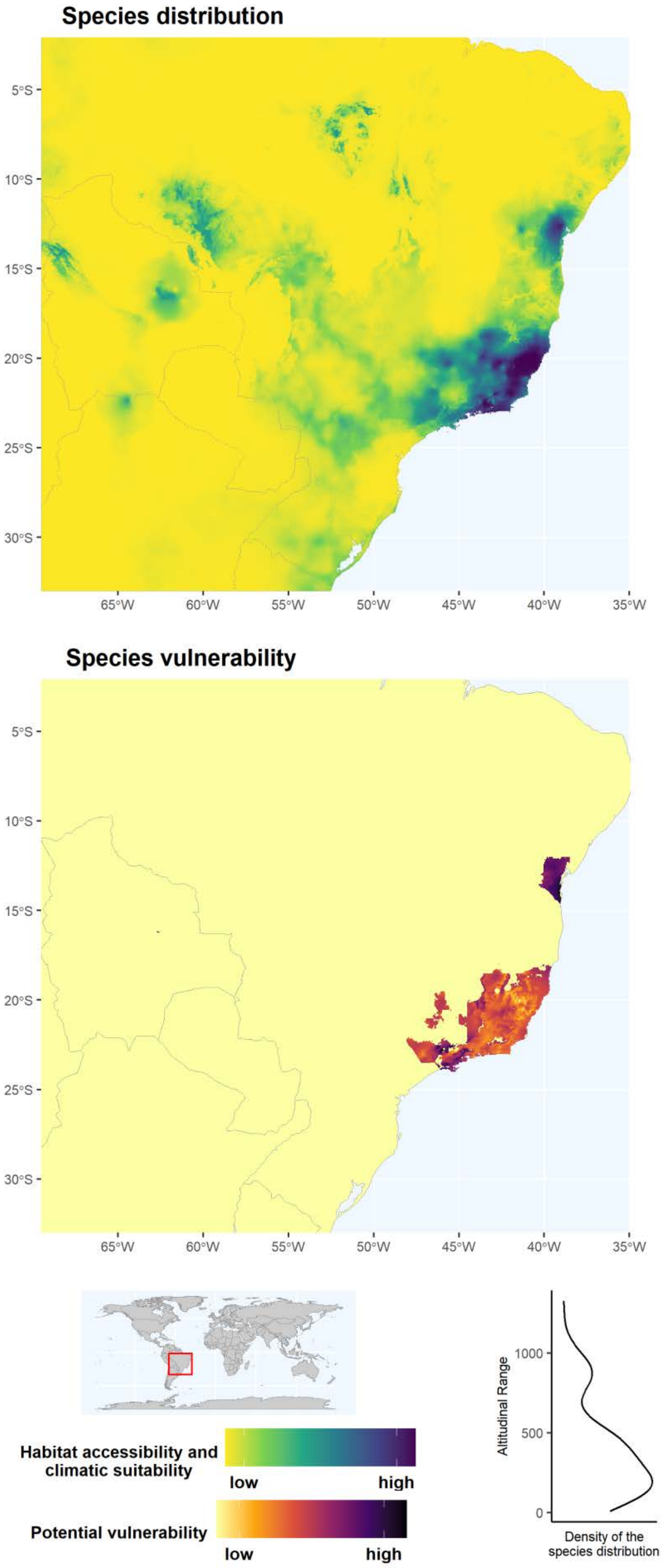
A. flexuosa is a plant whose distribution comprises Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Colombia, Ecuador, Peru, Suriname, Venezuela. *A. flexuosa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 84 to 4185 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to precipitation is extremely seasonal. *A. flexuosa* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Colombia, and Peru. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Anemia mexicana Klotzsch



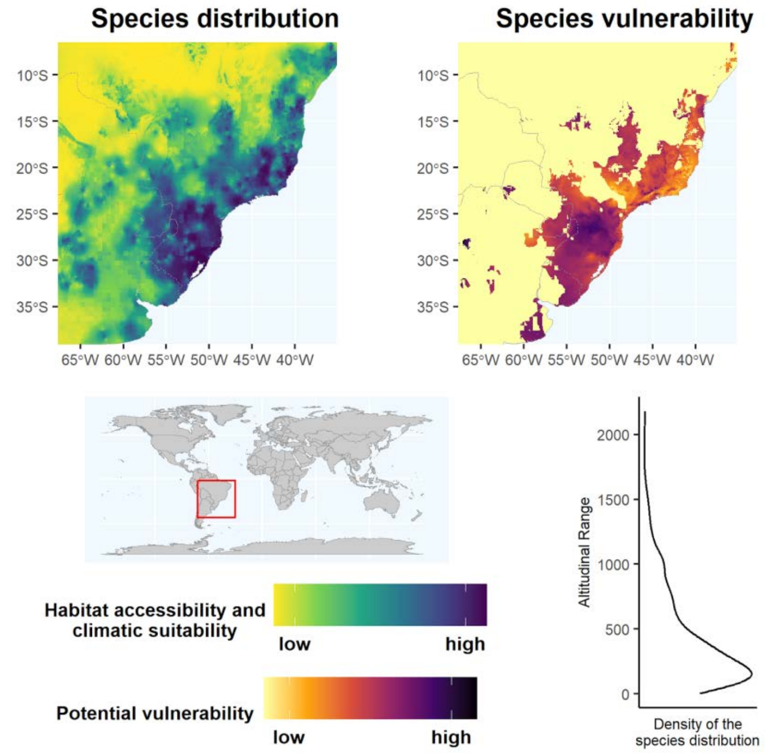
A. mexicana is a plant whose distribution comprises Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southwest, Texas. *A. mexicana* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 35 to 2193 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. mexicana* populations are expected to be potentially more vulnerable to climate change in parts of the pacific coast of Mexico. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

Anemia rotundifolia Schrad.



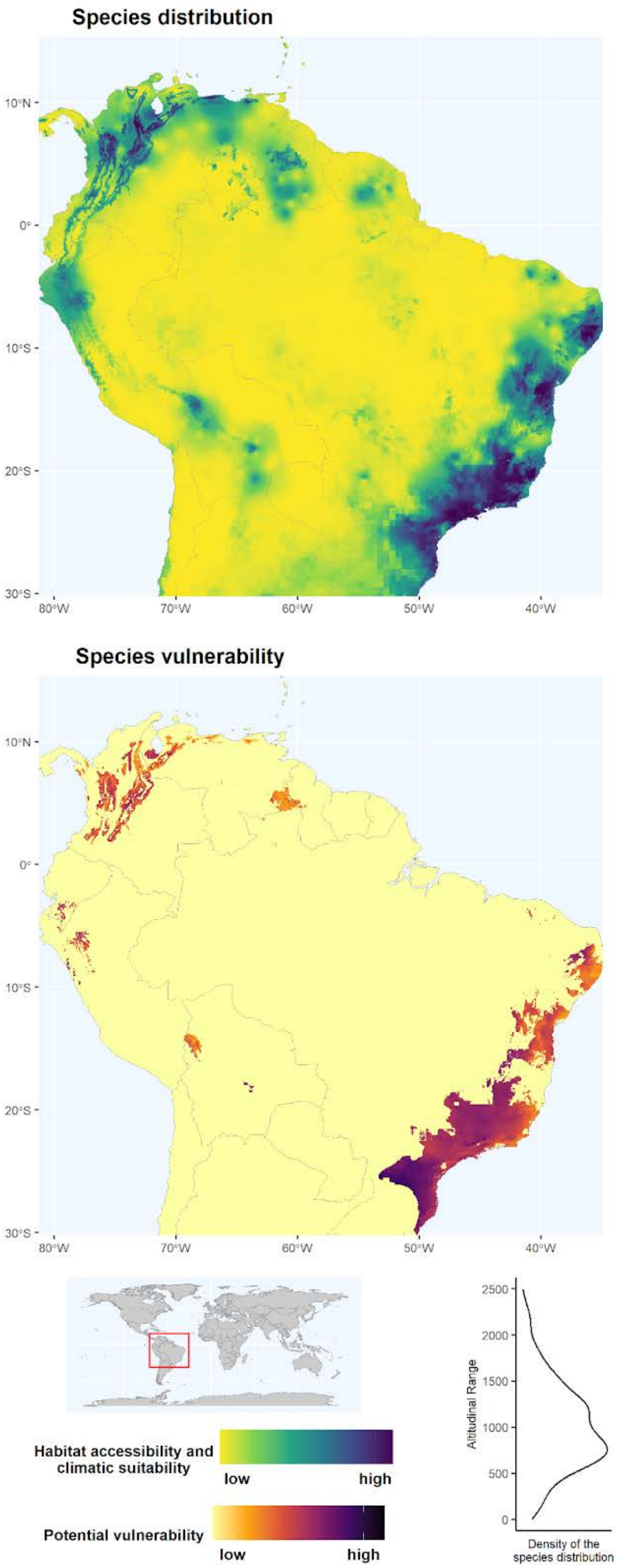
A. rotundifolia is a plant whose distribution comprises Bolivia, Brazil Northeast, Brazil Southeast. *A. rotundifolia* individuals can be primarily found inequatorial, arid, and warm temperate climates, ranging from 8 to 1328 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *A. rotundifolia* populations are expected to be potentially more vulnerable to climate change in parts of its small location in Bolivia and northeastern parts of Brazil. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Anemia tomentosa (Savigny) Sw.



A. tomentosa is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Argentina South, Brazil Northeast, Brazil South, Brazil Southeast, Paraguay, Uruguay, Venezuela. *A. tomentosa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 2181 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. tomentosa* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Brazil, and Paraguay. This species has not yet been assessed by IUCN, and only 11% of its distribution range is currently found within protected areas.

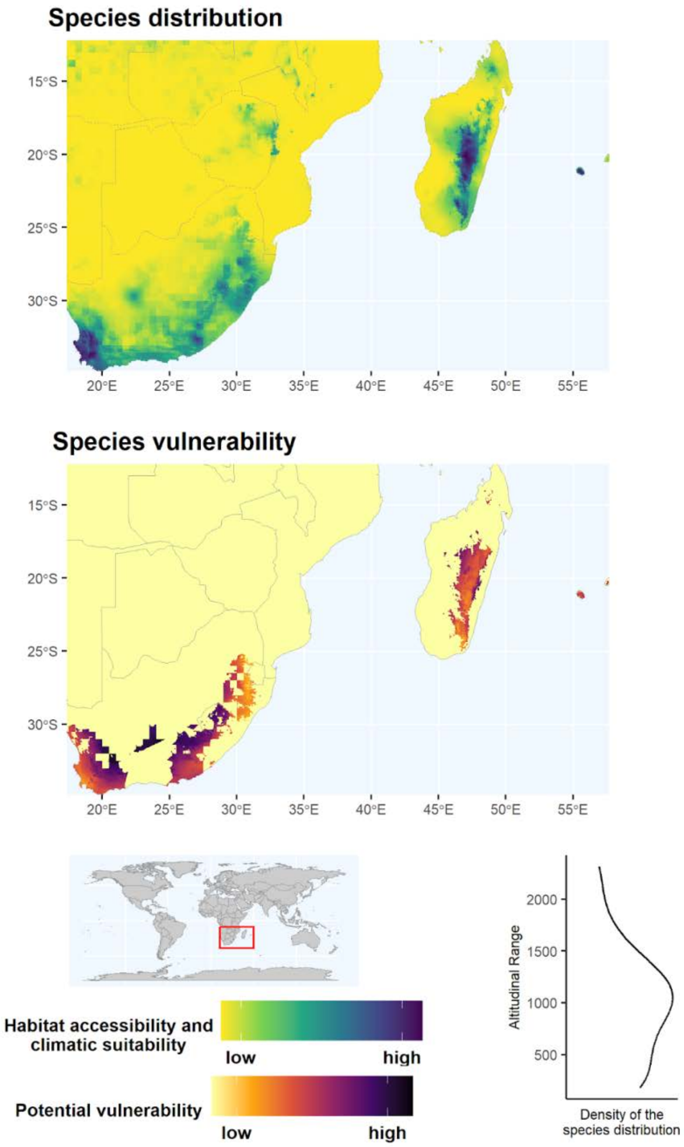
Anemia villosa Humb. & Bonpl. ex Willd.



A. villosa is a plant whose distribution comprises Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela. *A. villosa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 6 to 2494 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. villosa* populations are expected to be potentially more vulnerable to climate change in parts of southern Brazil, besides parts of Bolivia, Colombia, Peru, and Venezuela. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Mohria caffrorum (L.) Desv.

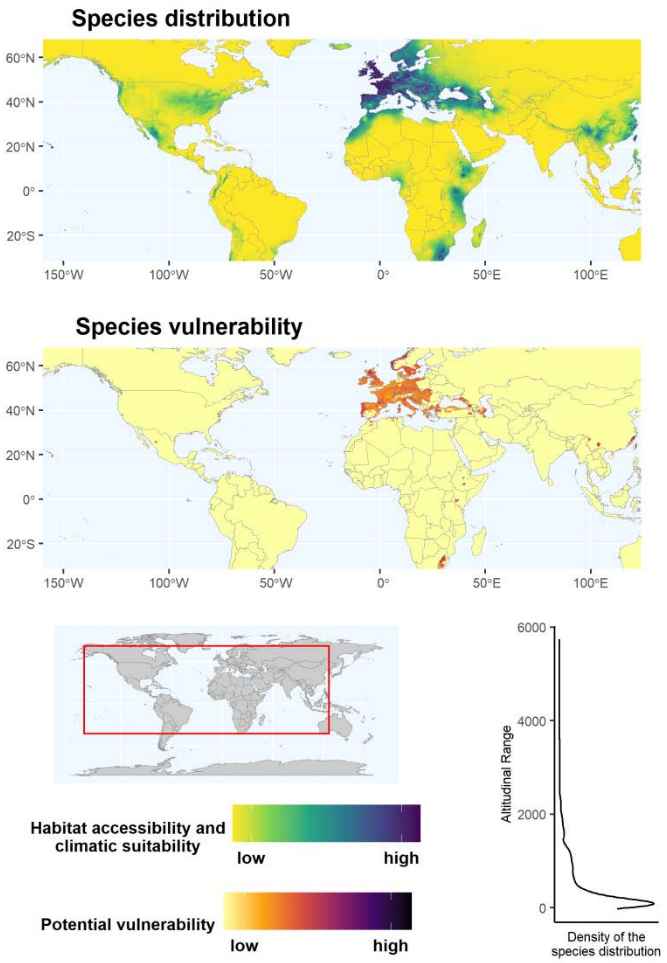
(also cited as *Polypodium caffrorum* and *Anemia caffrorum*)



M. caffrorum is a homoiochlorophyllous plant whose distribution is restricted to Cape Provinces. *M. caffrorum* individuals can be primarily found in arid and warm temperate climates, ranging from 180 to 2316 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *M. caffrorum* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar, South Africa, and Lesotho. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

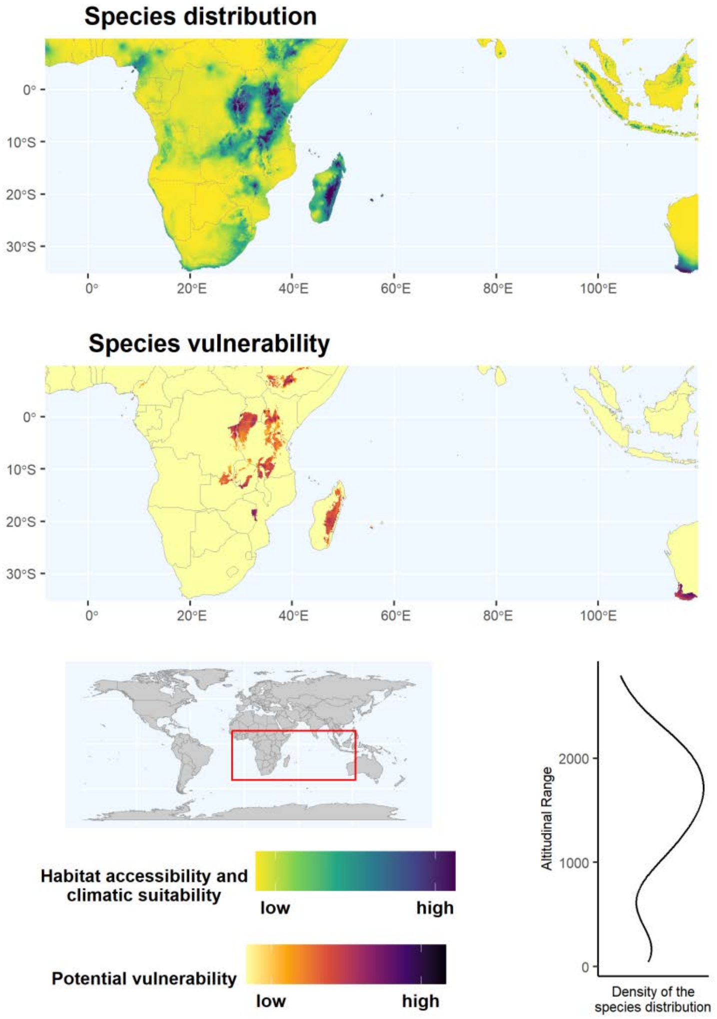
Aspleniaceae

Asplenium adiantum-nigrum L.



A. adiantum-nigrum is a homoiochlorophyllous plant whose distribution comprises Afghanistan, Albania, Algeria, Arizona, Austria, Azores, Belgium, Bulgaria, Cameroon, Canary Is., Cape Provinces, Cape Verde, Chad, China North-Central, China South-Central, Colorado, Corse, Cyprus, Czechoslovakia, Denmark, East Himalaya, France, Free State, Føroyar, Germany, Great Britain, Greece, Hawaii, Hungary, Iran, Ireland, Italy, Kenya, Krym, KwaZulu-Natal, Lebanon-Syria, Lesotho, Madeira, Mexico Northeast, Mexico Northwest, Morocco, Netherlands, North Caucasus, Northwest European R, Norway, Pakistan, Palestine, Poland, Portugal, Romania, Réunion, Sardegna, Saudi Arabia, Sicilia, Sinai, Spain, Sweden, Switzerland, Taiwan, Tanzania, Tibet, Transcaucasus, Tunisia, Turkey, Turkey-in-Europe, Ukraine, Utah, West Himalaya, Yemen, Yugoslavia. *A. adiantum-nigrum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from -23 to 5739 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. adiantum-nigrum* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Kenya, Norway, Tanzania, United States, and Taiwan. This species is listed as Least concern by IUCN, although only 35% of its distribution range is currently found within protected areas.

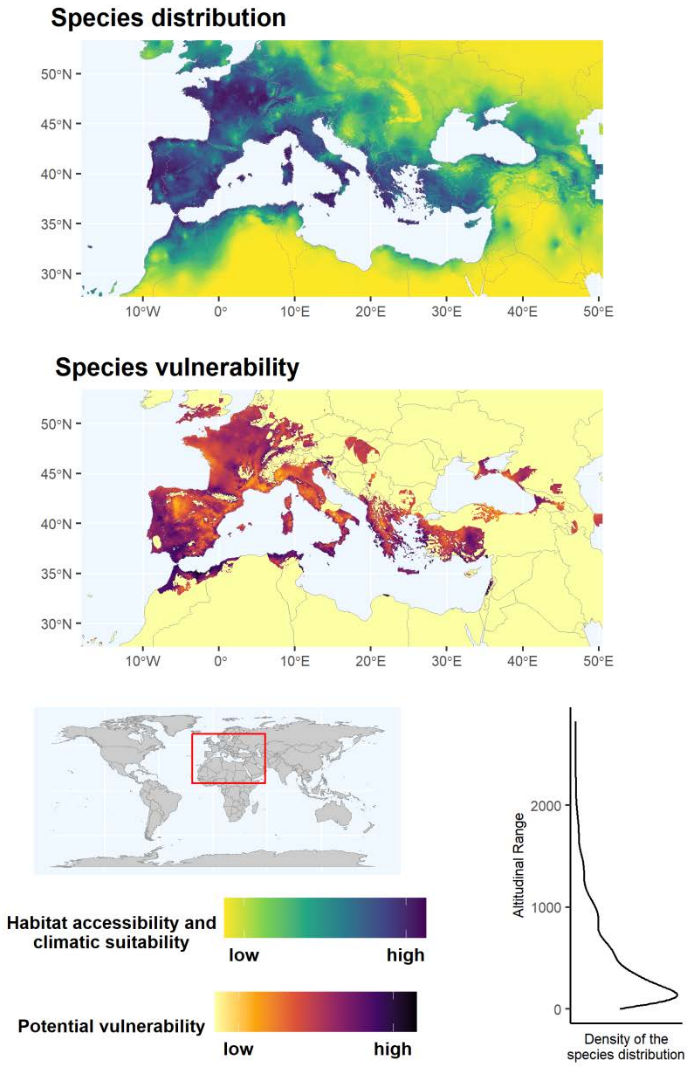
Asplenium aethiopicum (Burm. f.) Bech.



A. aethiopicum is a homoiochlorophyllous plant whose distribution comprises Andaman Is., Angola, Assam, Burundi, Cameroon, Cape Provinces, Caroline Is., Central African Republic, Chad, China South-Central, China Southeast, Comoros, Djibouti, Equatorial Guinea, Ethiopia, Fiji, Free State, Gabon, Guinea, Gulf of Guinea Is., Hawaii, India, Ivory Coast, Jawa, Kazan-retto, Kenya, KwaZulu-Natal, Lesser Sunda Is., Liberia, Madagascar, Malawi, Malaya, Maluku, Marianas, Mauritius, Morocco, Mozambique, Myanmar, New Caledonia, New Guinea, New South Wales, Niger, Nigeria, Niue, Northern Provinces, Ogasawara-shoto, Philippines, Queensland, Rwanda, Réunion, Samoa, Saudi Arabia, Seychelles, Sierra Leone, Society Is., Socotra, Somalia, Sri Lanka, St.Helena, Sulawesi, Tanzania, Tonga, Tubuai Is., Uganda, Victoria, Vietnam, Western Australia, Yemen, Zambia, Zaïre, Zimbabwe. *A. aethiopicum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 46 to 2795 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. aethiopicum* populations are expected to be potentially more vulnerable to climate change in parts of Australia, Democratic Republic of the Congo, Cameroon, Ethiopia, Kenya, Rwanda, Tanzania, Uganda, Zimbabwe. This species is listed as Vulnerable by IUCN, and only 28% of its distribution range is currently found within protected areas.

Asplenium ceterach L.

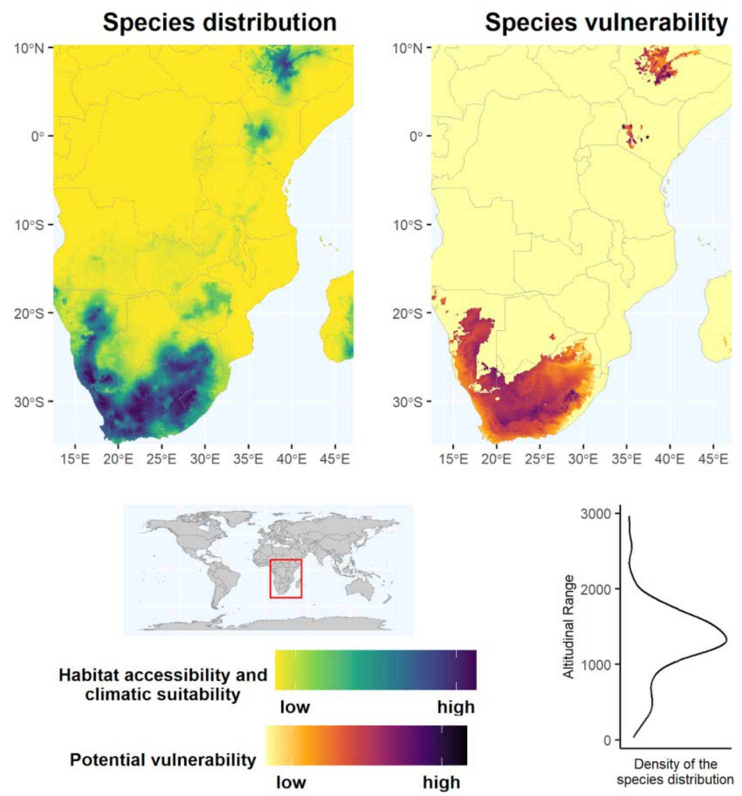
(also cited as *Ceterach officinarum* and *Ceterach ceterach*)



A. ceterach is a homoiochlorophyllous plant whose distribution comprises Afghanistan, Albania, Algeria, Austria, Baleares, Belgium, Bulgaria, Corse, Cyprus, Czechoslovakia, Djibouti, France, Germany, Great Britain, Greece, Hungary, Iran, Iraq, Ireland, Italy, Kazakhstan, Kriti, Krym, Lebanon-Syria, Libya, Morocco, Netherlands, North Caucasus, Pakistan, Palestine, Poland, Portugal, Romania, Sardegna, Saudi Arabia, Sicilia, Sinai, Spain, Sweden, Switzerland, Tadzhikistan, Tibet, Transcaucasus, Tunisia, Turkey, Turkey-in-Europe, West Himalaya, Xinjiang, Yemen, Yugoslavia. *A. ceterach* individuals can be primarily found in arid and warm temperate climates, ranging from 0 to 2822 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. ceterach* populations are expected to be potentially more vulnerable to climate change in parts of Algeria, Albania, Austria, France, Georgia, Germany, Greece, Croatia, Israel, Italy, Lebanon, Libya, Morocco, Malta, Gibraltar, Montenegro, Portugal, Slovenia, Spain, Syrian Arab Republic, Switzerland, Tunisia, Turkey. This species is listed as Least concern by IUCN, although only 33% of its distribution range is currently found within protected areas.

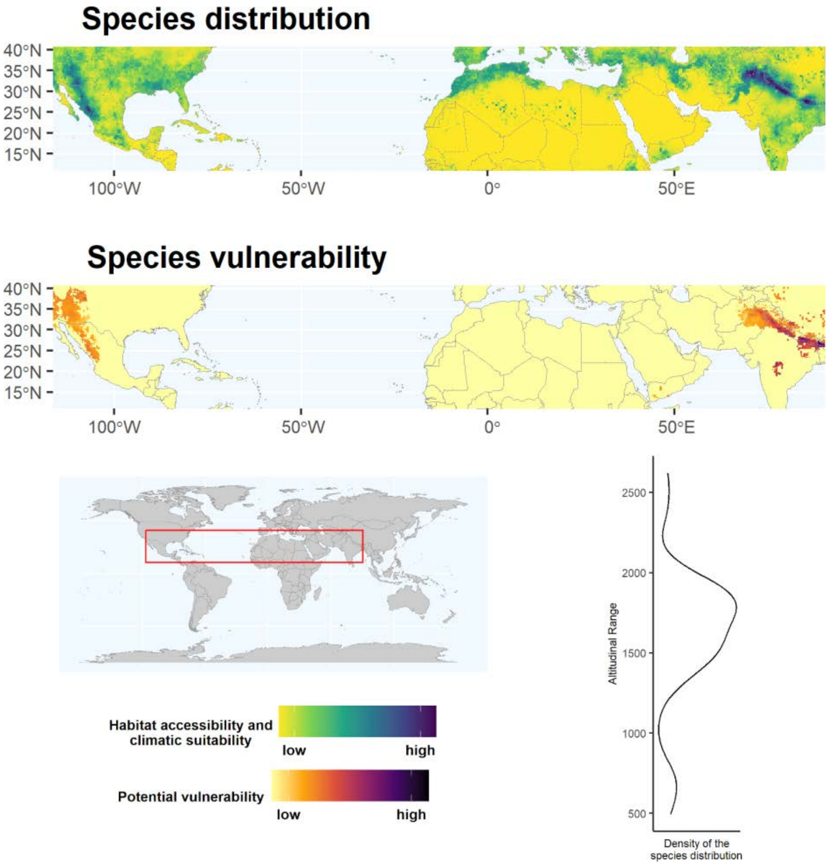
Asplenium cordatum (Thunb.) Sw.

(also cited as *Ceterach cordatum*)



A. cordatum is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Cape Provinces, Ethiopia, Free State, Kenya, KwaZulu-Natal, Lesotho, Namibia, Northern Provinces, Réunion, Socotra, Somalia, St.Helena, Tanzania, Zimbabwe. *A. cordatum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 34 to 2966 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. cordatum* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Kenya, South Africa, Lesotho, Uganda. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

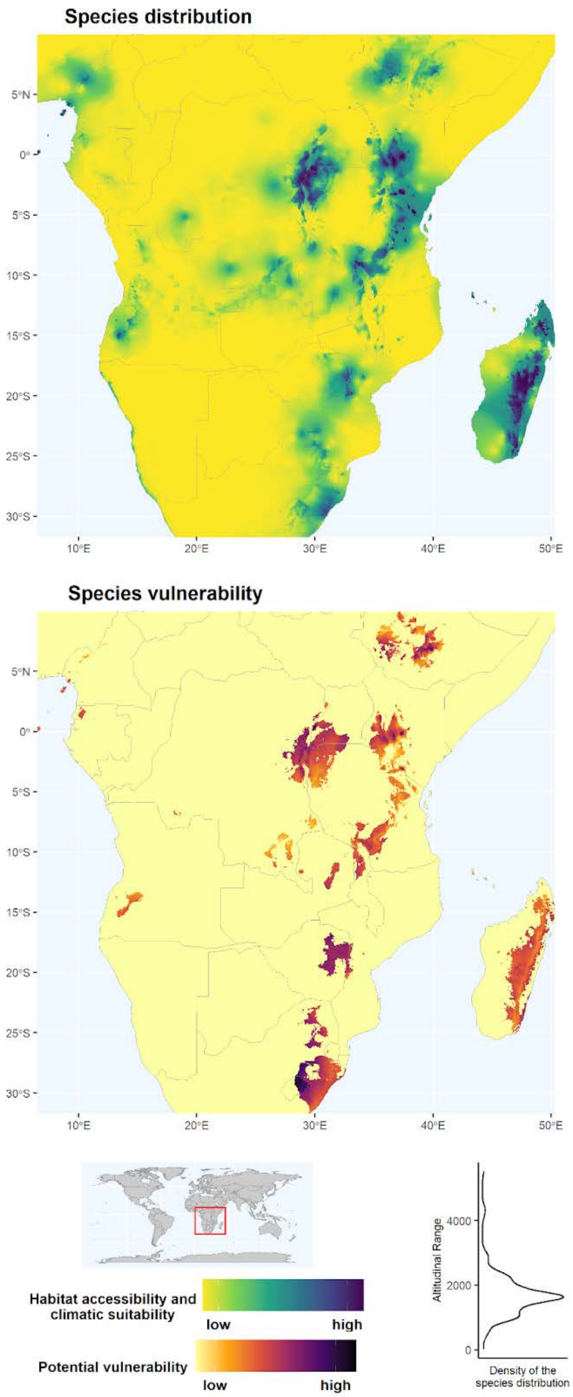
Asplenium dalhousiae Hook.



A. dalhousiae is a plant whose distribution comprises Afghanistan, Arizona, East Himalaya, Eritrea, India, Mexico Northeast, Mexico Northwest, Nepal, West Himalaya, Yemen. *A. dalhousiae* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 495 to 2620 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. dalhousiae* populations are expected to be potentially more vulnerable to climate change in parts of Bhutan, India, Nepal. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

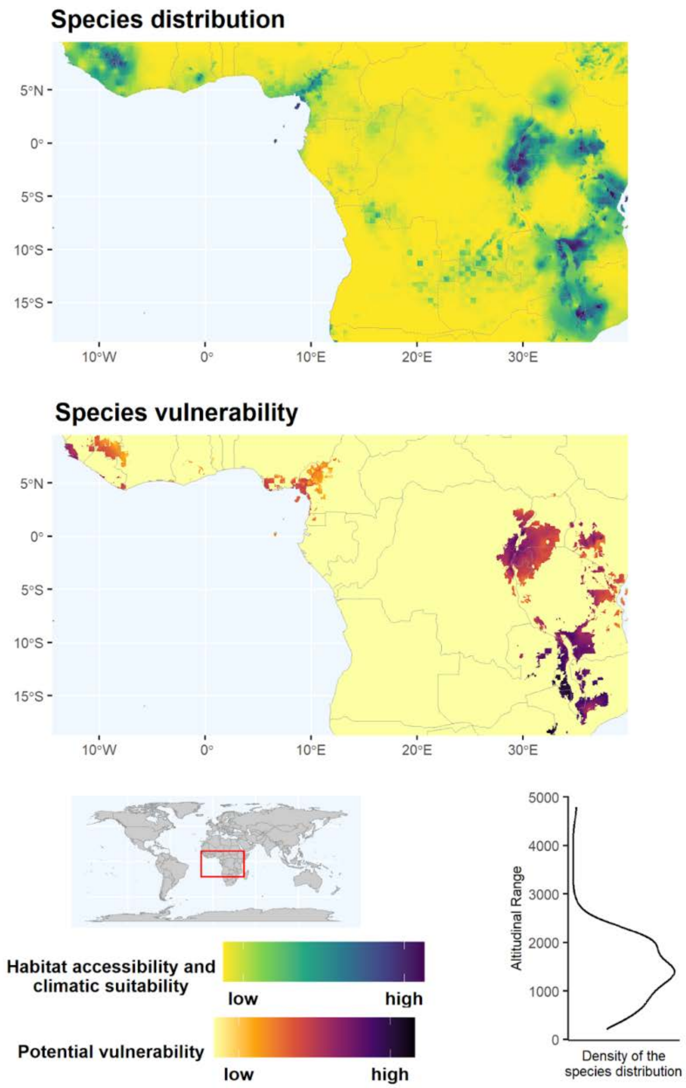
Asplenium friesiorum C. Chr.

(also cited as *Asplenium gueinzianum*)



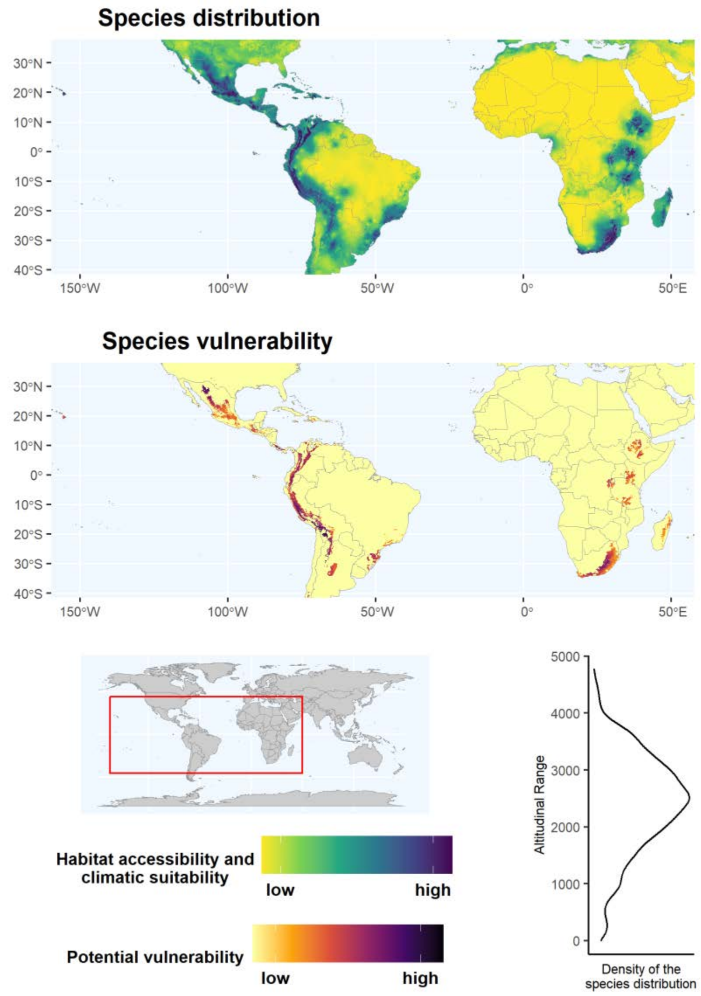
A. friesiorum is a plant whose distribution comprises Angola, Burundi, Cameroon, Comoros, Ethiopia, Gulf of Guinea Is., Kenya, KwaZulu-Natal, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Northern Provinces, Rwanda, Réunion, Sudan, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *A. friesiorum* individuals can be primarily found in equatorial, arid, and warm temperate limates, ranging from 23 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. friesiorum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, South Africa, Lesotho, Tanzania, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 25% of its distribution range is currently found within protected areas.

Asplenium megalura Hieron.



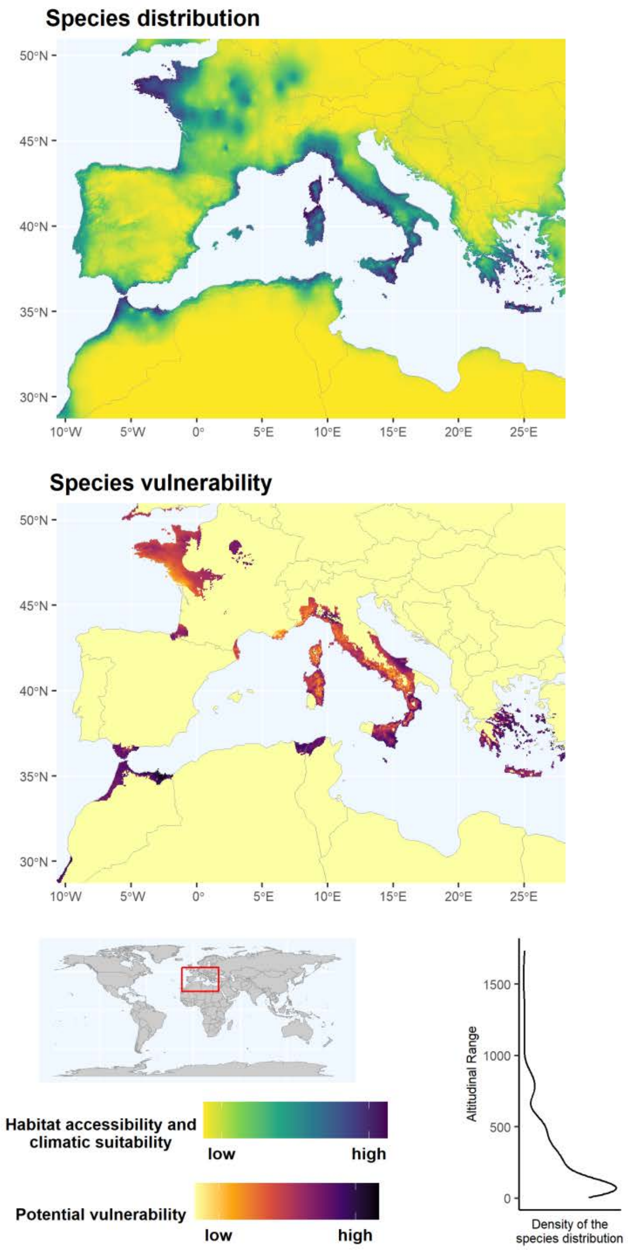
A. megalura is a plant whose distribution comprises Burundi, Cameroon, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, Liberia, Malawi, Mozambique, Rwanda, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Zambia, Zaïre. *A. megalura* individuals can be primarily found in equatorial and warm temperate climates, ranging from 213 to 4794 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. megalura* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Kenya, Mozambique, Malawi, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Asplenium monanthes L.



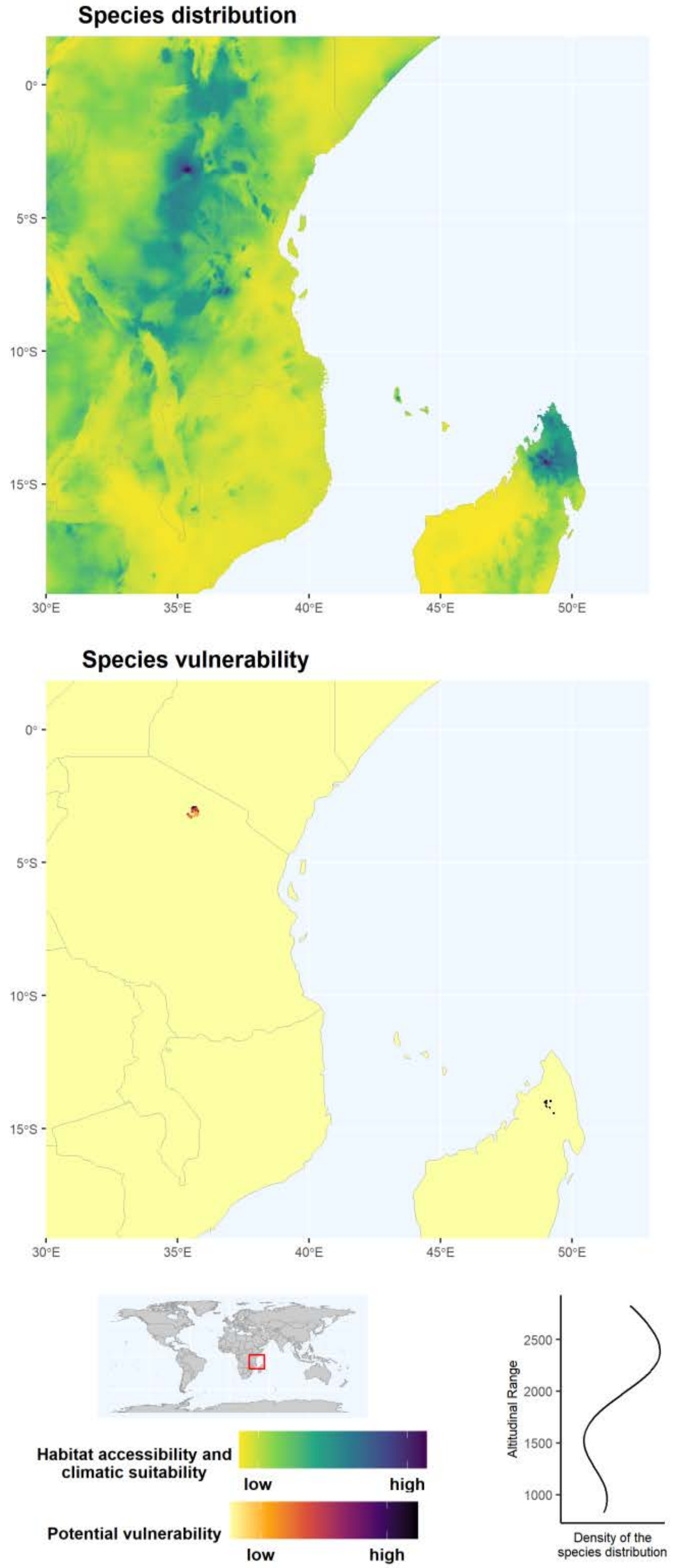
A. monanthes is a plant whose distribution comprises Alabama, Argentina Northeast, Argentina Northwest, Arizona, Azores, Bolivia, Brazil South, Brazil Southeast, Cameroon, Canary Is., Cape Provinces, Chile Central, Chile South, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Ethiopia, Florida, Free State, Guatemala, Gulf of Guinea Is., Haiti, Hawaii, Honduras, Jamaica, Kenya, KwaZulu-Natal, Lesotho, Madagascar, Madeira, Malawi, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, North Carolina, Northern Provinces, Panamá, Peru, Rwanda, Réunion, Somalia, South Carolina, Sudan, Tanzania, Tristan da Cunha, Uganda, Uruguay, Venezuela, Zimbabwe. *A. monanthes* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from -1 to 4776 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *A. monanthes* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Brazil, Democratic Republic of the Congo, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Kenya, Mexico, Nicaragua, Peru, Panama, South Africa, Lesotho, Uganda, United States, Venezuela. This species is listed as Least concern by IUCN, although only 22% of its distribution range is currently found within protected areas.

Asplenium obovatum Viv.



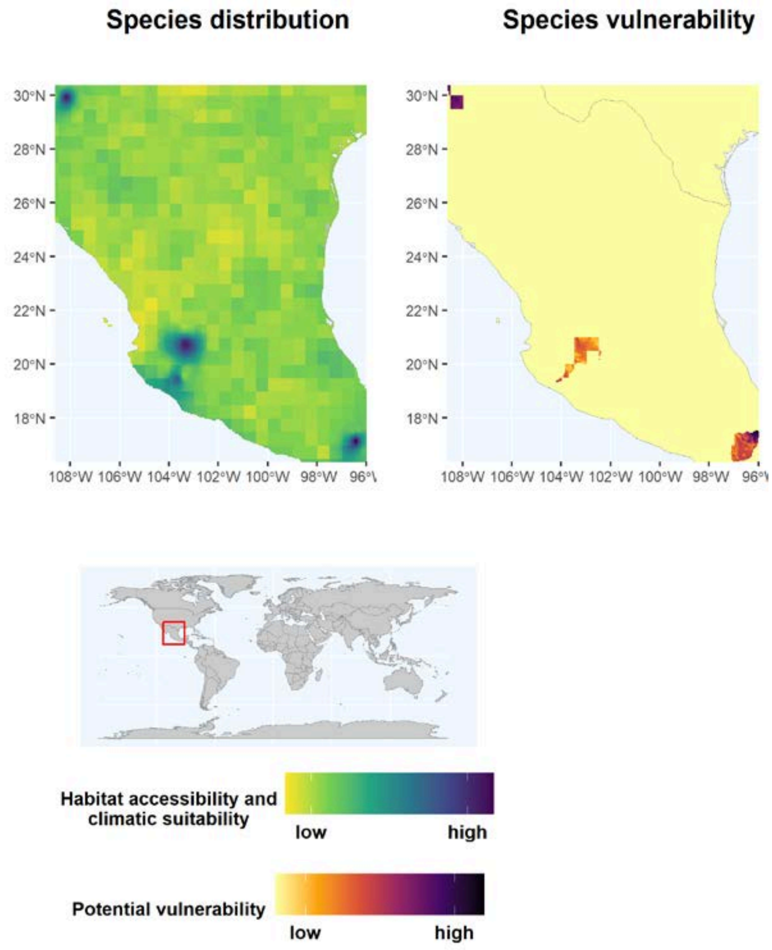
A. obovatum is a homoiochlorophyllous plant whose distribution comprises Algeria, Corse, France, Greece, Italy, Kriti, Morocco, Sardegna, Sicilia, Tunisia, Turkey, Turkey-in-Europe. *A. obovatum* individuals can be primarily found in arid and warm temperate climates, ranging from 5 to 1733 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. obovatum* populations are expected to be potentially more vulnerable to climate change in parts of Algeria, France, Greece, Italy, Morocco, Malta, Gibraltar, Spain, Tunisia, Turkey. This species has not yet been assessed by IUCN, and only 38% of its distribution range is currently found within protected areas.

Asplenium praegracile Rosenst.



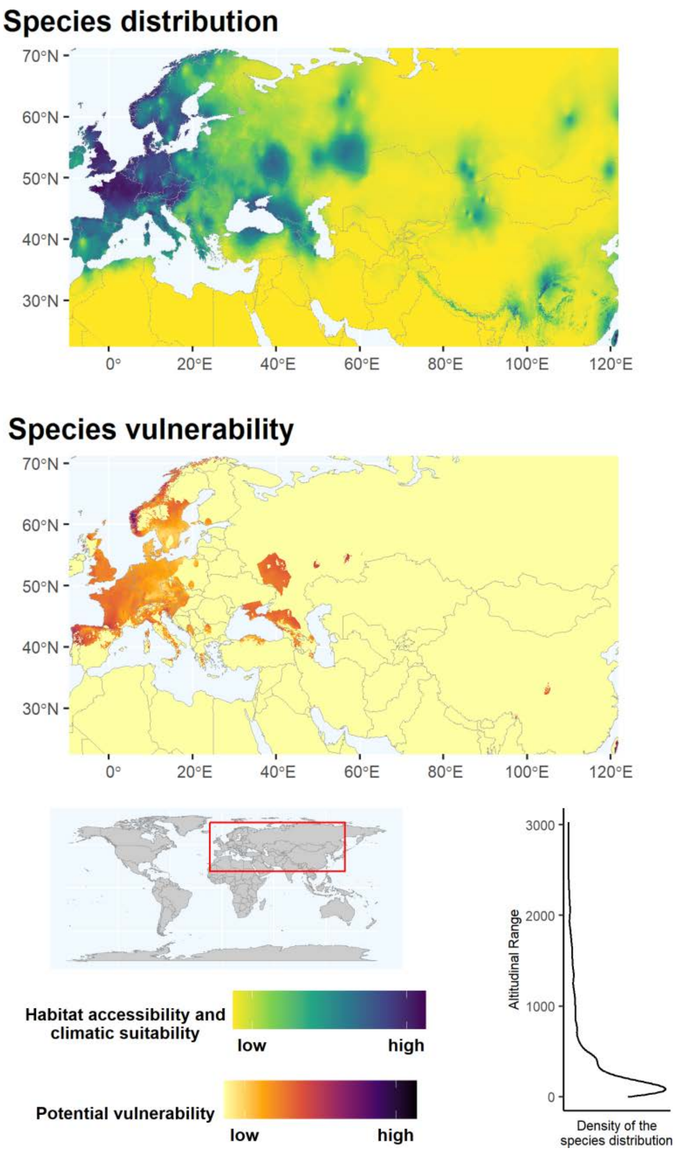
A. praegracile is a plant whose distribution comprises Madagascar, Tanzania. *A. praegracile* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 827 to 2829 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. praegracile* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar, Tanzania. This species has not yet been assessed by IUCN, but the totality of its distribution range is currently found within protected areas.

Asplenium pringlei Davenp.



A. pringlei is a homoiochlorophyllous plant whose distribution comprises Mexico Northeast, Mexico Southwest. *A. pringlei* individuals can be primarily found in equatorial climates, ranging from 1405 to 1405 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). *A. pringlei* populations are expected to be potentially more vulnerable to climate change in parts of Mexico. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

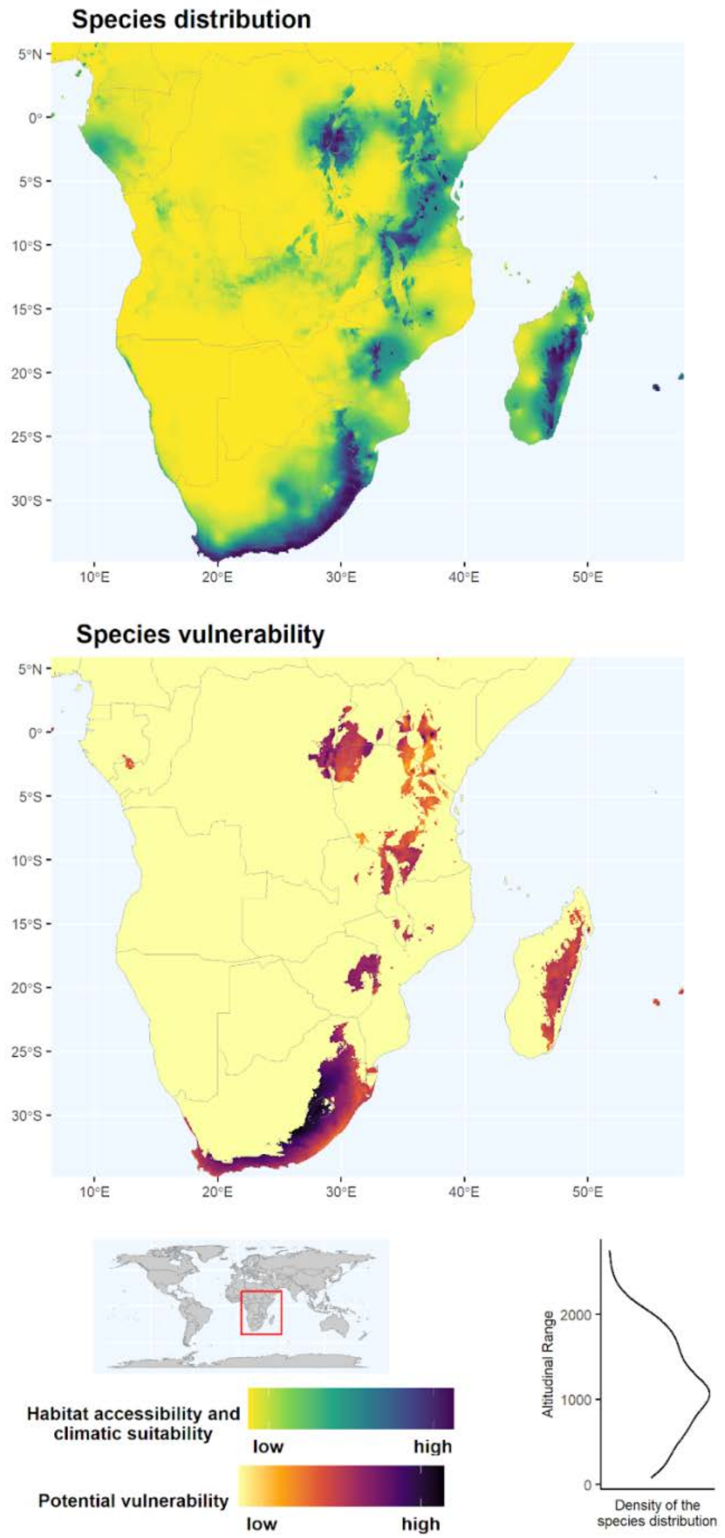
Asplenium ruta-muraria L.



A. ruta-muraria is a homoiochlorophyllous plant whose distribution comprises Afghanistan, Albania, Algeria, Altay, Assam, Austria, Baleares, Baltic States, Belarus, Belgium, Bulgaria, Buryatiya, Central European Rus, China North-Central, China South-Central, China Southeast, Chita, Corse, Cyprus, Czechoslovakia, Denmark, East European Russia, Finland, France, Germany, Great Britain, Greece, Hungary, Inner Mongolia, Iran, Ireland, Irkutsk, Italy, Japan, Kazakhstan, Khabarovsk, Kirgizstan, Korea, Krasnoyarsk, Krym, Lebanon-Syria, Manchuria, Morocco, Nepal, Netherlands, North Caucasus, North European Russi, Northwest European R, Norway, Pakistan, Poland, Portugal, Primorye, Romania, Sakhalin, Sardegna, Sicilia, Spain, Sweden, Switzerland, Tadzhikistan, Taiwan, Tibet, Transcaucasus, Turkey, Turkey-in-Europe, Tuva, Ukraine, West Himalaya, Xinjiang, Yakutskiya, Yugoslavia. *A. ruta-muraria* individuals can be primarily found in equatorial, arid, warm temperate, and snow climates, ranging from 0 to 3029 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. ruta-muraria* populations are expected to be potentially more vulnerable to climate change in parts of China, Norway, Taiwan. This species is listed as Least concern by IUCN, although only 33% of its distribution range is currently found within protected areas.

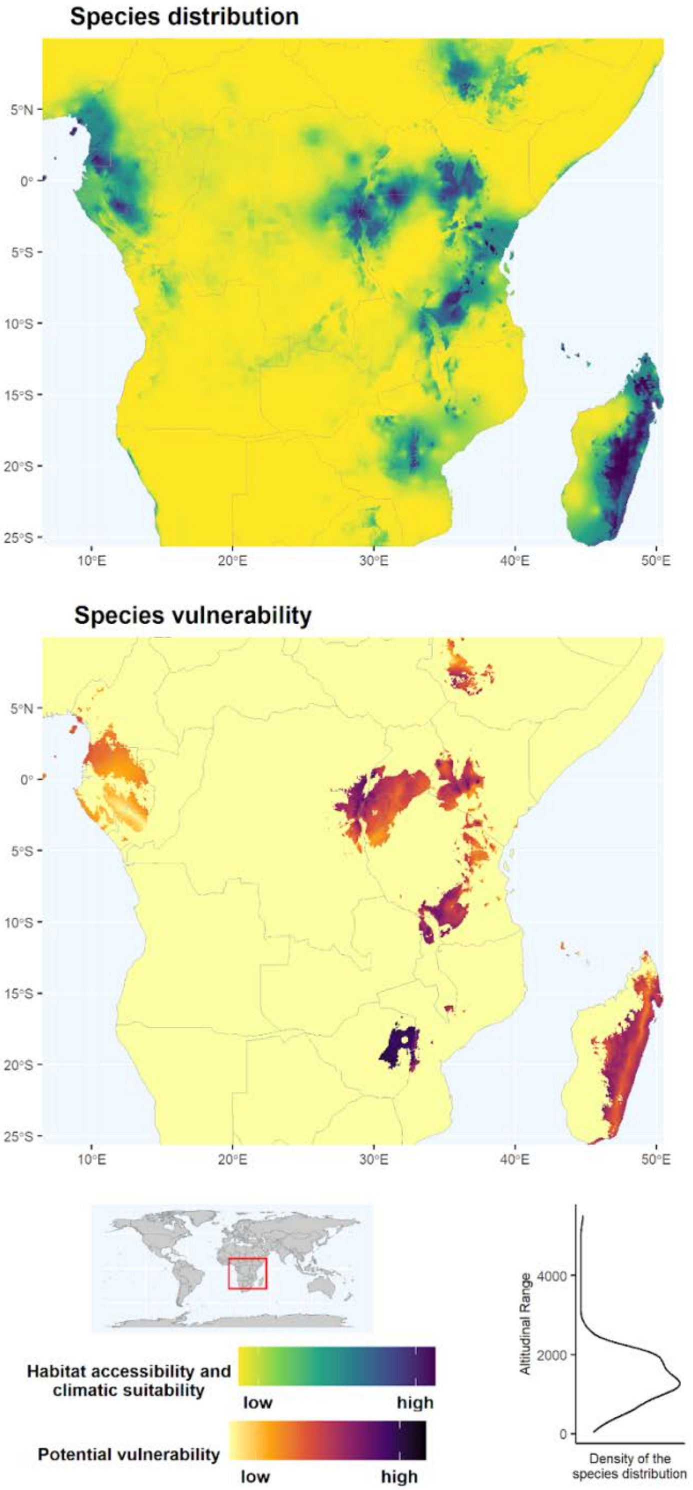
Asplenium rutifolium (P.J. Bergius) Kunze

(also cited as *Asplenium rutifolium* var. *bipinnatum*)



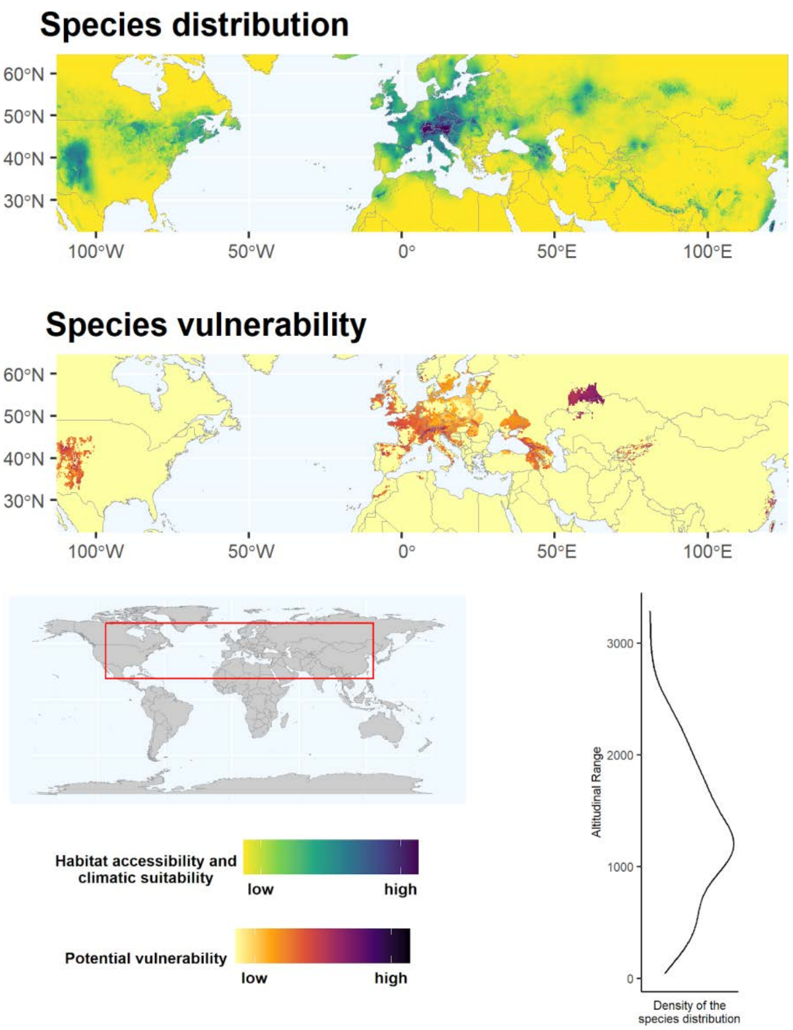
A. rutifolium is a homoiochlorophyllous plant whose distribution comprises Cape Provinces, Comoros, Kenya, KwaZulu-Natal, Madagascar, Malawi, Mauritius, Mozambique, Northern Provinces, Rwanda, Réunion, Swaziland, Tanzania, Uganda, Yemen, Zimbabwe. *A. rutifolium* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 81 to 2752 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. rutifolium* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Kenya, Rwanda, South Africa, Lesotho, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

Asplenium sandersonii Hook.



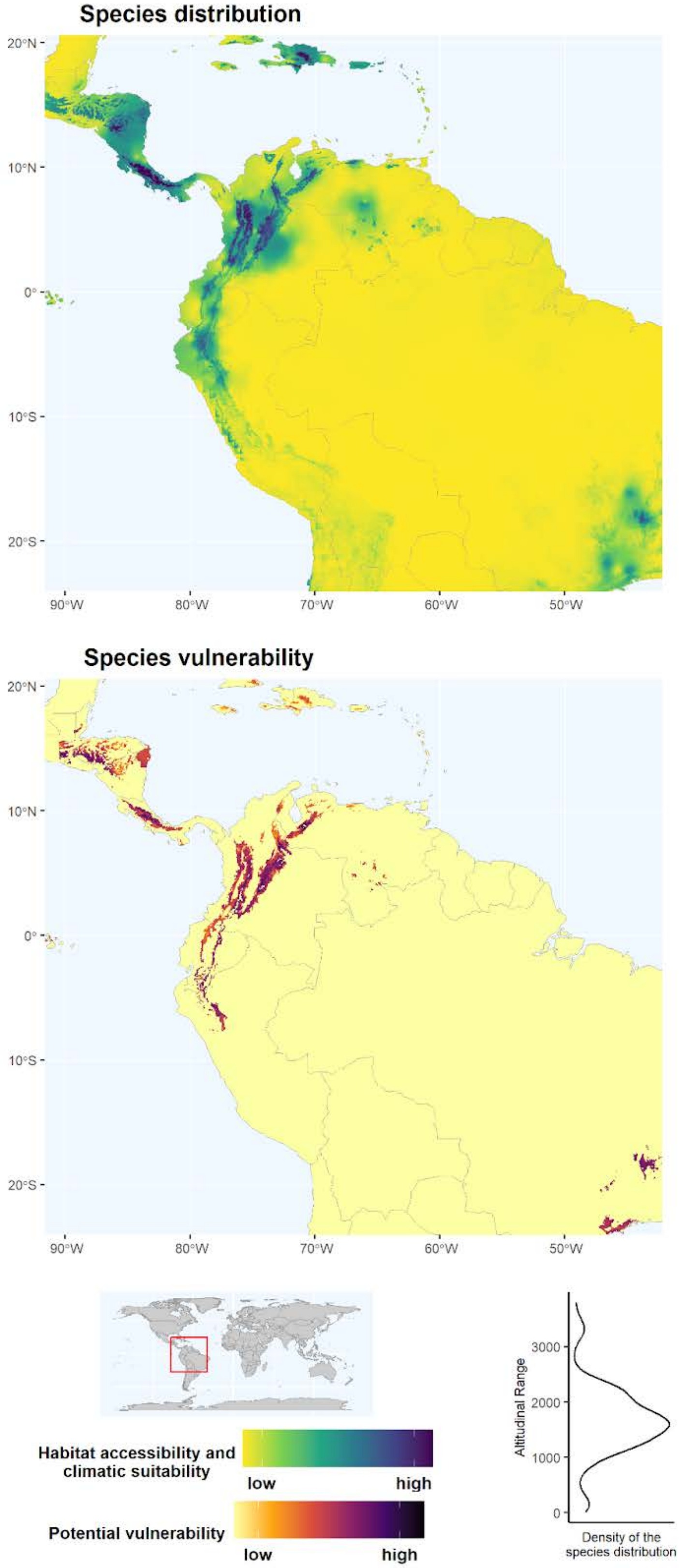
A. sandersonii is a homoiochlorophyllous plant whose distribution comprises Angola, Burundi, Cameroon, Cape Provinces, Comoros, Equatorial Guinea, Ethiopia, Gabon, Gulf of Guinea Is., Kenya, KwaZulu-Natal, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Northern Provinces, Rwanda, Sudan, Tanzania, Uganda, Zaïre, Zimbabwe. *A. sandersonii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 34 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. sandersonii* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Madagascar, Mozambique, Malawi, Rwanda, Tanzania, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Asplenium septentrionale (L.) Hoffm.



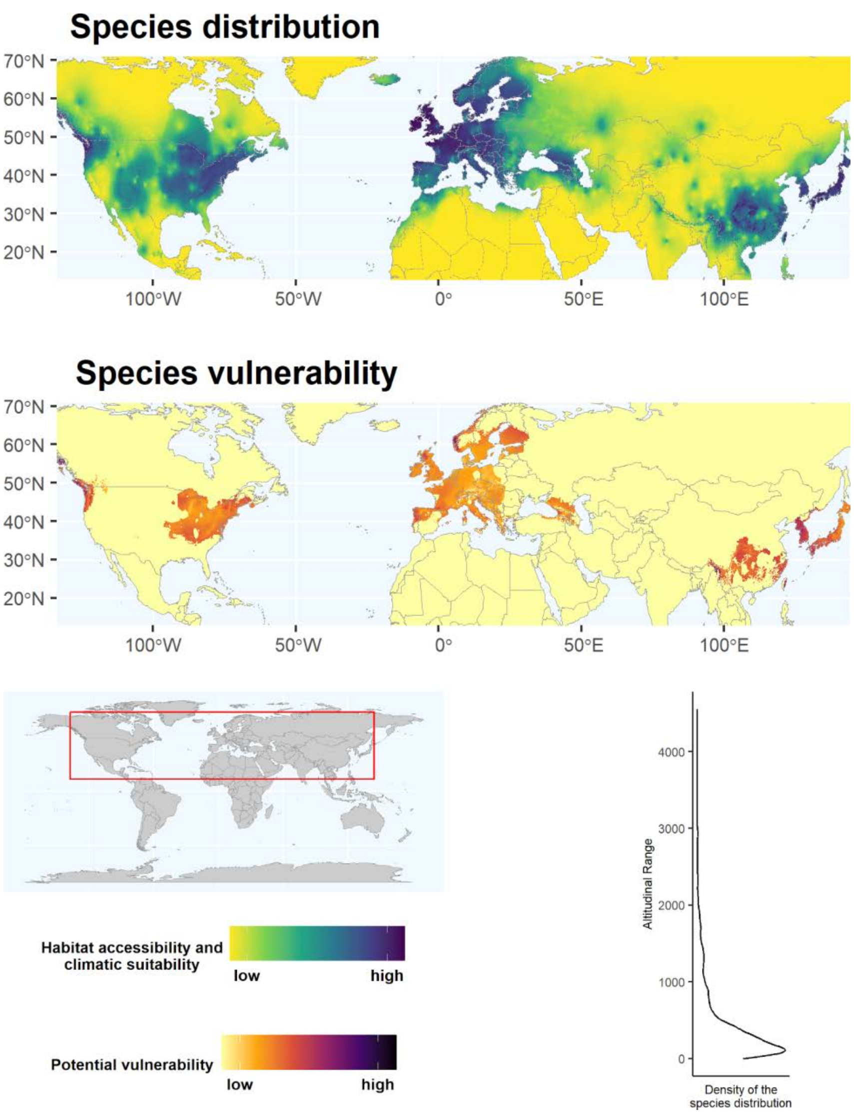
A. septentrionale is a homoiochlorophyllous plant whose distribution comprises Afghanistan, Albania, Altay, Arizona, Austria, Belarus, Belgium, Bulgaria, California, Canary Is., Central European Rus, China North-Central, Colorado, Corse, Czechoslovakia, Denmark, East European Russia, East Himalaya, Finland, France, Germany, Great Britain, Greece, Hungary, Iceland, Idaho, Iran, Italy, Japan, Kazakhstan, Kirgizstan, Krasnoyarsk, Krym, Madeira, Mexico Northwest, Mongolia, Morocco, Nepal, New Mexico, North Caucasus, North European Russi, Northwest European R, Norway, Oklahoma, Oregon, Pakistan, Poland, Portugal, Romania, Sardegna, Sicilia, South Dakota, Spain, Sweden, Switzerland, Tadzhikistan, Taiwan, Texas, Tibet, Transcaucasus, Turkey, Turkey-in-Europe, Tuva, Ukraine, Utah, West Himalaya, West Siberia, West Virginia, Wyoming, Xinjiang, Yugoslavia. *A. septentrionale* individuals can be primarily found in equatorial, arid, warm temperate, and snow climates, ranging from 43 to 3288 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *A. septentrionale* populations are expected to be potentially more vulnerable to climate change in parts of Austria, Italy, Switzerland, Taiwan. This species is listed as Least concern by IUCN, although only 29% of its distribution range is currently found within protected areas.

Asplenium theciferum (Kunth) Mett.



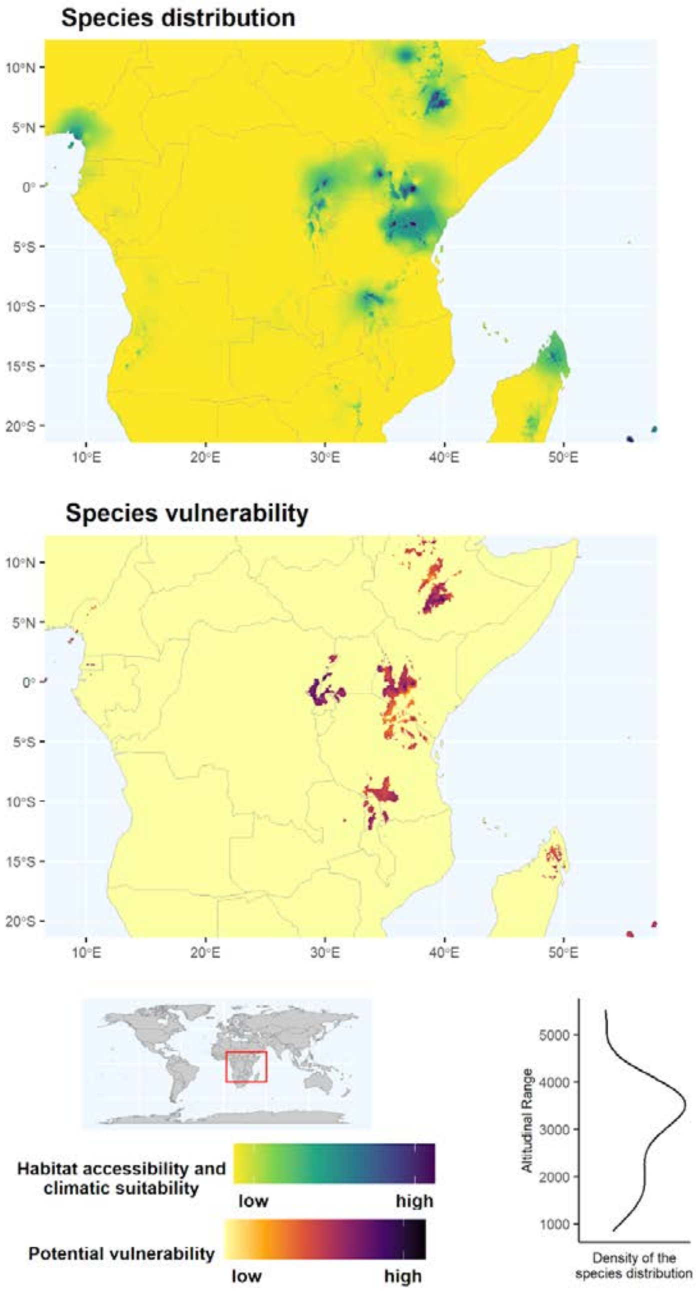
A. theciferum is a plant whose distribution comprises Bolivia, Brazil Southeast, Colombia, Costa Rica, Dominican Republic, Ecuador, Haiti, Honduras, Mexico Gulf, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Peru, Venezuela. *A. theciferum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 14 to 3803 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *A. theciferum* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Peru, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 37% of its distribution range is currently found within protected areas.

Asplenium trichomanes L.



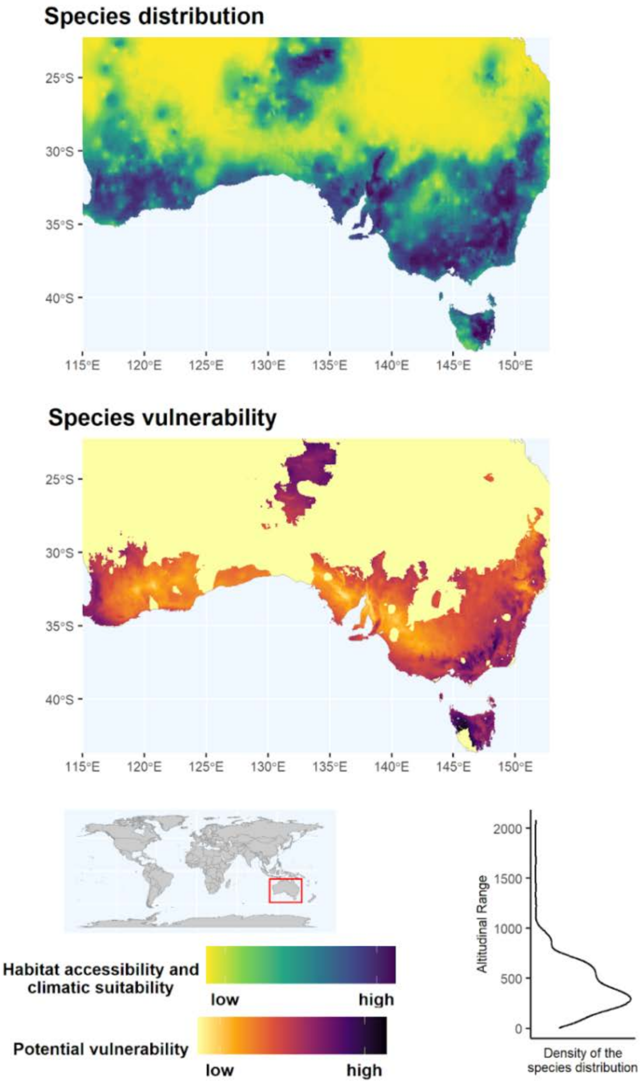
A. trichomanes is a homoiochlorophyllous plant whose distribution comprises Alabama, Alaska, Alberta, Altay, Arizona, Arkansas, Austria, Baleares, British Columbia, Bulgaria, California, Canary Is., Central European Rus, China North-Central, China South-Central, China Southeast, Colorado, Connecticut, Czechoslovakia, Delaware, District of Columbia, Finland, Florida, France, Georgia, Germany, Great Britain, Greece, Idaho, Illinois, India, Indiana, Iran, Ireland, Italy, Japan, Kansas, Kazakhstan, Kentucky, Kirgizstan, Krasnoyarsk, Lebanon-Syria, Louisiana, Maine, Maryland, Massachusetts, Mexico Northeast, Michigan, Minnesota, Mississippi, Missouri, Montana, Nepal, New Brunswick, New Hampshire, New Jersey, New Mexico, New York, Newfoundland, North Carolina, North Caucasus, North European Russi, Norway, Nova Scotia, Ohio, Oklahoma, Ontario, Oregon, Pennsylvania, Poland, Québec, Rhode I., Romania, Sardegna, Saudi Arabia, South Carolina, South Dakota, Spain, Sweden, Switzerland, Taiwan, Tennessee, Texas, Tibet, Transcaucasus, Turkey, Turkey-in-Europe, Utah, Vermont, Virginia, Washington, West Himalaya, West Siberia, West Virginia, Wisconsin, Wyoming, Xinjiang, Yugoslavia. *A. trichomanes* individuals can be primarily found in equatorial, arid, warm temperate, and snow climates, ranging from 0 to 4554 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. trichomanes* populations are expected to be potentially more vulnerable to climate change in parts of Burma, India, Norway, United States, Taiwan. This species is listed as Least concern by IUCN, although only 24% of its distribution range is currently found within protected areas.

Asplenium uhligii Hieron.



A. uhligii is a plant whose distribution comprises Cameroon, Ethiopia, Kenya, Tanzania, Uganda. *A. uhligii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 851 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *A. uhligii* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, Tanzania, Uganda. This species has not yet been assessed by IUCN, and 34% of its distribution range is currently found within protected areas.

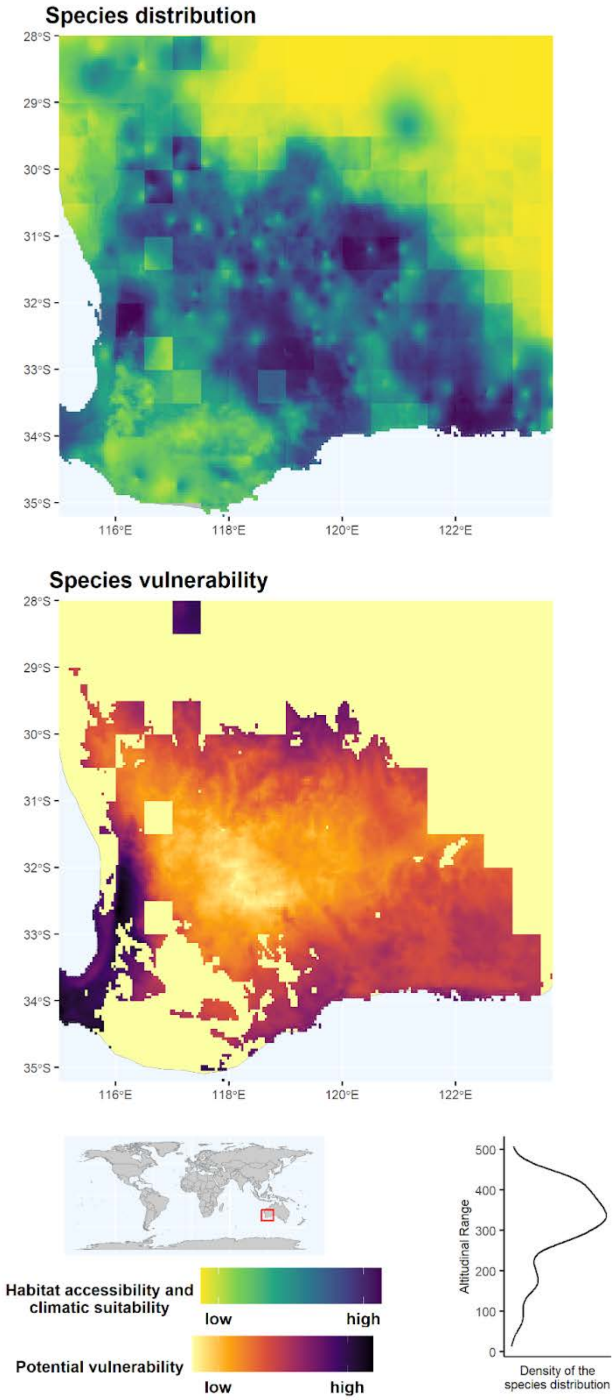
Pleurosorus rutifolius Fée



P. rutifolius is a homoiochlorophyllous plant whose distribution comprises New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia. *P. rutifolius* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 4 to 2081 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *P. rutifolius* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

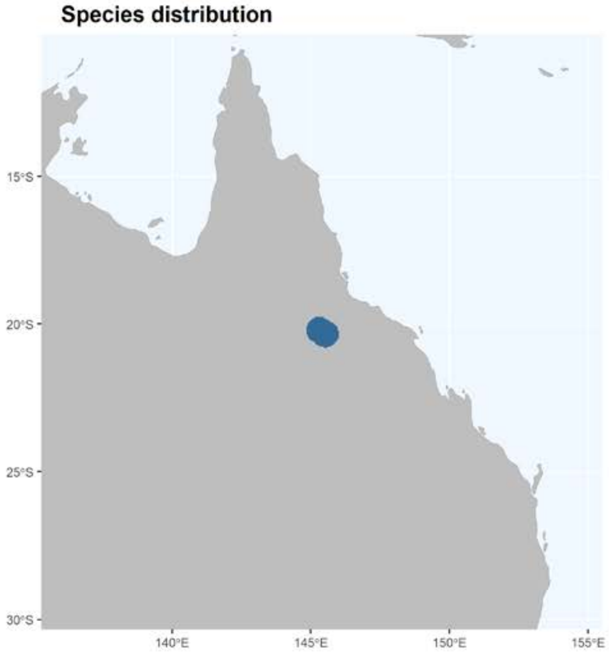
Boryaceae

Borya constricta Churchill

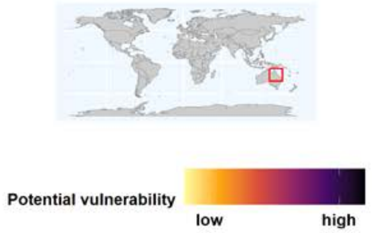


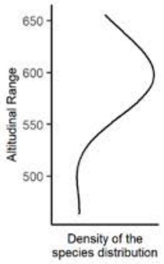
B. constricta is a DT plant whose distribution is restricted to Western Australia. *B. constricta* individuals can be primarily found in arid and warm temperate climates, ranging from 13 to 508 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *B. constricta* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 25% of its distribution range is currently found within protected areas.

Borya inopinata P.I. Forst. & E.J. Thomps.

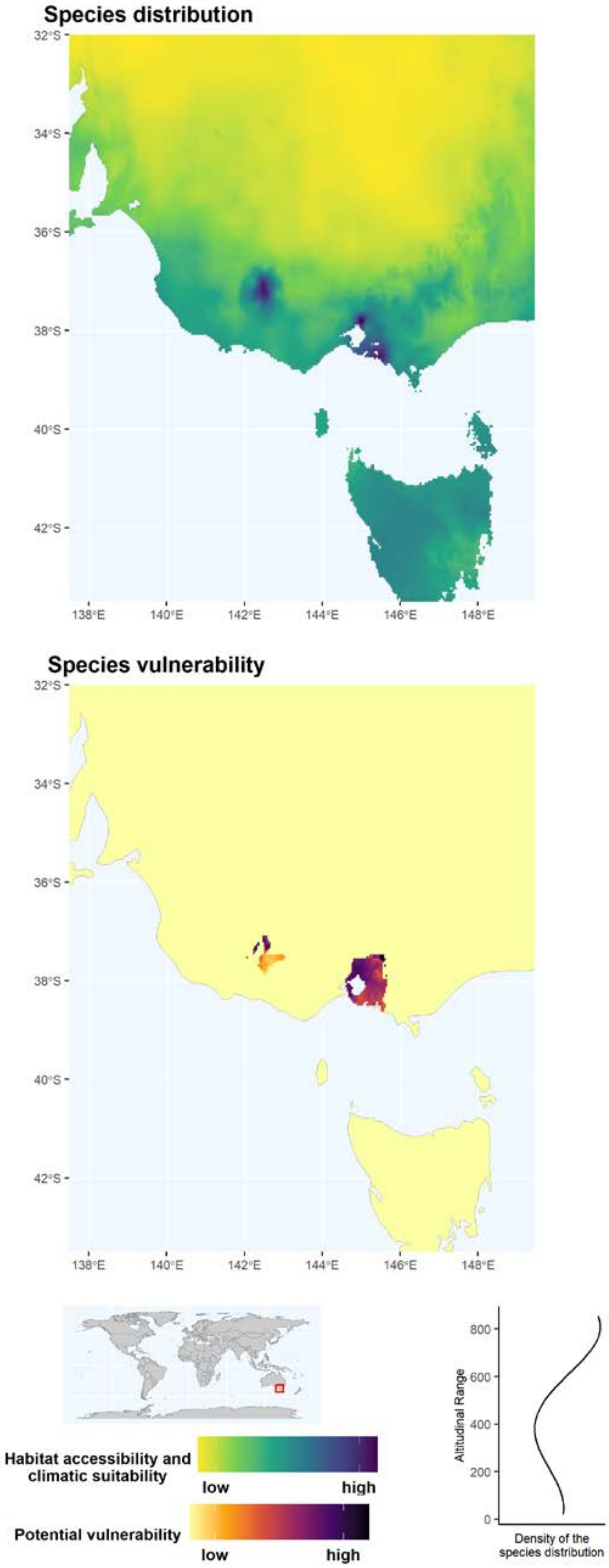


B. inopinata is a DT plant whose distribution is restricted to Queensland. *B. inopinata* individuals can be primarily found in arid climates, ranging from 463 to 656 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. More occurrence points are needed for a consistent evaluation of the conservation of *B. inopinata* populations. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.



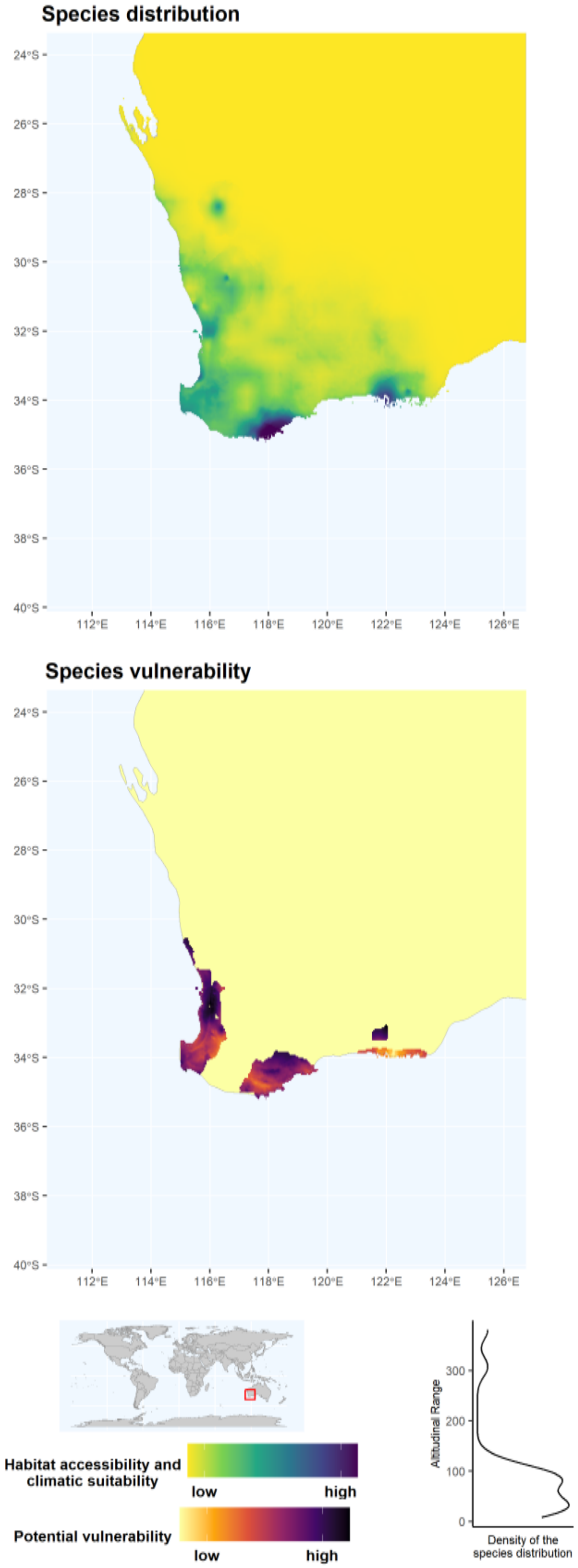


Borya mirabilis Churchill



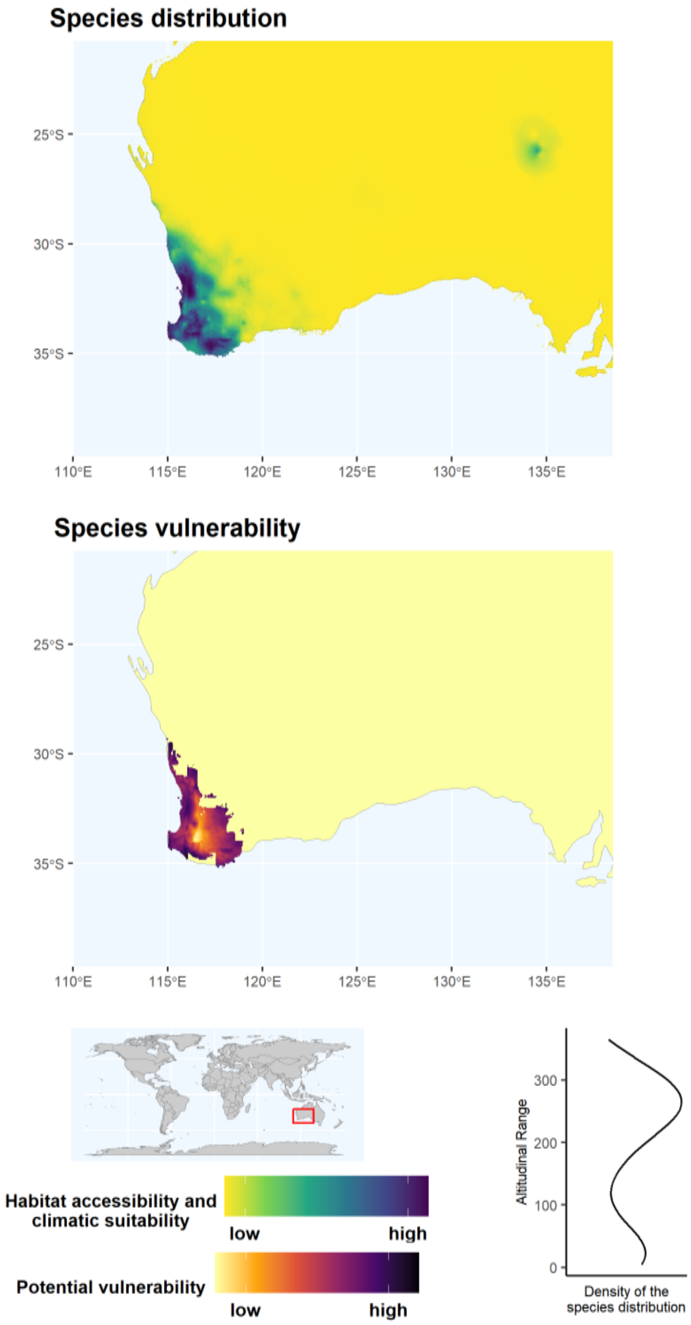
B. mirabilis is a DT plant whose distribution is restricted to Victoria. *B. mirabilis* individuals can be primarily found in warm temperate climates, ranging from 20 to 854 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *B. mirabilis* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 33% of its distribution range is currently found within protected areas.

Borya nitida Labill.



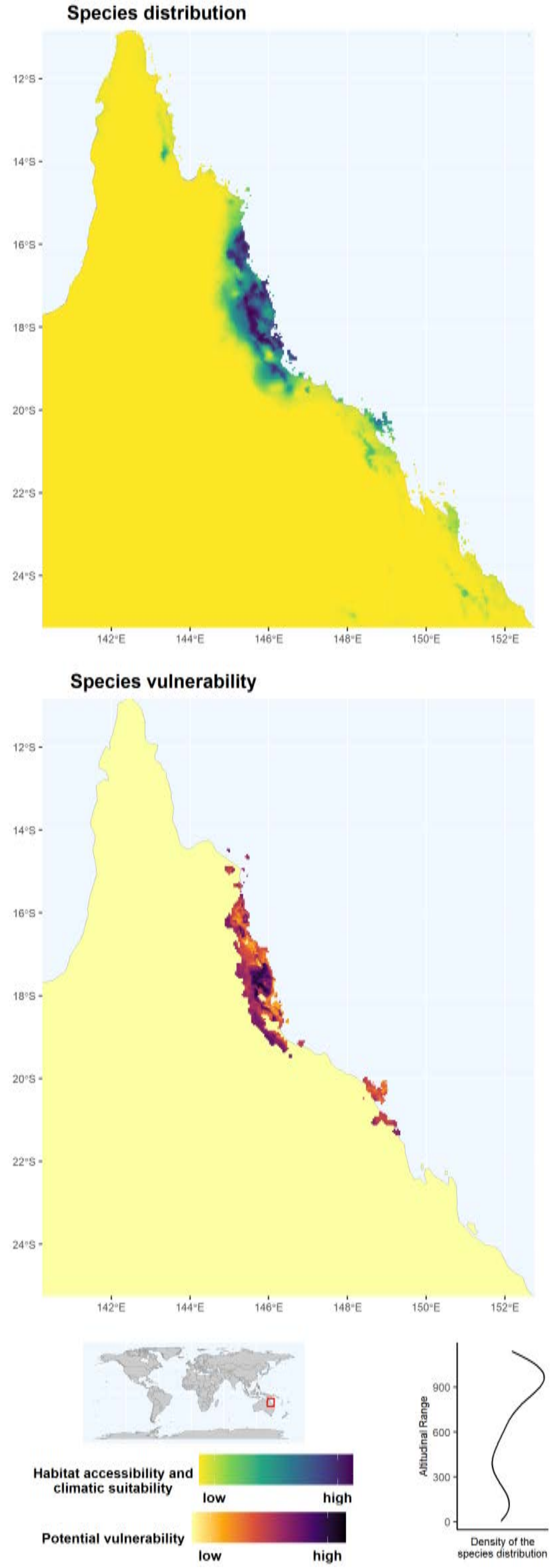
B. nitida is a DT plant whose distribution is restricted to Western Australia. *B. nitida* individuals can be primarily found in arid and warm temperate climates, ranging from 8 to 381 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *B. nitida* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 25% of its distribution range is currently found within protected areas.

Borya scirpoidea Lindl.



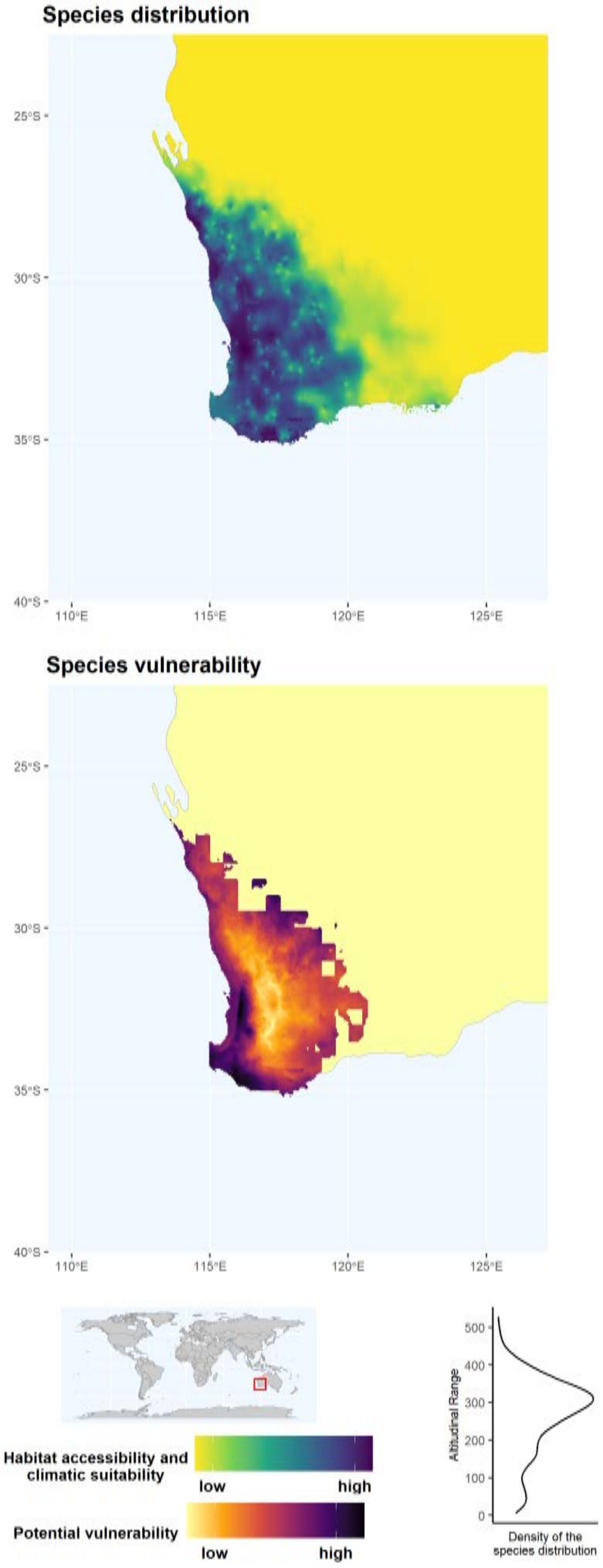
B. scirpoidea is a DT plant whose distribution is restricted to Western Australia. *B. scirpoidea* individuals can be primarily found in arid and warm temperate climates, ranging from 5 to 365 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *B. scirpoidea* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Borya septentrionalis F. Muell.



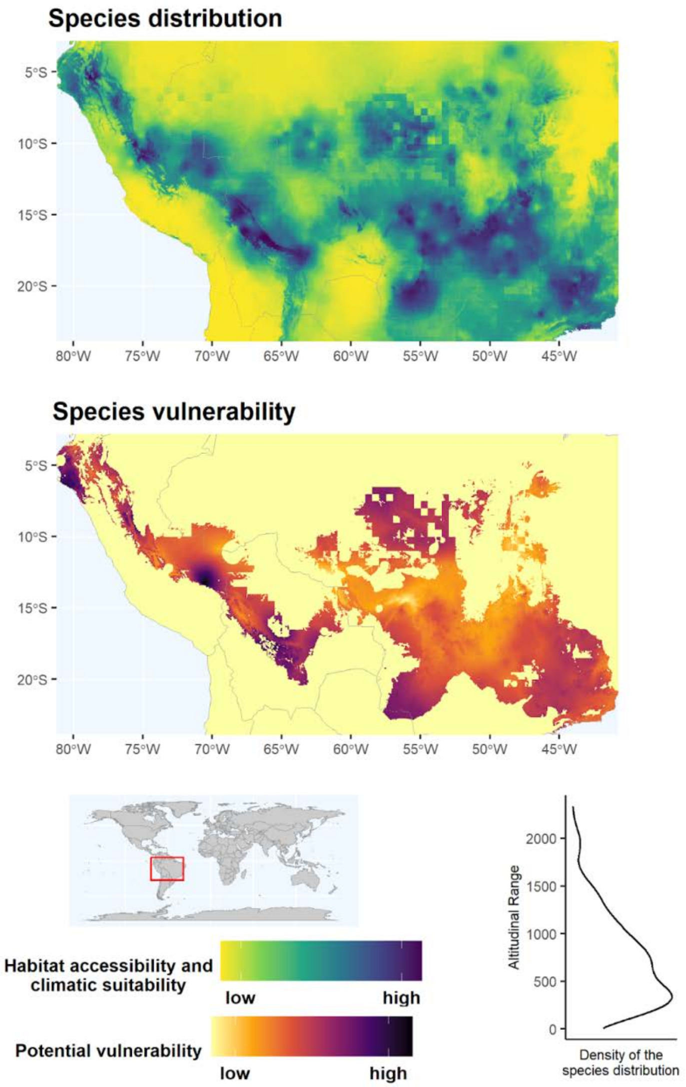
B. septentrionalis is a DT plant whose distribution is restricted to Australia. *B. septentrionalis* individuals can be primarily found in equatorial and warm temperate climates, ranging from 5 to 1140 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *B. septentrionalis* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, although 71% of its distribution range is currently found within protected areas.

Borya sphaerocephala R. Br.



B. sphaerocephala is a DT plant whose distribution is restricted to Western Australia. *B. sphaerocephala* individuals can be primarily found in equatorial and warm temperate climates, ranging from 6 to 528 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *B. sphaerocephala* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Bromeliaceae

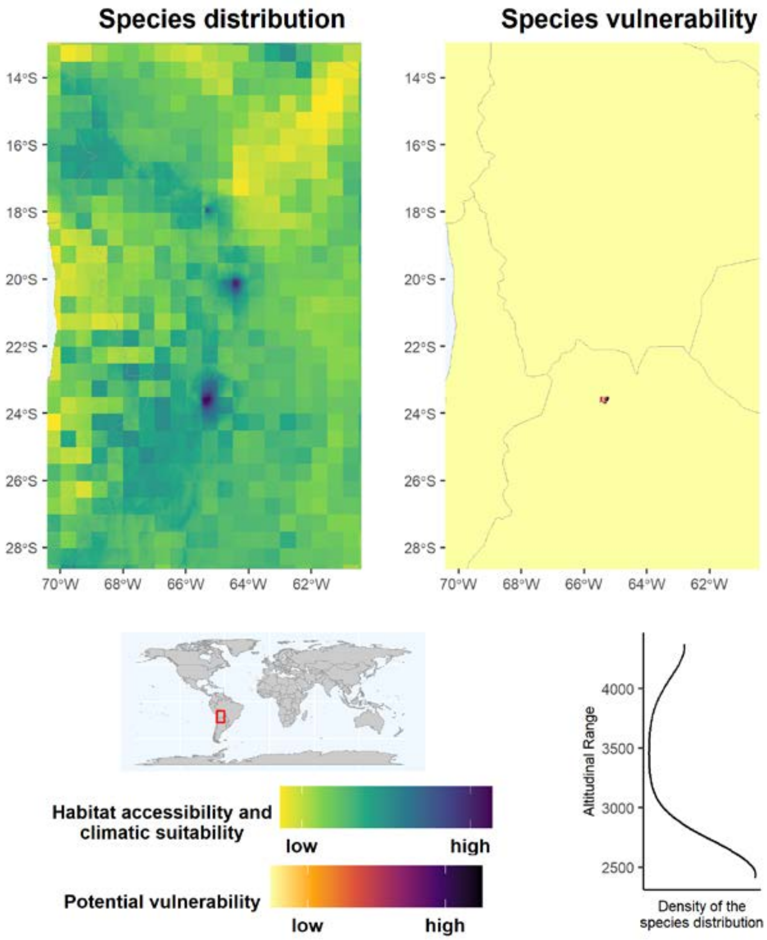


Pitcairnia lanuginosa Ruiz & Pav. (also cited as *Pitcairnia burchellii*)

P. lanuginosa is a DT plant whose distribution comprises Bolivia, Brazil North, Brazil Southeast, Brazil West-Central, Peru. *P. lanuginosa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 8 to 2337 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *P. lanuginosa* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Brazil, Ecuador, Paraguay, Peru. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Cactaceae

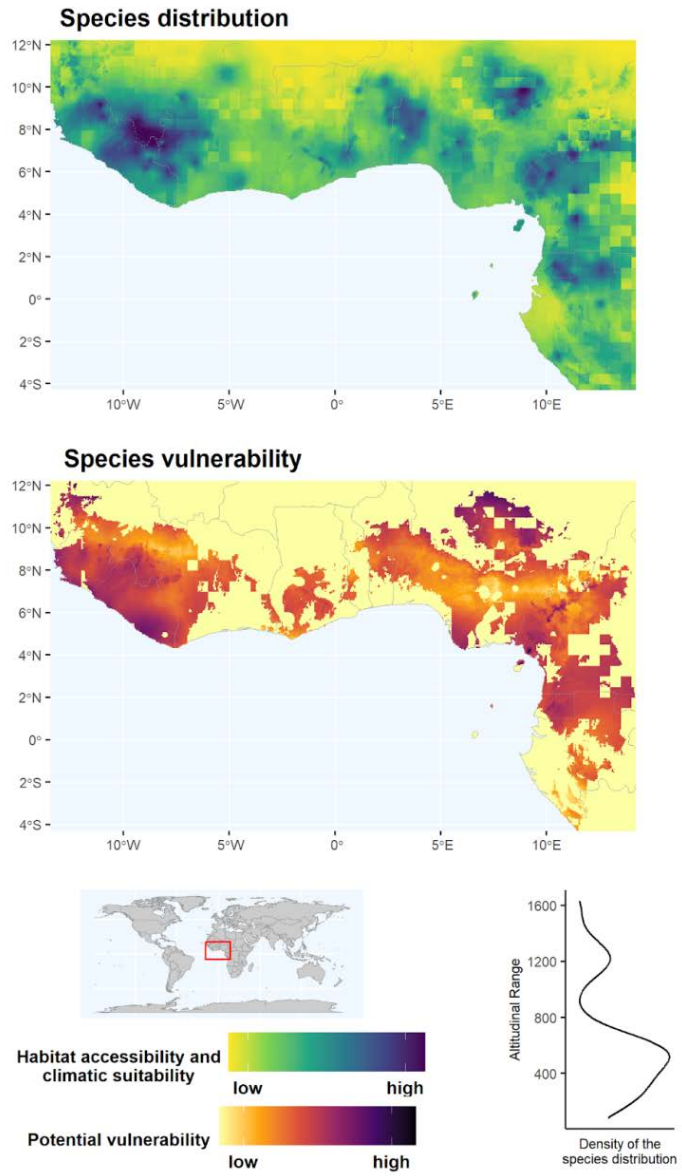
Blossfeldia liliputana Werderm.



B. liliputana is a homoiochlorophyllous plant whose distribution comprises Argentina Northwest, Bolivia. *B. liliputana* individuals can be primarily found in warm temperate climates, ranging from 2411 to 4372 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *B. liliputana* populations are expected to be potentially more vulnerable to climate change in parts of Argentina. This species is listed as Least concern by IUCN, and 70% of its distribution range is currently found within protected areas.

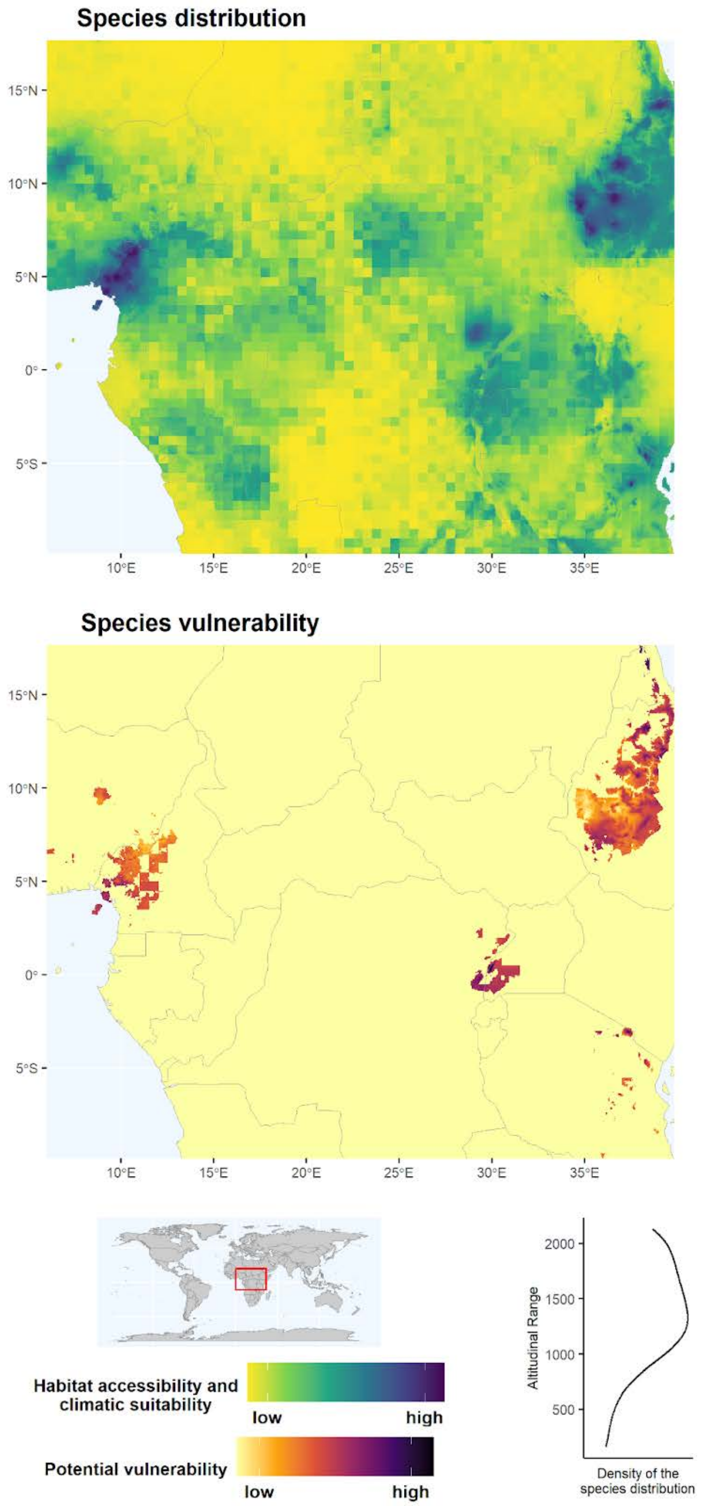
Cyperaceae

Afrotrilepis pilosa (Boeckeler) J. Raynal
(also cited as *Trilepis pilosa*)



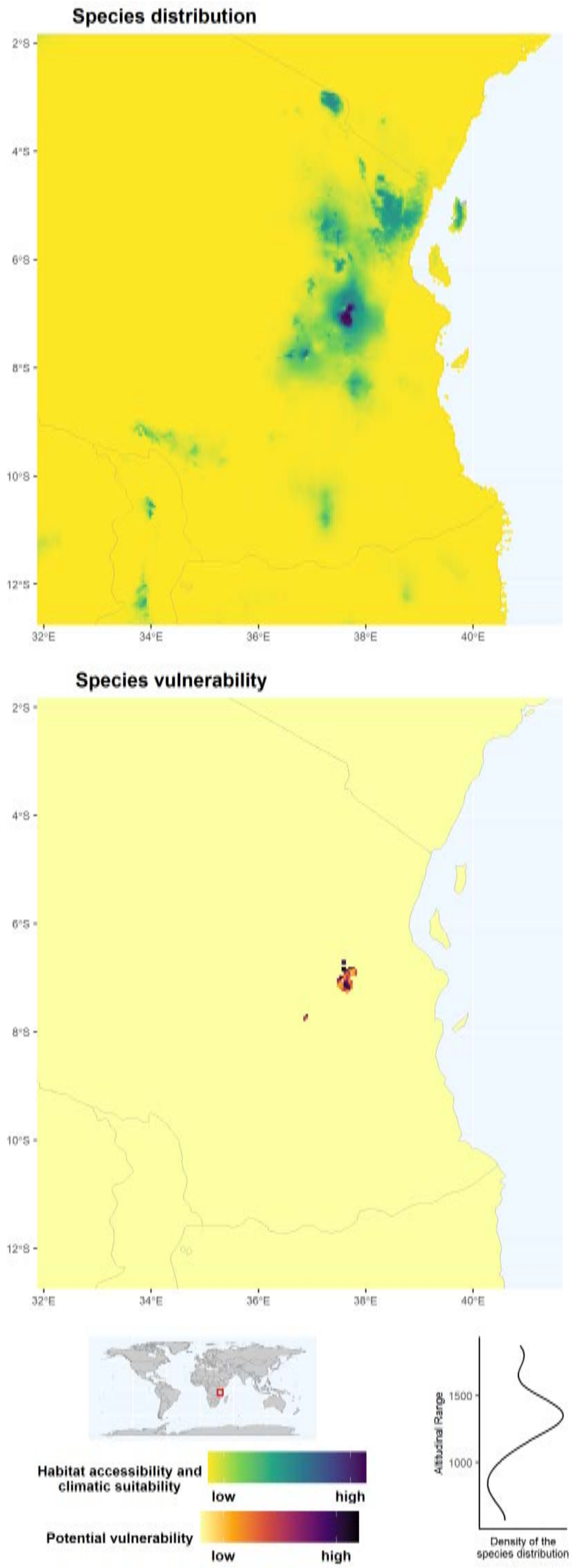
A. pilosa is a poikilochlorophyllous terrestrial hemicryptophytes whose distribution comprises Benin, Burkina, Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Ivory Coast, Liberia, Mali, Nigeria, Senegal, Sierra Leone, Togo. *A. pilosa* individuals can be primarily found in equatorial climates, ranging from 84 to 1632 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. pilosa* populations are expected to be potentially more vulnerable to climate change in parts of coastal areas of Liberia, northern parts of Nigeria, and montane areas of Cameroon. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Coleochloa abyssinica (Hochst. ex A. Rich.) Gilly



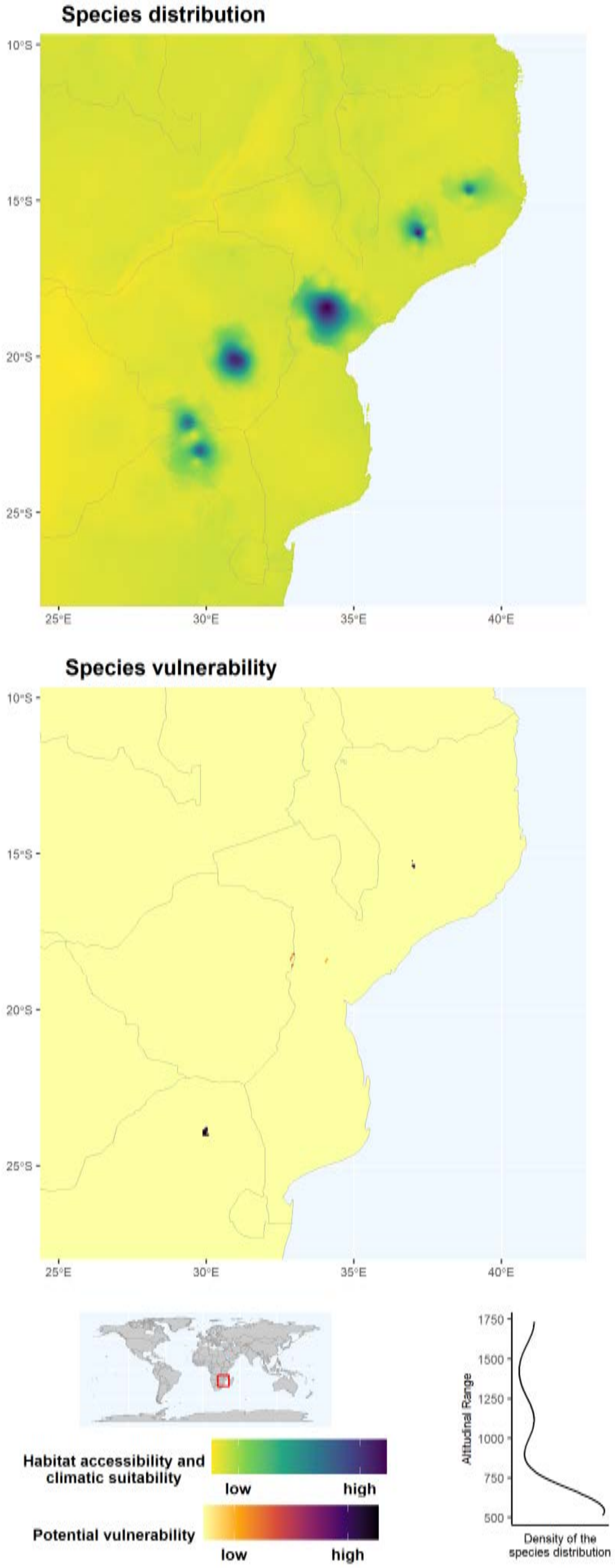
C. abyssinica is a poikilochlorophyllous terrestrial hemicryptophytes whose distribution comprises Angola, Cameroon, Eritrea, Ethiopia, Nigeria, Sudan, Tanzania, Uganda, Zaïre. *C. abyssinica* individuals can be primarily found in equatorial and warm temperate climates, ranging from 160 to 2132 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *C. abyssinica* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Cameroon, Eritrea, Ethiopia, Sudan, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

Coleochloa microcephala Nelmes



C. microcephala is a DT plant whose distribution is restricted to Tanzania. *C. microcephala* individuals can be primarily found in Cwb, Aw, Cwa climates, ranging from 567 to 1875 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *C. microcephala* populations are expected to be potentially more vulnerable to climate change in parts of Tanzania. This species has not yet been assessed by IUCN, and 40% of its distribution range is currently found within protected areas.

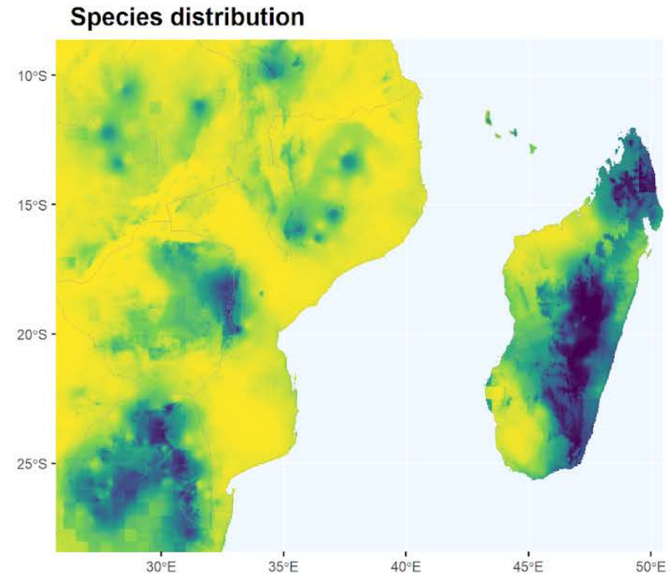
Coleochloa pallidior Nelmes

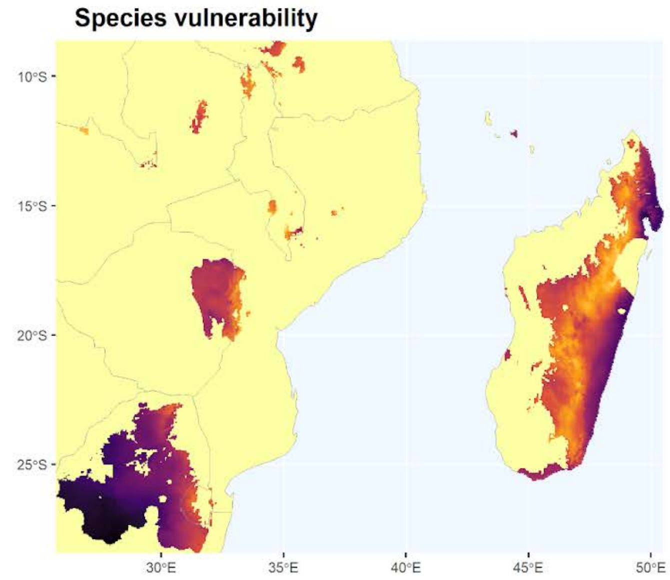


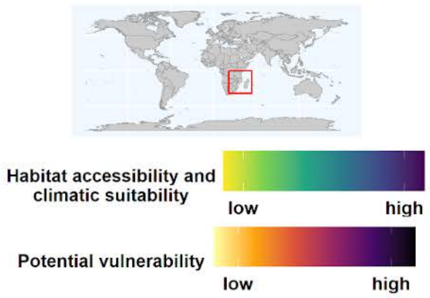
C. pallidior is a DT plant whose distribution comprises Malawi, Mozambique, Northern Provinces, Zimbabwe. *C. pallidior* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 514 to 1733 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *C. pallidior* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, South Africa, Zimbabwe. This species has not yet been assessed by IUCN, and 69% of its distribution range is currently found within protected areas.

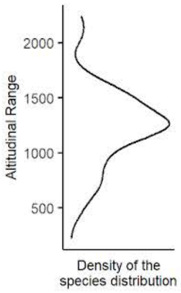
Coleochloa setifera (Ridl.) Gilly

C. setifera is a DT plant whose distribution comprises Kenya, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Northern Provinces, Swaziland, Tanzania, Zambia, Zaïre, Zimbabwe. C. setifera individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 223 to 2245 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. setifera* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar, South Africa. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.



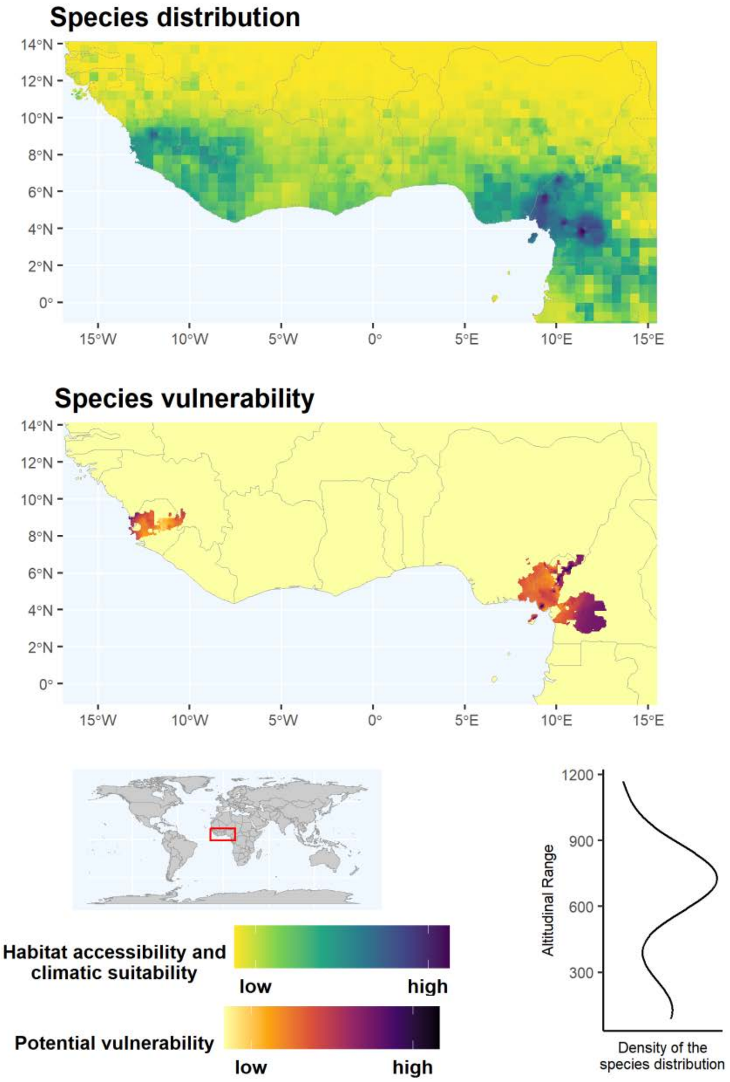




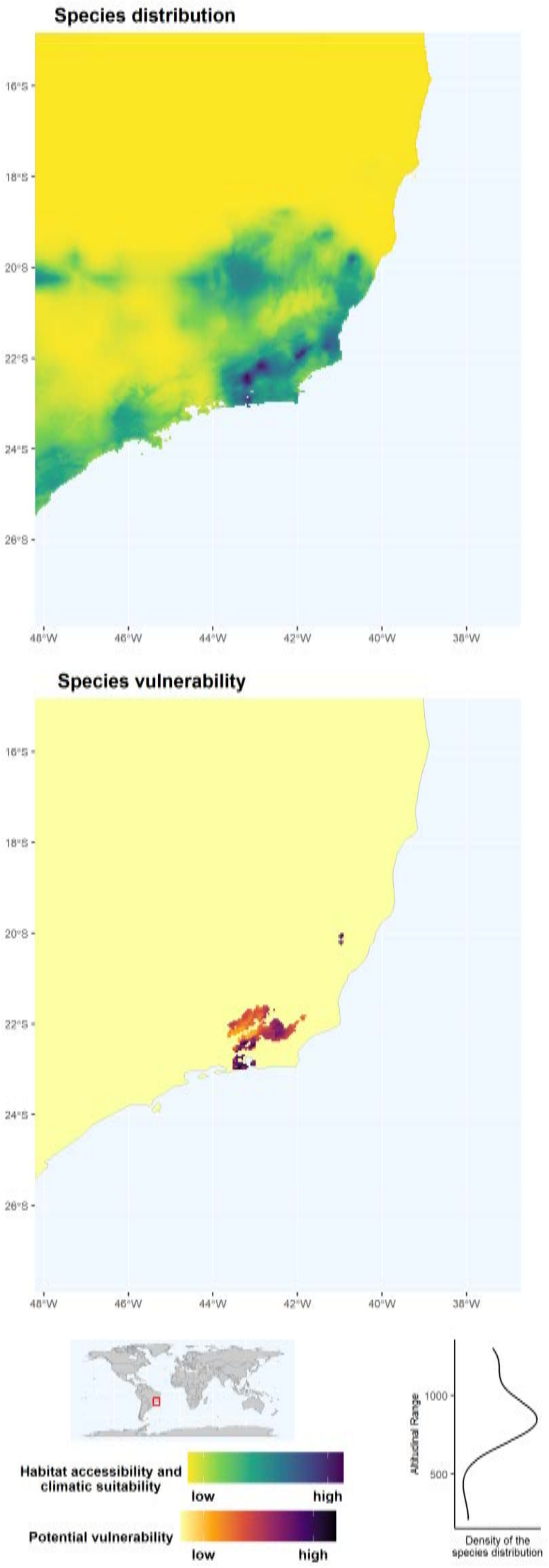


Microdracoides squamosus Hua
(also cited as *Microdracoides squamosa*)

M. squamosus is a DT plant whose distribution comprises Cameroon, Guinea, Nigeria, Sierra Leone. *M. squamosus* individuals can be primarily found in equatorial climates, ranging from 88 to 1169 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *M. squamosus* populations are expected to be potentially more vulnerable to climate change in parts of Cameroon, Equatorial Guinea, Nigeria, Sierra Leone. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

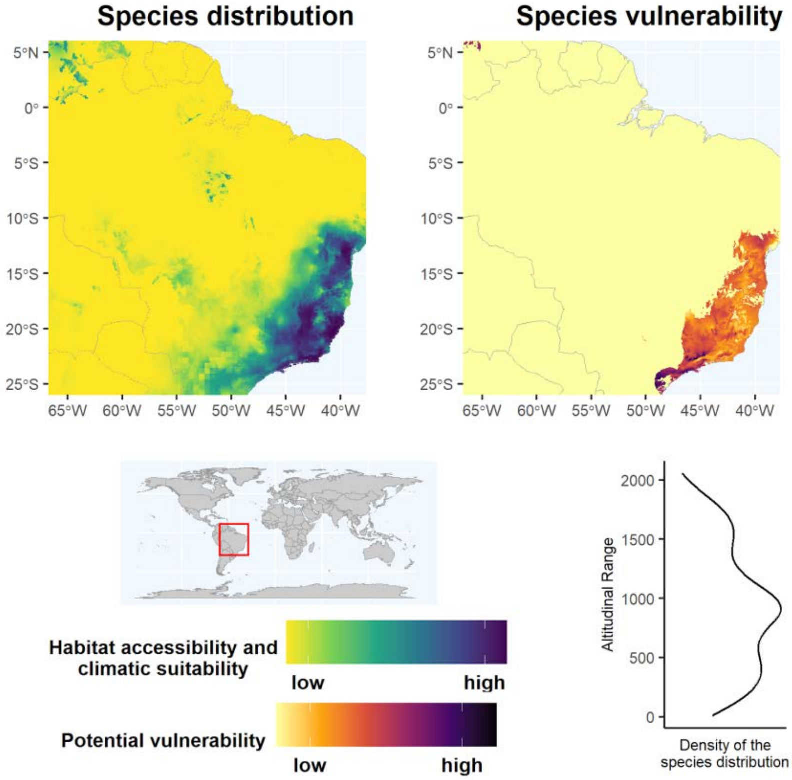


Trilepis ciliatifolia T. Koyama



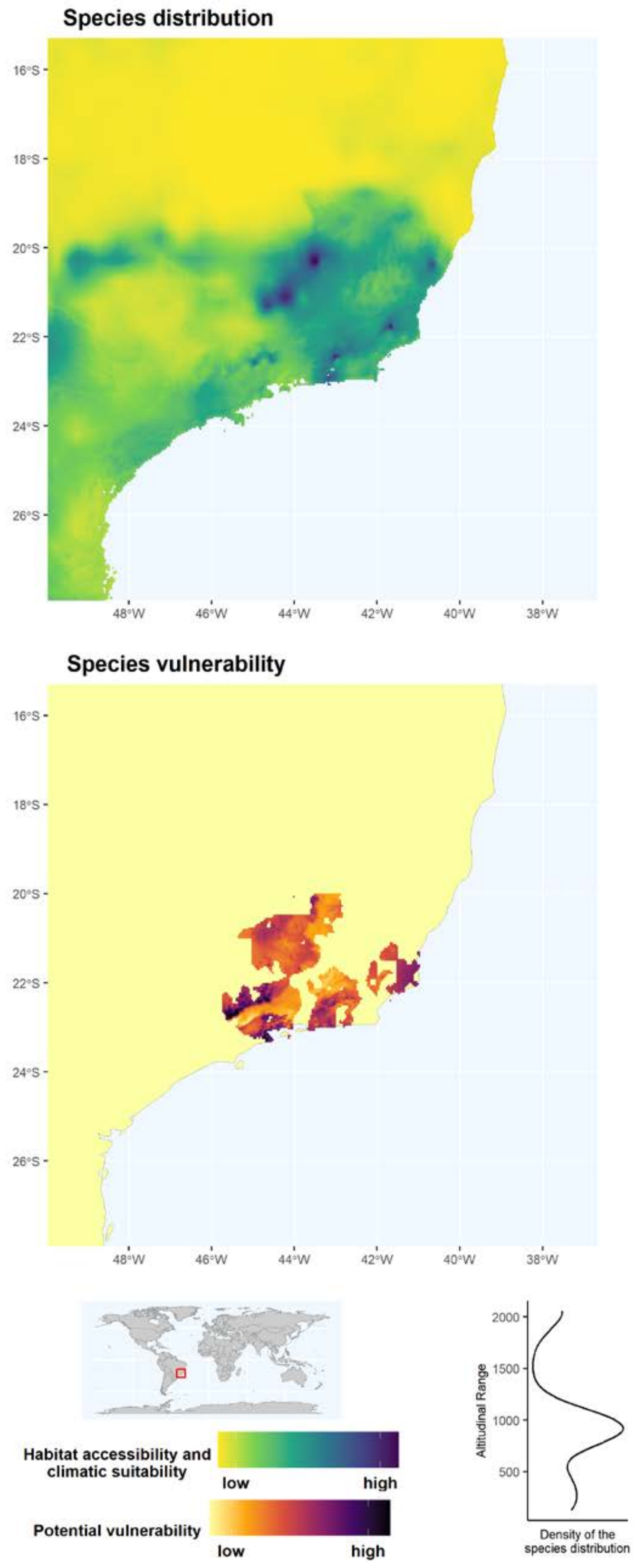
T. ciliatifolia is a DT plant whose distribution is restricted to Brazil Southeast. *T. ciliatifolia* individuals can be primarily found in equatorial and warm temperate climates, ranging from 210 to 1301 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *T. ciliatifolia* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Trilepis lhotzkiana Nees ex Arn.



T. lhotzkiana is a DT plant whose distribution comprises Brazil Northeast, Brazil Southeast, Venezuela. *T. lhotzkiana* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 8 to 2058 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *T. lhotzkiana* populations are expected to be potentially more vulnerable to climate change in parts of Brazil, Venezuela. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

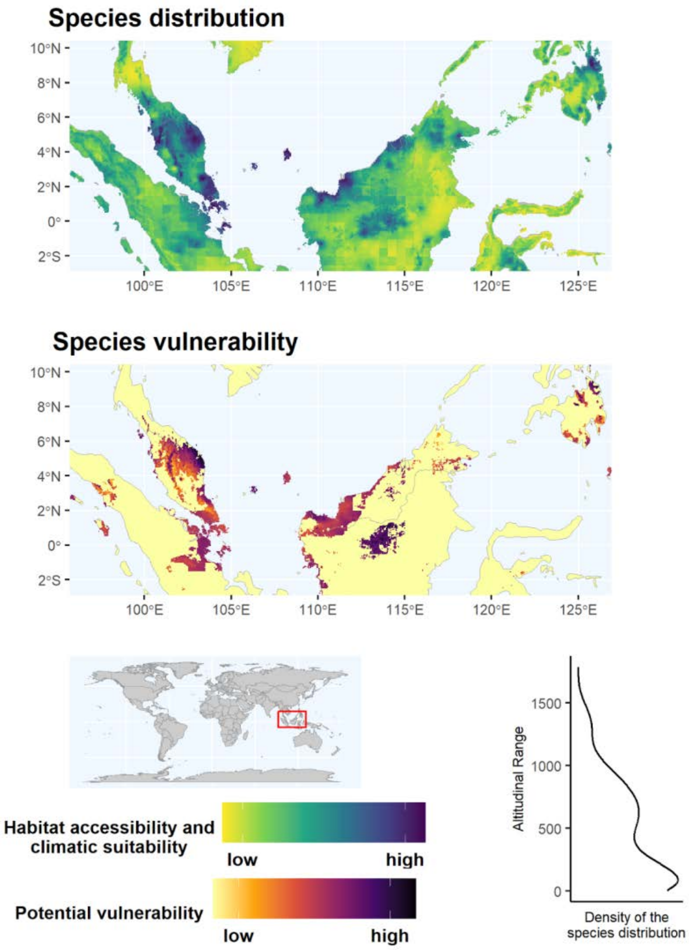
Trilepis microstachya (C.B. Clarke) H. Pfeiff.



T. microstachya is a DT plant whose distribution is restricted to Brazil southeast. *T. microstachya* individuals can be primarily found in equatorial and warm temperate climates, ranging from 125 to 2058 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *T. microstachya* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Davalliaceae

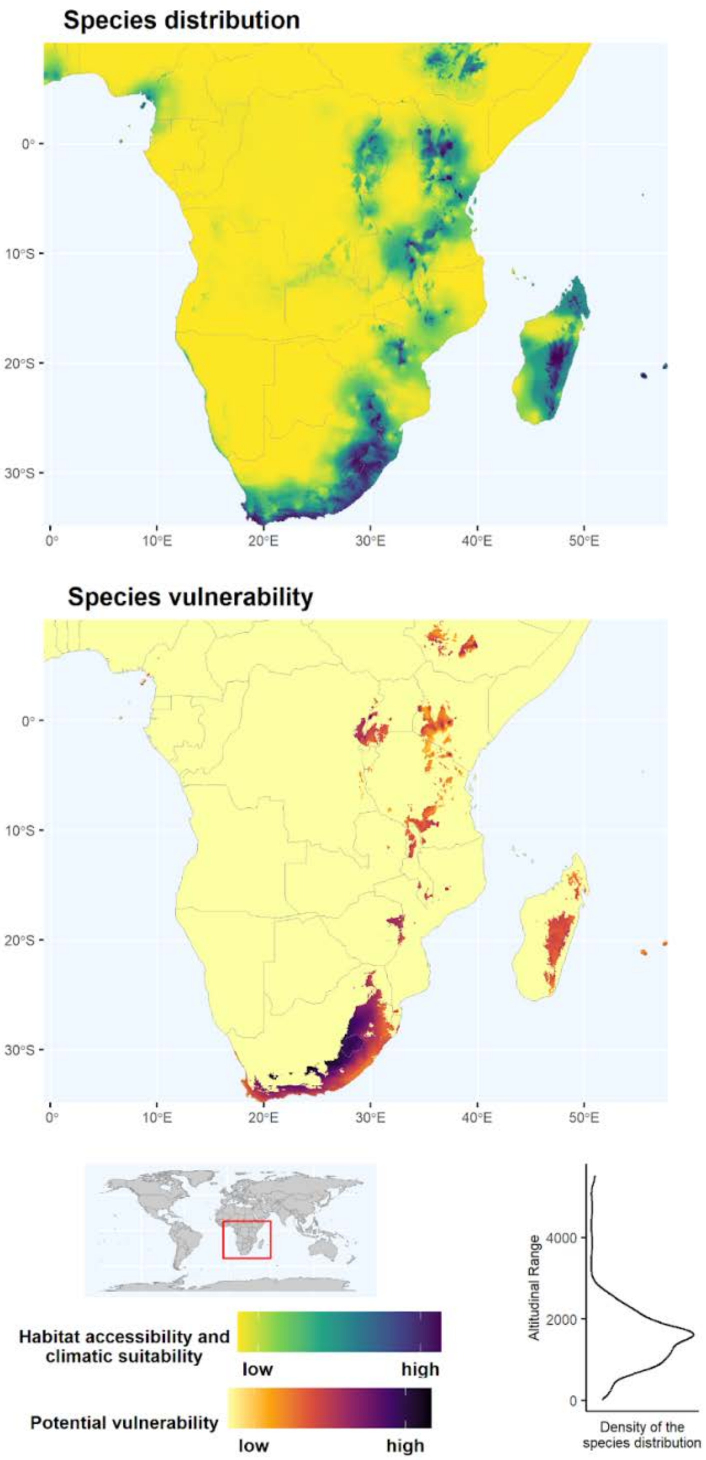
Davallia angustata Wall. ex Hook. & Grev.



D. angustata is a plant whose distribution comprises Borneo, Caroline Is., Malaya, Philippines, Sulawesi, Sumatera, Thailand, Vietnam. *D. angustata* individuals can be primarily found in equatorial climates, ranging from 6 to 1785 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the drier season is short). *D. angustata* populations are expected to be potentially more vulnerable to climate change in parts of Malaysia, Philippines, Thailand, Indonesia. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

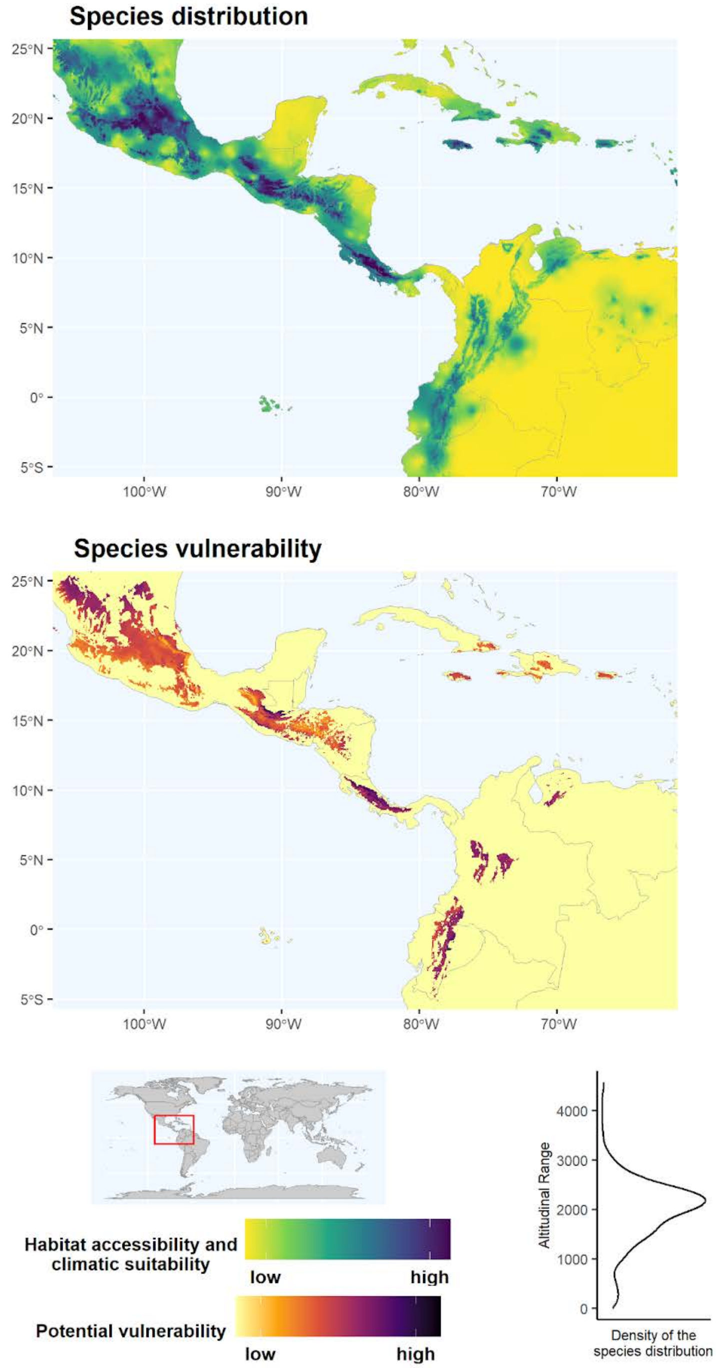
Dryopteridaceae

Elaphoglossum acrostichoides (Hook. & Grev.) Schelpe



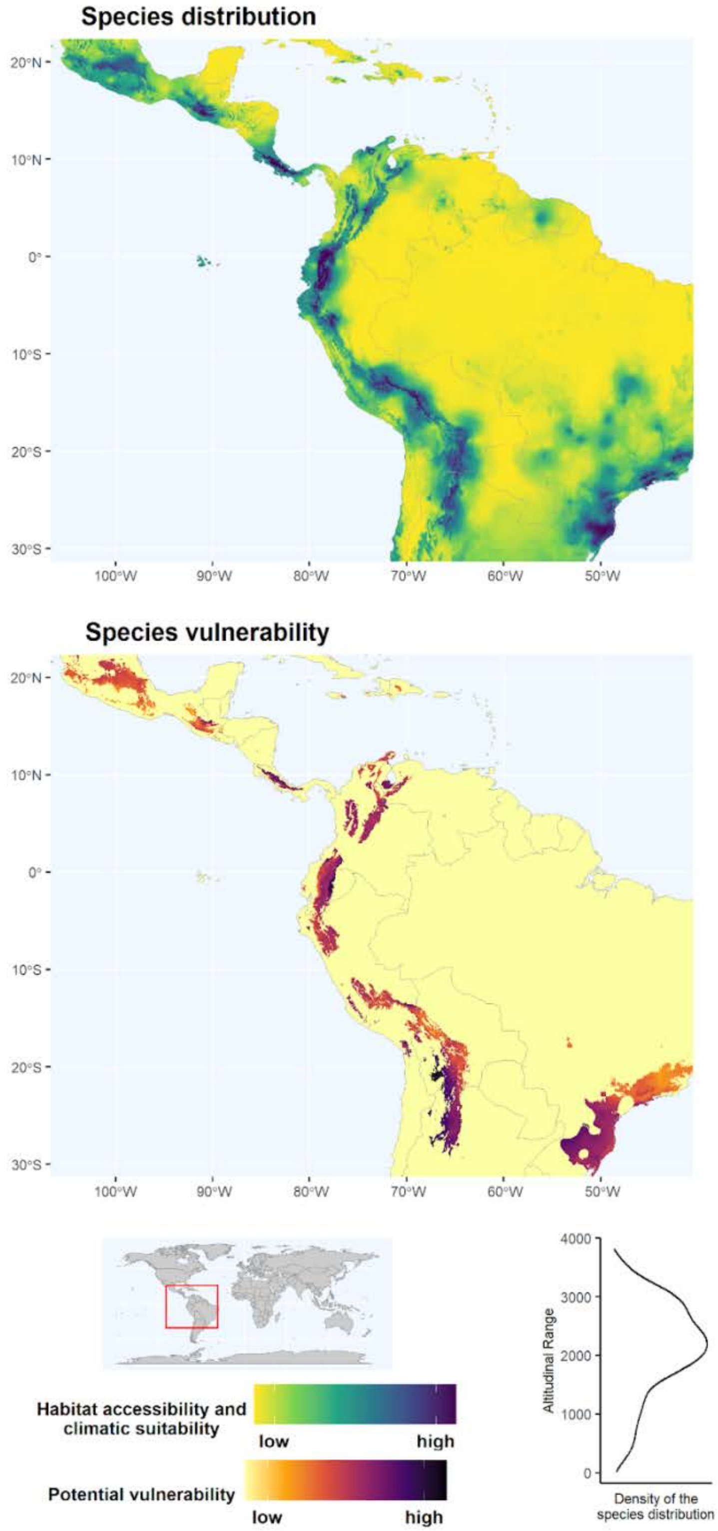
E. acrostichoides is a plant whose distribution comprises Angola, Burundi, Cameroon, Cape Provinces, Comoros, Ethiopia, Free State, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, KwaZulu-Natal, Lesotho, Liberia, Madagascar, Malawi, Mozambique, Northern Provinces, Rwanda, Réunion, Swaziland, Tanzania, Uganda, Zaïre, Zimbabwe. *E. acrostichoides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 13 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *E. acrostichoides* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Kenya, South Africa, Lesotho, Tanzania, Uganda. This species is listed as Least concern by IUCN, although only 27% of its distribution range is currently found within protected areas.

Elaphoglossum petiolatum (Sw.) Urb.



E. petiolatum is a plant whose distribution comprises Argentina Northeast, Brazil Southeast, Brazil West-Central, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Venezuela. *E. petiolatum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 7 to 4575 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *E. petiolatum* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Nicaragua, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Elaphoglossum piloselloides (C. Presl) T. Moore
(also cited as *Elaphoglossum spathulatum*)

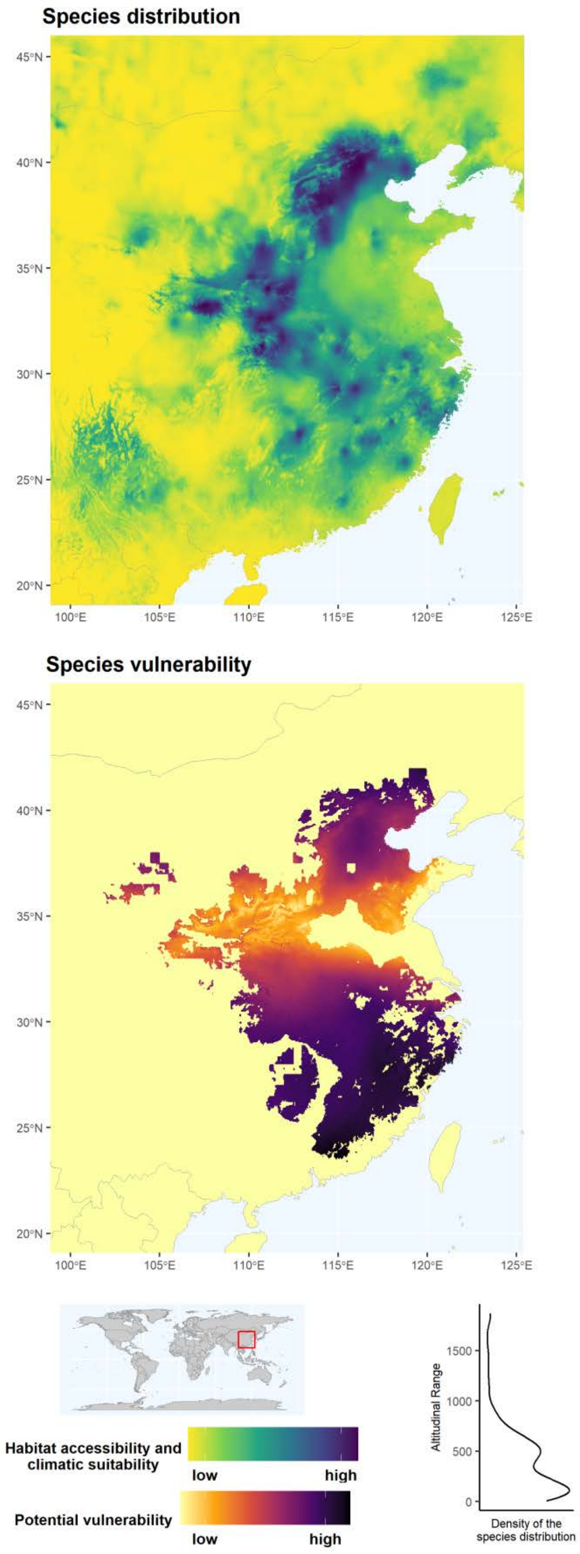

Species distribution

Species vulnerability

E. piloselloides is a plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil South, Colombia, Costa Rica, Ecuador, El Salvador, French Guiana, Guatemala, Honduras, Jamaica, Leeward Is., Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Peru, Puerto Rico, Suriname, Uruguay, Venezuela, Windward Is. *E. piloselloides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 15 to 3815 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *E. piloselloides* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Peru, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Gesneriaceae

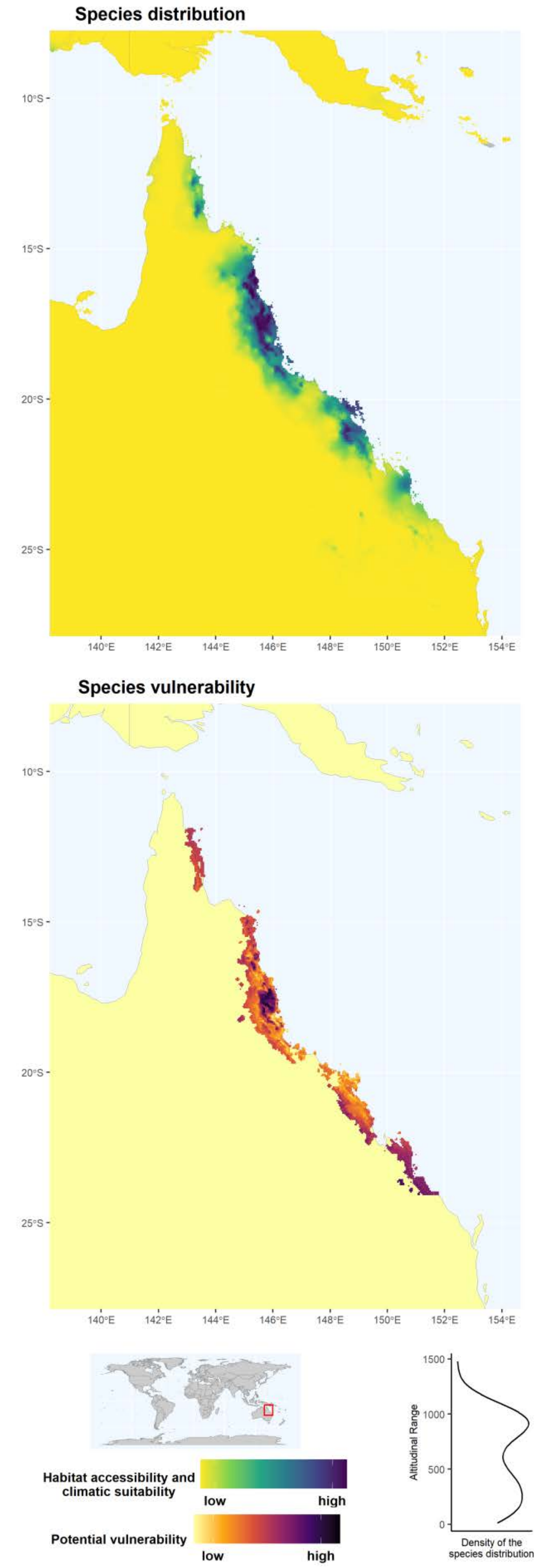
Boea hygrometrica (Bunge) R. Br.



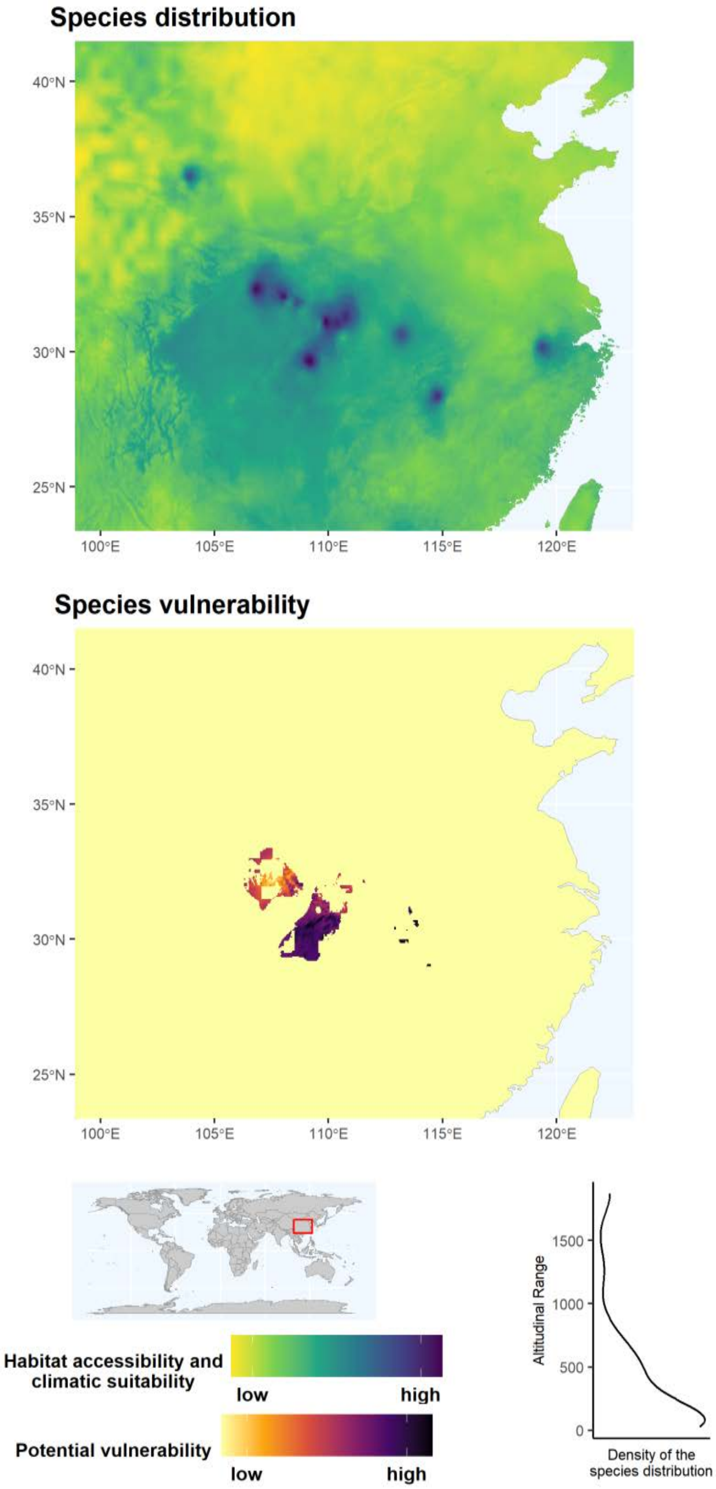
B. hygrometrica is a plant whose distribution comprises China North-Central, China South-Central, China Southeast, Manchuria. *B. hygrometrica* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 6 to 1869 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *B. hygrometrica* populations are expected to be potentially more vulnerable to climate change in parts of China. This species has not yet been assessed by IUCN, and only 1% of its distribution range is currently found within protected areas.

Boea hygroscopica F. Muell.

B. hygroscopica is a homoiochlorophyllous plant whose distribution is restricted to Queensland. *B. hygroscopica* individuals can be primarily found in equatorial and warm temperate climates, ranging from 12 to 1478 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *B. hygroscopica* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 53% of its distribution range is currently found within protected areas.

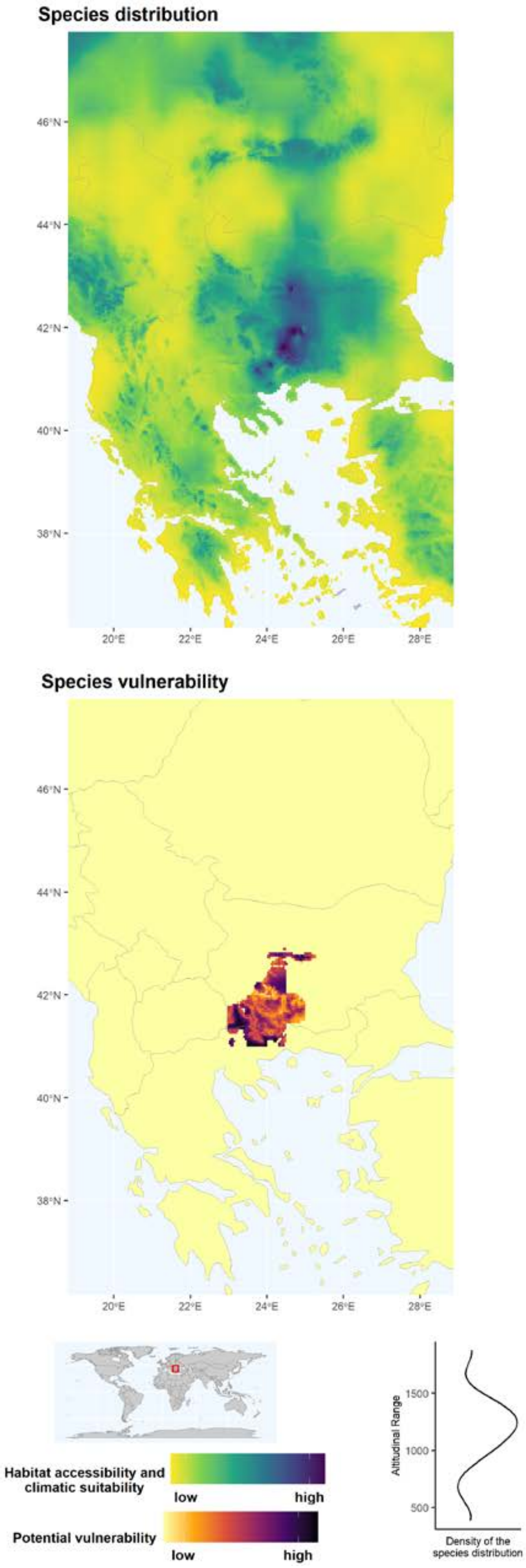


Damrongia clarkeana (Hemsl.) C. Puglisi
(also cited as *Boea clarkeana*)



D. clarkeana is a plant whose distribution comprises China North-Central, China South-Central, China Southeast. *D. clarkeana* individuals can be primarily found in arid and warm temperate climates, ranging from 30 to 1869 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *D. clarkeana* populations are expected to be potentially more vulnerable to climate change in parts of China. This species has not yet been assessed by IUCN, and less than 1% of its distribution range is currently found within protected areas.

Haberlea rhodopensis Friv.

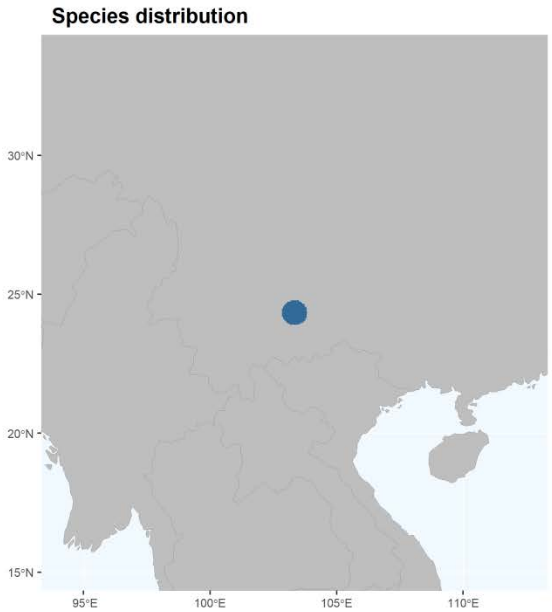


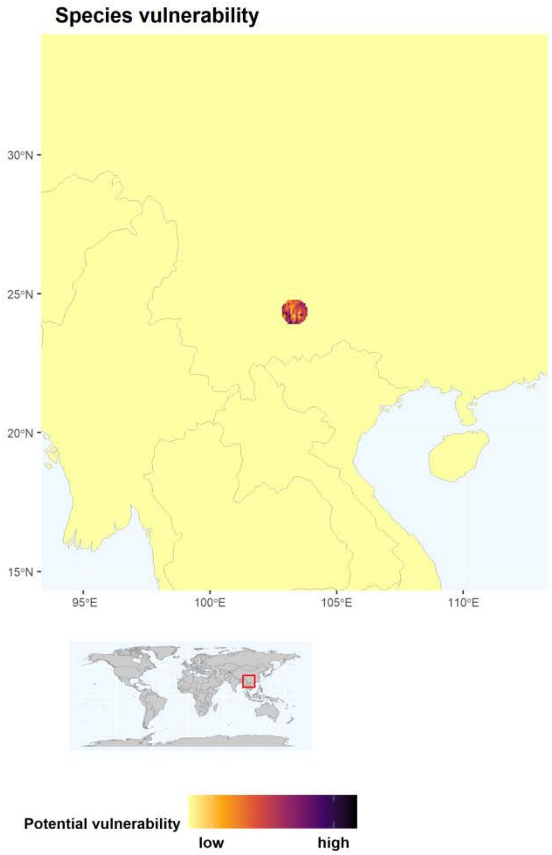
H. rhodopensis is a homoiochlorophyllous plant whose distribution comprises Bulgaria, Greece. *H. rhodopensis* individuals can be primarily found in warm temperate climates, ranging from 386 to 1878 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. H. rhodopensis populations are expected to be potentially more vulnerable to climate change in parts of Bulgaria, Greece. This species is listed as Least concern by IUCN, and 76% of its distribution range is currently found within protected areas.

Oreocharis mileensis (W.T. Wang) Mich. Möller & A. Weber

(also cited as *Paraisometrum mileense*)

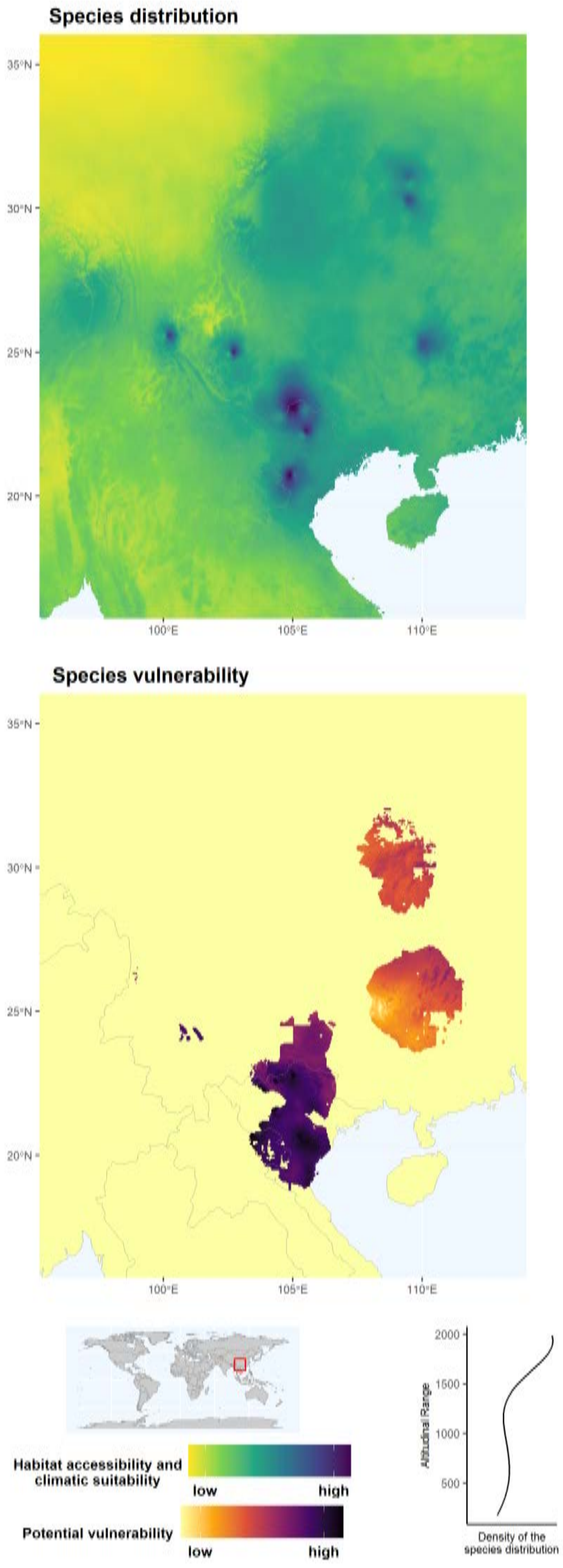
O. mileensis is a plant whose distribution is restricted to China South-Central. *O. mileensis* individuals can be primarily found in warm temperate climates, circa 1883 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime. More occurrence points are needed for a consistent evaluation of the conservation of *O. mileensis* populations. This species has not yet been assessed by IUCN, and 3% of its distribution range is currently found within protected areas.



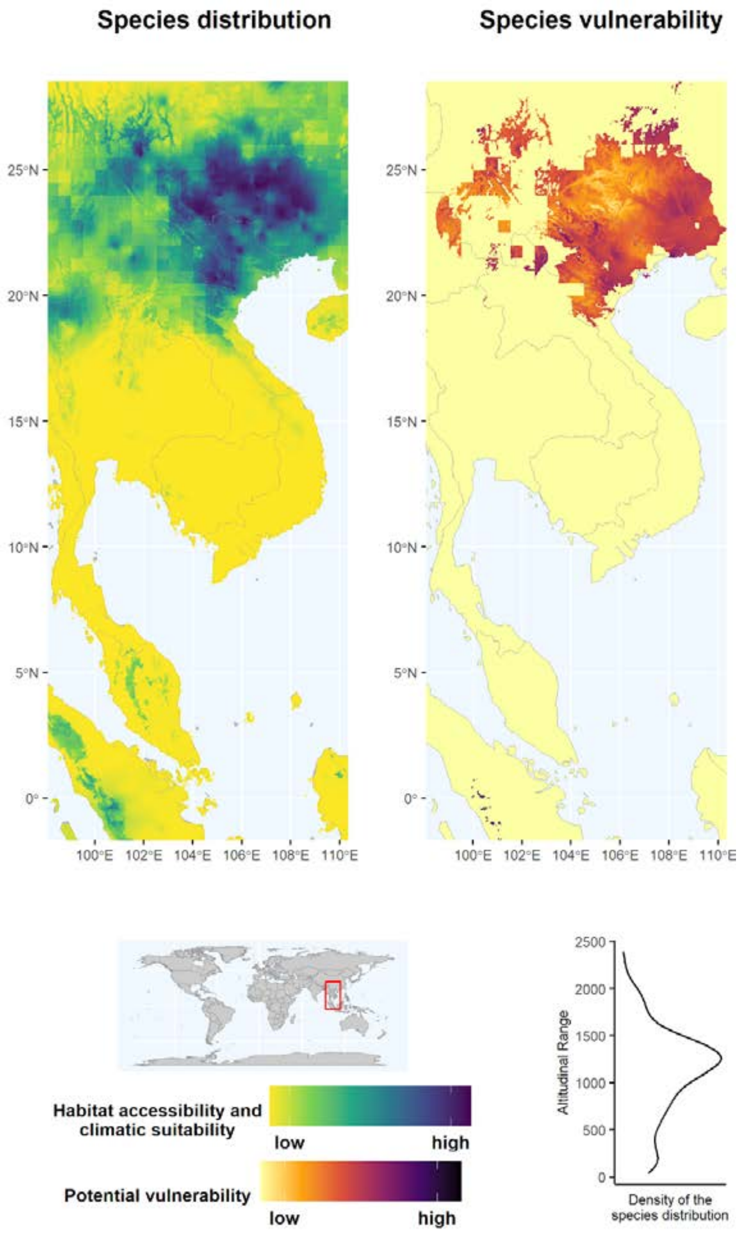


Paraboea crassifolia (Hemsl.) B.L. Burtt (also cited as *Boea crassifolia*)

P. crassifolia is a plant whose distribution comprises China South-Central, Laos, Viet Nam. *P. crassifolia* individuals can be primarily found in warm temperate climates, ranging from 175 to 1984 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *P. crassifolia* populations are expected to be potentially more vulnerable to climate change in parts of China, Laos, Viet Nam. This species has not yet been assessed by IUCN, and only 6% of its distribution range is currently found within protected areas.



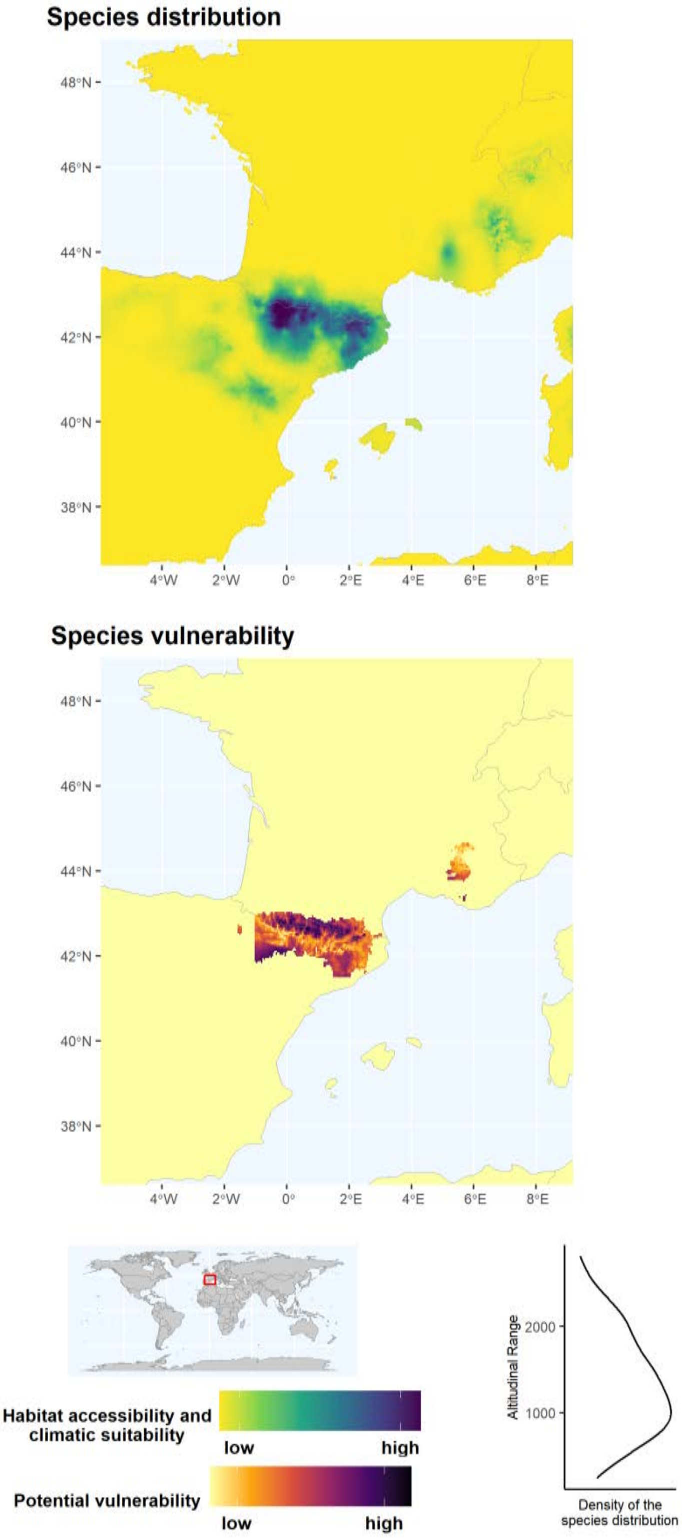
Paraboea rufescens (Franch.) B.L. Burtt



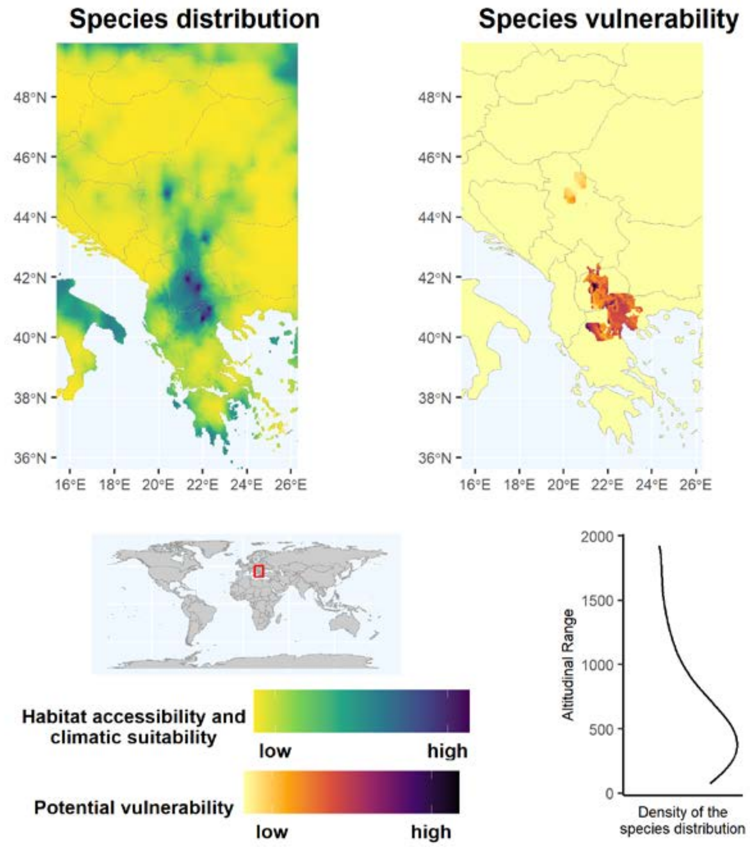
P. rufescens is a plant whose distribution comprises China South-Central, China Southeast, Thailand, Vietnam. *P. rufescens* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 41 to 2396 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. rufescens* populations are expected to be potentially more vulnerable to climate change in parts of China, Indonesia. This species has not yet been assessed by IUCN, and only 5% of its distribution range is currently found within protected areas.

Ramonda myconi (L.) Rchb.
(also cited as *Ramonda pyrenaica*)

R. myconi is a homoiochlorophyllous plant whose distribution comprises France, Spain. *R. myconi* individuals can be primarily found in warm temperate climates, ranging from 246 to 2812 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *R. myconi* populations are expected to be potentially more vulnerable to climate change in parts of France, Andorra, Spain. This species is listed as Least concern by IUCN, and 71% of its distribution range is currently found within protected areas.

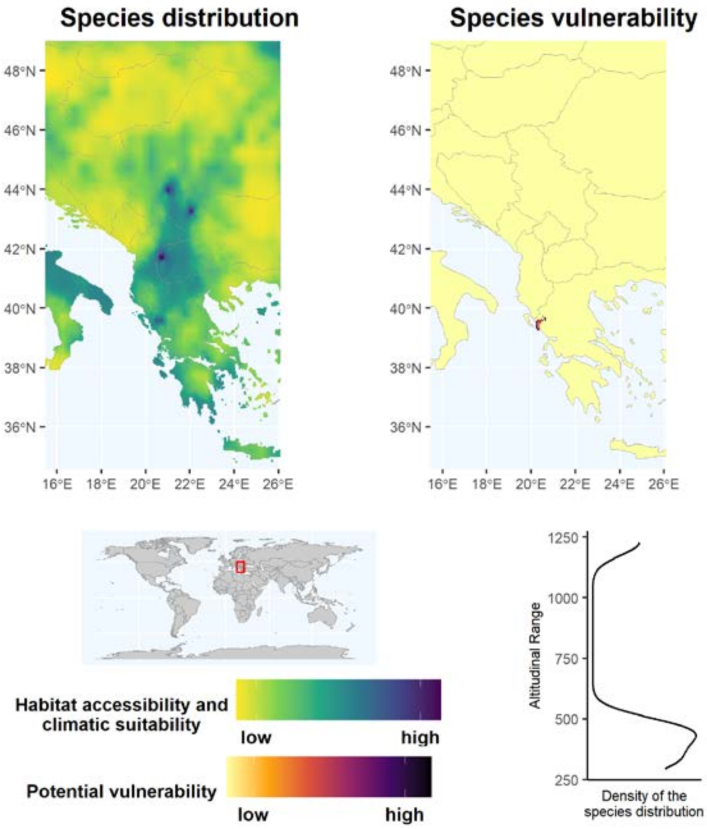


Ramonda nathaliae Pančić & Petrovič



R. nathaliae is a homoiochlorophyllous plant whose distribution comprises Greece, Yugoslavia. *R. nathaliae* individuals can be primarily found in warm temperate climates, ranging from 75 to 1924 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and is restricted to areas which precipitation is spread throughout the year (with a definite wetter season). *R. nathaliae* populations are expected to be potentially more vulnerable to climate change in parts of Greece, North Macedonia. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

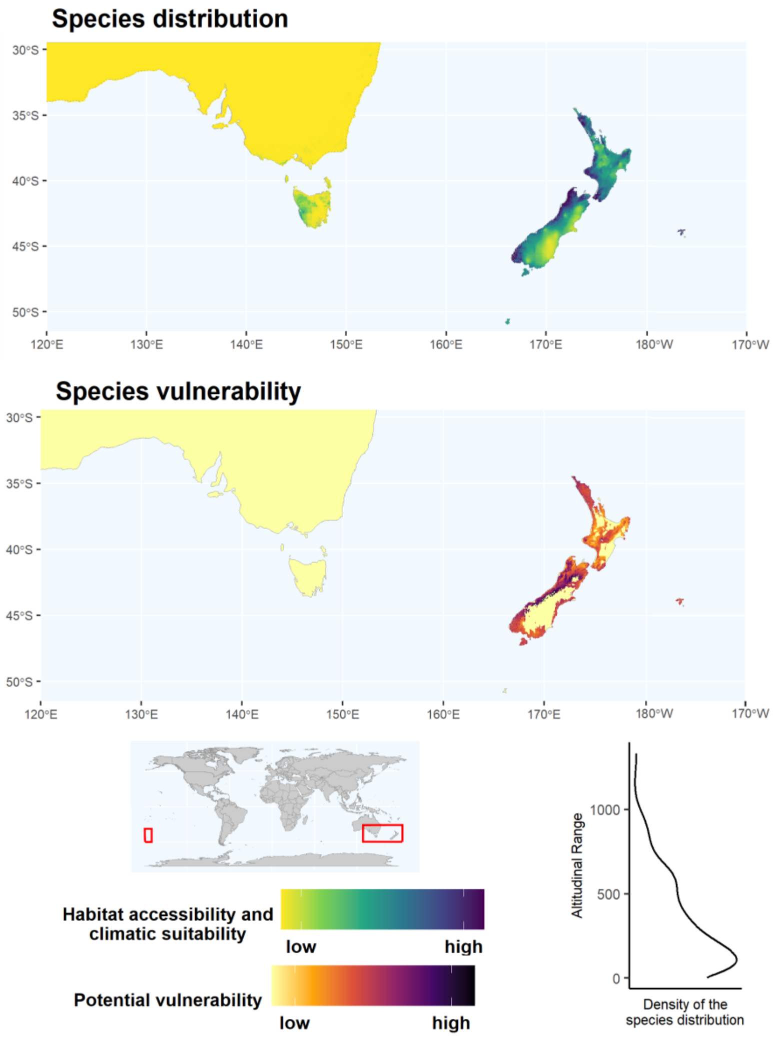
Ramonda serbica Pančić



R. serbica is a homoiochlorophyllous plant whose distribution comprises Albania, Bulgaria, Greece, Yugoslavia. *R. serbica* individuals can be primarily found in warm temperate climates, ranging from 296 to 1229 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the drier season is short). *R. serbica* populations are expected to be potentially more vulnerable to climate change in parts of Greece. This species has not yet been assessed by IUCN, and 42% of its distribution range is currently found within protected areas.

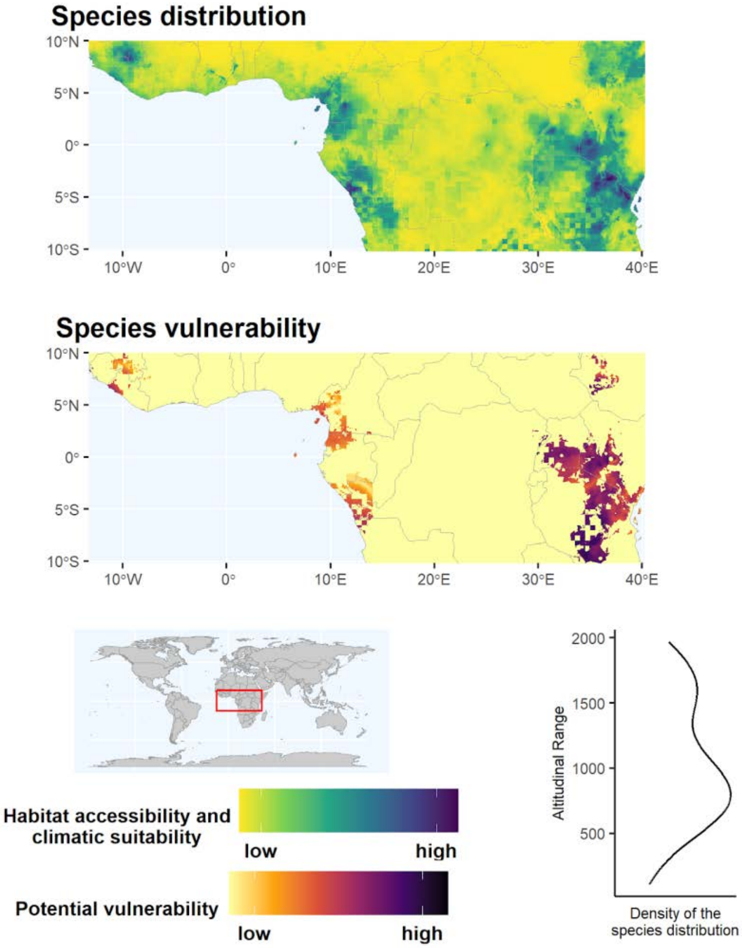
Hymenophyllaceae

Cardiomanes reniforme (G. Forst.) C. Presl
(also cited as *Hymenophyllum nephrophyllum*)



C. reniforme is a plant whose distribution comprises Chatham Is., New Zealand North, New Zealand South. *C. reniforme* individuals can be primarily found in warm temperate climates, ranging from 5 to 1332 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *C. reniforme* populations are expected to be potentially more vulnerable to climate change in parts of New Zealand. This species has not yet been assessed by IUCN, and 43% of its distribution range is currently found within protected areas.

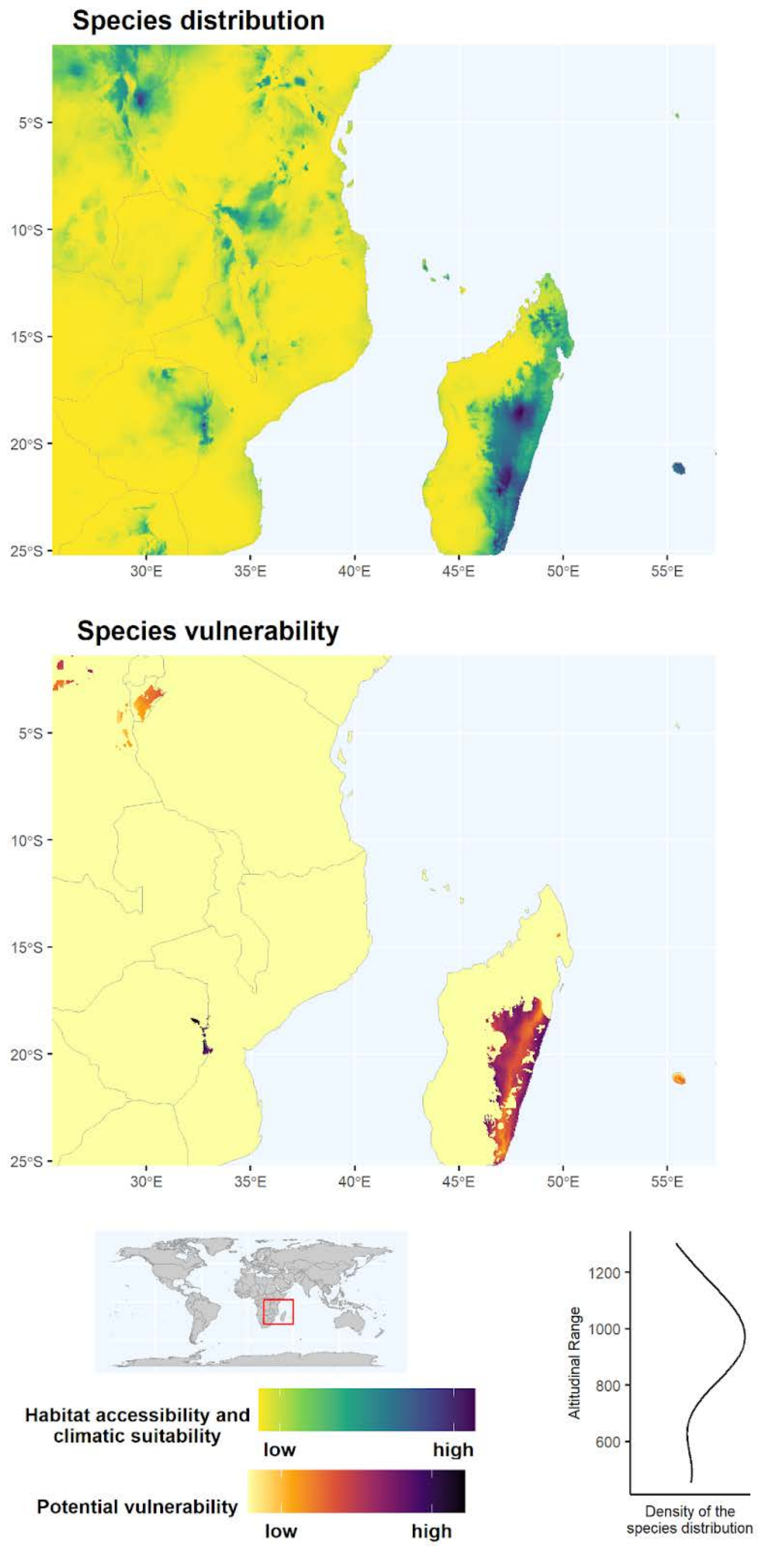
Crepidomanes chevalieri (Christ) Ebihara & Dubuisson
(also cited as *Trichomanes chevalieri*)



C. chevalieri is a plant whose distribution comprises Cameroon, Central African Republic, Ethiopia, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, Liberia, Nigeria, Sierra Leone, Tanzania, Uganda, Zaïre. *C. chevalieri* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 111 to 1970 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. chevalieri* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Malawi, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

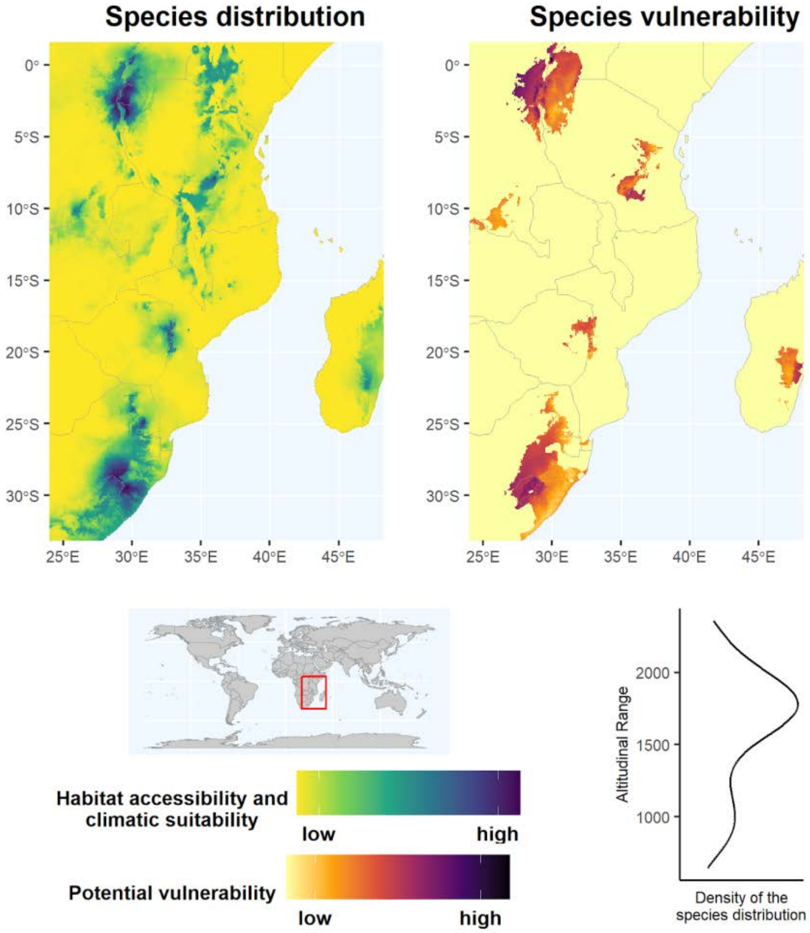
Crepidomanes frappieri (Cordem.) J.P. Roux (also cited as *Trichomanes ramitrichum*)

C. frappieri is a plant whose distribution comprises Burundi, Kenya, Mozambique, Rwanda, Réunion, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *C. frappieri* individuals can be primarily found in equatorial and warm temperate climates, ranging from 455 to 1304 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *C. frappieri* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar, Mozambique, Zimbabwe. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.


Species distribution

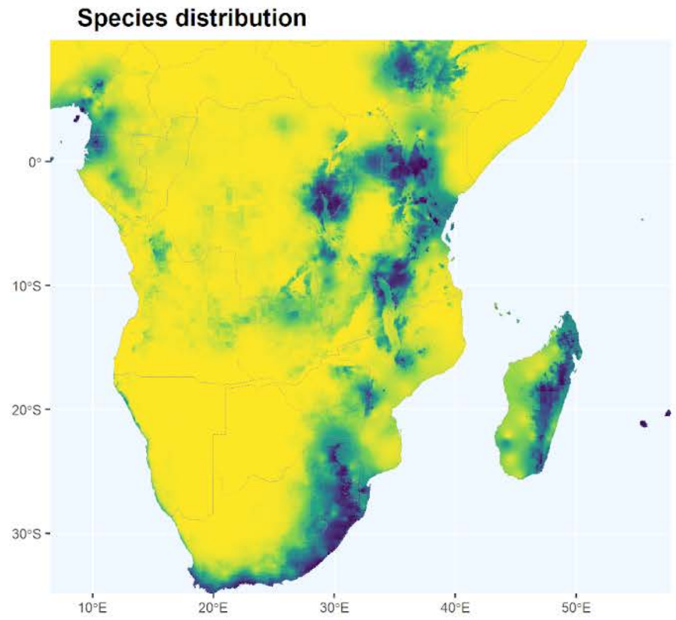
Species vulnerability

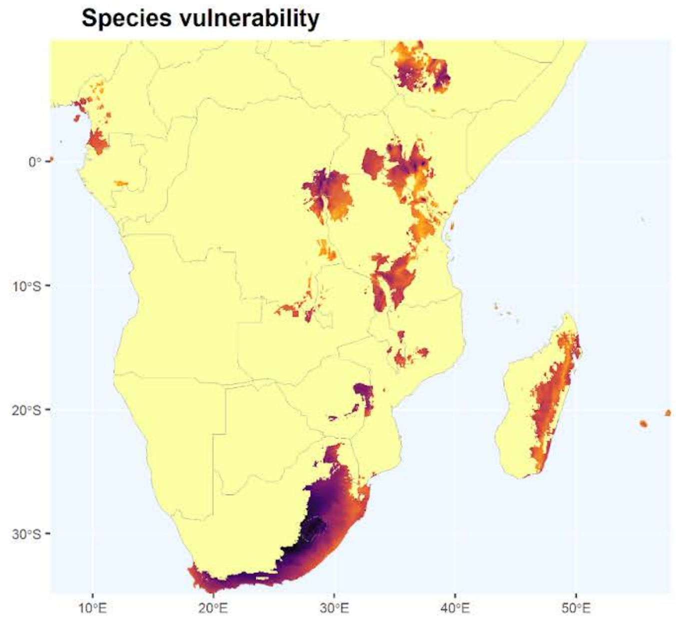
Crepidomanes inopinatum (Pic. Serm.) J.P. Roux

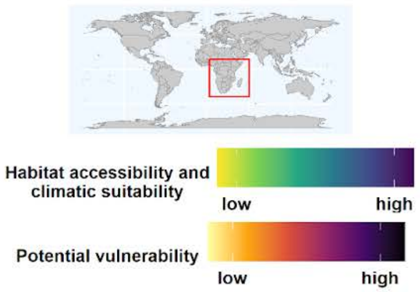


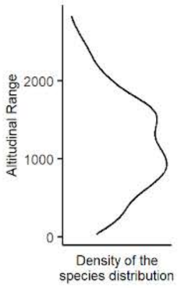
C. inopinatum is a homoiochlorophyllous plant whose distribution comprises Burundi, Cape Provinces, Comoros, Free State, KwaZulu-Natal, Madagascar, Northern Provinces, Rwanda, Réunion, Swaziland, Zaïre. *C. inopinatum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 646 to 2358 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. inopinatum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Uganda. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Crepidomanes melanotrichum (Schltdl.) J.P. Roux (also cited as *Trichomanes melanotrichum*)



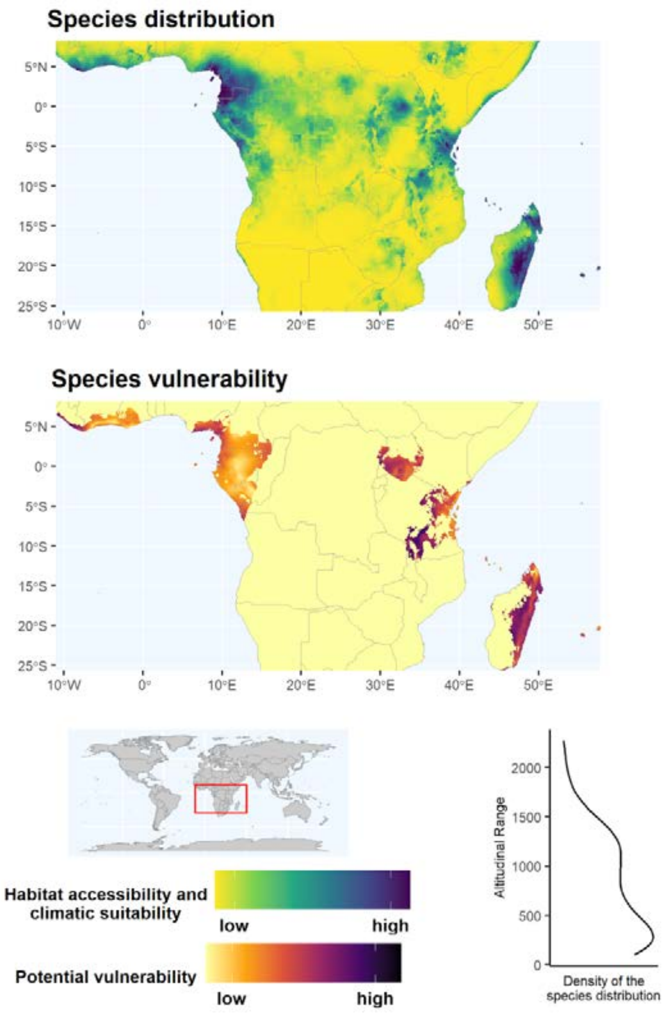






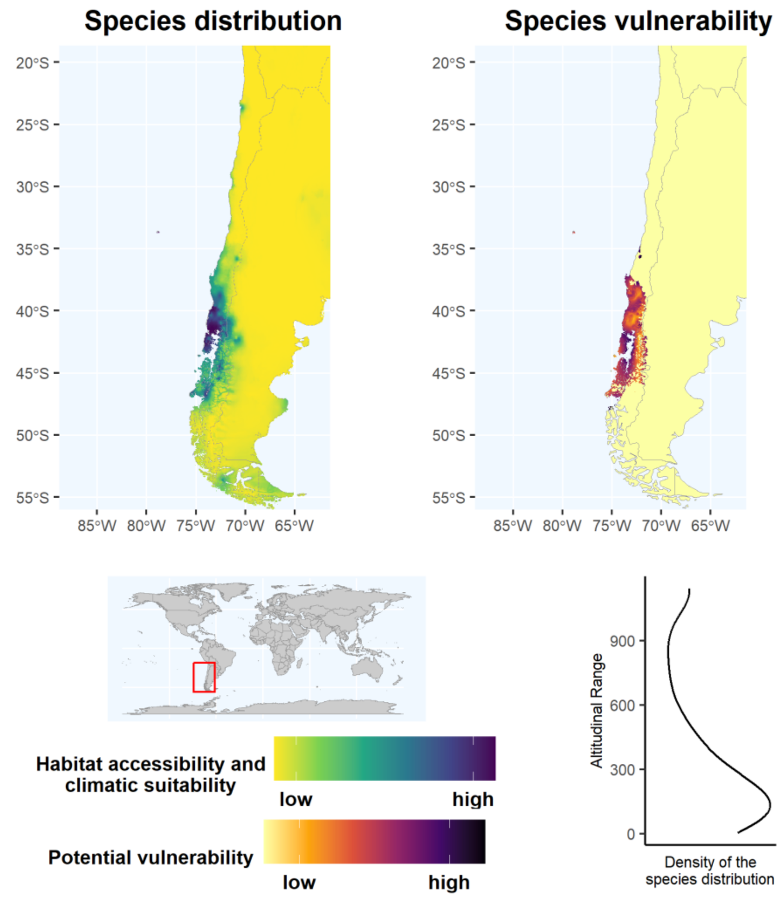
C. melanotrichum is a plant whose distribution comprises Angola, Burundi, Cameroon, Cape Provinces, Central African Republic, Equatorial Guinea, Ethiopia, Free State, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, KwaZulu-Natal, Liberia, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Northern Provinces, Réunion, Sierra Leone, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *C. melanotrichum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 37 to 2831 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *C. melanotrichum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, South Africa, Lesotho, Tanzania, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

Didymoglossum erosum (Willd.) J.P. Roux
(also cited as *Trichomanes erosum*)



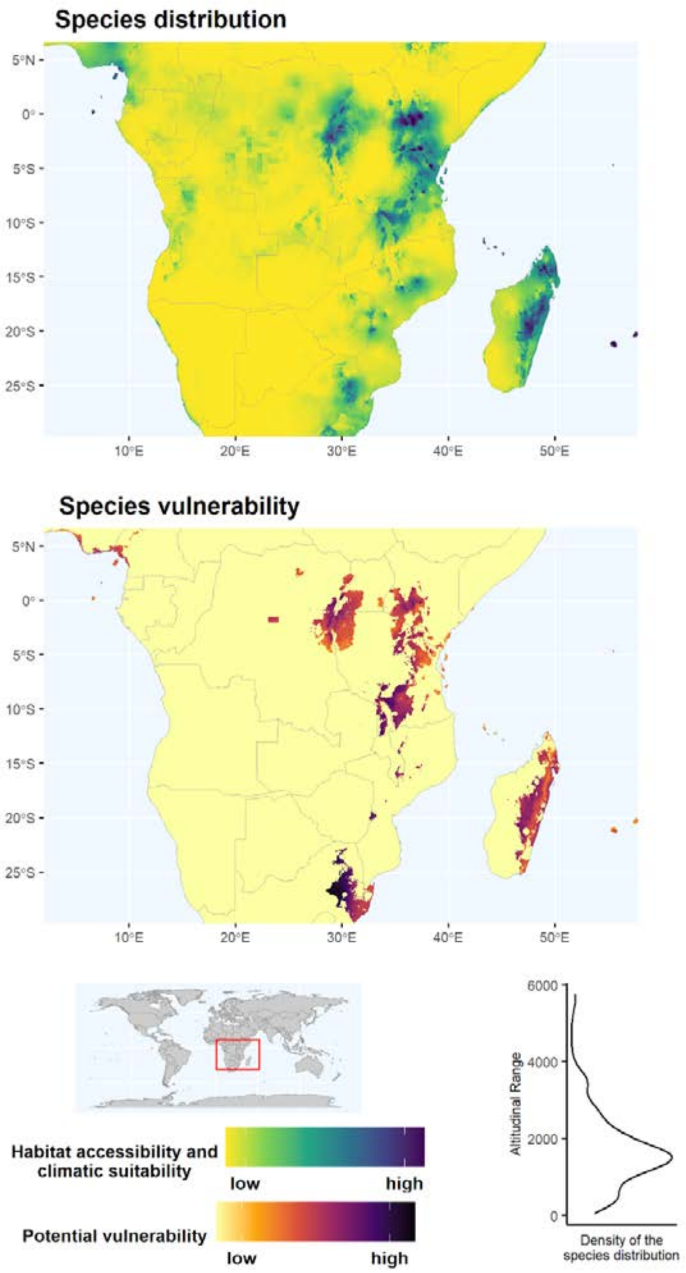
D. erosum is a plant whose distribution comprises Angola, Burundi, Cameroon, Central African Republic, Comoros, Gabon, Ghana, Guinea, Ivory Coast, Kenya, KwaZulu-Natal, Liberia, Mozambique, Nigeria, Rwanda, Seychelles, Sierra Leone, Tanzania, Uganda, Zaïre, Zimbabwe. *D. erosum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 100 to 2278 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *D. erosum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Cameroon, Kenya, Liberia, Madagascar, Mozambique, Malawi, Tanzania, Uganda, Zambia. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Hymenoglossum cruentum (Cav.) C. Presl
(also cited as *Hymenophyllum cruentum*)



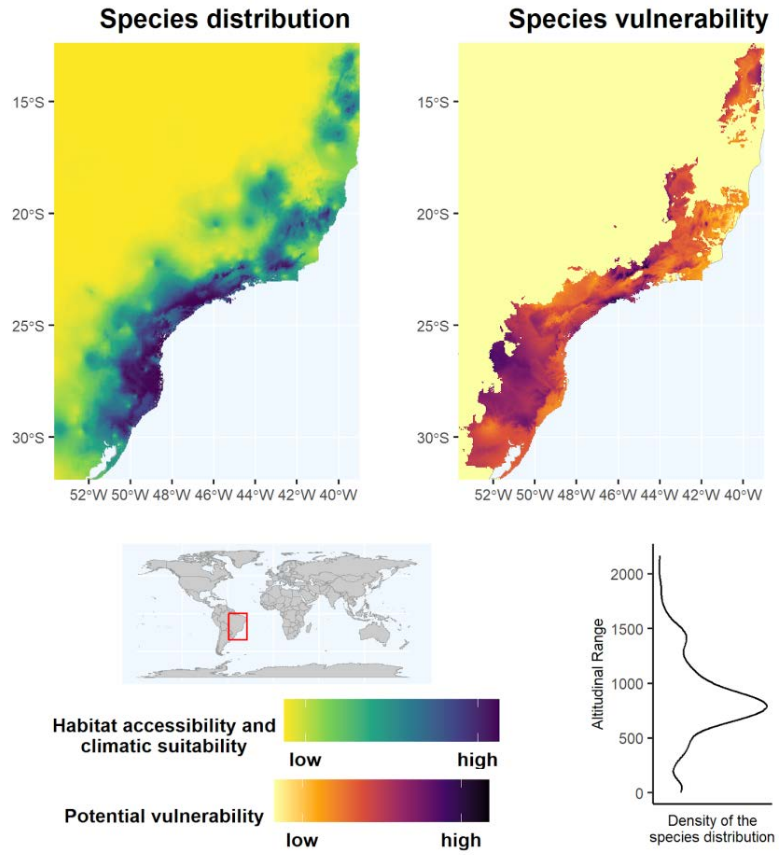
H. cruentum is a homoiochlorophyllous plant whose distribution comprises Argentina South, Chile Central, Chile South, Juan Fernández Is. *H. cruentum* individuals can be primarily found in warm temperate climates, ranging from 5 to 1142 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *H. cruentum* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Chile. This species has not yet been assessed by IUCN, and only 35% of its distribution range is currently found within protected areas.

Hymenophyllum capillare Desv.



H. capillare is a plant whose distribution comprises Burundi, Cameroon, Comoros, Ghana, Gulf of Guinea Is., Kenya, Madagascar, Malawi, Mozambique, Northern Provinces, Rwanda, Réunion, Tanzania, Tristan da Cunha, Uganda, Zaïre, Zimbabwe. *H. capillare* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 53 to 5761 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *H. capillare* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Cameroon, Kenya, Madagascar, Mozambique, Malawi, Rwanda, South Africa, Tanzania, Uganda, Zambia, Zimbabwe. This species has not yet been assessed by IUCN, and only 27% of its distribution range is currently found within protected areas.

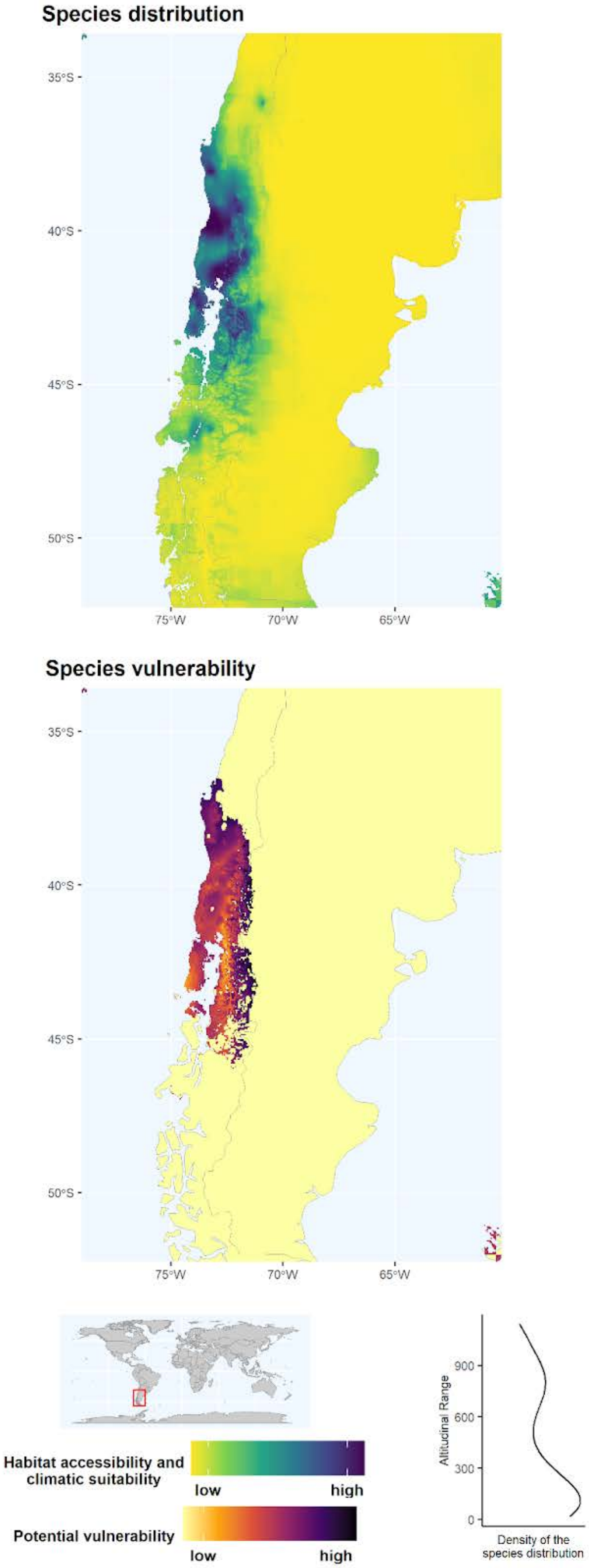
Hymenophyllum caudiculatum Mart.



H. caudiculatum is a homoiochlorophyllous plant whose distribution comprises Brazil Northeast, Brazil South, Brazil Southeast, Paraguay. *H. caudiculatum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 8 to 2165 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *H. caudiculatum* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

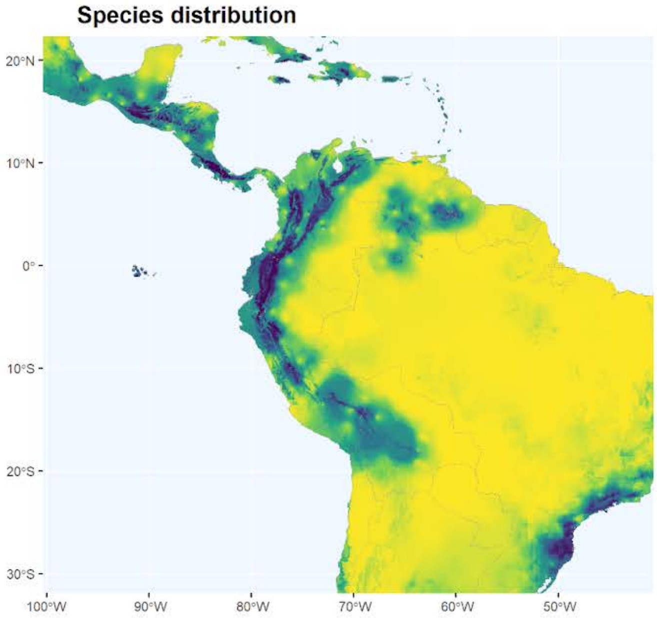
Hymenophyllum dentatum Cav.

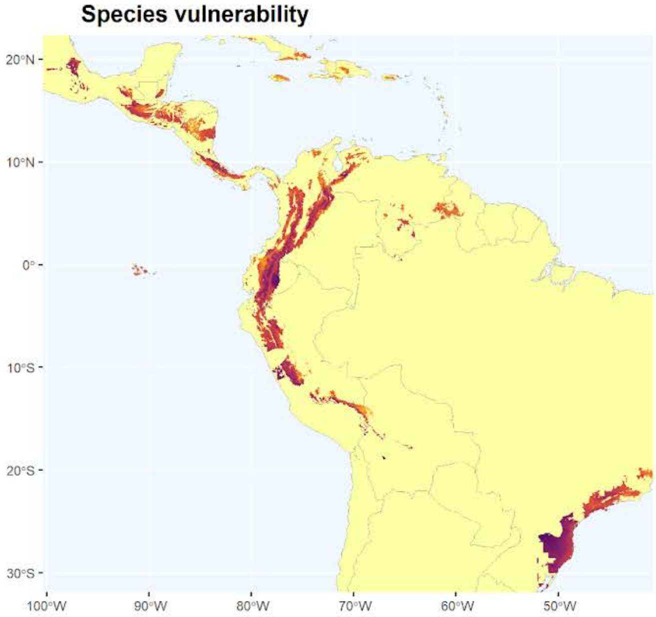
H. dentatum is a homoiochlorophyllous plant whose distribution comprises Argentina South, Chile Central, Chile South. *H. dentatum* individuals can be primarily found in warm temperate climates, ranging from 18 to 1142 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *H. dentatum* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Chile. This species has not yet been assessed by IUCN, and 38% of its distribution range is currently found within protected areas.

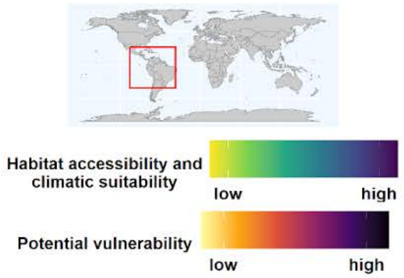


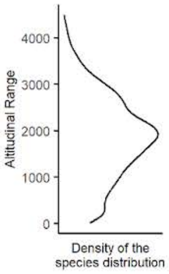
Hymenophyllum fucoides (Sw.) Sw.

H. fucoides is a plant whose distribution comprises Argentina South, Chile Central, Chile South, Juan Fernández Is. *H. fucoides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 14 to 4495 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *H. fucoides* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Brazil, Chile, Costa Rica, Ecuador, Guatemala, Peru, Venezuela. This species has not yet been assessed by IUCN, and only 30% of its distribution range is currently found within protected areas.

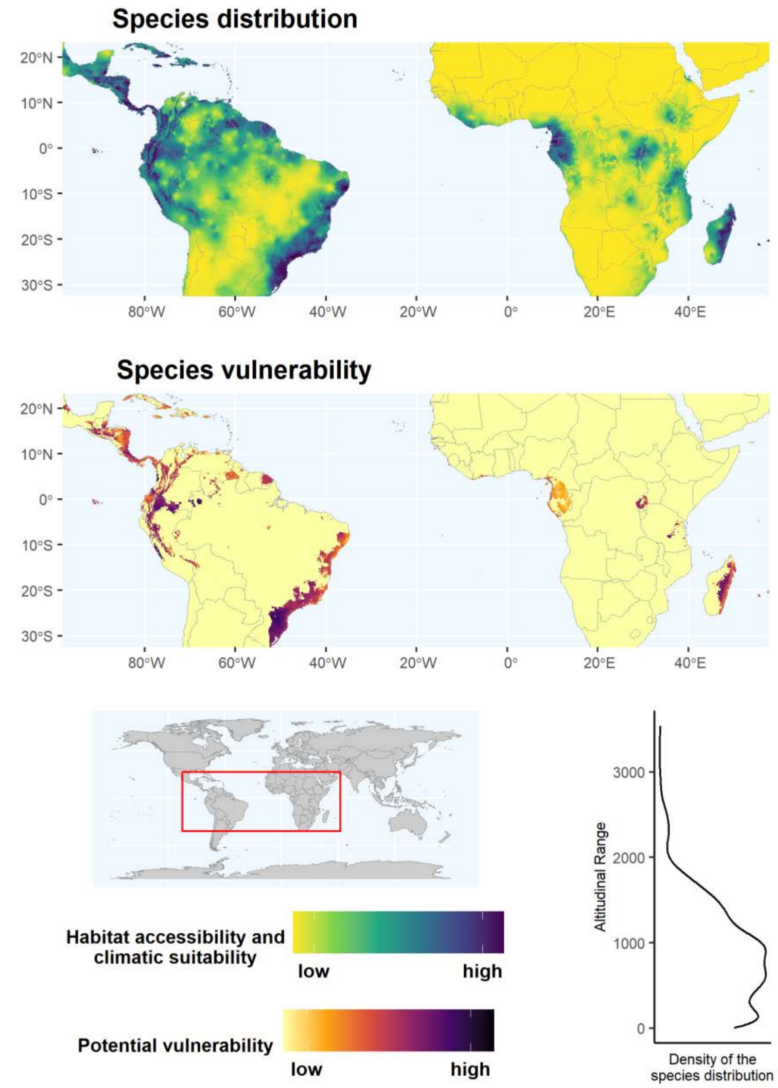






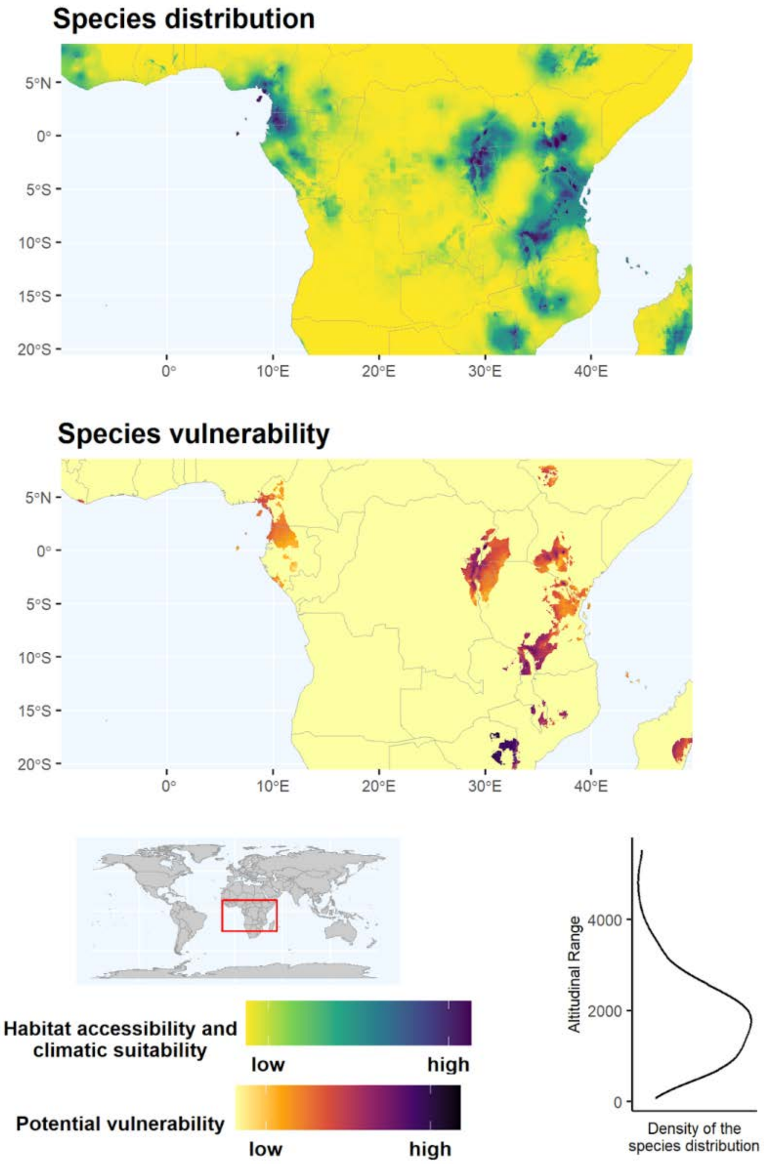


Hymenophyllum hirsutum (L.) Sw.
(also cited as *Sphaerocionium hirsutum* and *Trichomanes hirsutum*)



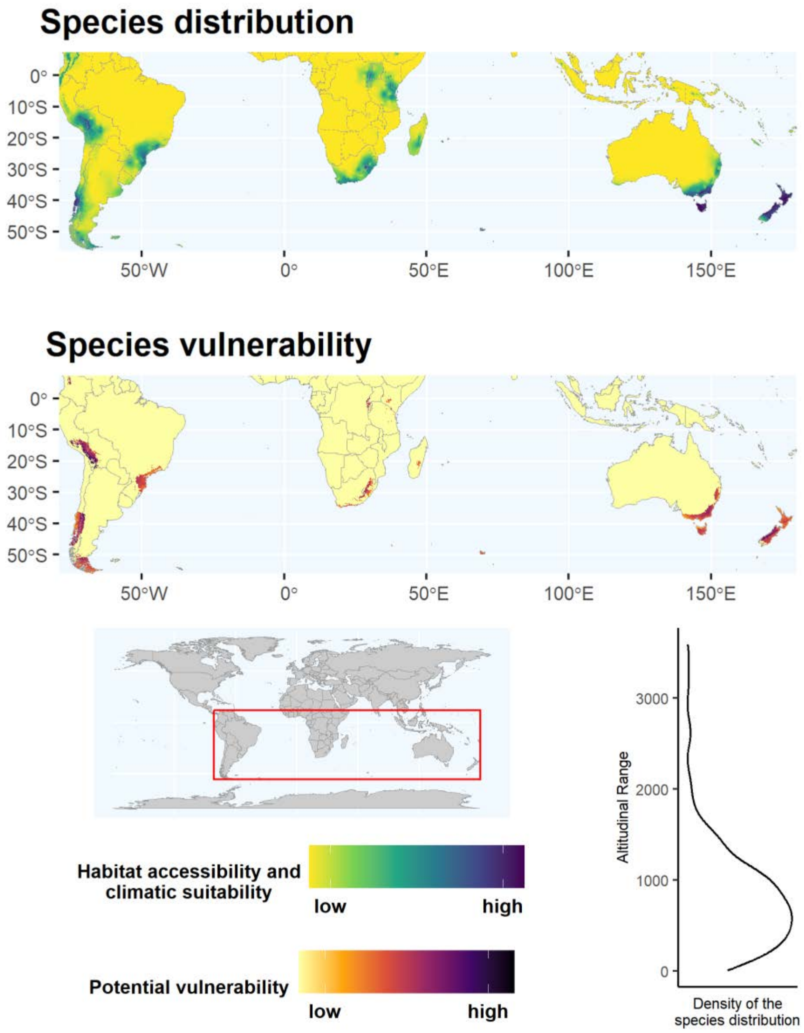
H. hirsutum is a plant whose distribution comprises Belize, Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Cameroon, Central African Republic, Colombia, Comoros, Costa Rica, Cuba, Dominican Republic, Ecuador, Equatorial Guinea, French Guiana, Gabon, Galápagos, Ghana, Guatemala, Gulf of Guinea Is., Guyana, Haiti, Honduras, Ivory Coast, Jamaica, Leeward Is., Liberia, Madagascar, Mauritius, Mexico Central, Mexico Gulf, Mexico Southeast, Mexico Southwest, Mozambique, Nicaragua, Panamá, Peru, Puerto Rico, Réunion, Seychelles, Suriname, Tanzania, Trinidad-Tobago, Uganda, Venezuela, Windward Is., Zaïre. *H. hirsutum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 5 to 3538 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *H. hirsutum* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Madagascar, Mexico, Nicaragua, Peru, Panama, Tanzania, Venezuela. This species has not yet been assessed by IUCN, and only 25% of its distribution range is currently found within protected areas.

Hymenophyllum kuhnii C. Chr.



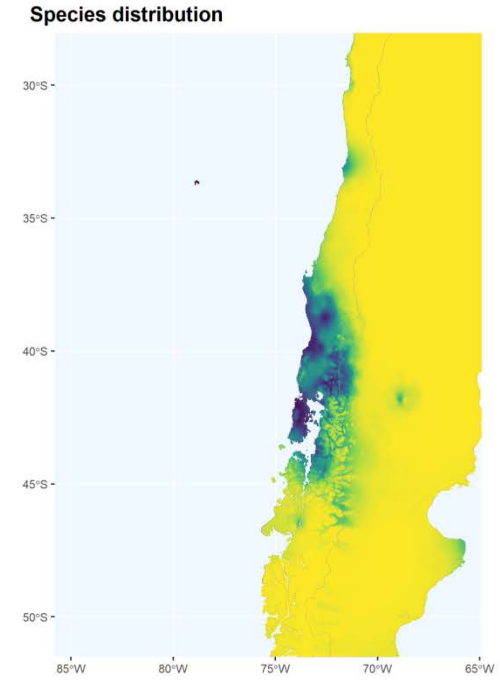
H. kuhnii is a plant whose distribution comprises Angola, Cameroon, Equatorial Guinea, Gabon, Ghana, Guinea, Gulf of Guinea Is., Kenya, Liberia, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Sierra Leone, Tanzania, Uganda, Zaïre, Zimbabwe. *H. kuhnii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 69 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *H. kuhnii* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Kenya, Mozambique, Malawi, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

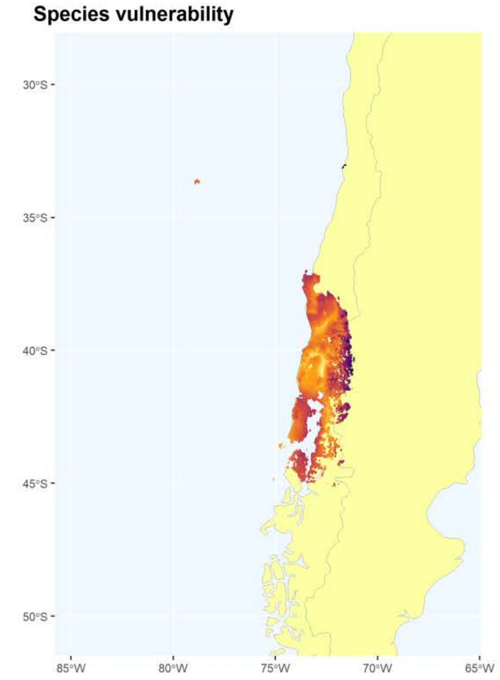
Hymenophyllum peltatum (Poir.) Desv.
(also cited as *Hymenophyllum wilsonii*)

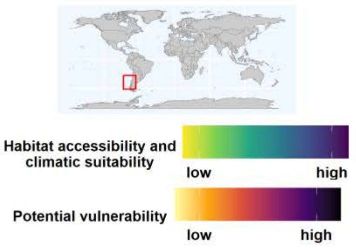


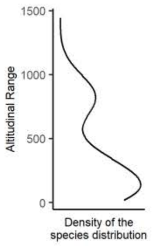
H. peltatum is a homoiochlorophyllous plant whose distribution comprises Argentina South, Bolivia, Borneo, Brazil South, Brazil Southeast, Cape Provinces, Chile Central, Chile South, Colombia, Crozet Is., Free State, Kerguelen, KwaZulu-Natal, Macquarie Is., Madagascar, Marion-Prince Edward, New South Wales, New Zealand North, New Zealand South, Peru, Prince Edward I., Queensland, Rwanda, Réunion, Tanzania, Tasmania, Tristan da Cunha, Uganda, Victoria, Zaïre. *H. peltatum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 7 to 3590 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *H. peltatum* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Australia, Bolivia, Democratic Republic of the Congo, Chile, Colombia, Vanuatu, New Zealand, Peru, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 29% of its distribution range is currently found within protected areas.

Hymenophyllum plicatum Kaulf.



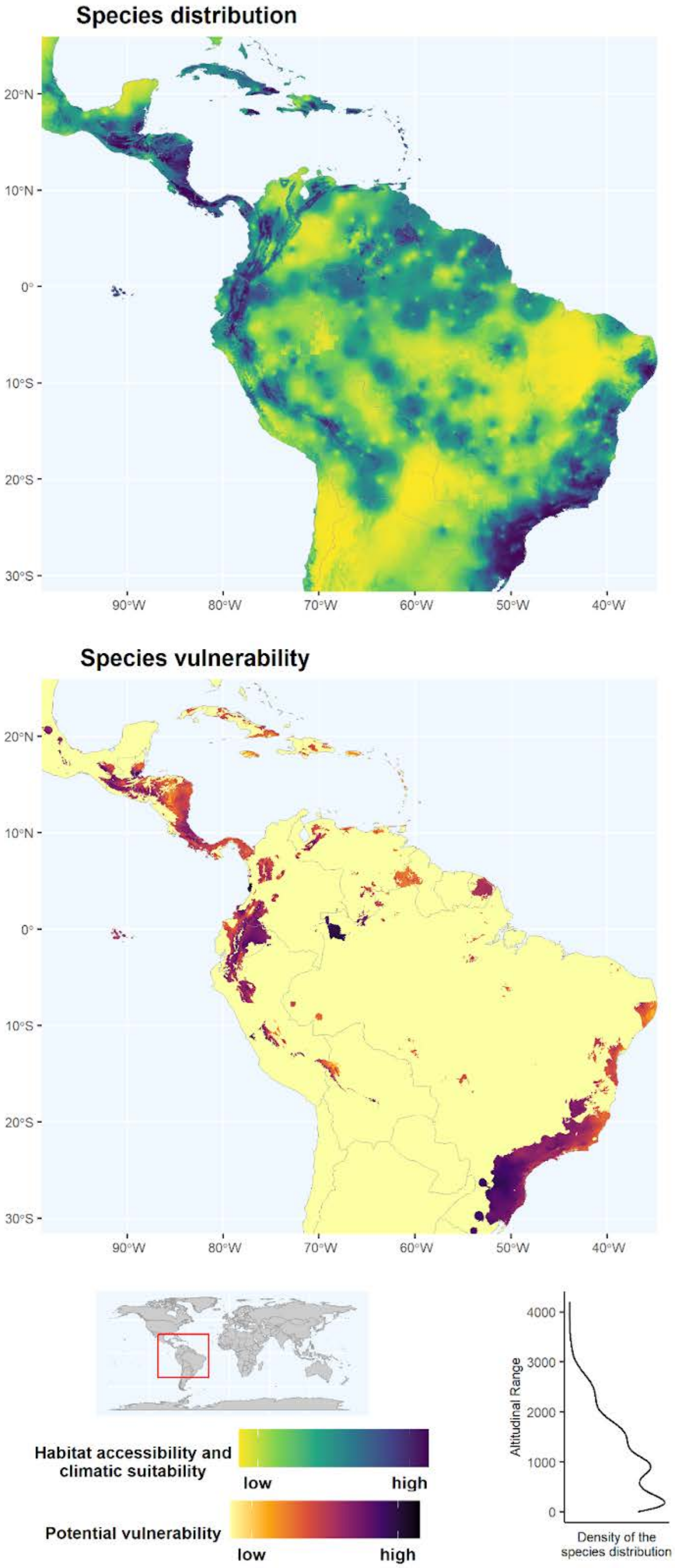






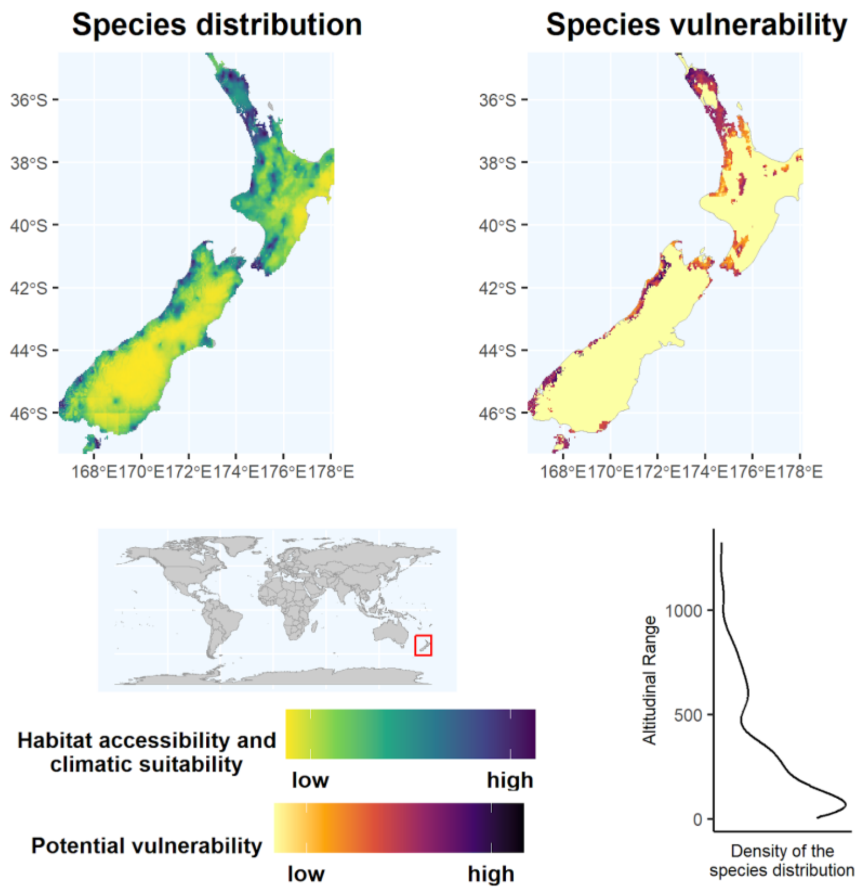
H. plicatum is a plant whose distribution comprises Argentina South, Chile Central, Chile South, Juan Fernández Is. *H. plicatum* individuals can be primarily found in arid and warm temperate climates, ranging from 18 to 1445 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the drier season is short). *H. plicatum* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Chile. This species has not yet been assessed by IUCN, and 36% of its distribution range is currently found within protected areas.

Hymenophyllum polyanthos (Sw.) Sw.



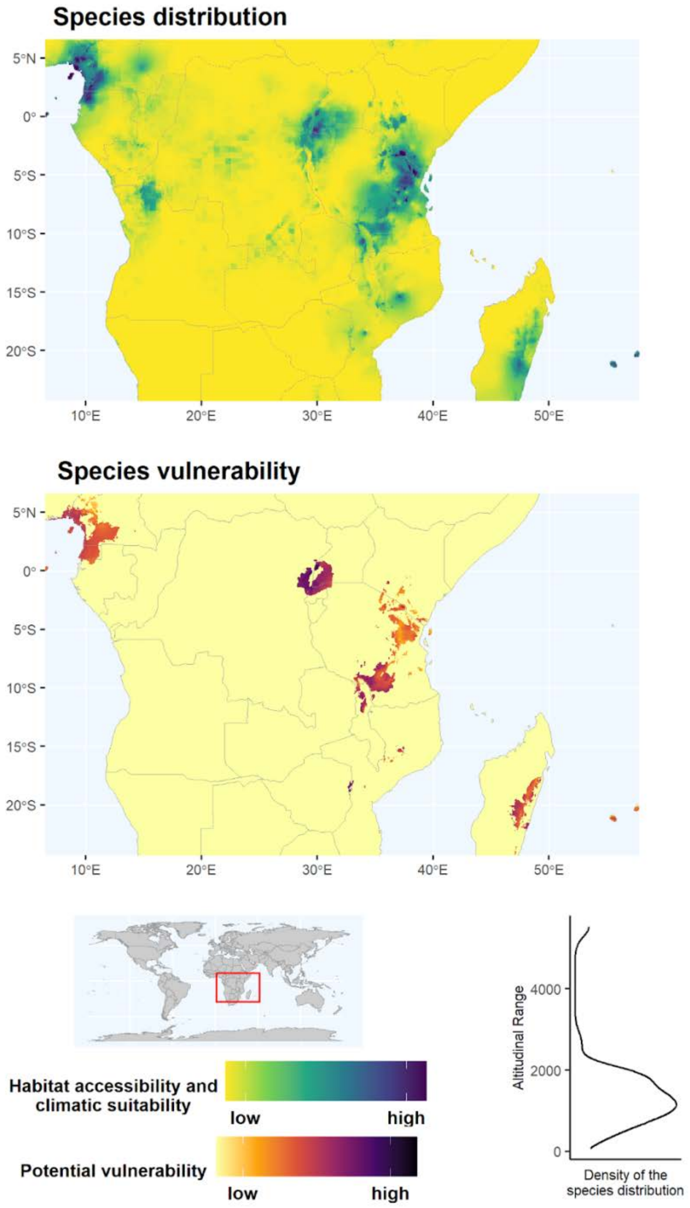
H. polyanthos is a plant whose distribution comprises Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, French Guiana, Galápagos, Guatemala, Guyana, Haiti, Honduras, Jamaica, Leeward Is., Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Peru, Puerto Rico, Suriname, Venezuela, Venezuelan Antilles, Windward Is. *H. polyanthos* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 4201 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *H. polyanthos* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Peru, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 29% of its distribution range is currently found within protected areas.

Hymenophyllum sanguinolentum (G. Forst.) Sw.



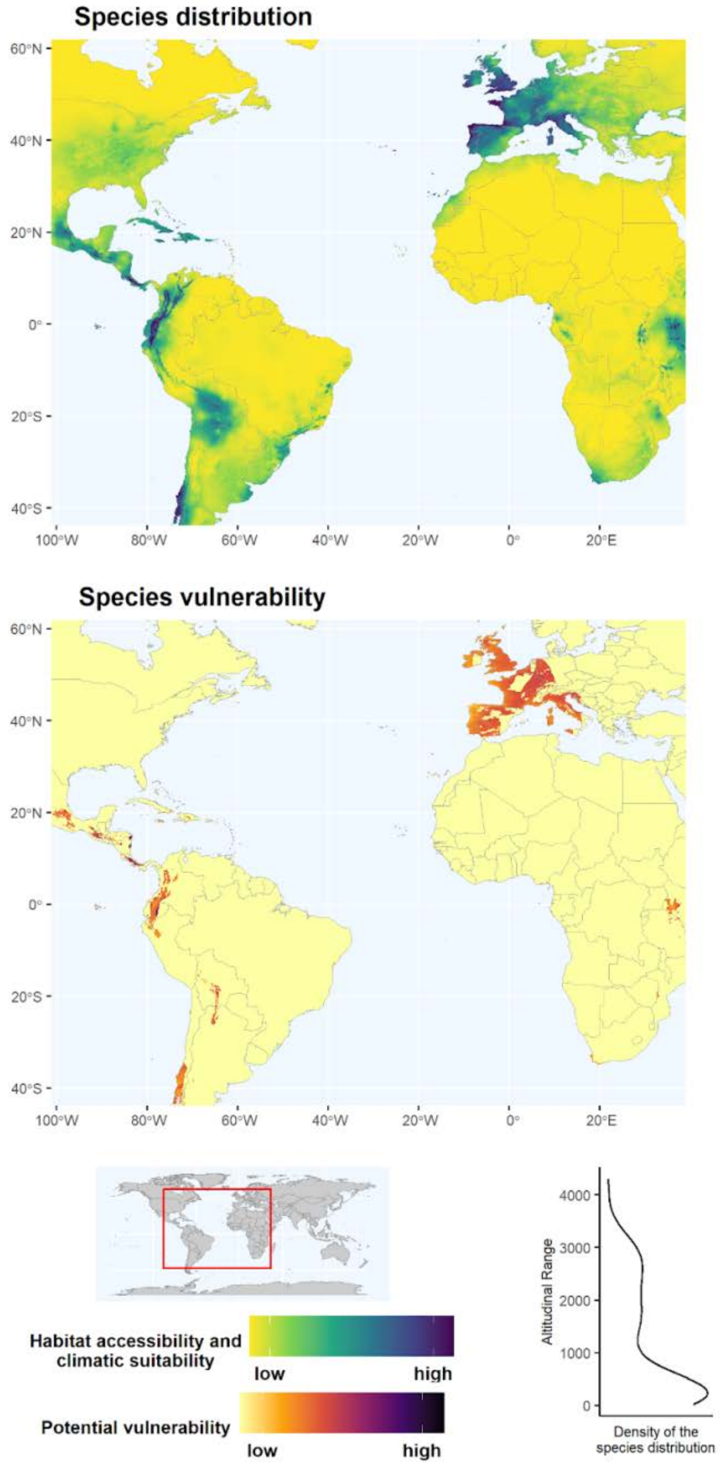
H. sanguinolentum is a homoiochlorophyllous plant whose distribution comprises Antipodean Is., New Zealand North, New Zealand South. *H. sanguinolentum* individuals can be primarily found in warm temperate climates, ranging from 6 to 1325 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *H. sanguinolentum* populations are expected to be potentially more vulnerable to climate change in parts of New Zealand. This species has not yet been assessed by IUCN, and only 41% of its distribution range is currently found within protected areas.

Hymenophyllum splendidum Bosch



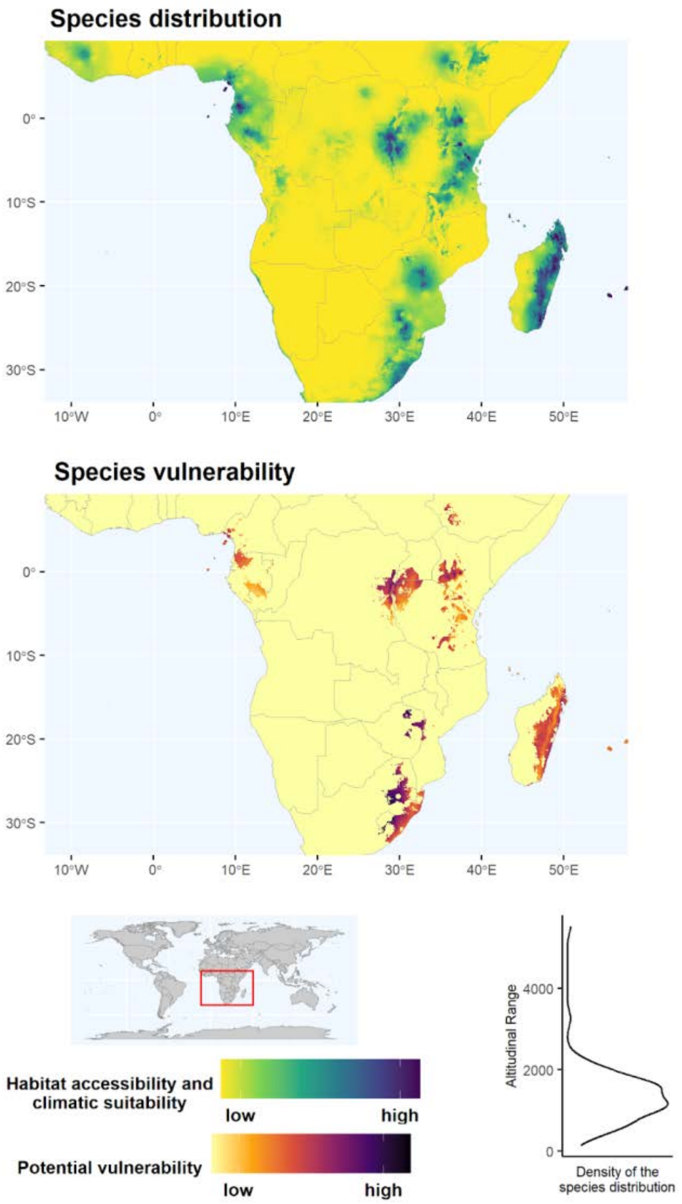
H. splendidum is a plant whose distribution comprises Burundi, Cameroon, Gabon, Gulf of Guinea Is., Kenya, Rwanda, Tanzania, Uganda, Zaïre. *H. splendidum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 74 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *H. splendidum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Mozambique, Malawi, Rwanda, Tanzania, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and 28% of its distribution range is currently found within protected areas.

Hymenophyllum tunbrigense (L.) Sm.



H. tunbrigense is a homoiochlorophyllous plant whose distribution comprises Alabama, Argentina South, Azores, Belgium, Bolivia, Canary Is., Cape Provinces, Chile Central, Chile South, Colombia, Costa Rica, Ecuador, France, Free State, Gabon, Germany, Great Britain, Guatemala, Haiti, Honduras, Ireland, Italy, Jamaica, Kenya, KwaZulu-Natal, Madagascar, Madeira, Malawi, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Mozambique, Northern Provinces, South Carolina, Spain, Swaziland, Tanzania, Tristan da Cunha, Turkey, Venezuela, Zimbabwe. *H. tunbrigense* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 20 to 4309 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *H. tunbrigense* populations are expected to be potentially more vulnerable to climate change in parts of Colombia, Costa Rica, Guatemala, Nicaragua. This species is listed as Least concern by IUCN, although only 36% of its distribution range is currently found within protected areas.

Polyphlebium borbonicum (Bosch) Ebihara & Dubuisson
(also cited as *Trichomanes borbonicum*)

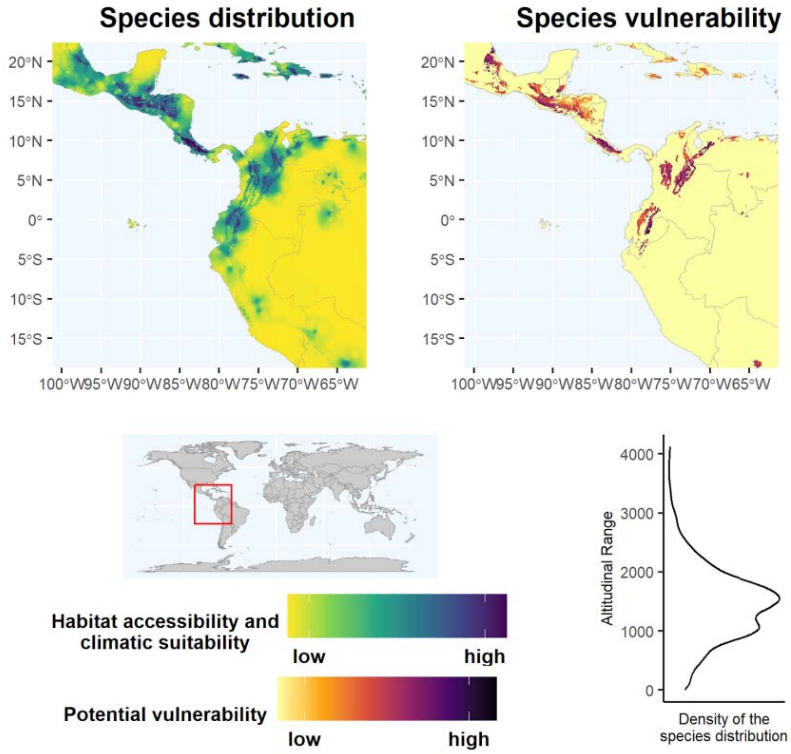


P. borbonicum is a plant whose distribution comprises Belize, Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Cameroon, Cape Provinces, Colombia, Comoros, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, French Guiana, Ghana, Guatemala, Guinea, Gulf of Guinea Is., Guyana, Honduras, Ivory Coast, Jamaica, Kenya, KwaZulu-Natal, Leeward Is., Liberia, Madagascar, Malawi, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Mozambique, Nicaragua, Northern Provinces, Panamá, Paraguay, Peru, Puerto Rico, Rwanda, Réunion, Suriname, Swaziland, Tanzania, Trinidad-Tobago, Venezuela, Windward Is., Zaïre, Zimbabwe. *P. borbonicum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 141 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. borbonicum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Cameroon, Ethiopia, Kenya, Liberia, Rwanda, South Africa, Lesotho, Sierra Leone, Tanzania, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Trichomanes bucinatum Mickel & Beitel

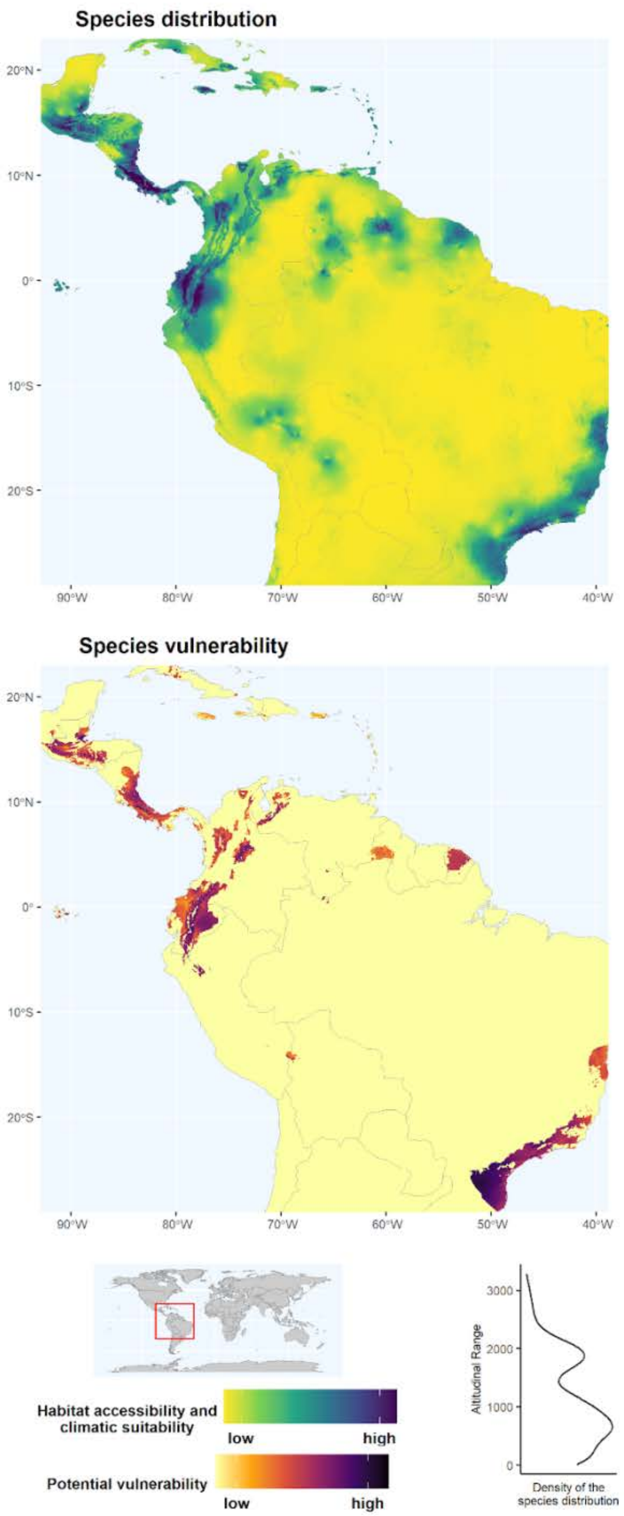
T. bucinatum is a plant whose distribution comprises Mexico Northeast, Mexico Southeast, Mexico Southwest. *T. bucinatum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 1100 to 2568 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *T. bucinatum* populations are expected to be potentially more vulnerable to climate change in parts of Mexico. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

Trichomanes capillaceum L.



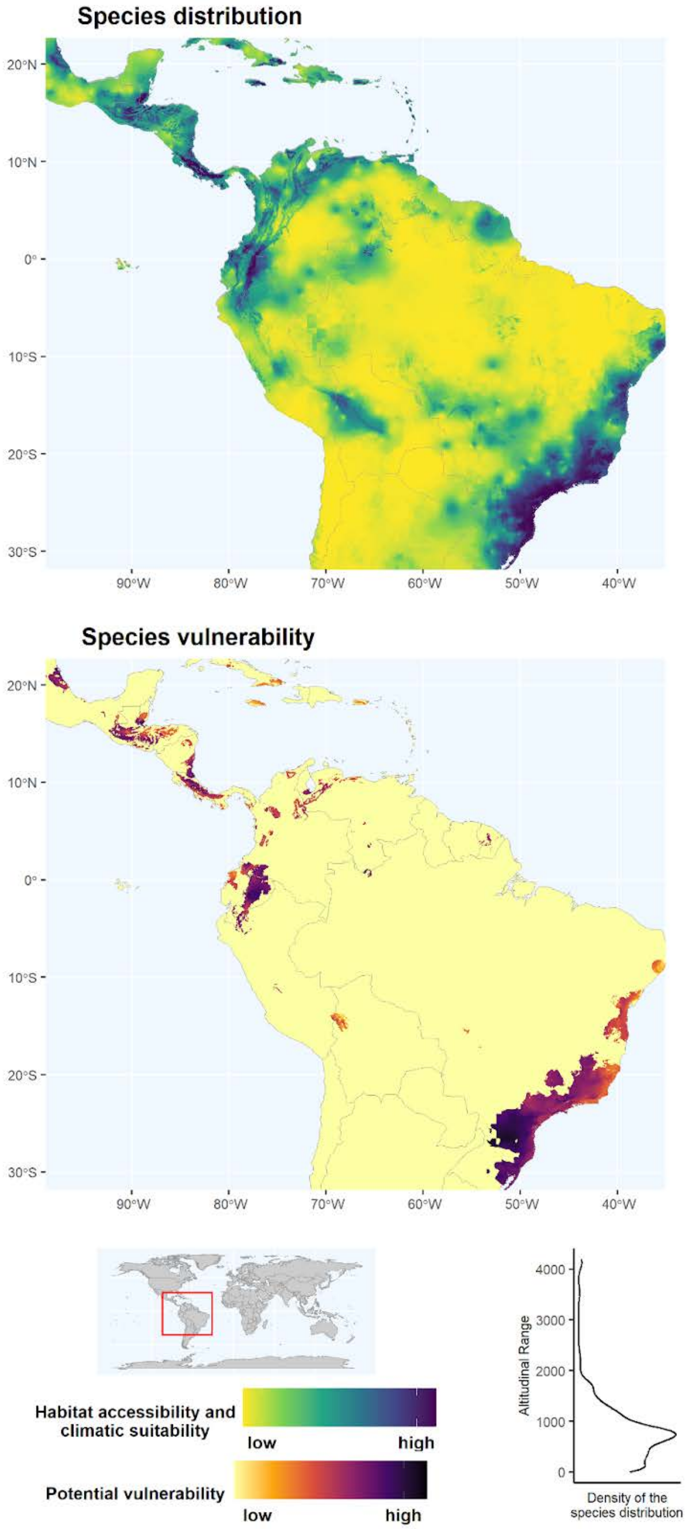
T. capillaceum is a plant whose distribution comprises Belize, Bolivia, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Peru, Puerto Rico, Venezuela. *T. capillaceum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 7 to 4123 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *T. capillaceum* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 30% of its distribution range is currently found within protected areas.

Trichomanes diaphanum Kunth



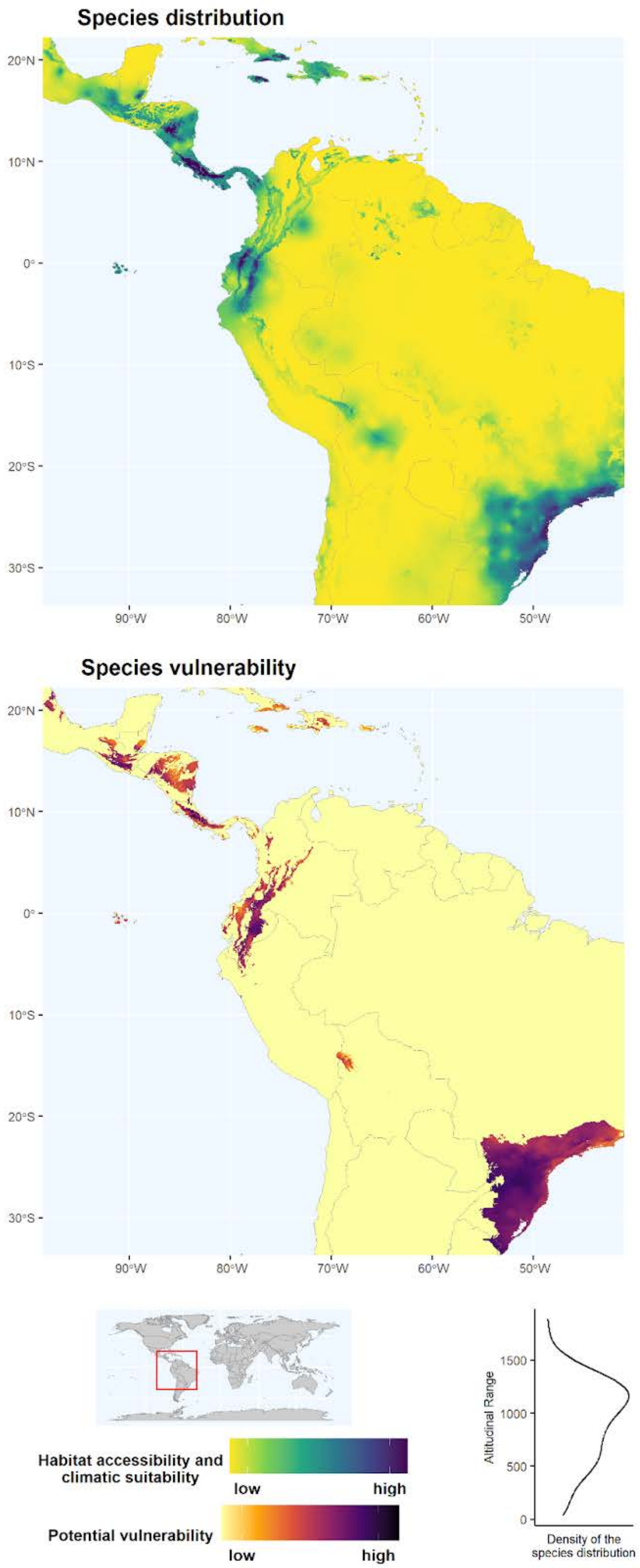
T. diaphanum is a plant whose distribution comprises Belize, Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Cameroon, Cape Provinces, Colombia, Comoros, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, French Guiana, Ghana, Guatemala, Guinea, Gulf of Guinea Is., Guyana, Honduras, Ivory Coast, Jamaica, Kenya, KwaZulu-Natal, Leeward Is., Liberia, Madagascar, Malawi, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Mozambique, Nicaragua, Northern Provinces, Panamá, Paraguay, Peru, Puerto Rico, Rwanda, Réunion, Suriname, Swaziland, Tanzania, Trinidad-Tobago, Venezuela, Windward Is., Zaïre, Zimbabwe. *T. diaphanum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 10 to 3291 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *T. diaphanum* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Peru, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 29% of its distribution range is currently found within protected areas.

Trichomanes polypodioides L.



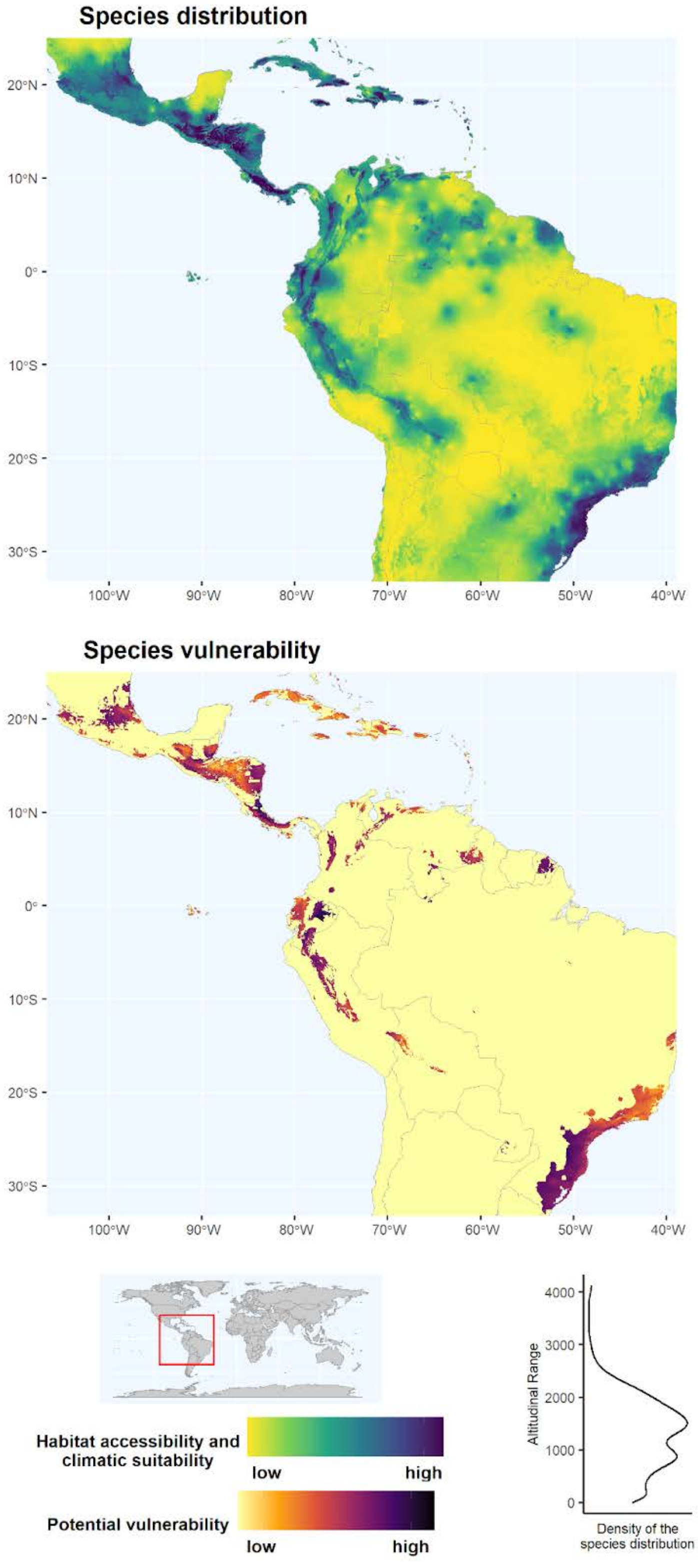
T. polypodioides is a plant whose distribution comprises Belize, Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Cuba, Ecuador, French Guiana, Guatemala, Guyana, Honduras, Jamaica, Leeward Is., Mexico Gulf, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Paraguay, Peru, Puerto Rico, Suriname, Trinidad-Tobago, Uruguay, Venezuela, Venezuelan Antilles, Windward Is. *T. polypodioides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 4201 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *T. polypodioides* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Peru, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Trichomanes pyxidiferum L.



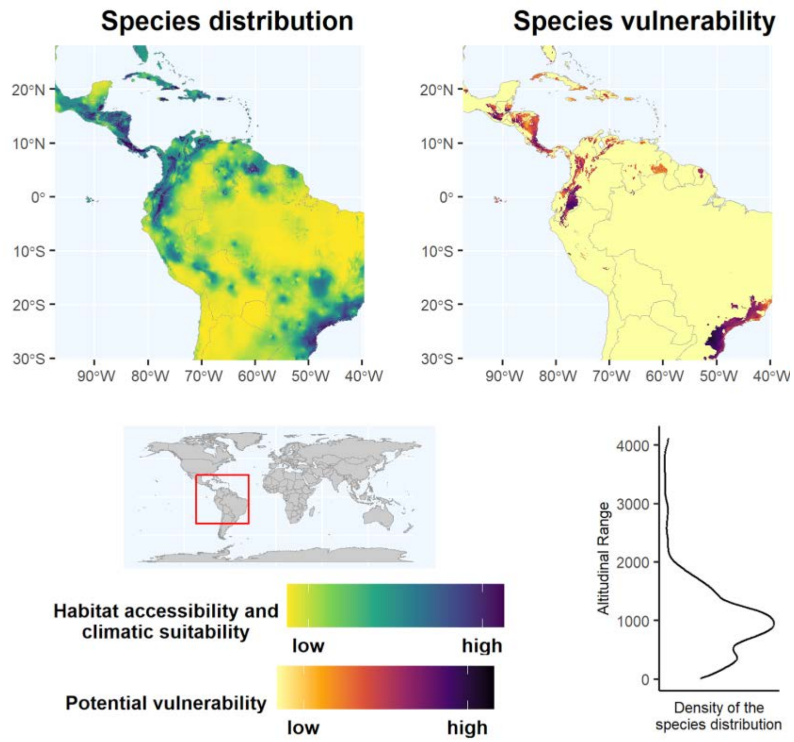
T. pyxidiferum is a plant whose distribution comprises Argentina Northeast, Belize, Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Central American Pac, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Jamaica, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Paraguay, Venezuela. *T. pyxidiferum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 36 to 1889 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *T. pyxidiferum* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Belize, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Paraguay, Peru, Panama, Uruguay. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Trichomanes radicans Sw.
(also cited as *Vandenboschia radicans*)



T. radicans is a plant whose distribution comprises Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Central American Pac, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Haiti, Honduras, Jamaica, Leeward Is., Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Paraguay, Peru, Puerto Rico, Suriname, Venezuela, Windward Is. *T. radicans* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 2 to 4123 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *T. radicans* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Belize, Brazil, Colombia, Costa Rica, Ecuador, French Guiana, Guatemala, Mexico, Nicaragua, Paraguay, Peru, Panama, Uruguay, Venezuela. This species has not yet been assessed by IUCN, and only 28% of its distribution range is currently found within protected areas.

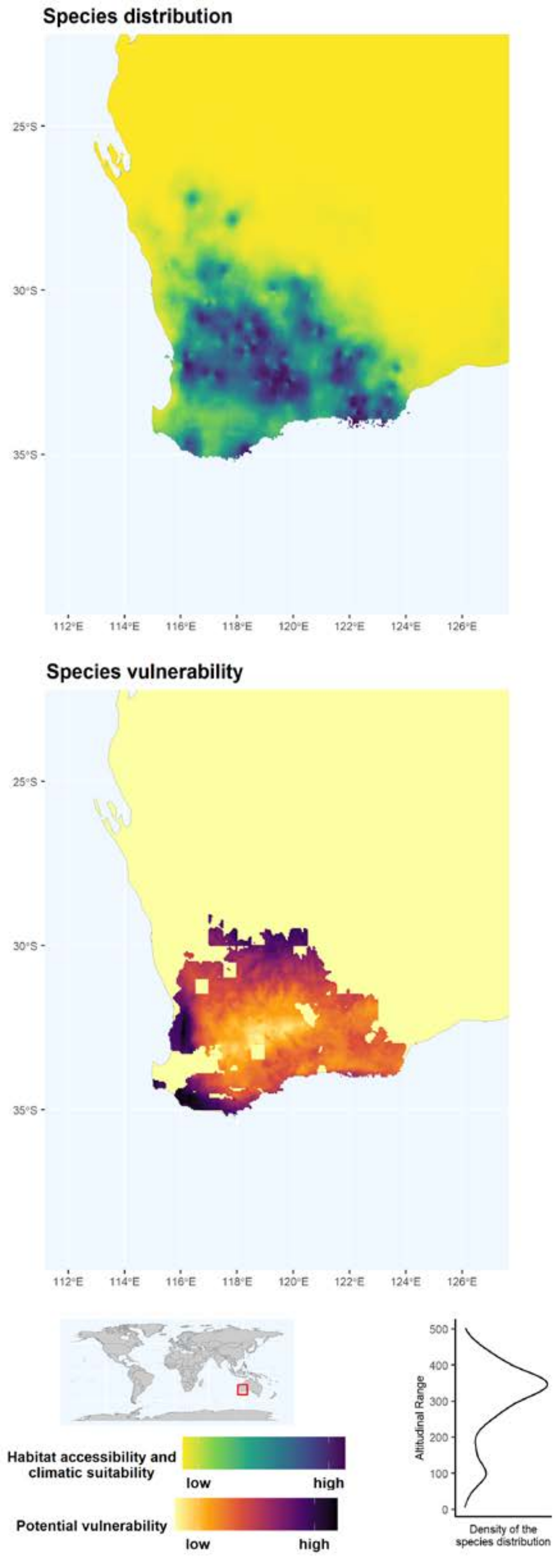
Trichomanes rigidum Sw.
(also cited as *Abrodictyum rigidum*)



T. rigidum is a plant whose distribution comprises Belize, Bolivia, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, French Guiana, Guatemala, Guyana, Haiti, Honduras, Jamaica, Leeward Is., Mexico Gulf, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Paraguay, Peru, Puerto Rico, Suriname, Venezuela, Windward Is. *T. rigidum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 9 to 4123 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *T. rigidum* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Peru, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 31% of its distribution range is currently found within protected areas.

Isoetaceae

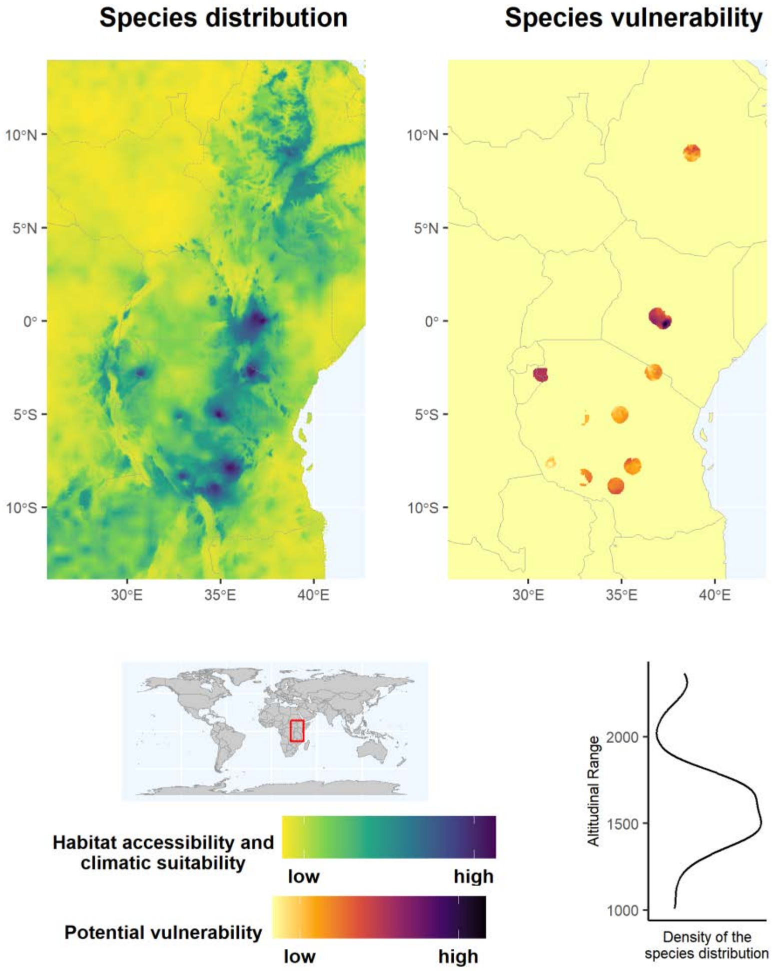
Isoetes australis R.O. Williams



I. australis is a homoiochlorophyllous plant whose distribution is restricted to Western Australia. *I. australis* individuals can be primarily found in arid and warm temperate climates, ranging from 5 to 503 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *I. australis* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 29% of its distribution range is currently found within protected areas.

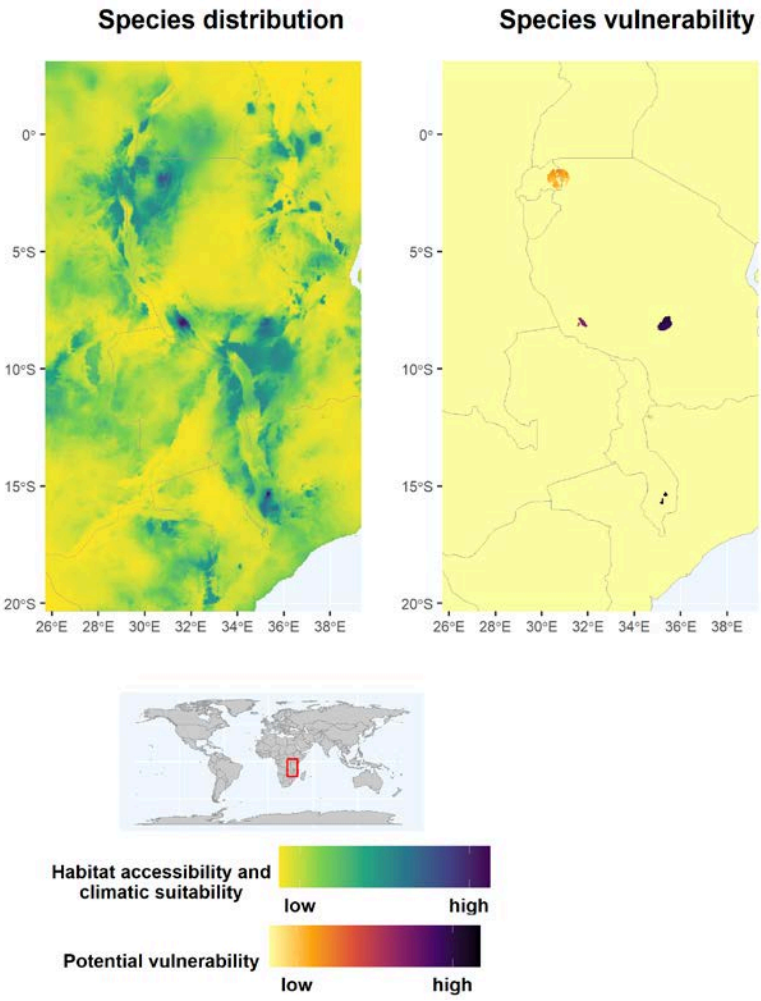
Linderniaceae

Craterostigma hirsutum S. Moore



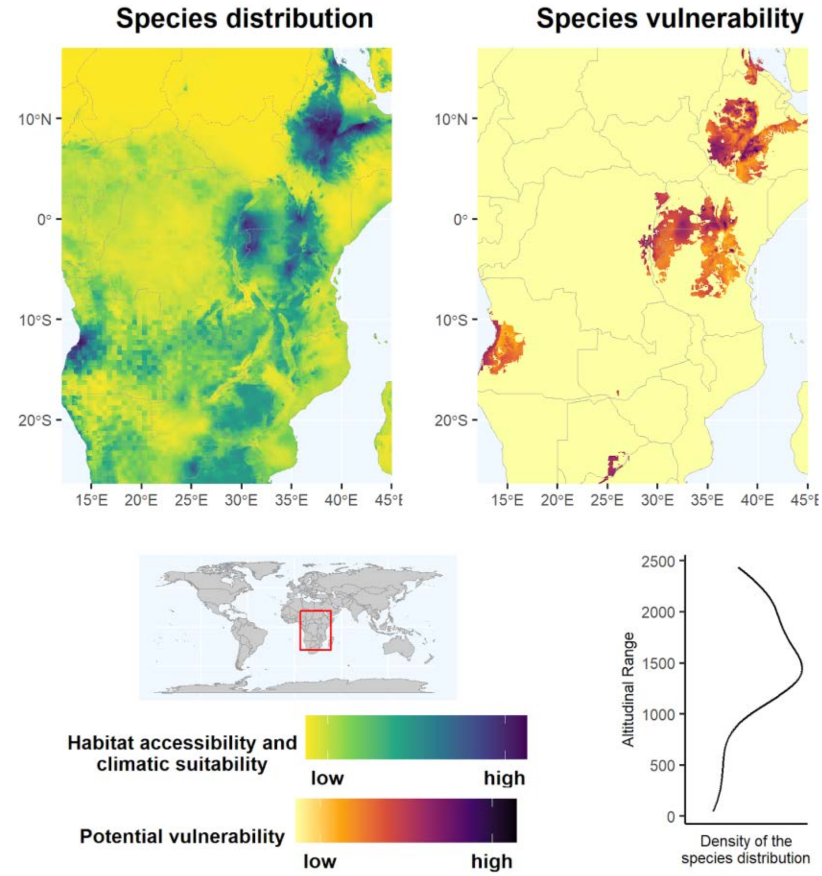
C. hirsutum is a plant whose distribution comprises Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zimbabwe. *C. hirsutum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 1009 to 2365 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *C. hirsutum* populations are expected to be potentially more vulnerable to climate change in parts of Kenya. This species has not yet been assessed by IUCN, and 25% of its distribution range is currently found within protected areas.

Craterostigma lanceolatum (Engl.) Skan



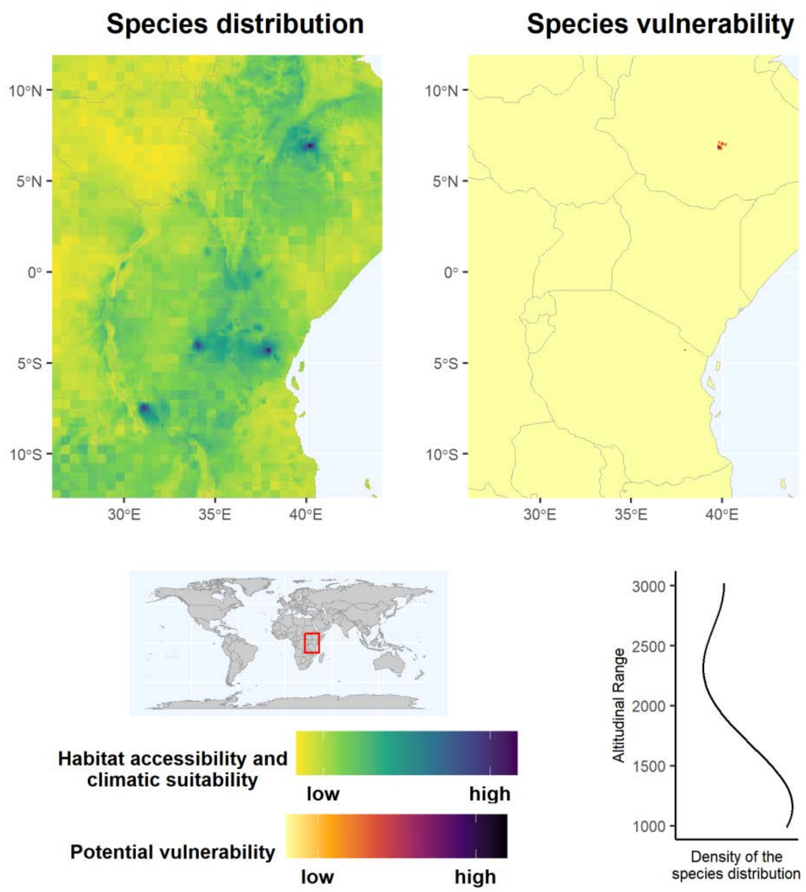
C. lanceolatum is a plant whose distribution comprises Kenya, Malawi, Rwanda, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. More occurrence points are needed for a consistent evaluation of the ecological aspects of *C. lanceolatum*. Its populations are expected to be potentially more vulnerable to climate change in parts of Malawi, Tanzania. This species has not yet been assessed by IUCN, and only 11% of its distribution range is currently found within protected areas.

Craterostigma plantagineum Hochst.
(also cited as *Craterostigma nanum*)



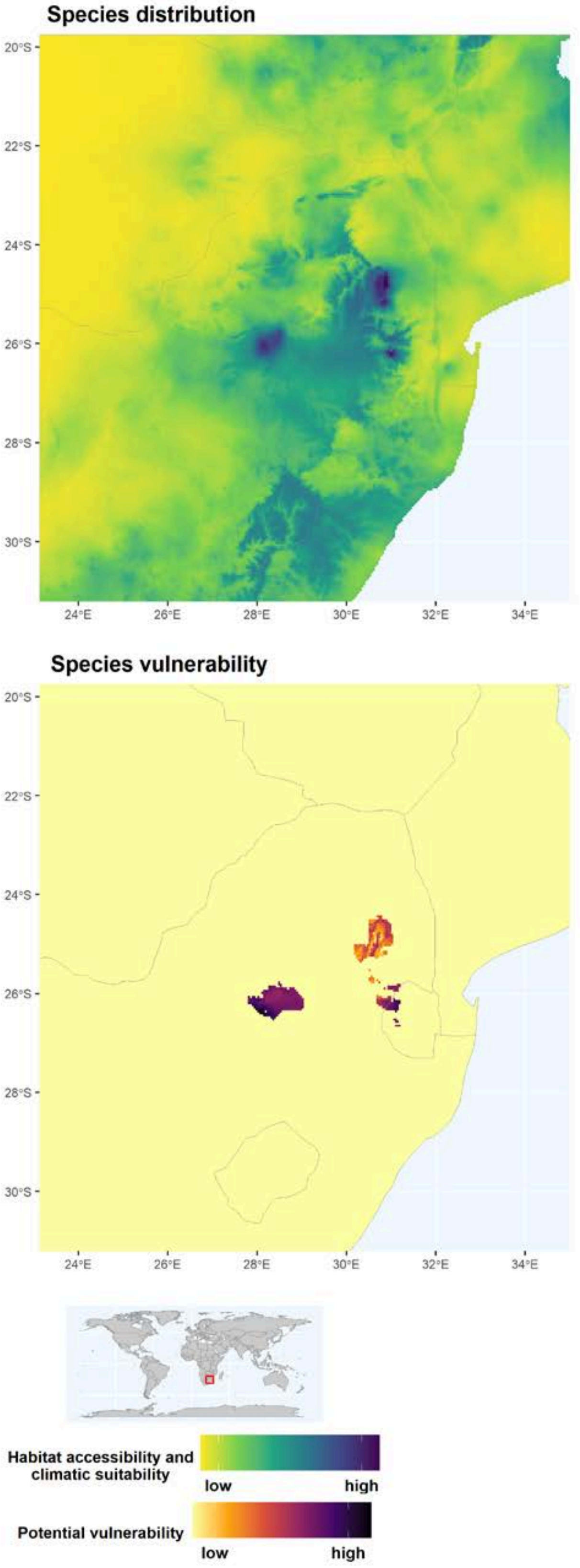
C. plantagineum is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Burkina, Burundi, Chad, Eritrea, Ethiopia, Kenya, KwaZulu-Natal, Namibia, Niger, Northern Provinces, Rwanda, Somalia, Sudan, Tanzania, Uganda, Yemen, Zambia, Zaïre, Zimbabwe, India. *C. plantagineum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 45 to 2437 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. plantagineum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Craterostigma pumilum Hochst.



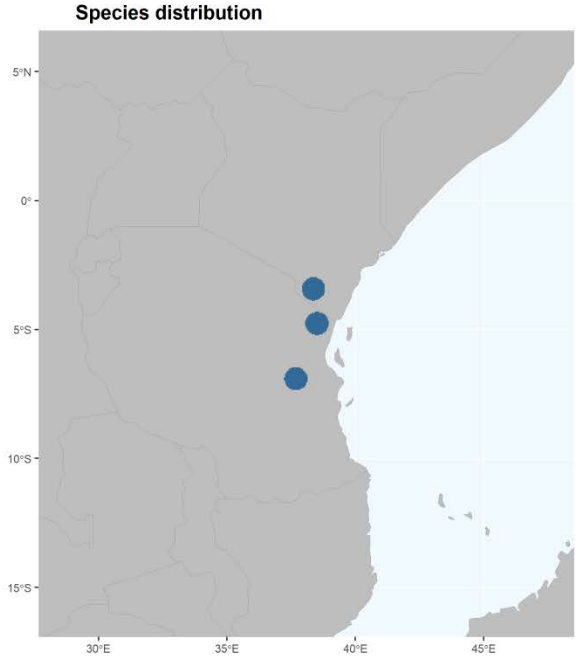
C. pumilum is a homoiochlorophyllous plant whose distribution comprises Botswana, Eritrea, Ethiopia, Kenya, Oman, Saudi Arabia, Socotra, Somalia, Sudan, Tanzania, Uganda, Yemen, Zambia, Zimbabwe. *C. pumilum* individuals can be primarily found in equatorial and warm temperate climates, ranging from 989 to 3020 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *C. pumilum* populations are expected to be potentially more vulnerable to climate change in parts of Tanzania. This species has not yet been assessed by IUCN, and only 64% of its distribution range is currently found within protected areas.

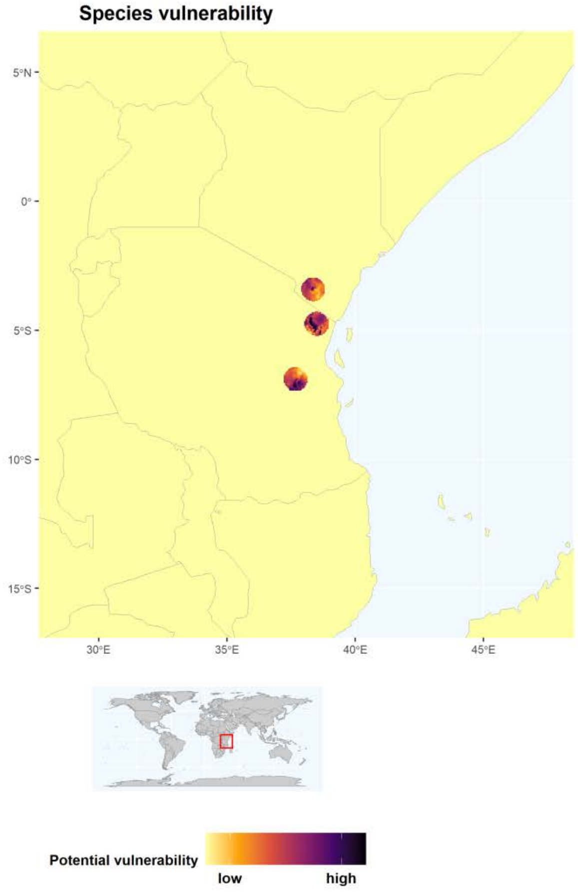
Craterostigma wilmsii Engl. ex Diels



C. wilmsii is a homoiochlorophyllous plant whose distribution comprises Free State, Northern Provinces. More occurrence points are needed for a consistent evaluation of the ecological aspects of *C. wilmsii*. Its populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Swaziland. This species has not yet been assessed by IUCN, and only 29% of its distribution range is currently found within protected areas.

Lindernia brevidens Skan

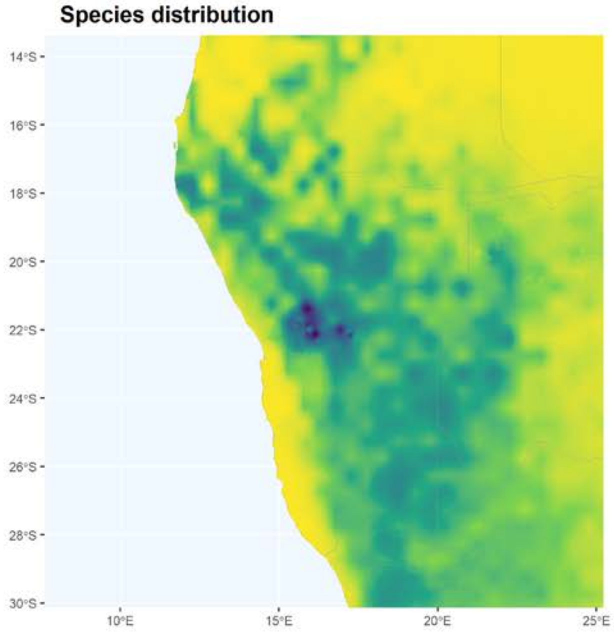

Species distribution

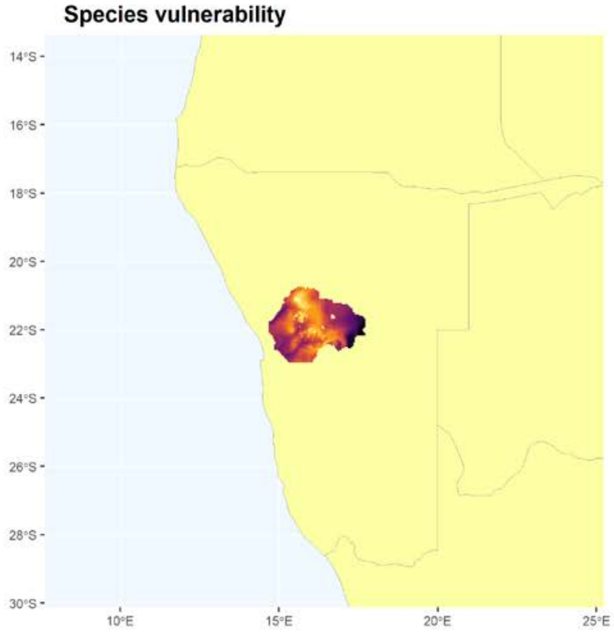

Species vulnerability

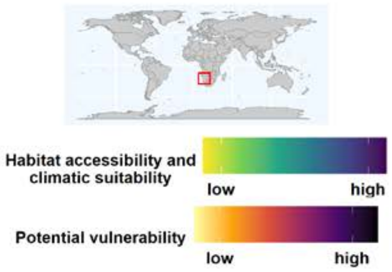
L. brevidens is a plant whose distribution comprises Kenya, Tanzania. More occurrence points are needed for a consistent evaluation of the ecological aspects and conservation of *L. brevidens* populations. This species has not yet been assessed by IUCN, and only 35% of its distribution range is currently found within protected areas.

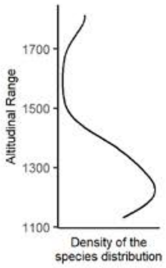
Lindernia intrepidus (Dinter) Oberm.
(also cited as *Chamaegigas intrepidus* and *Lindernia intrepida*)

L. intrepidus is a plant whose distribution is restricted to Namibia. *L. intrepidus* individuals can be primarily found in arid climates, ranging from 1131 to 1814 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *L. intrepidus* populations are expected to be potentially more vulnerable to climate change in parts of Namibia. This species is listed as Least concern by IUCN, although 25% of its distribution range is currently found within protected areas.

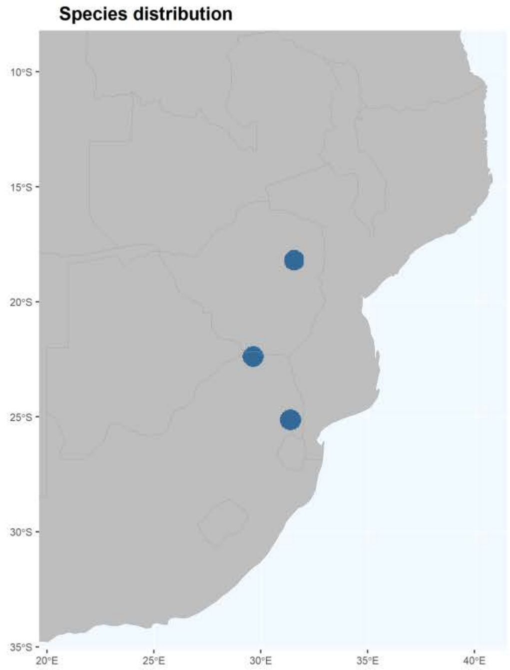


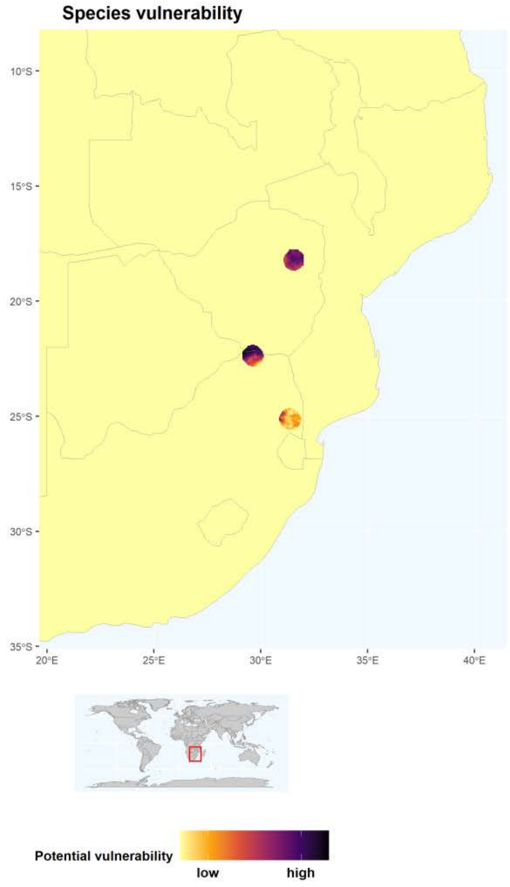






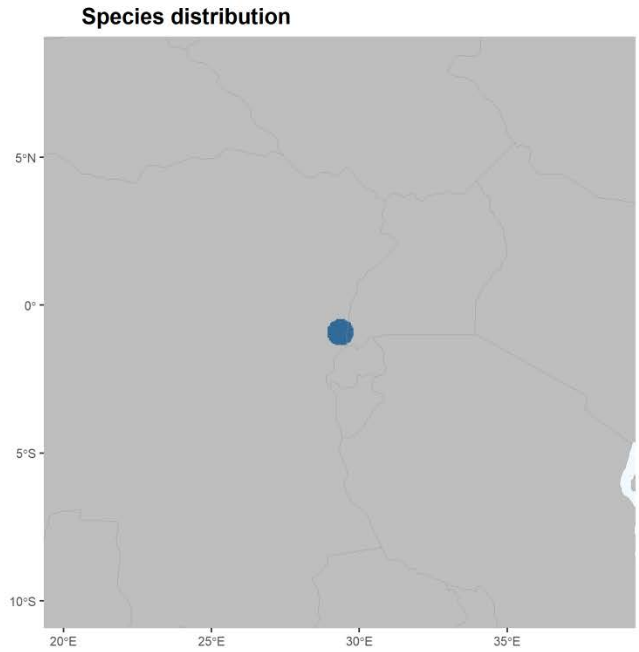
Lindernia monroi (S. Moore) Eb. Fisch.
(also cited as *Craterostigma monroi* and *Lindernia monroi*)



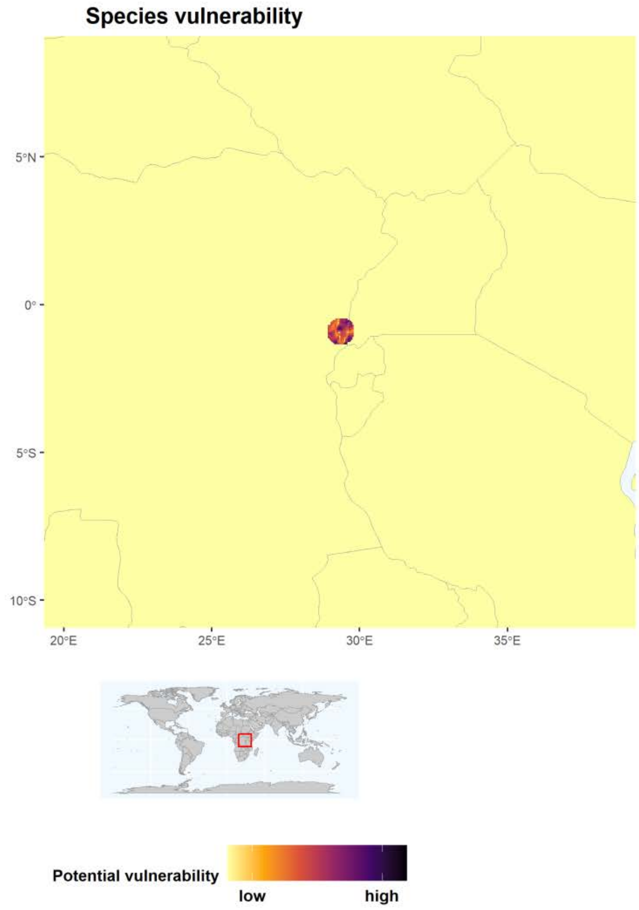


L. monroi is a homoiochlorophyllous plant whose distribution comprises Northern Provinces, Zimbabwe. More occurrence points are needed for a consistent evaluation of the ecological aspects and conservation of *L. monroi* populations. This species is listed as Least concern by IUCN, although 52% of its distribution range is currently found within protected areas.

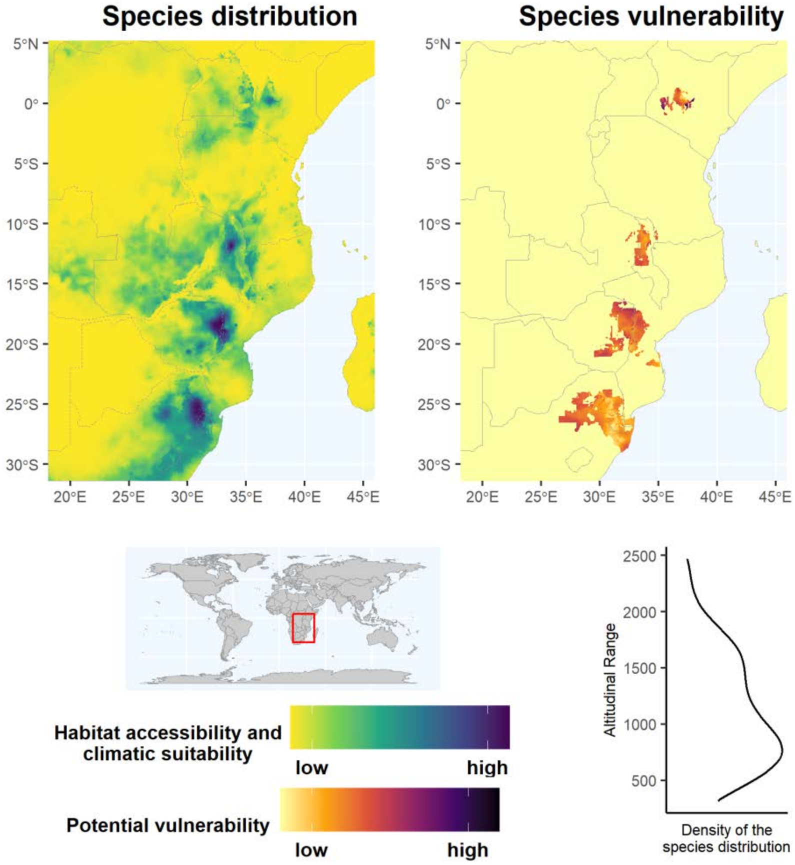
Lindernia purpurea (Lebrun & Touss.) R. Germ.
(also cited as *Craterostigma purpureum*)



L. purpurea is a plant whose distribution comprises Burundi, Zaïre. *L. purpurea* individuals can be primarily found in equatorial climates, circa 959 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas which precipitation is spread throughout the year. More occurrence points are needed for a consistent evaluation of the conservation of *L. purpurea* populations. This species has not yet been assessed by IUCN, and 54% of its distribution range is currently found within protected areas.

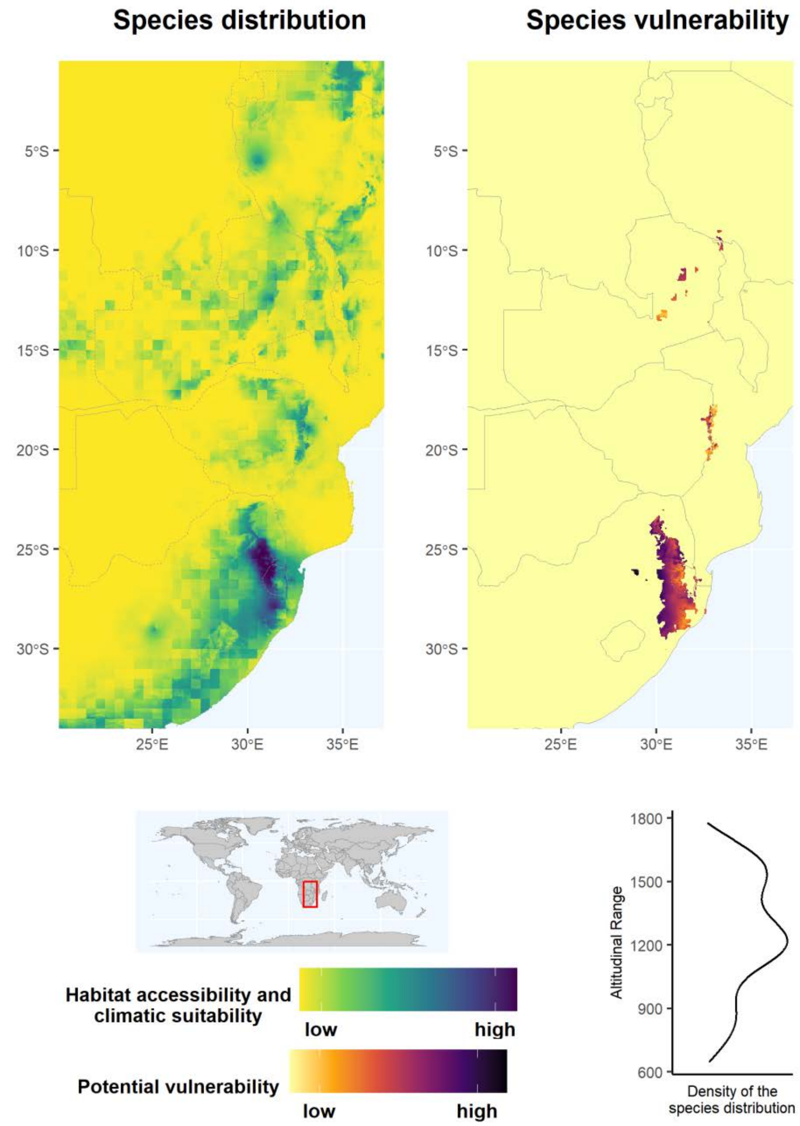


Linderniella pulchella (Skan) Eb. Fisch., Schäferh. & Kai Müll.
(also cited as *Ilysanthes purpurascens*)



L. pulchella is a homoiochlorophyllous plant whose distribution comprises Angola, Ethiopia, Kenya, Malawi, Mozambique, Northern Provinces, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *L. pulchella* individuals can be primarily found in arid and warm temperate climates, ranging from 320 to 2467 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *L. pulchella* populations are expected to be potentially more vulnerable to climate change in parts of Kenya. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

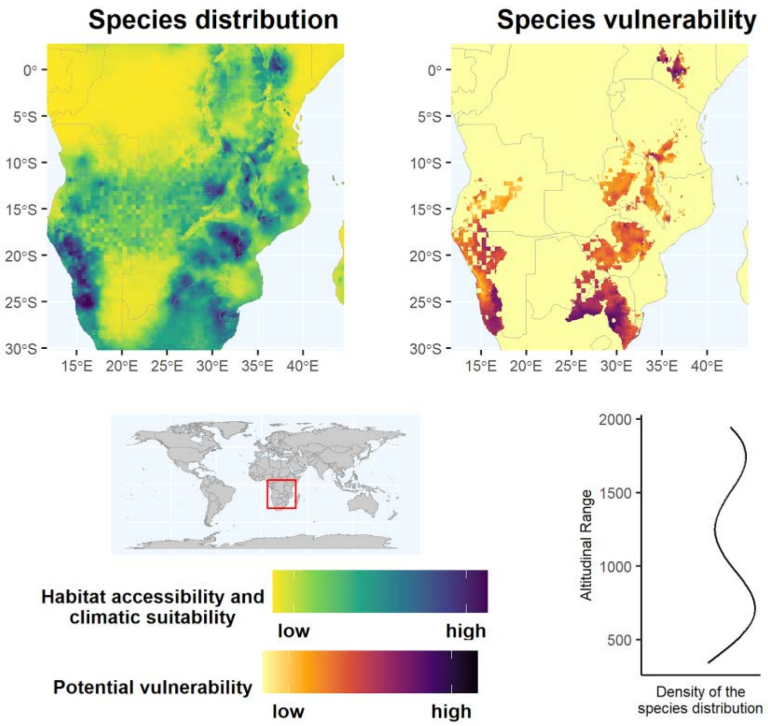
Linderniella wilmsii (Engl. ex Diels) Eb. Fisch., Schäferh. & Kai Müll.
(also cited as *Ilysanthes wilmsii* and *Lindernia wilmsii*)



L. wilmsii is a homoiochlorophyllous plant whose distribution comprises Angola, Burundi, Kenya, KwaZulu-Natal, Mozambique, Northern Provinces, Rwanda, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *L. wilmsii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 645 to 1779 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *L. wilmsii* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, South Africa, Tanzania, Zimbabwe. This species is listed as Least concern by IUCN, although only 22% of its distribution range is currently found within protected areas.

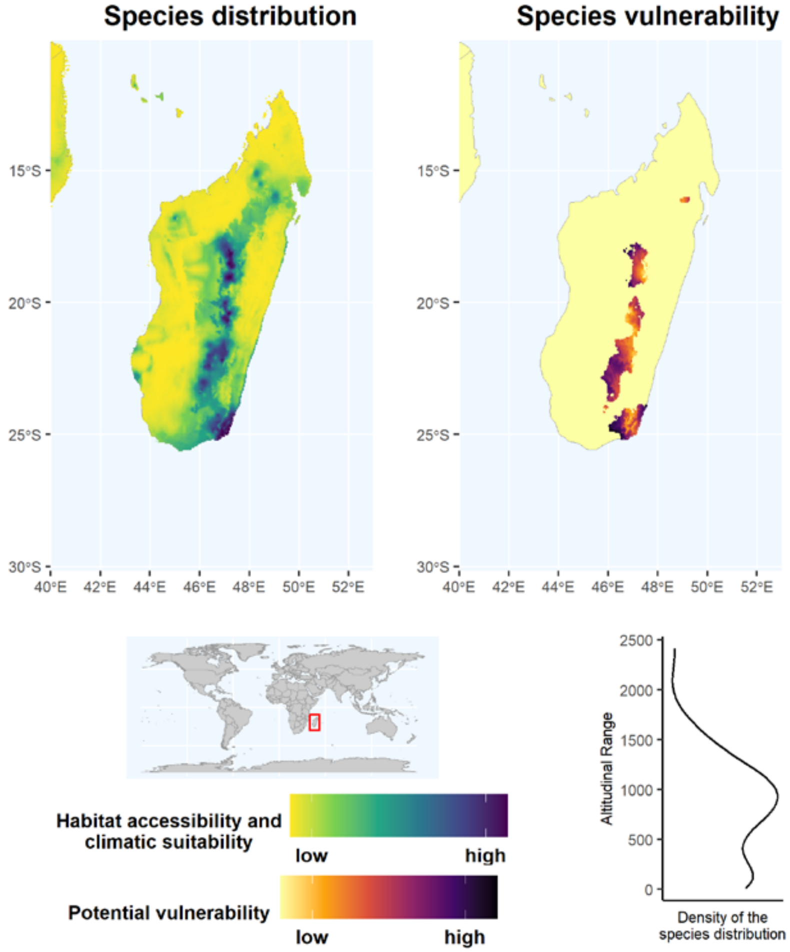
Myrothamnaceae

Myrothamnus flabellifolius Welw.
(also cited as *Myrothamnus flabellifolia*)



M. flabellifolius is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Free State, Kenya, KwaZulu-Natal, Lesotho, Malawi, Mozambique, Namibia, Northern Provinces, Swaziland, Tanzania, Zambia, Zaïre, Zimbabwe. *M. flabellifolius* individuals can be primarily found in equatorial and warm temperate climates, ranging from 340 to 1948 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. flabellifolius* populations are expected to be potentially more vulnerable to climate change in parts of Kenya, South Africa, Uganda, Namibia, Zimbabwe. This species has not yet been assessed by IUCN, and only 28% of its distribution range is currently found within protected areas.

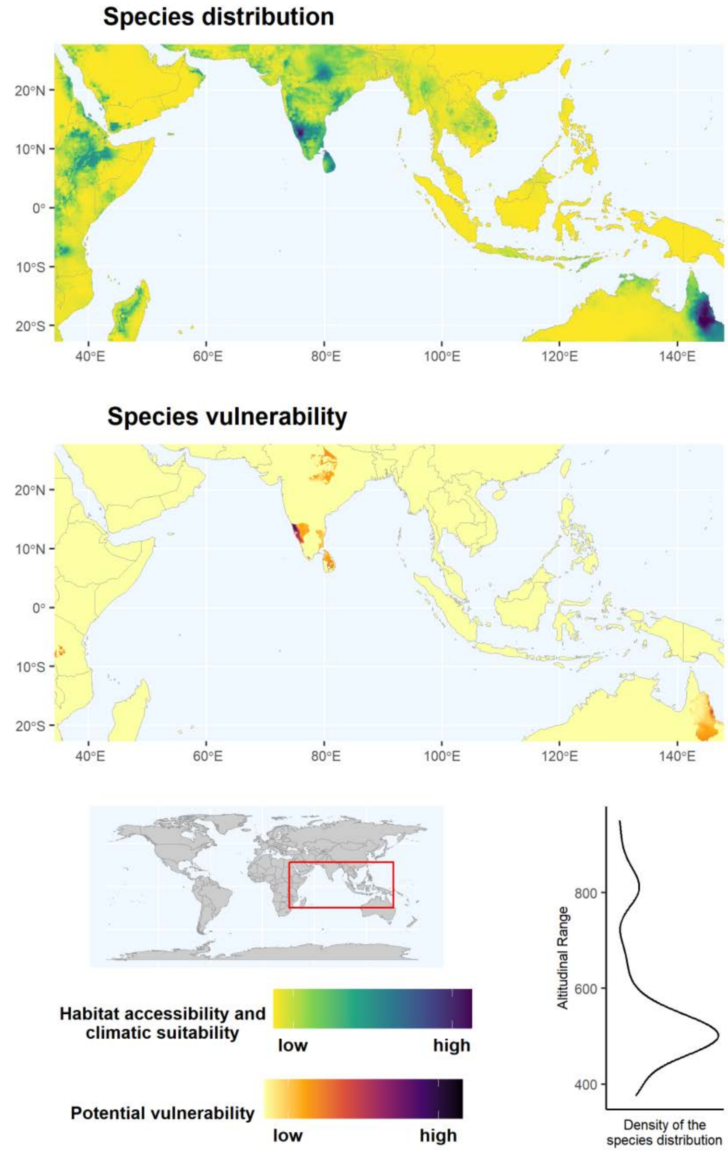
Myrothamnus moschatus (Baill.) Baill. ex Nied.



M. moschatus is a homoiochlorophyllous plant whose distribution is restricted to Madagascar. *M. moschatus* individuals can be primarily found in equatorial and warm temperate climates, ranging from 9 to 2413 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. moschatus* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 9% of its distribution range is currently found within protected areas.

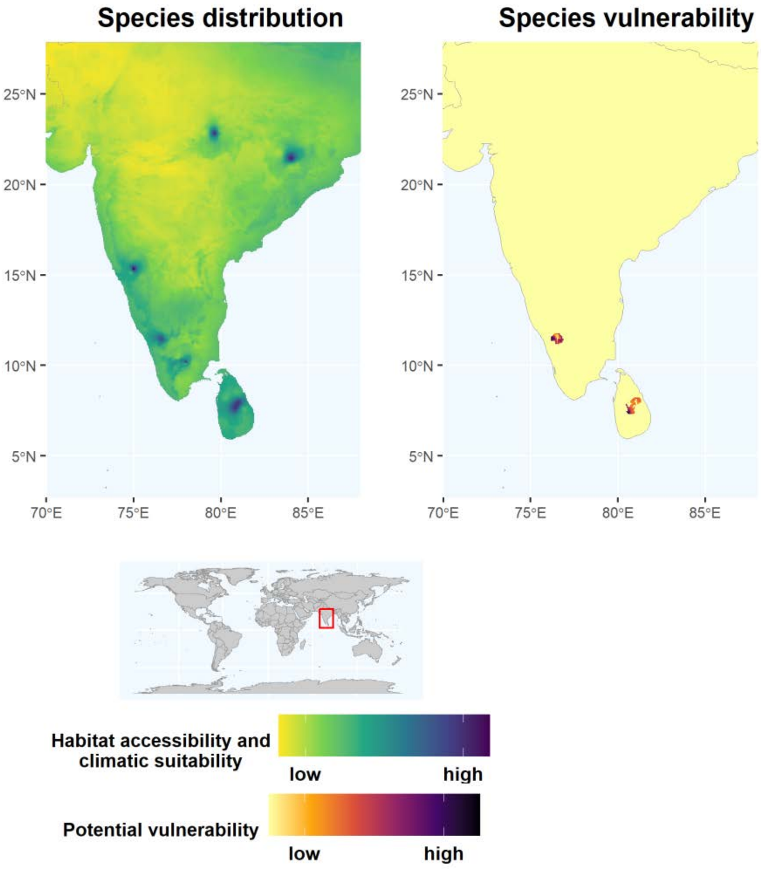
Poaceae

Eragrostiella bifaria (Vahl) Bor



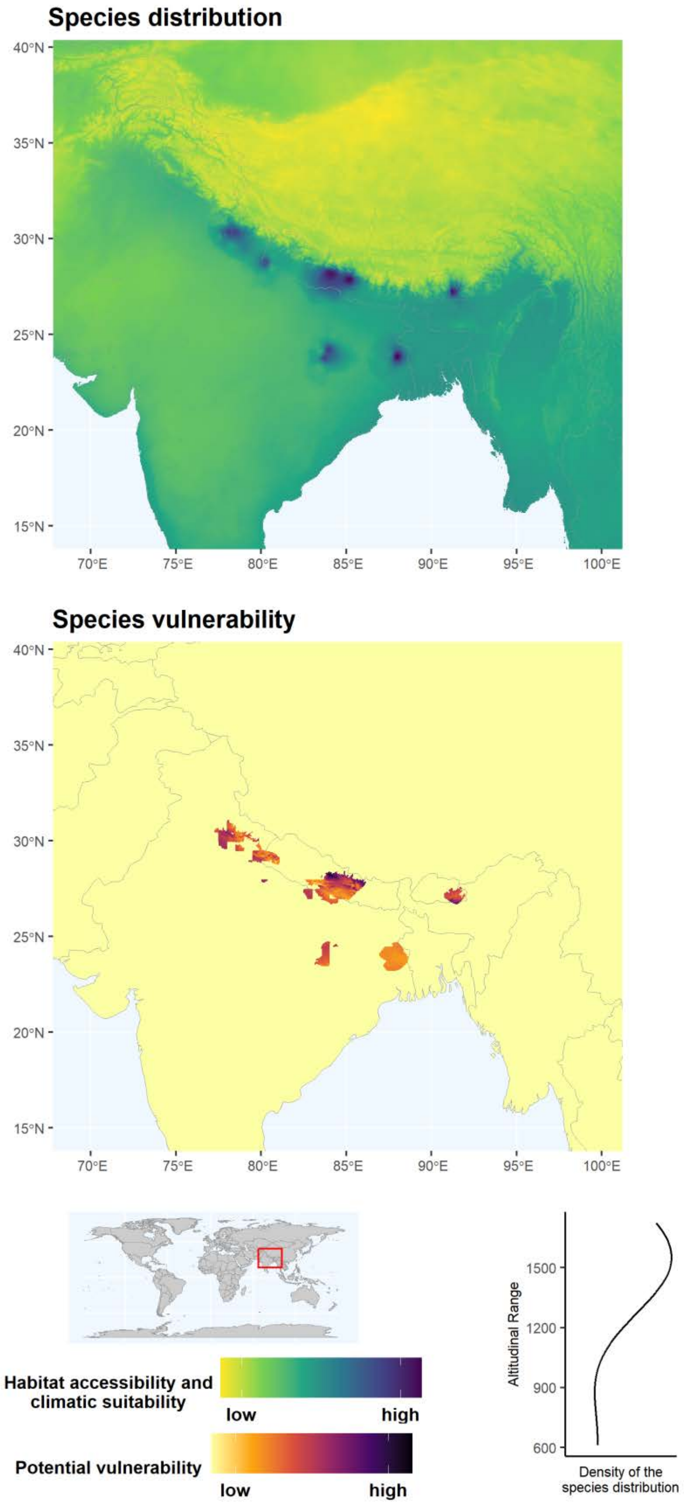
E. bifaria is a DT plant whose distribution comprises Andaman Is., Ethiopia, India, Kenya, Myanmar, Queensland, Sri Lanka, Tanzania, Thailand, West Himalaya. *E. bifaria* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 376 to 951 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *E. bifaria* populations are expected to be potentially more vulnerable to climate change in parts of Sri Lanka, India. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

Eragrostiella brachyphylla (Stapf) Bor



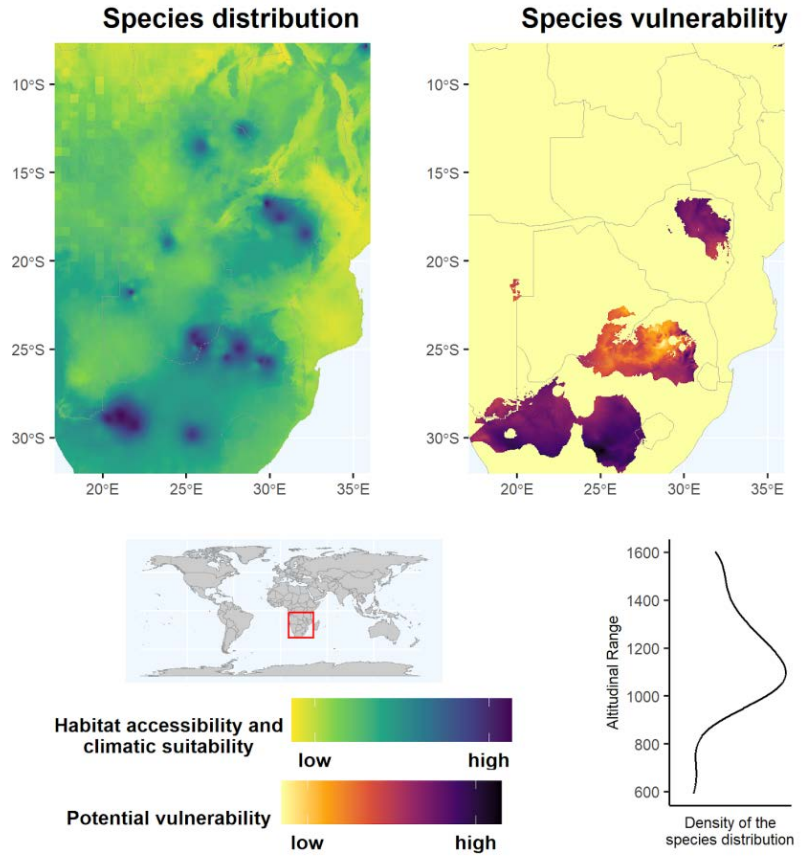
E. brachyphylla is a DT plant whose distribution comprises Bangladesh, India, Sri Lanka. *E. brachyphylla* individuals can be primarily found in equatorial climates, circa 495 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *E. brachyphylla* populations are expected to be potentially more vulnerable to climate change in parts of Sri Lanka, India. This species has not yet been assessed by IUCN, and 39% of its distribution range is currently found within protected areas.

Eragrostiella nardoides (Trin.) Bor



E. nardoides is a DT plant whose distribution comprises East Himalaya, India, Nepal, West Himalaya. *E. nardoides* individuals can be primarily found in warm temperate climates, ranging from 612 to 1724 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *E. nardoides* populations are expected to be potentially more vulnerable to climate change in parts of Bhutan, India, Nepal. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

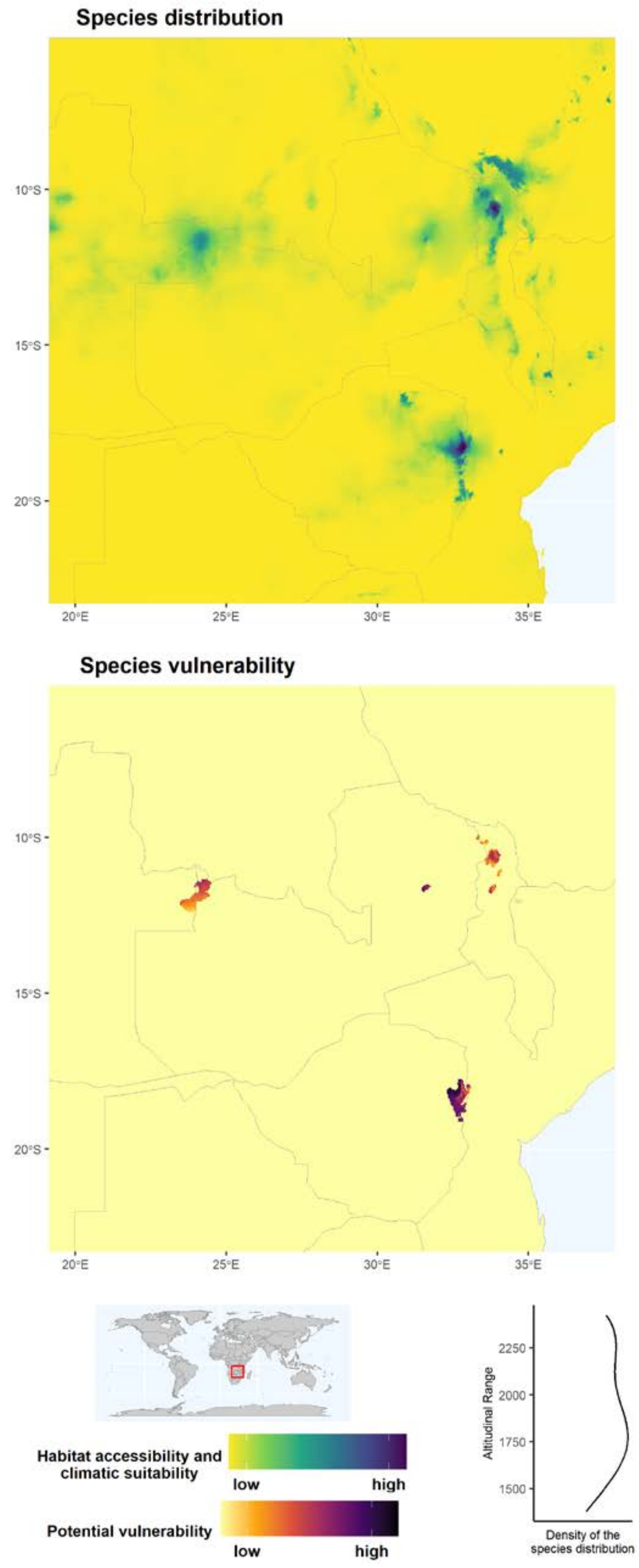
Eragrostis nindensis Ficalho & Hiern



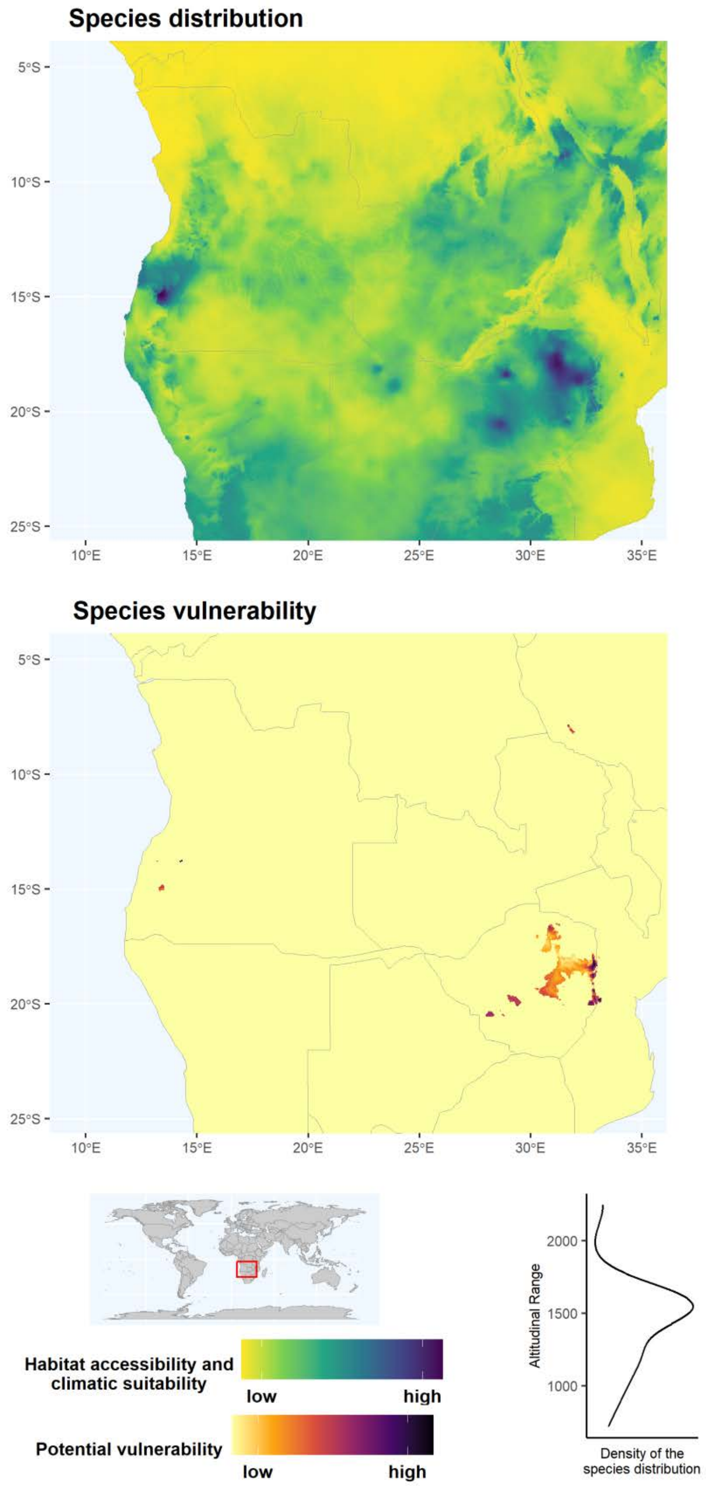
E. nindensis is a DT plant whose distribution comprises Angola, Botswana, Cape Provinces, Free State, KwaZulu-Natal, Malawi, Mozambique, Namibia, Northern Provinces, Tanzania, Zambia, Zaïre, Zimbabwe. *E. nindensis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 593 to 1604 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *E. nindensis* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho, Tanzania, Zimbabwe. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

Eragrostis paradoxa Launert

E. paradoxa is a DT plant whose distribution comprises Malawi, Zambia, Zimbabwe. *E. paradoxa* individuals can be primarily found in warm temperate climates, ranging from 1380 to 2425 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *E. paradoxa* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, Zambia, Zimbabwe. This species has not yet been assessed by IUCN, and 30% of its distribution range is currently found within protected areas.



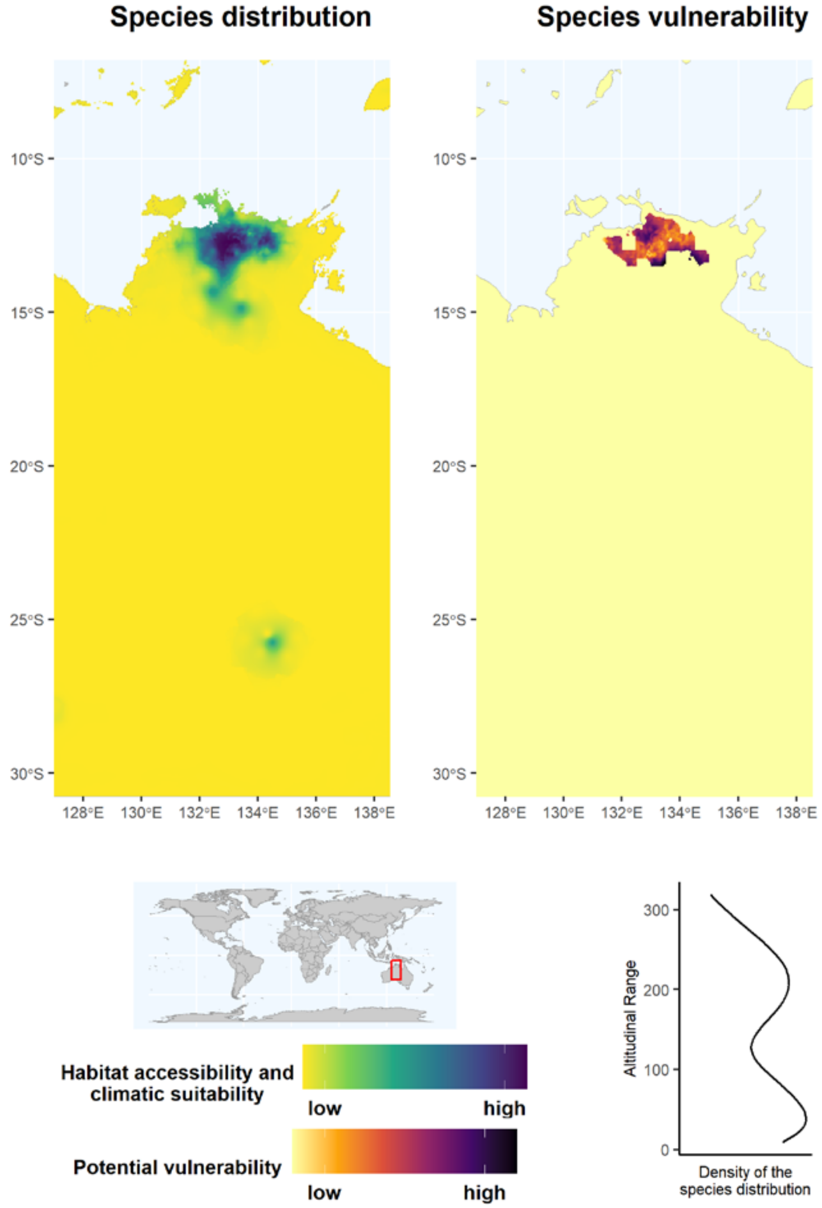
Micrachne patentiflora (Stent & J.M. Rattray) P.M. Peterson
(also cited as *Brachyachne patentiflora*)


Species distribution

Species vulnerability

M. patentiflora is a DT plant whose distribution comprises Angola, Botswana, Kenya, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *M. patentiflora* individuals can be primarily found in arid and warm temperate climates, ranging from 719 to 2247 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). *M. patentiflora* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Mozambique, Zimbabwe. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

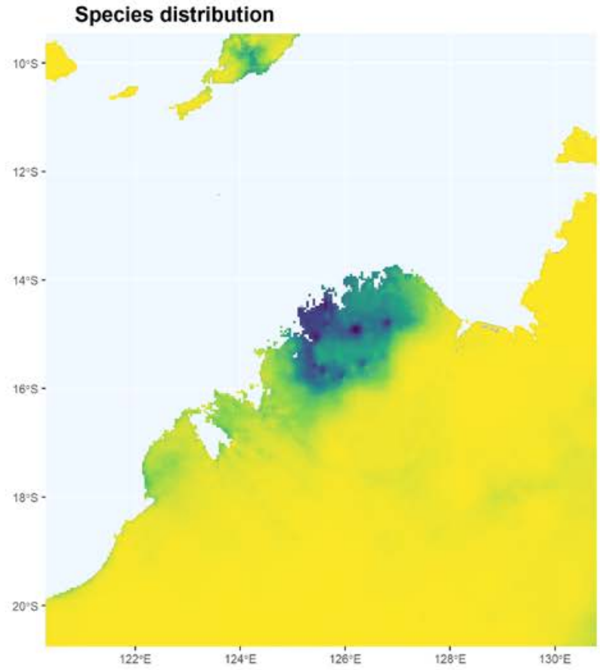
Micraira adamsii Lazarides

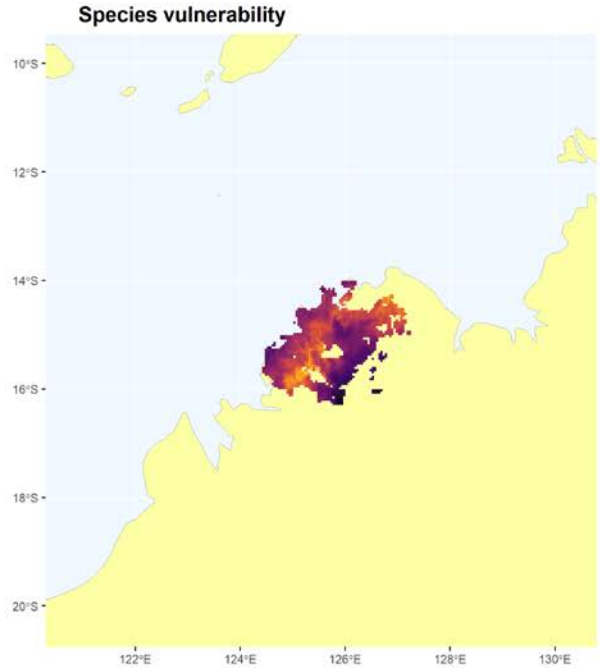


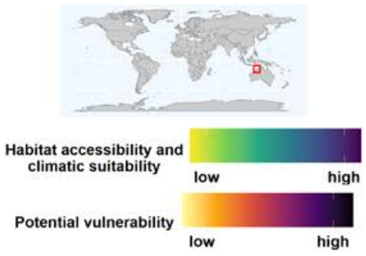
M. adamsii is a DT plant whose distribution is restricted to Northern Territory. *M. adamsii* individuals can be primarily found in equatorial and arid climates, ranging from 9 to 319 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. adamsii* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 68% of its distribution range is currently found within protected areas.

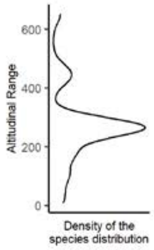
Micraira lazaridis L.G. Clark, Wendel & Craven

M. lazaridis is a DT plant whose distribution is restricted to Western Australia. *M. lazaridis* individuals can be primarily found in equatorial climates, ranging from 9 to 653 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. lazaridis* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, although 76% of its distribution range is currently found within protected areas.

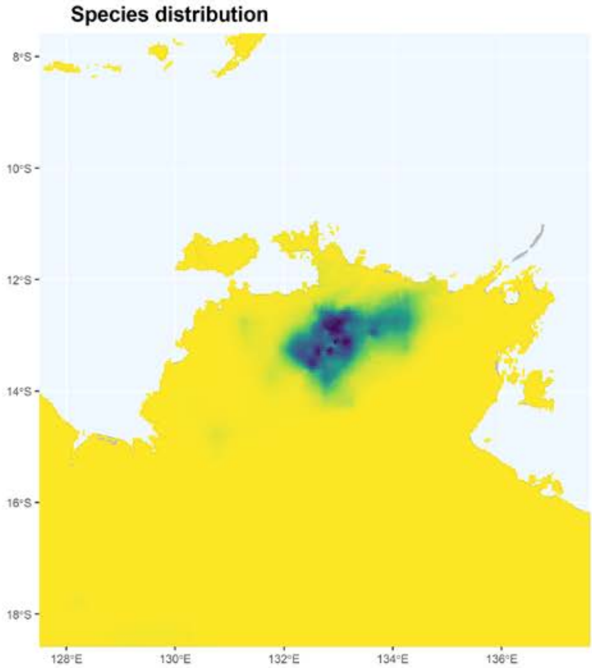


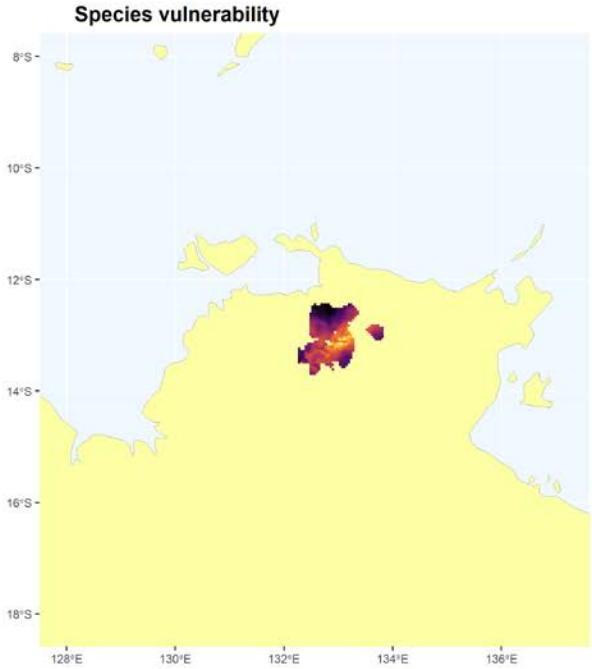


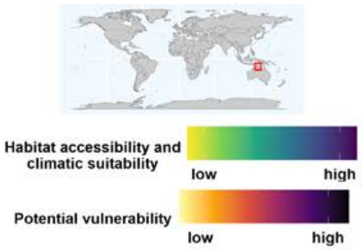


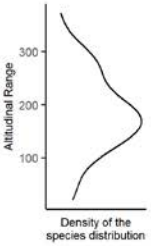


Micraira multinervia Lazarides





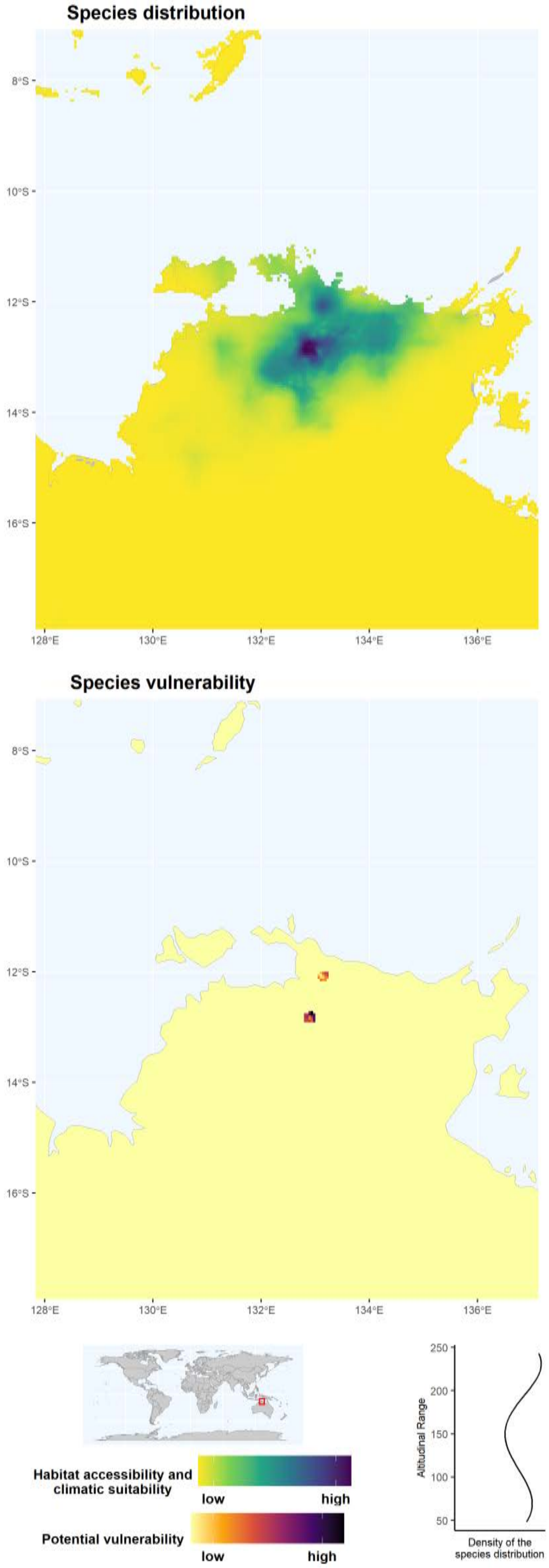




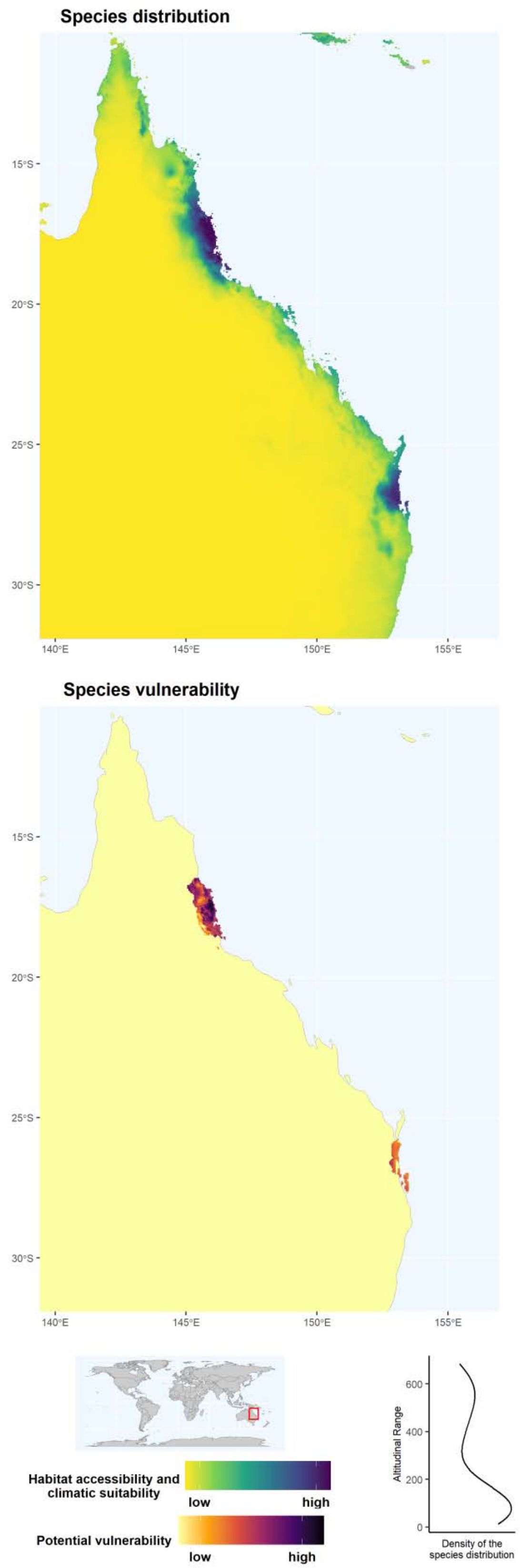
M. multinervia is a DT plant whose distribution is restricted to Northern Territory. *M. multinervia* individuals can be primarily found in equatorial climates, ranging from 21 to 373 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). *M. multinervia* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 95% of its distribution range is currently found within protected areas.

Micraira spinifera Lazarides

M. spinifera is a DT plant whose distribution is restricted to Northern Territory. *M. spinifera* individuals can be primarily found in equatorial climates, ranging from 48 to 243 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). *M. spinifera* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 48% of its distribution range is currently found within protected areas.

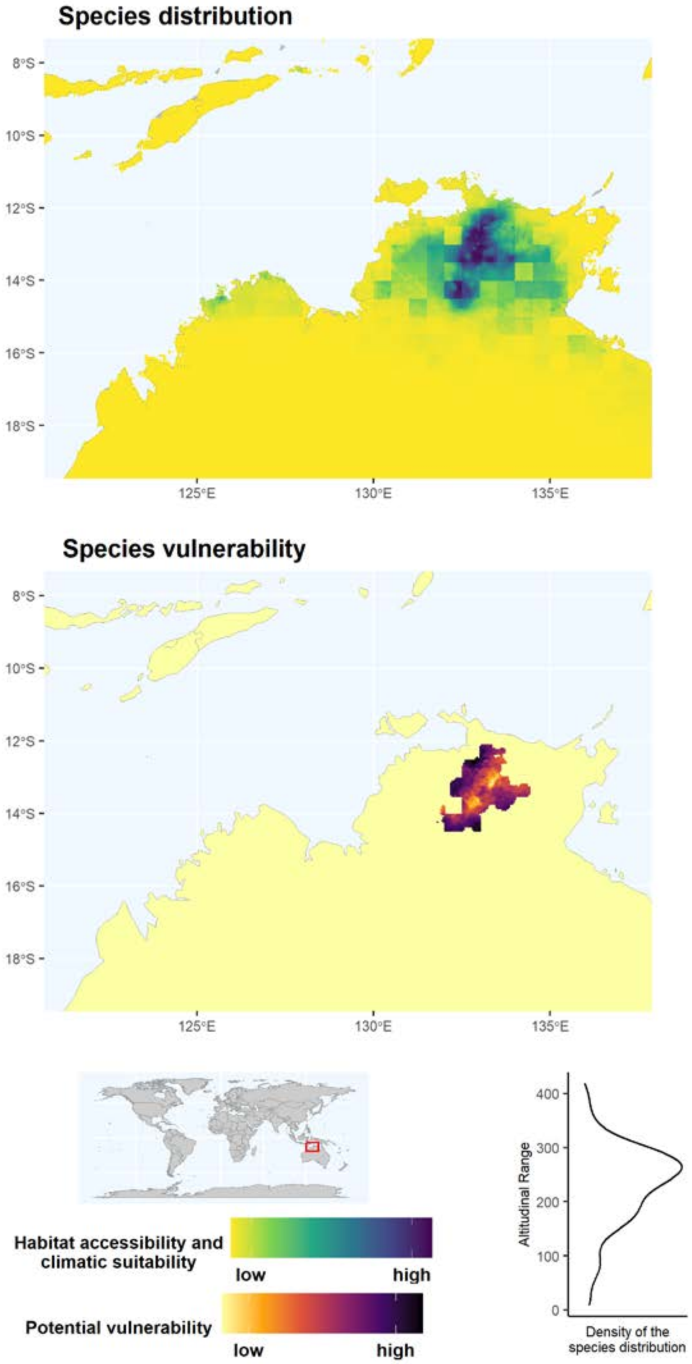


Micraira subulifolia F. Muell.



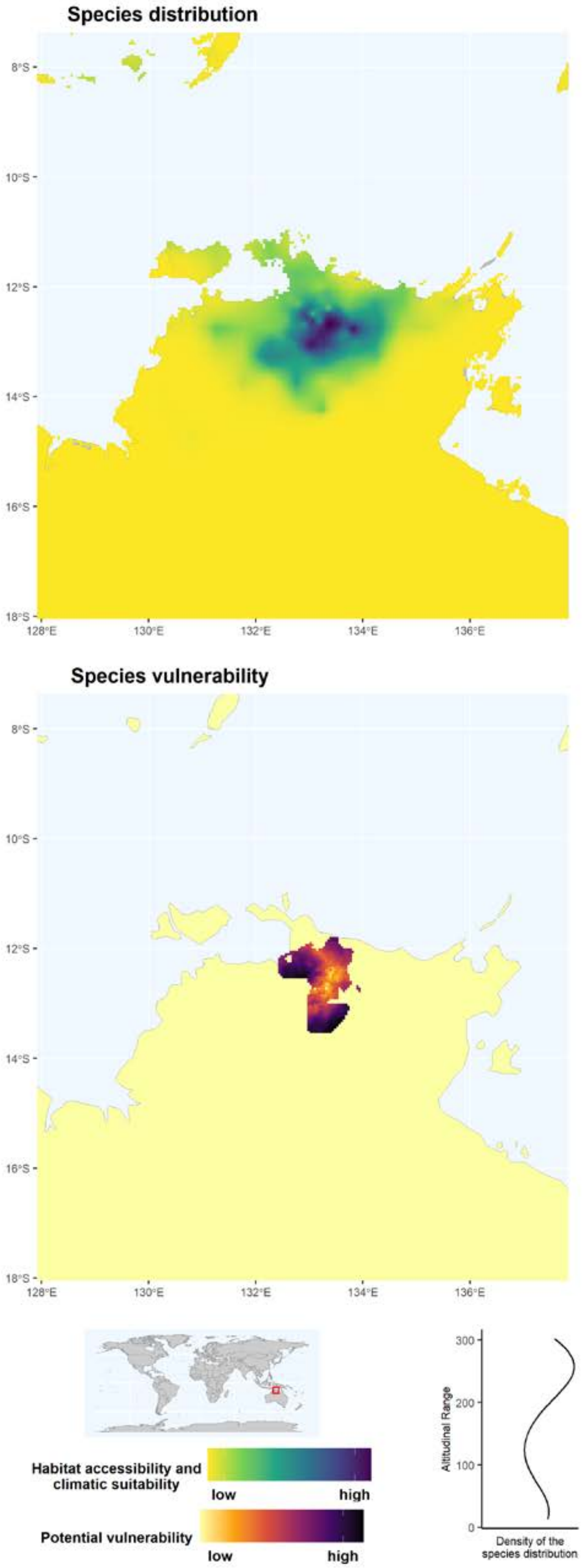
M. subulifolia is a DT plant whose distribution is restricted to Australia. *M. subulifolia* individuals can be primarily found in equatorial and warm temperate climates, ranging from 12 to 685 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *M. subulifolia* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, although 69% of its distribution range is currently found within protected areas.

Micraira tenuis Lazarides



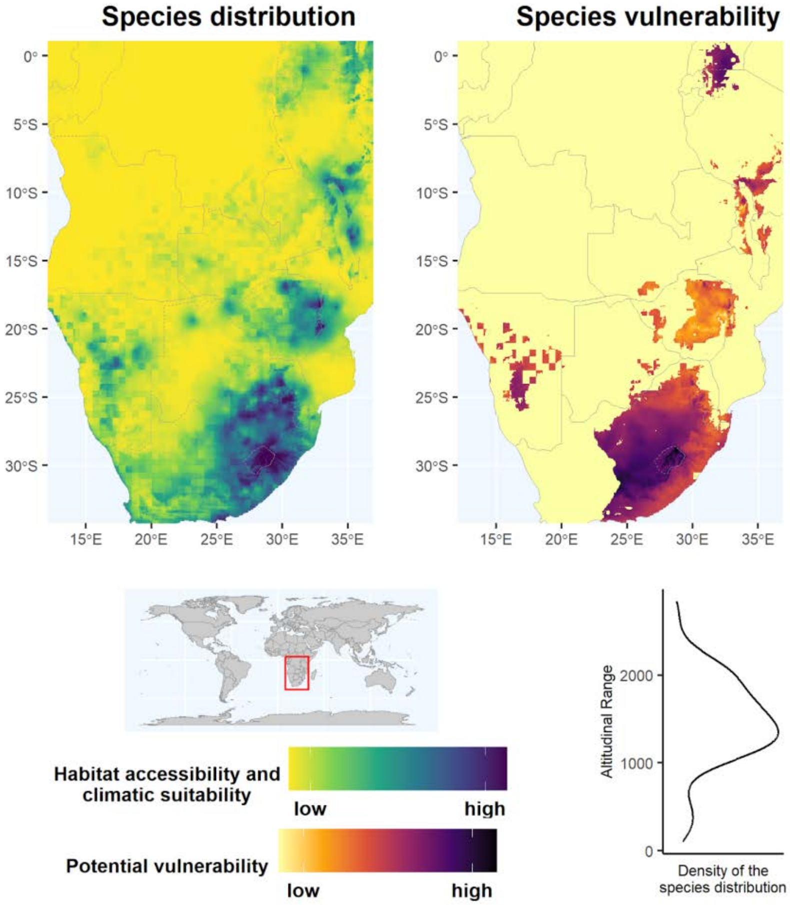
M. tenuis is a DT plant whose distribution comprises Aldabra, Angola, Benin, Botswana, Burkina, Burundi, Cameroon, Cape Provinces, Cape Verde, Caprivi Strip, Central African Republic, Chad, Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Free State, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, Kuwait, KwaZulu-Natal, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Northern Provinces, Oman, Rwanda, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Socotra, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Western Sahara, Yemen, Zambia, Zaïre, Zimbabwe. *M. tenuis* individuals can be primarily found in equatorial climates, ranging from 9 to 419 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. tenuis* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 64% of its distribution range is currently found within protected areas.

Micraira viscidula Lazarides



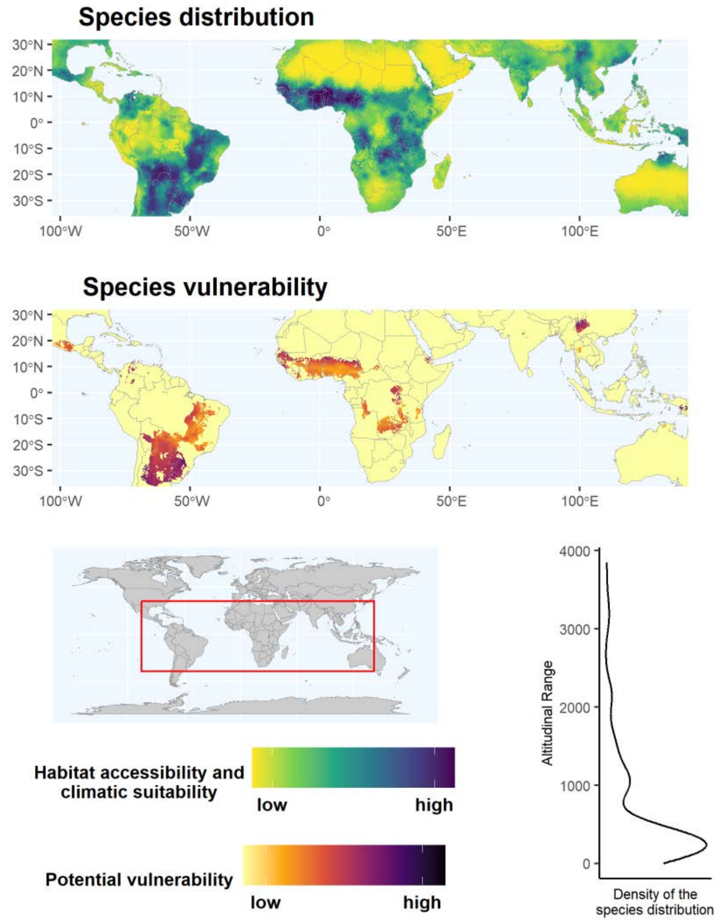
M. viscidula is a DT plant whose distribution is restricted to Northern Territory. *M. viscidula* individuals can be primarily found in equatorial climates, ranging from 13 to 302 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. viscidula* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 64% of its distribution range is currently found within protected areas.

Microchloa caffra Nees



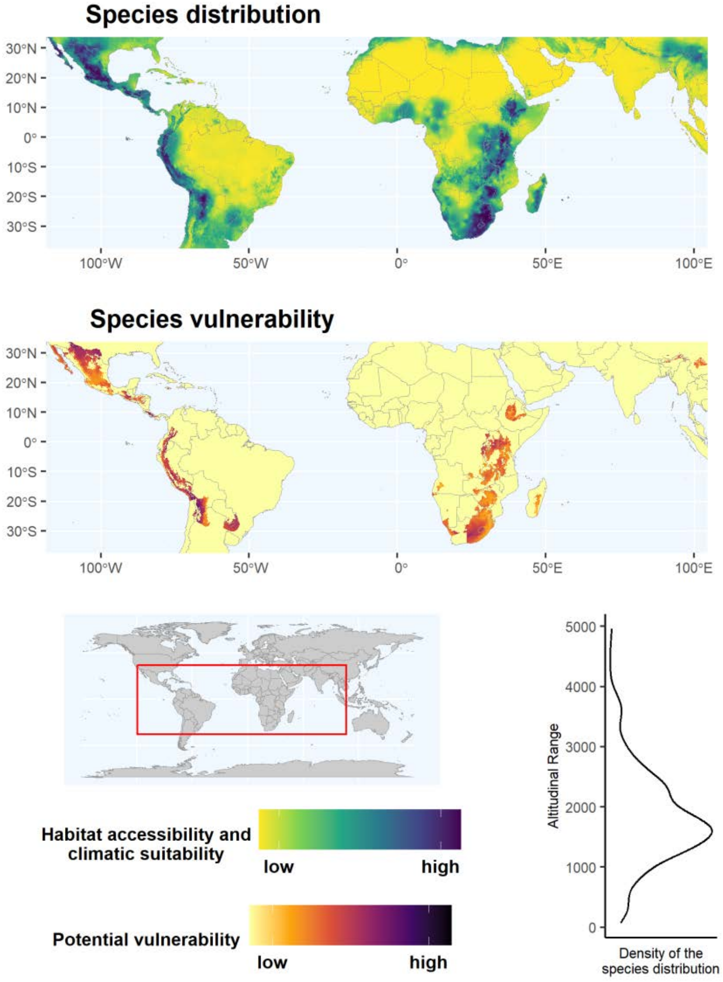
M. caffra is a DT plant whose distribution comprises Angola, Botswana, Cape Provinces, Free State, KwaZulu-Natal, Lesotho, Namibia, Northern Provinces, Swaziland, Tanzania, Uganda, Zambia, Zaïre. *M. caffra* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 103 to 2843 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. caffra* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Microchloa indica (L. f.) P. Beauv.



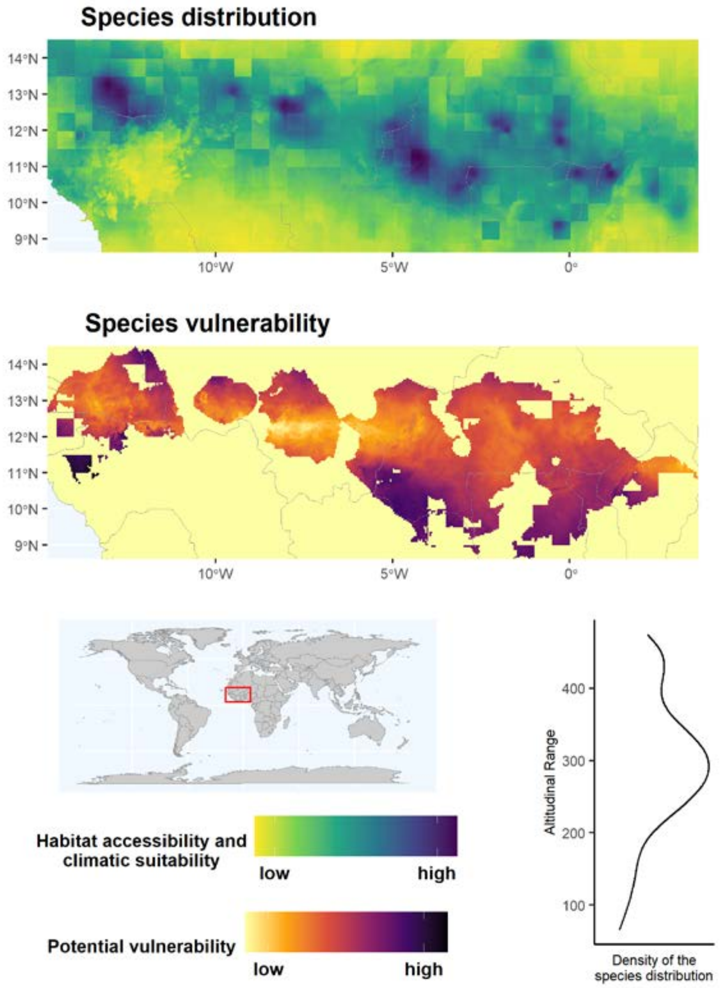
M. indica is a DT plant whose distribution comprises Angola, Assam, Bangladesh, Benin, Botswana, Burkina, Burundi, Cameroon, Central African Republic, Chad, China South-Central, China Southeast, Ethiopia, Ghana, Guinea, Guinea-Bissau, Hainan, India, Ivory Coast, Jawa, Kenya, Malawi, Mali, Mozambique, Myanmar, Namibia, Niger, Nigeria, Northern Territory, Philippines, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Thailand, Togo, Vietnam, Zambia, Zaïre, Zimbabwe. *M. indica* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 2 to 3848 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *M. indica* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Myanmar, Brazil, China, Colombia, Mexico, Papua New Guinea, Indonesia. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

Microchloa kunthii Desv.



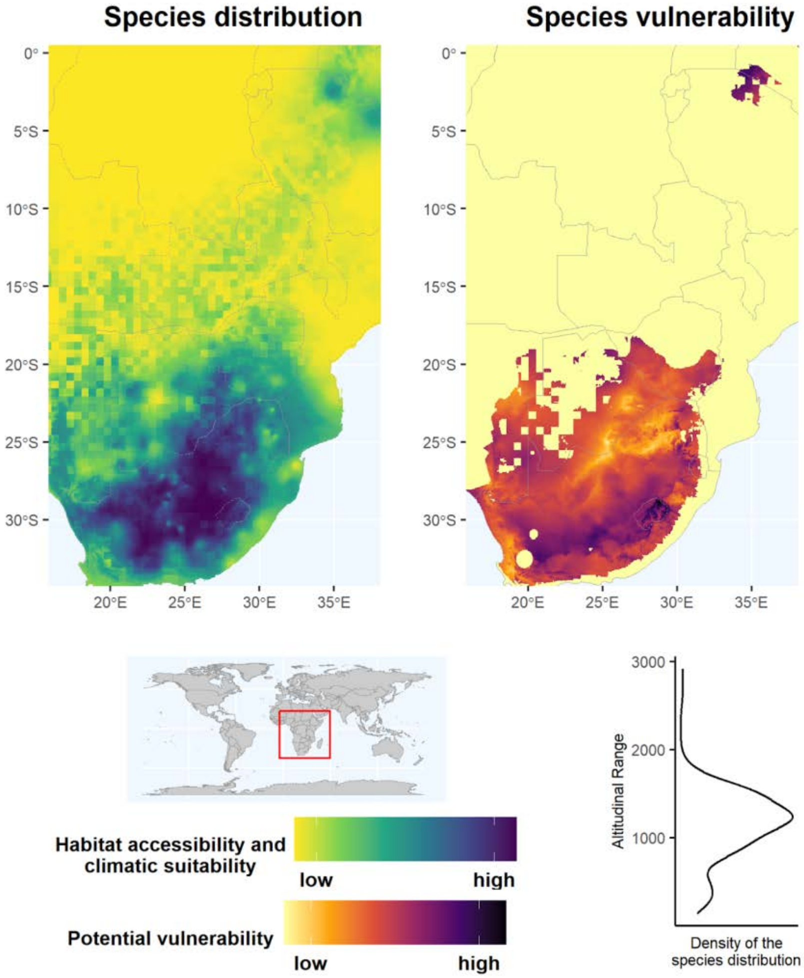
M. kunthii is a DT plant whose distribution comprises Angola, Benin, Botswana, Burkina, Burundi, Cameroon, Cape Provinces, Caprivi Strip, Eritrea, Ethiopia, Free State, Ghana, Ivory Coast, Kenya, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Namibia, Nigeria, Northern Provinces, Rwanda, Socotra, Somalia, Tanzania, Togo, Uganda, Yemen, Zambia, Zaïre, Zimbabwe, Argentina Northeast, Argentina Northwest, Bolivia , Chile North, Colombia, Peru, Ecuador, Guatemala, Honduras, , Nicaragua, Arizona, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Texas,Assan, India China South-Central, East Himalaya, Myanmar, Texas, Thailand, Vietnam, Oman, Saudi, Arabia. *M. kunthii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 75 to 4959 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *M. kunthii* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, China, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Peru, Panama, United States. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

Oropetium aristatum (Stapf) Pilg.



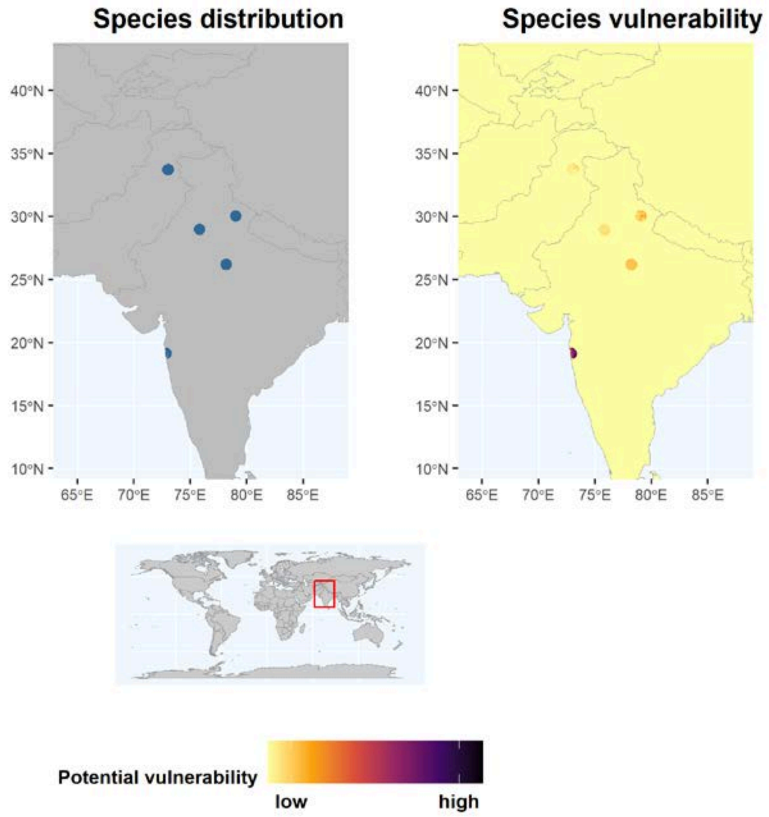
O. aristatum is a DT plant whose distribution comprises Benin, Burkina, Gambia, Ghana, Guinea-Bissau, Ivory Coast, Mali, Niger, Senegal, Togo. *O. aristatum* individuals can be primarily found in equatorial and arid climates, ranging from 66 to 474 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *O. aristatum* populations are expected to be potentially more vulnerable to climate change in parts of Benin, Ghana, Guinea, Cote d'Ivoire, Mali, Guinea-Bissau, Senegal, Burkina Faso. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

Oropetium capense Stapf



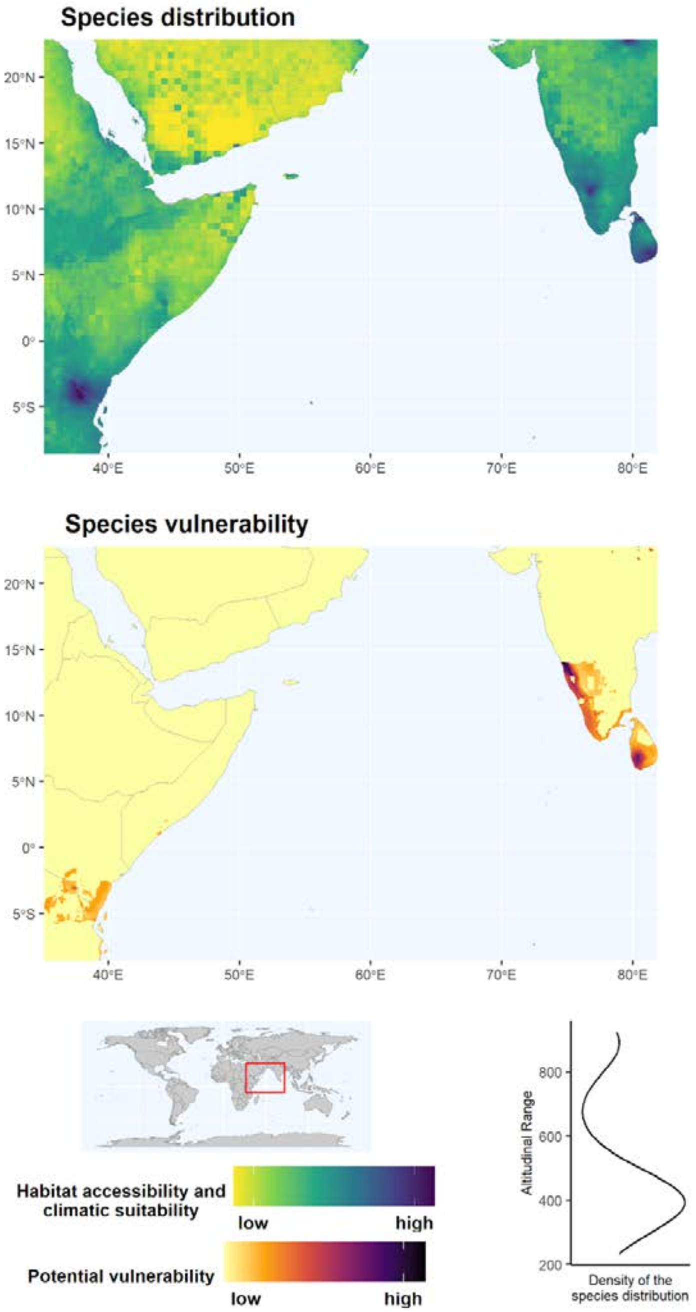
O. capense is a DT plant whose distribution comprises Angola, Botswana, Cape Provinces, Chad, Free State, Kenya, KwaZulu-Natal, Lesotho, Libya, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Northern Provinces, Oman, Saudi Arabia, Somalia, Tanzania, Western Sahara, Yemen, Zambia, Zimbabwe. *O. capense* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 141 to 2919 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *O. capense* populations are expected to be potentially more vulnerable to climate change in parts of Kenya, Mozambique, South Africa, Lesotho, Tanzania, Zimbabwe. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

Oropetium roxburghianum S.M. Phillips



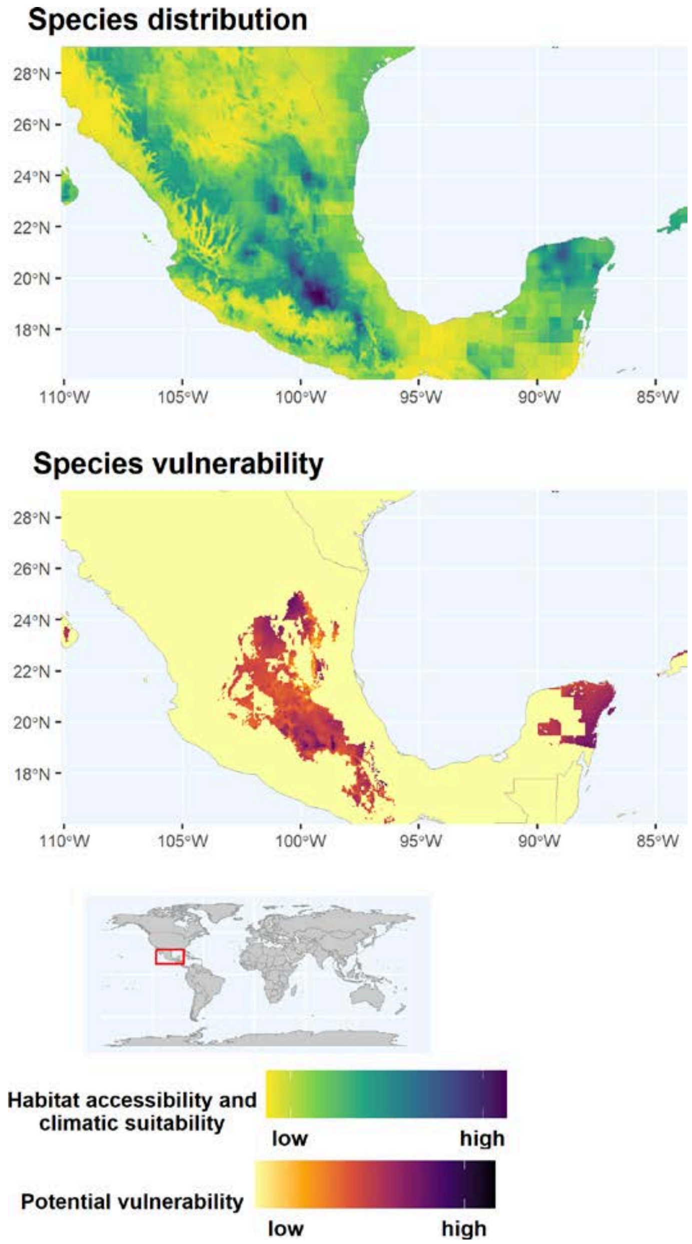
O. roxburghianum is a DT plant whose distribution comprises India, West Himalaya. More occurrence points are needed for a consistent evaluation of the ecological aspects of *O. roxburghianum*. Its populations are expected to be potentially more vulnerable to climate change in parts of India. This species has not yet been assessed by IUCN, and only 1% of its distribution range is currently found within protected areas.

Oropetium thomaeum (L. f.) Trin.



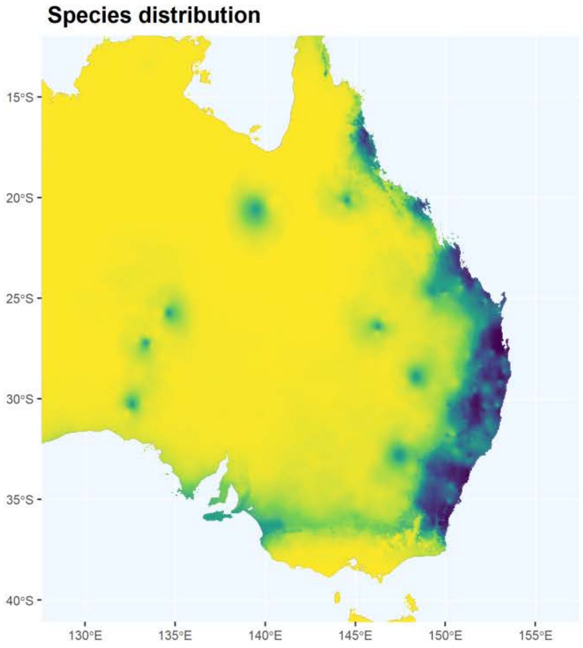
O. thomaeum is a DT plant whose distribution comprises Bangladesh, Chad, Ethiopia, India, Kenya, Myanmar, Pakistan, Somalia, Sri Lanka, Sudan, Tanzania, Vietnam, West Himalaya. *O. thomaeum* individuals can be primarily found in equatorial and arid climates, ranging from 234 to 925 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *O. thomaeum* populations are expected to be potentially more vulnerable to climate change in parts of Sri Lanka, India. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

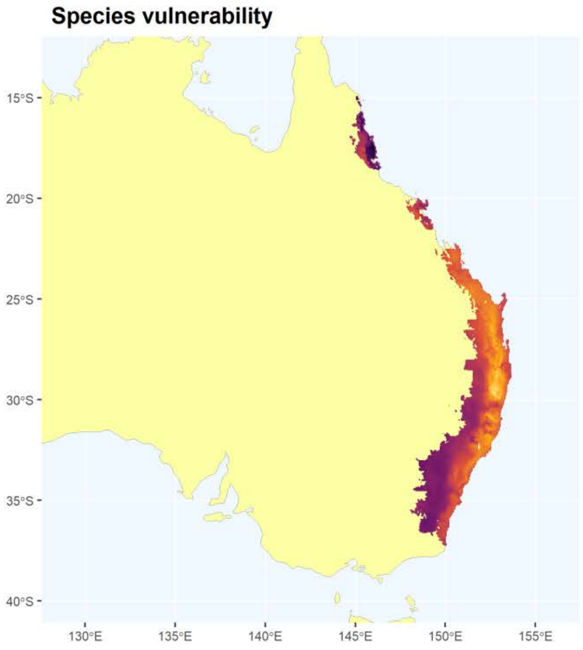
Sporobolus atrovirens (Kunth) Kunth

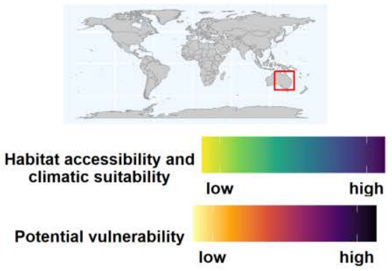


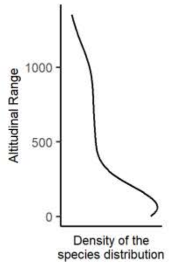
S. atrovirens is a DT plant whose distribution comprises Mexico Central, Mexico Northeast, Mexico Southeast, Mexico Southwest. *S. atrovirens* individuals can be primarily found in arid climates, circa 1052 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. atrovirens* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Sporobolus elongatus R. Br.



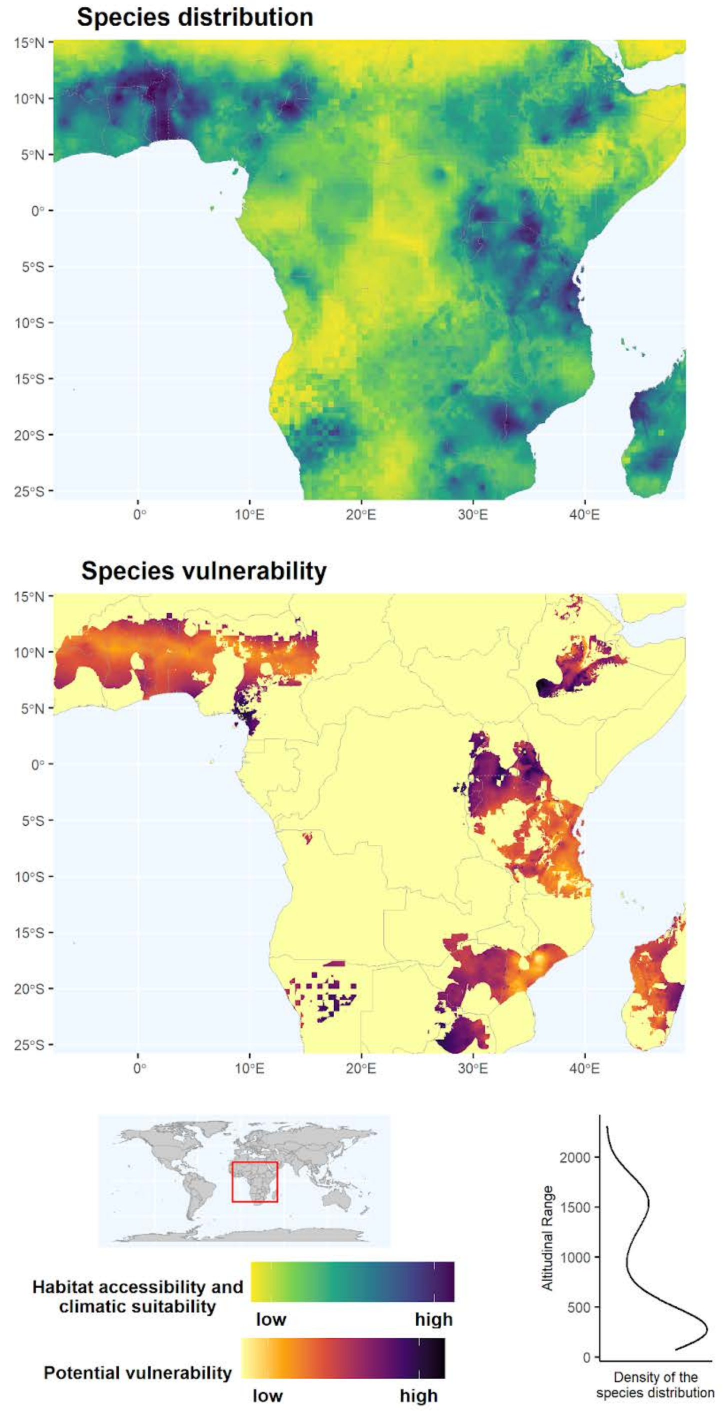






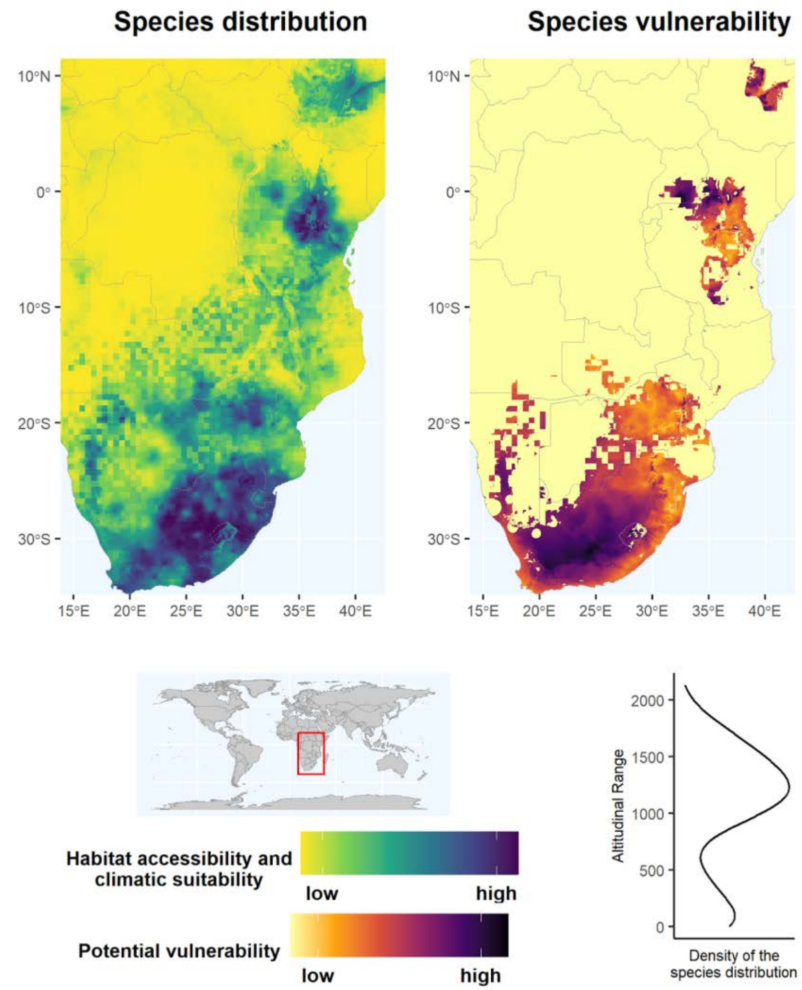
S. elongatus is a DT plant whose distribution comprises Bangladesh, New South Wales, Northern Territory, Queensland, South Australia. *S. elongatus* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 1354 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *S. elongatus* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 27% of its distribution range is currently found within protected areas.

Sporobolus festivus Hochst. ex A. Rich.



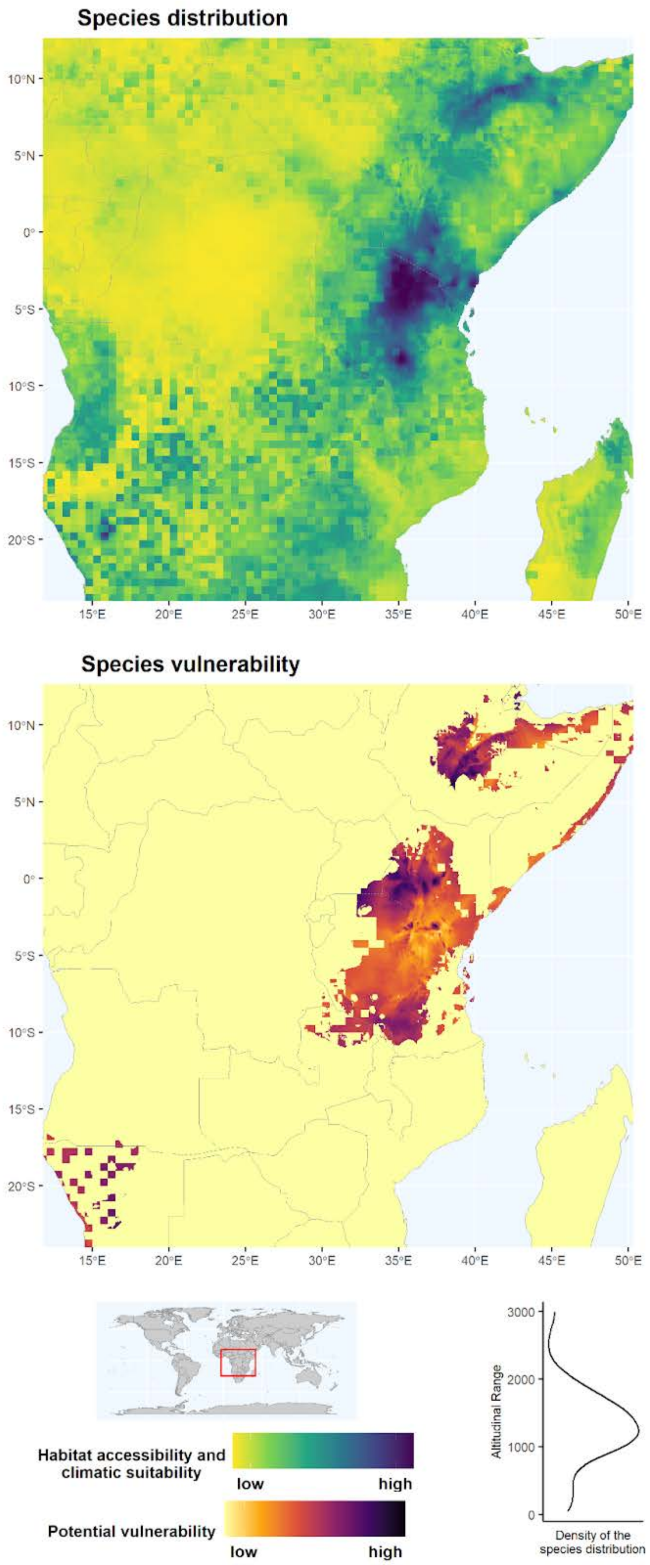
S. festivus is a DT plant whose distribution comprises Angola, Botswana, Burundi, Cape Provinces, Ethiopia, Kenya, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Namibia, Niger, Nigeria, Northern Provinces, Rwanda, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *S. festivus* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 70 to 2310 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. festivus* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Burundi, Cameroon, Chad, Equatorial Guinea, Ethiopia, Kenya, Madagascar, Niger, Nigeria, Rwanda, South Africa, Botswana, Somalia, Tanzania, Uganda, Namibia, Zimbabwe. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Sporobolus fimbriatus (Trin.) Nees



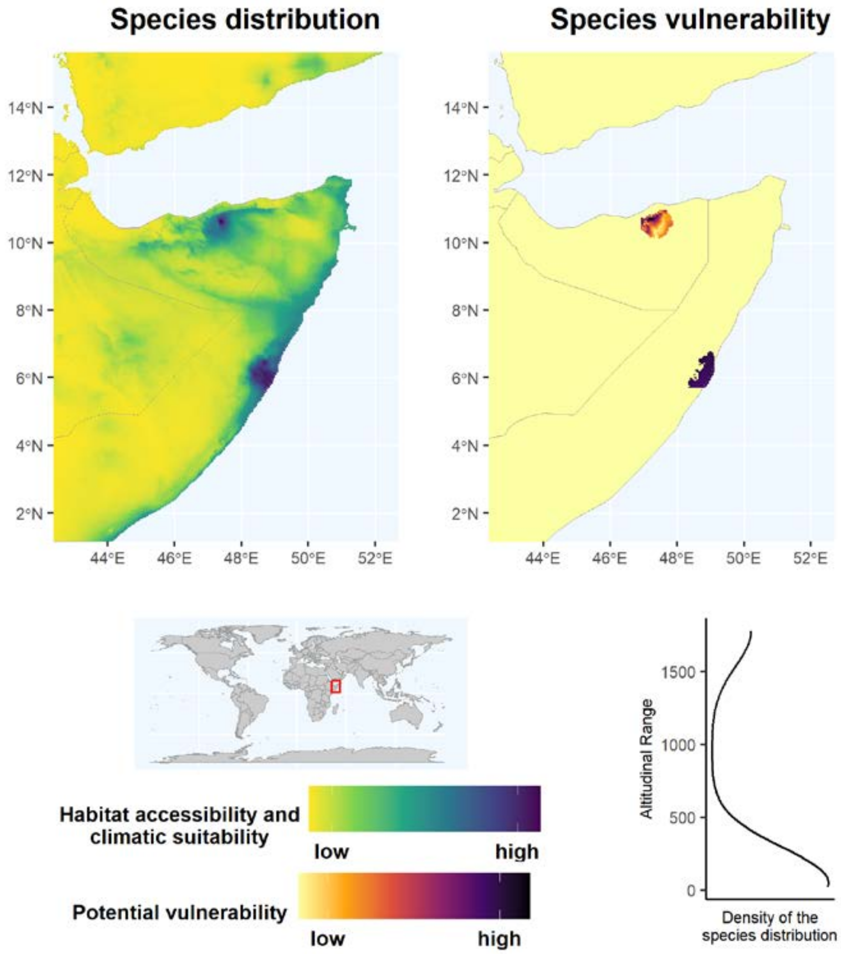
S. fimbriatus is a DT plant whose distribution comprises Angola, Botswana, Cape Provinces, Caprivi Strip, Ethiopia, Free State, Kenya, KwaZulu-Natal, Lesotho, Malawi, Mozambique, Namibia, Northern Provinces, Somalia, Sudan, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *S. fimbriatus* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 4 to 2134 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. fimbriatus* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Kenya, Mozambique, South Africa, Lesotho, Botswana, Tanzania, Uganda, Namibia, Zimbabwe. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Sporobolus pellucidus Hochst.



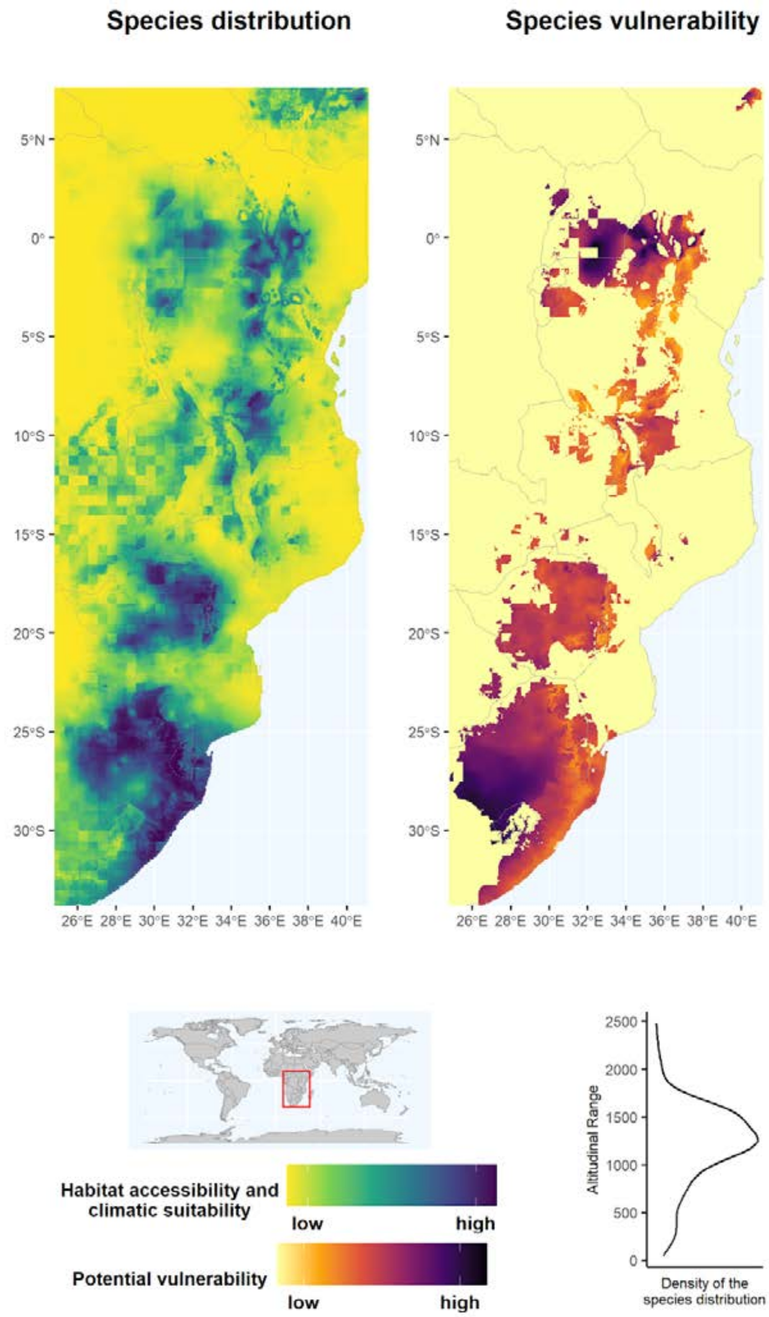
S. pellucidus is a DT plant whose distribution comprises Burkina, Chad, Ethiopia, Kenya, Namibia, Niger, Oman, Saudi Arabia, Somalia, Sudan, Tanzania, Uganda, Yemen, Zambia. *S. pellucidus* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 49 to 2996 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. pellucidus* populations are expected to be potentially more vulnerable to climate change in parts of Djibouti, Eritrea, Ethiopia, Kenya, Tanzania, Uganda, Namibia. This species has not yet been assessed by IUCN, and 31% of its distribution range is currently found within protected areas.

Sporobolus ruspolianus Chiov.



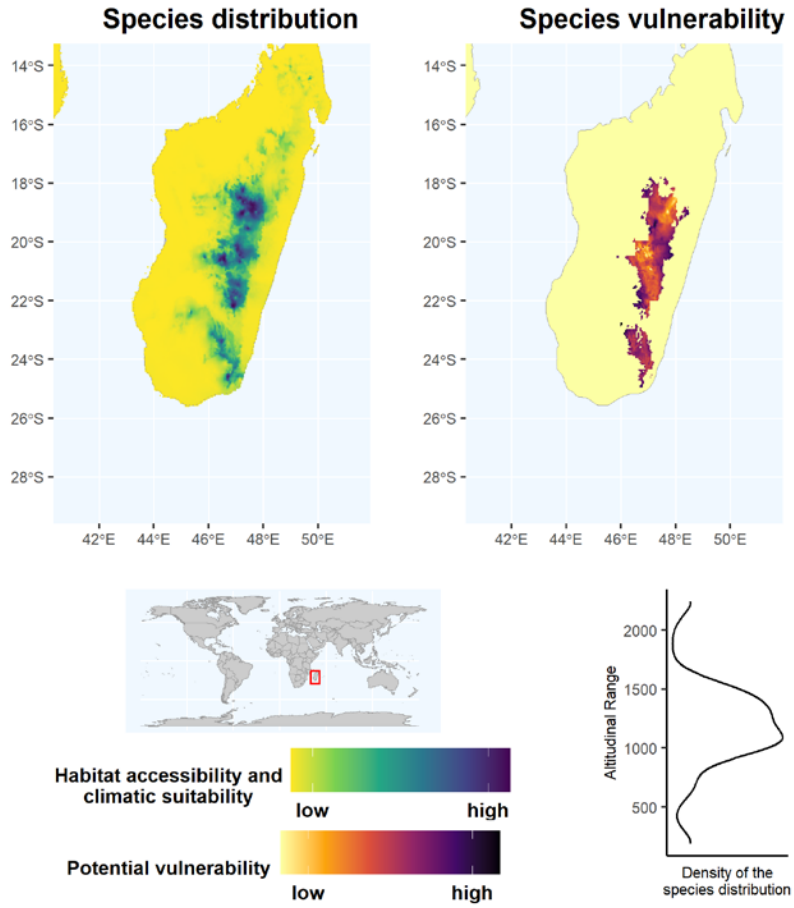
S. ruspolianus is a DT plant whose distribution comprises Ethiopia, Oman, Socotra, Somalia, Yemen. *S. ruspolianus* individuals can be primarily found in arid climates, ranging from 25 to 1781 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. ruspolianus* populations are expected to be potentially more vulnerable to climate change in parts of Somalia. This species has not yet been assessed by IUCN, and none of its distribution range is currently found within protected areas.

Sporobolus stapfianus Gand.



S. stapfianus is a DT plant whose distribution comprises Angola, Botswana, Burundi, Cape Provinces, Ethiopia, Kenya, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Namibia, Niger, Nigeria, Northern Provinces, Rwanda, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *S. stapfianus* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 53 to 2477 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. stapfianus* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Burundi, Ethiopia, Kenya, Rwanda, South Africa, Lesotho, Botswana, Tanzania, Uganda, Zimbabwe. This species is listed as Least concern by IUCN, although 20% of its distribution range is currently found within protected areas.

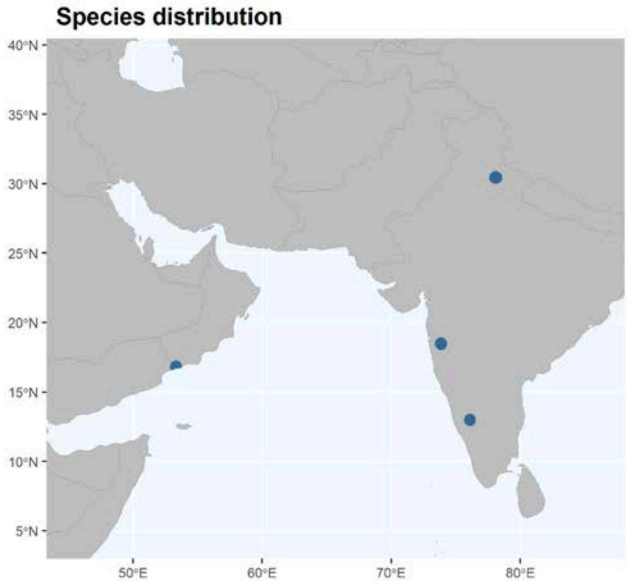
Styppeiochloa hitchcockii (A. Camus) Cope

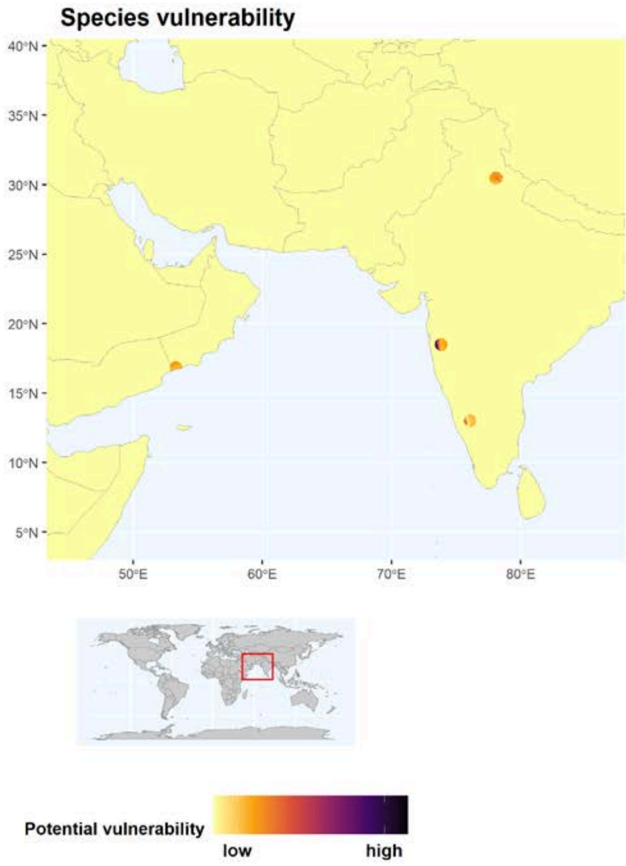


S. hitchcockii is a DT plant whose distribution is restricted to Madagascar. *S. hitchcockii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 190 to 2242 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *S. hitchcockii* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

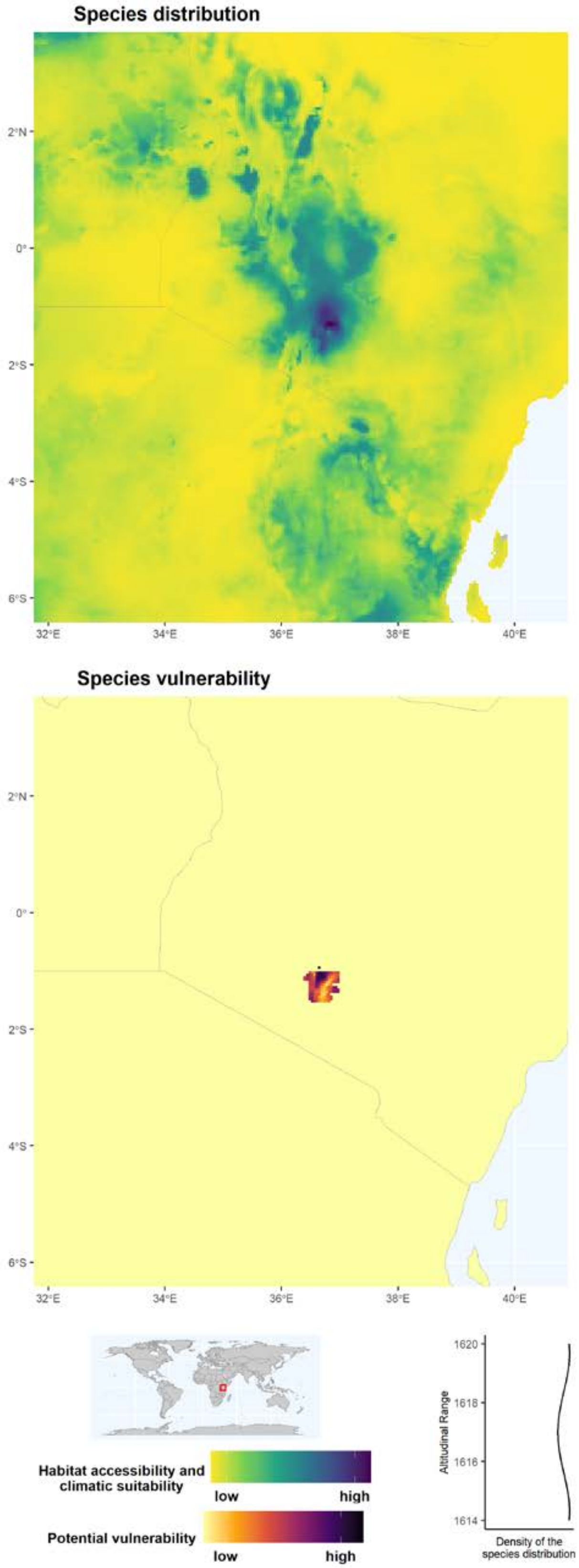
Tripogon capillatus Jaub. & Spach

T. capillatus is a DT plant whose distribution comprises India, Myanmar, Oman, West Himalaya. More occurrence points are needed for a consistent evaluation of the ecological aspects and conservation of *T. capillatus* populations. This species has not yet been assessed by IUCN, and none of its distribution range is currently found within protected areas.



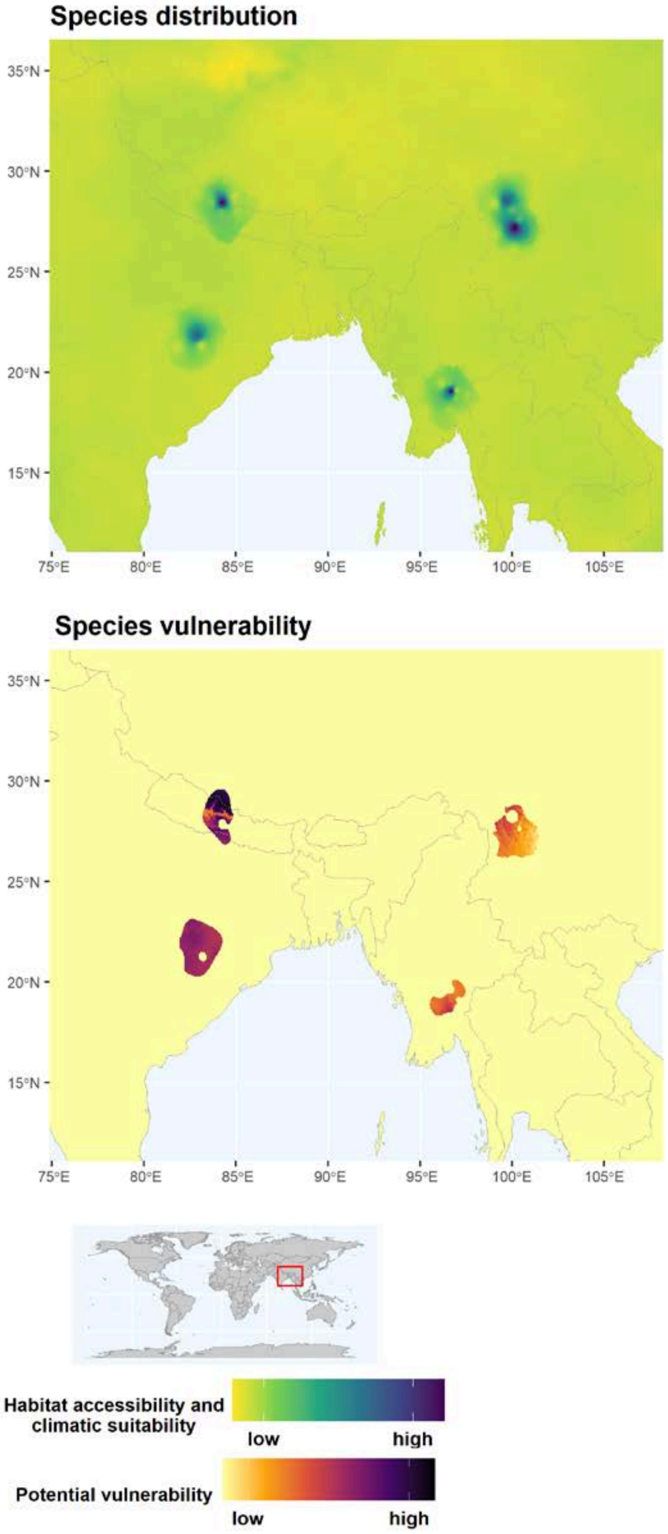


Tripogon curvatus S.M. Phillips & Launert



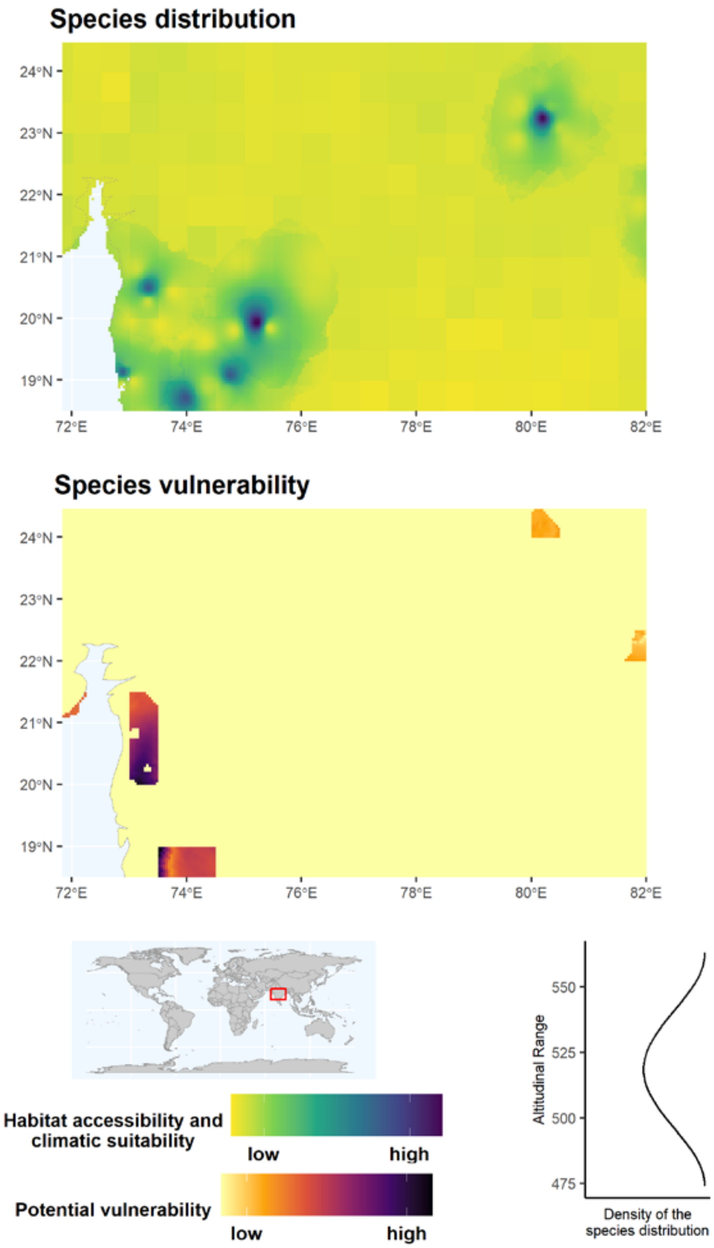
T. curvatus is a DT plant whose distribution is restricted to Kenya. *T. curvatus* individuals can be primarily found in warm temperate climates, ranging from 1614 to 1620 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *T. curvatus* populations are expected to be potentially more vulnerable to climate change in parts of China, Nepal. This species has not yet been assessed by IUCN, and only 5% of its distribution range is currently found within protected areas.

Tripogon filiformis Nees



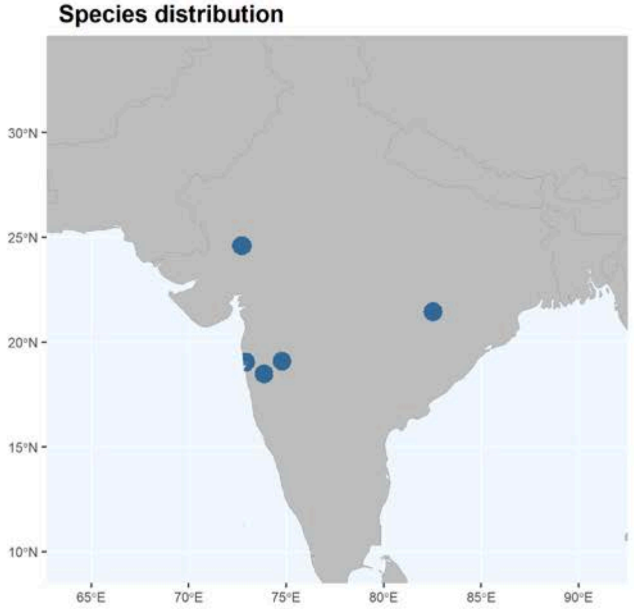
T. filiformis is a DT plant whose distribution comprises Assam, China North-Central, China South-Central, China Southeast, East Himalaya, India, Jawa, Lesser Sunda Is., Myanmar, Nepal, Tibet, West Himalaya. *T. filiformis* individuals can be primarily found in warm temperate climates, circa 2243 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). More occurrence points are needed for a consistent evaluation of the conservation of *T. filiformis* populations. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

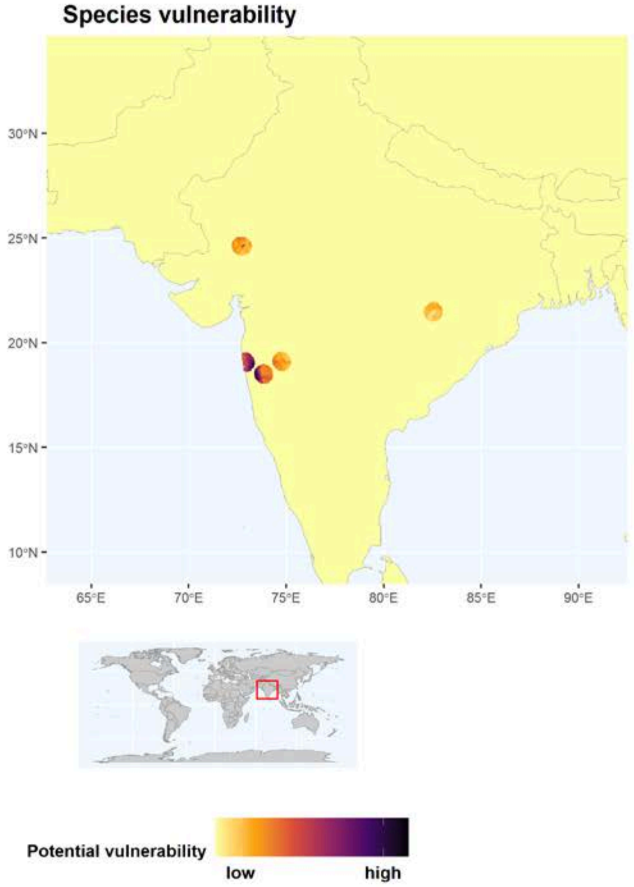
Tripogon jacquemontii Stapf



T. jacquemontii is a DT plant whose distribution comprises Bangladesh, India. *T. jacquemontii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 474 to 563 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *T. jacquemontii* populations are expected to be potentially more vulnerable to climate change in parts of India. This species has not yet been assessed by IUCN, and none of its distribution range is currently found within protected areas.

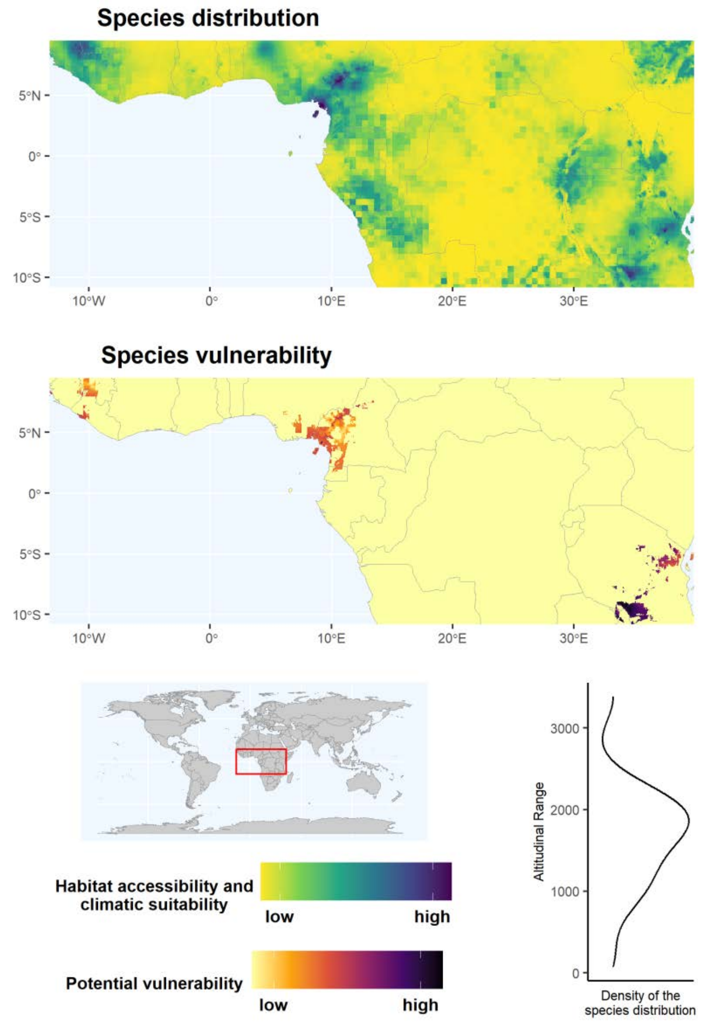
Tripogon lisboae Stapf





T. lisboae is a DT plant whose distribution is restricted to India. More occurrence points are needed for a consistent evaluation of the ecological aspects of *T. lisboae*. *T. lisboae* populations are expected to be potentially more vulnerable to climate change in parts of India. This species has not yet been assessed by IUCN, and none of its distribution range is currently found within protected areas.

Tripogon major Hook. f.



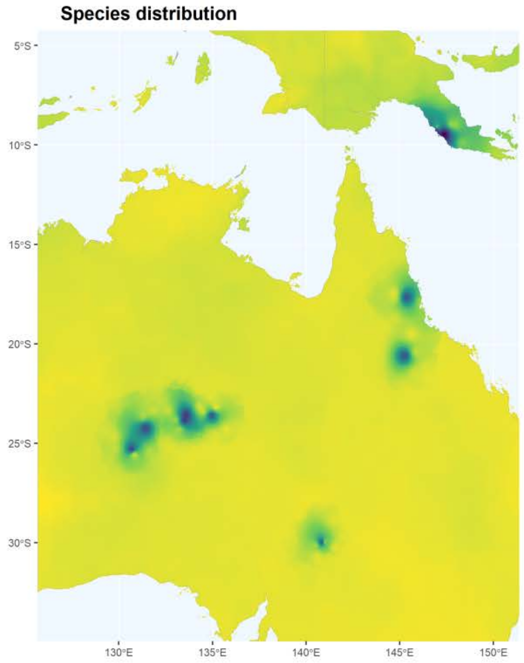
T. major is a DT plant whose distribution comprises Cameroon, Chad, Ethiopia, Kenya, Malawi, Nigeria, Sierra Leone, Sudan, Tanzania, Uganda. *T. major* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 69 to 3385 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *T. major* populations are expected to be potentially more vulnerable to climate change in parts of Cameroon, Malawi, Tanzania, Zambia. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

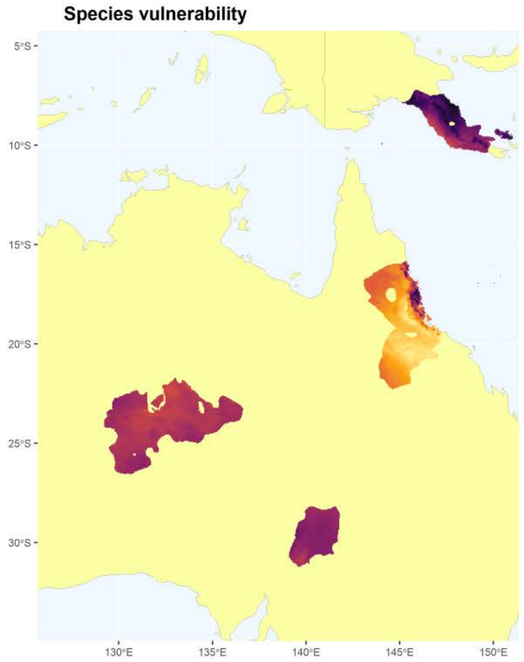
Tripogon polyanthus Naik & Patunkar

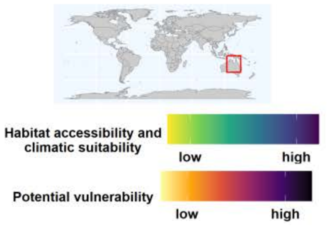
T. polyanthus is a DT plant whose distribution is restricted to India. No occurrence points was found for this species and they are needed for a consistent evaluation of the distribution, ecological aspects, and conservation of *T. polyanthus*.

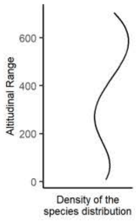
Tripogonella loliiformis (F. Muell.) P.M. Peterson & Romasch.
(also cited as *Tripogon loliiformis*)

T. loliiformis is a DT plant whose distribution comprises New Guinea, Australia. *T. loliiformis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 9 to 705 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *T. loliiformis* populations are expected to be potentially more vulnerable to climate change in parts of Kenya. This species has not yet been assessed by IUCN, and 19% of its distribution range is currently found within protected areas.

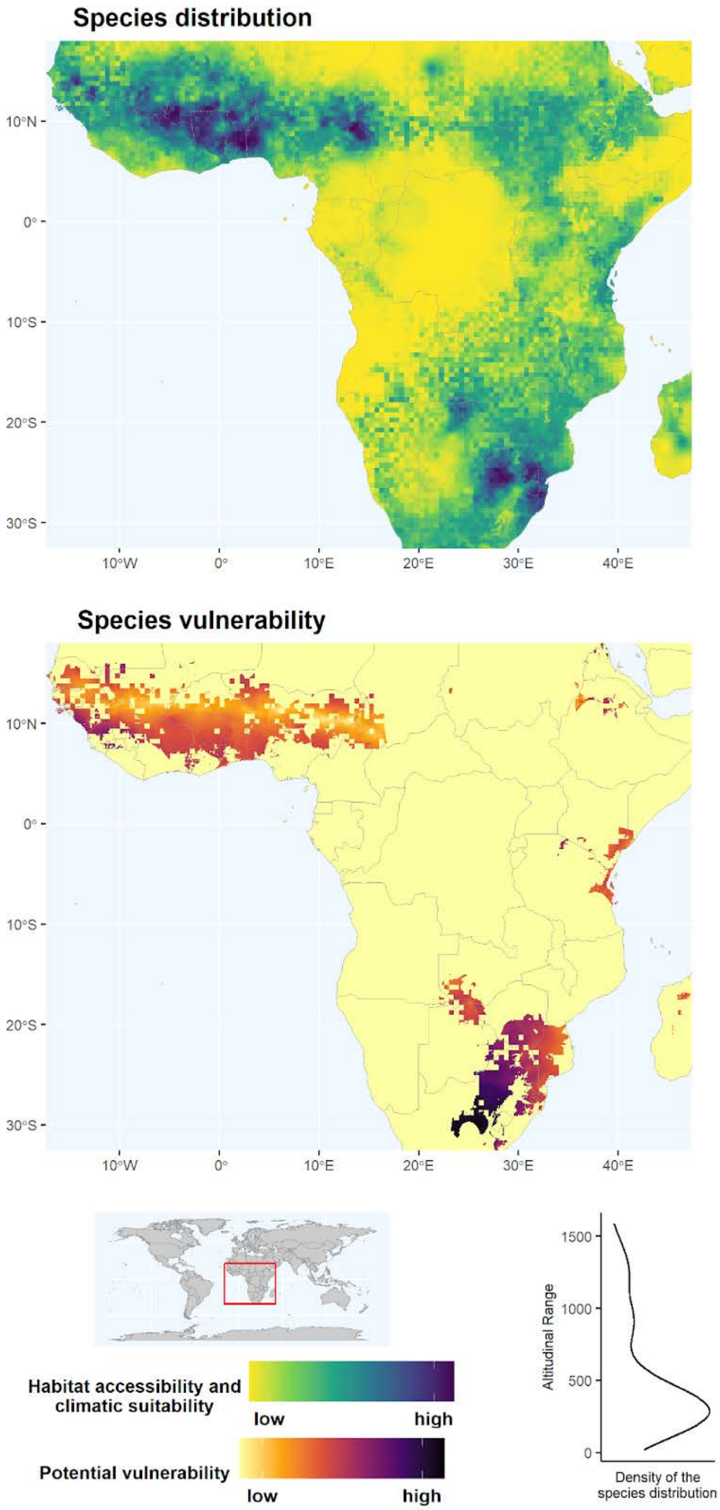








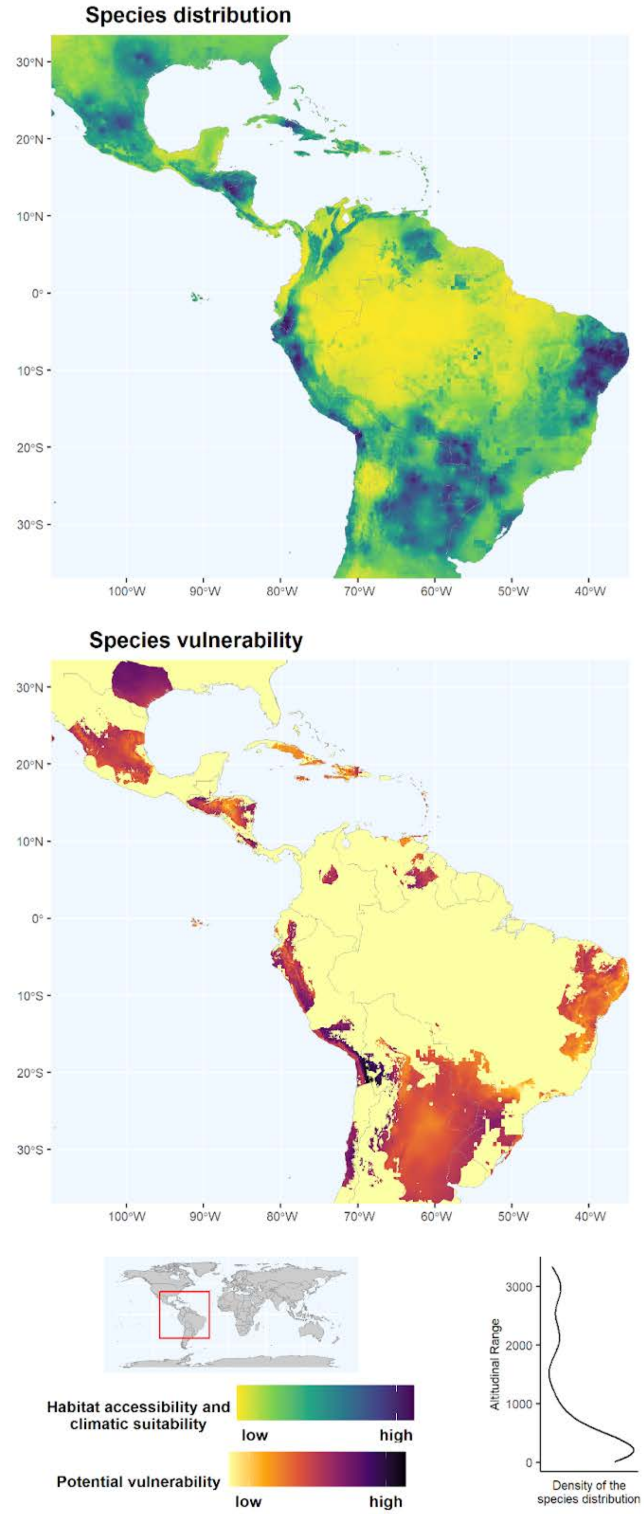
Tripogonella minima (A. Rich.) P.M. Peterson & Romasch. (also cited as *Tripogon minimus*)



T. minima is a DT plant whose distribution comprises Angola, Benin, Botswana, Burkina, Cameroon, Cape Verde, Caprivi Strip, Chad, Ethiopia, Ghana, Ivory Coast, Kenya, KwaZulu-Natal, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Northern Provinces, Senegal, Sudan, Swaziland, Tanzania, Togo, Zambia, Zimbabwe. *T. minima* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 19 to 1586 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to precipitation is extremely seasonal. *T. minima* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho, Botswana. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Tripogonella spicata (Nees) P.M. Peterson & Romasch.

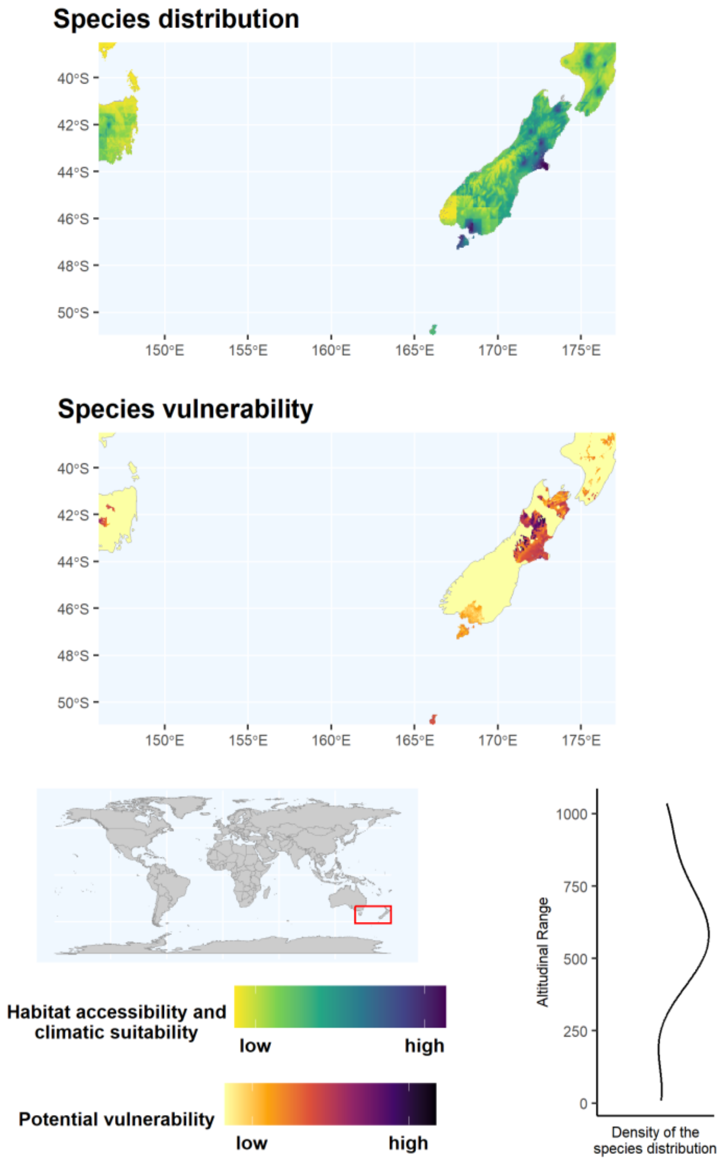
(also cited as *Tripogon spicatus*)



T. spicata is a DT plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Chile North, Colombia, Cuba, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Nicaragua, Paraguay, Peru, Texas, Uruguay, Venezuela. *T. spicata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 9 to 3336 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *T. spicata* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Chile, Costa Rica, Ecuador, Guatemala, Peru, United States. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

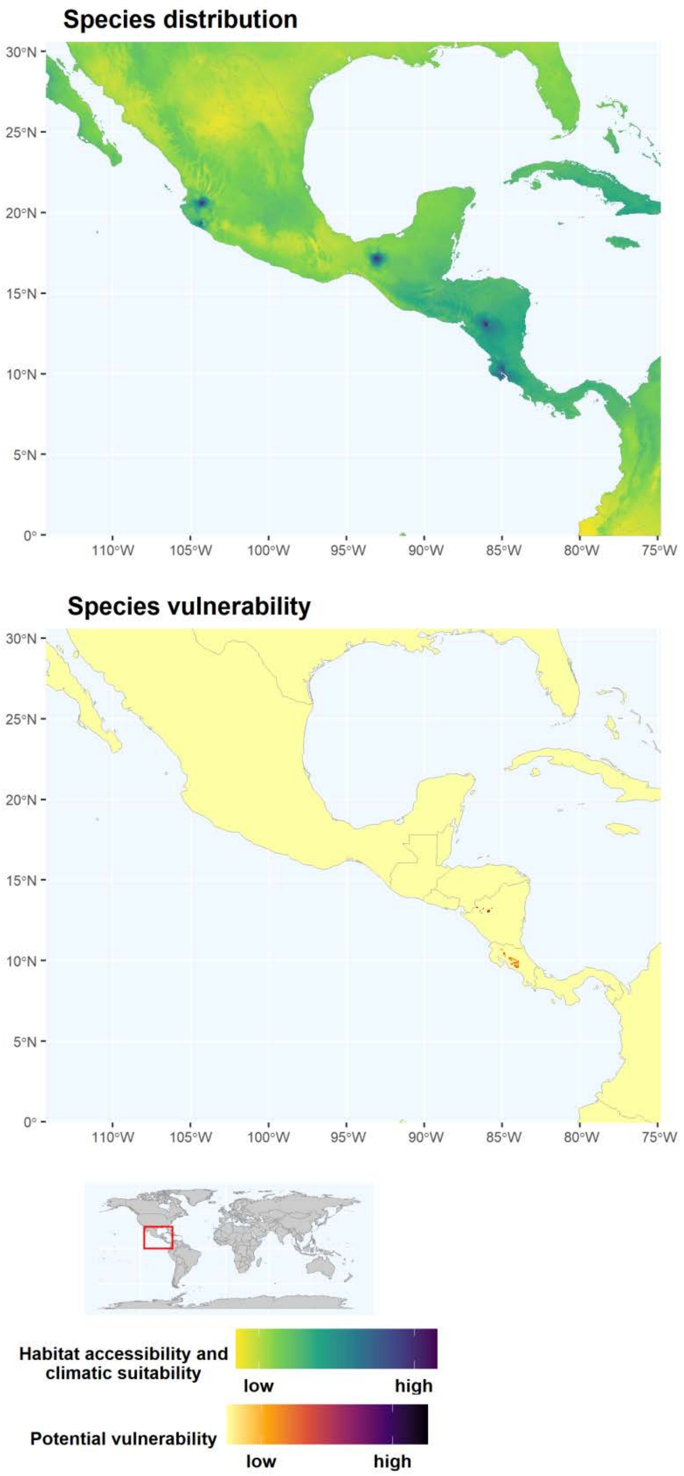
Polypodiaceae

Ctenopteris heterophylla Tindale



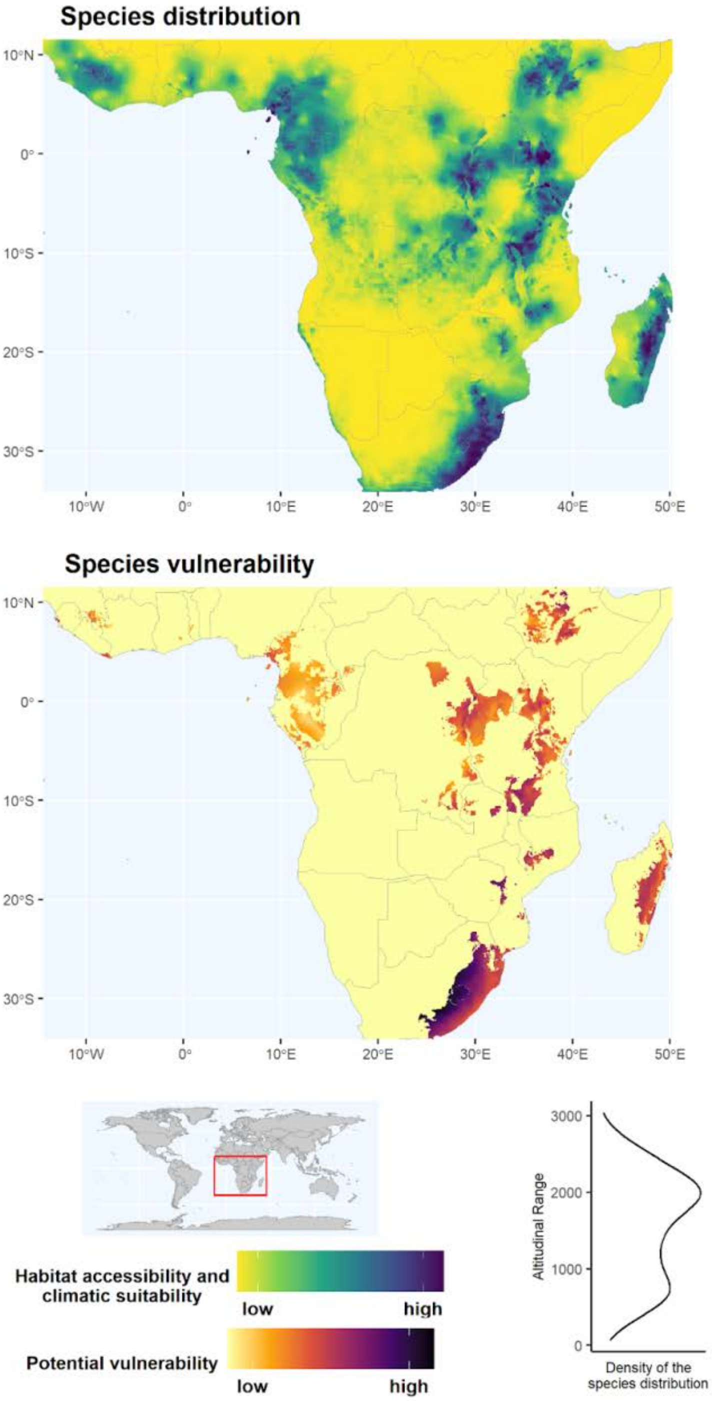
C. heterophylla is a homoiochlorophyllous plant whose distribution comprises Antipodean Is., Chatham Is., New Zealand North, New Zealand South, Tasmania, Victoria. *C. heterophylla* individuals can be primarily found in warm temperate climates, ranging from 8 to 1036 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *C. heterophylla* populations are expected to be potentially more vulnerable to climate change in parts of New Zealand. This species has not yet been assessed by IUCN, and only 37% of its distribution range is currently found within protected areas.

Goniophlebium furfuraceum (Schltdl. & Cham.) T. Moore (also cited as *Pleopeltis furfuracea*)



G. furfuraceum is a plant whose distribution comprises Costa Rica, El Salvador, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá. *G. furfuraceum* individuals can be primarily found in equatorial and warm temperate climates, and up to 1708 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime. *G. furfuraceum* populations are expected to be potentially more vulnerable to climate change in parts of Nicaragua. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

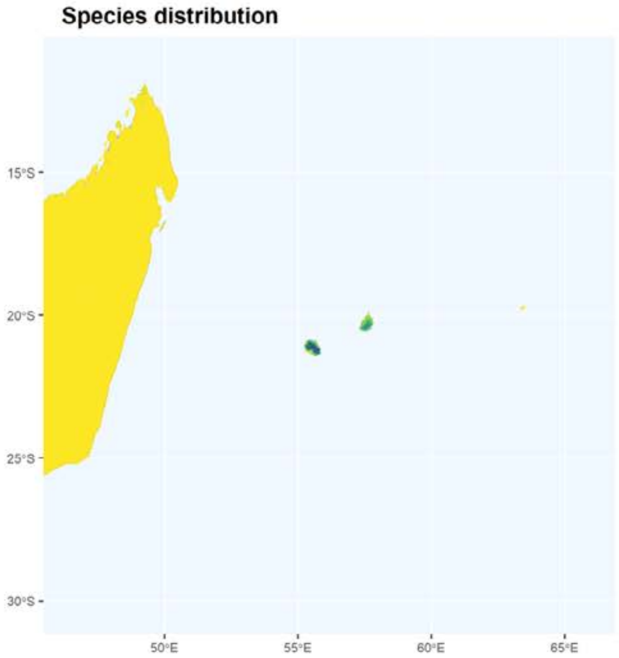
Loxogramme abyssinica (Baker) M.G. Price

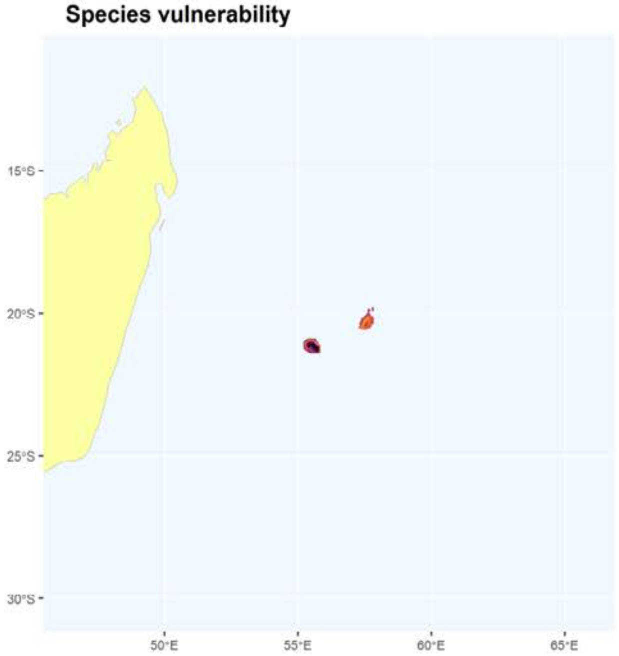


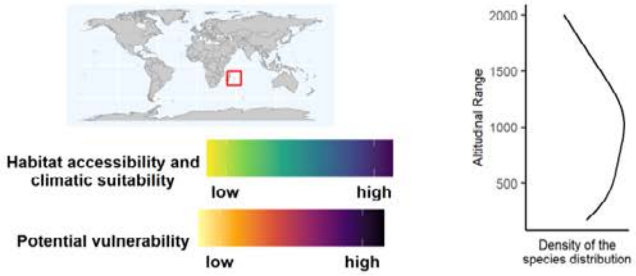
L. abyssinica is a homoiochlorophyllous plant whose distribution comprises Angola, Burundi, Cameroon, Cape Provinces, Central African Republic, Comoros, Equatorial Guinea, Ethiopia, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, KwaZulu-Natal, Liberia, Madagascar, Nigeria, Northern Provinces, Rwanda, Sierra Leone, Socotra, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Yemen, Zaïre. *L. abyssinica* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 68 to 3041 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *L. abyssinica* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, South Africa, Lesotho, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Loxogramme lanceolata (Sw.) C. Presl

L. lanceolata is a plant whose distribution comprises Mauritius, Réunion. *L. lanceolata* individuals can be primarily found in equatorial climates, ranging from 170 to 2006 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). *L. lanceolata* populations are expected to be potentially more vulnerable to climate change in parts of Reunion. This species has not yet been assessed by IUCN, and 42% of its distribution range is currently found within protected areas.

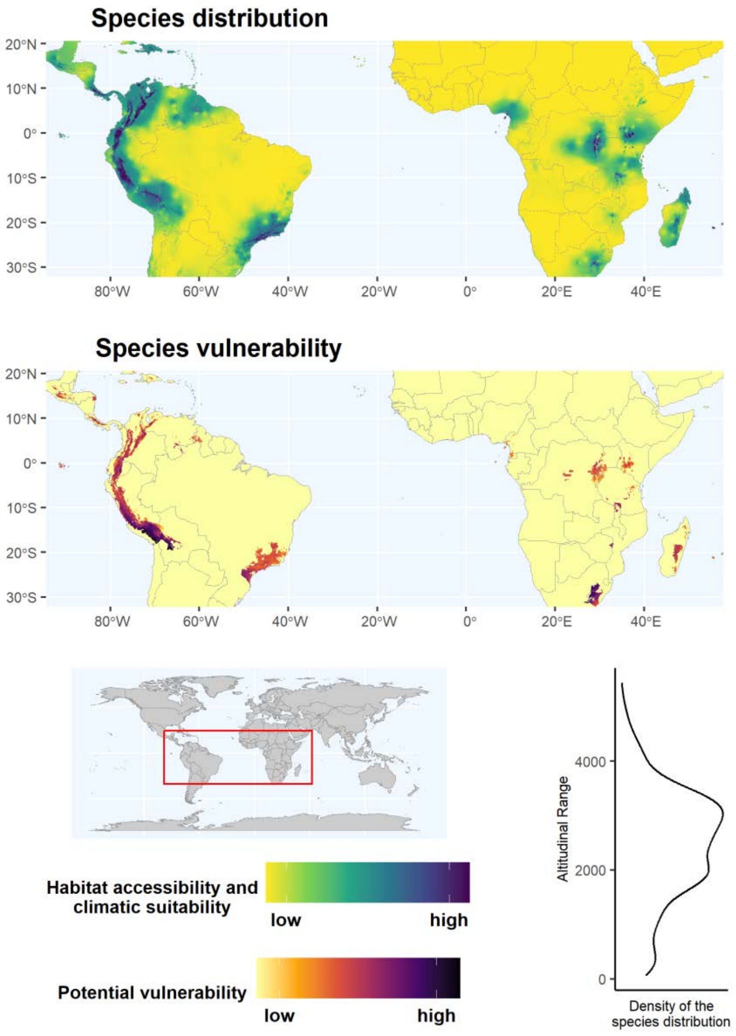






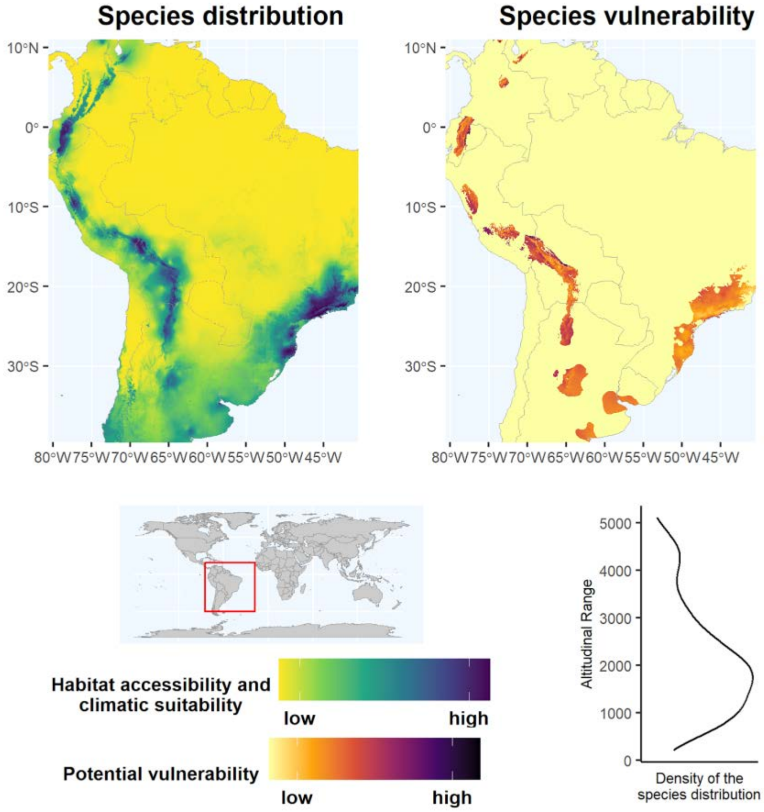
Melpomene flabelliformis (Poir.) A.R. Sm. & R.C. Moran

(also cited as *Grammitis flabelliformis*, *Ctenopteris flabelliformis* and *Xiphopteris flabelliformis*)



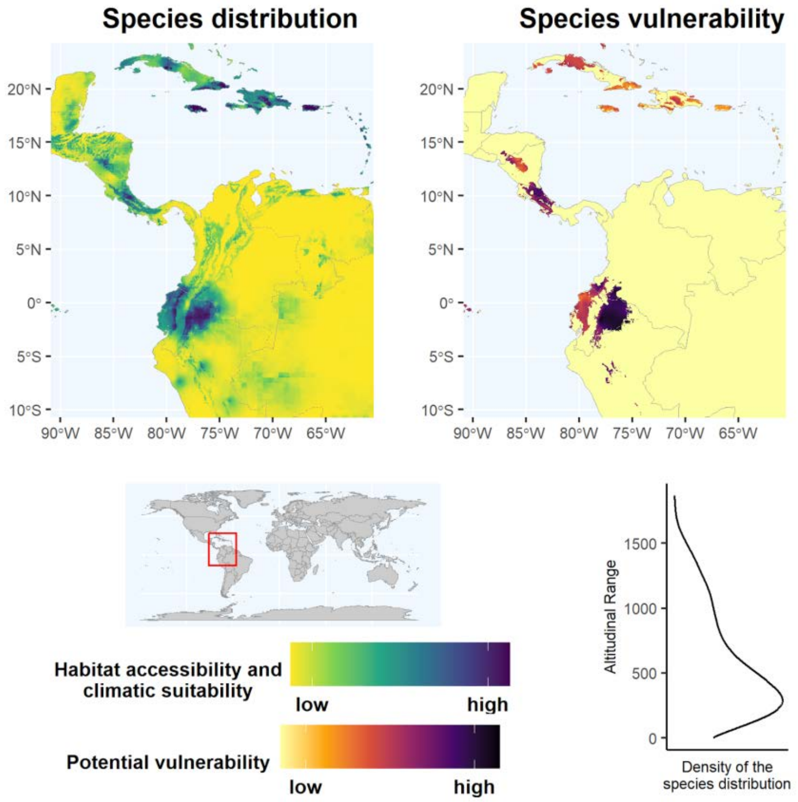
M. flabelliformis is a plant whose distribution comprises Bolivia, Brazil Southeast, Cameroon, Colombia, Costa Rica, Dominican Republic, Ecuador, Gulf of Guinea Is., Haiti, Kenya, KwaZulu-Natal, Lesotho, Madagascar, Malawi, Mexico Southeast, Mexico Southwest, Mozambique, Peru, Rwanda, Réunion, Somalia, Tanzania, Uganda, Venezuela, Venezuelan Antilles, Zaïre, Zimbabwe. *M. flabelliformis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 63 to 5441 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. flabelliformis* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Democratic Republic of the Congo, Chile, Colombia, Ecuador, Peru, South Africa, Lesotho, Uganda, Venezuela. This species has not yet been assessed by IUCN, and only 25% of its distribution range is currently found within protected areas.

Melpomene peruviana (Desv.) A.R. Sm. & R.C. Moran



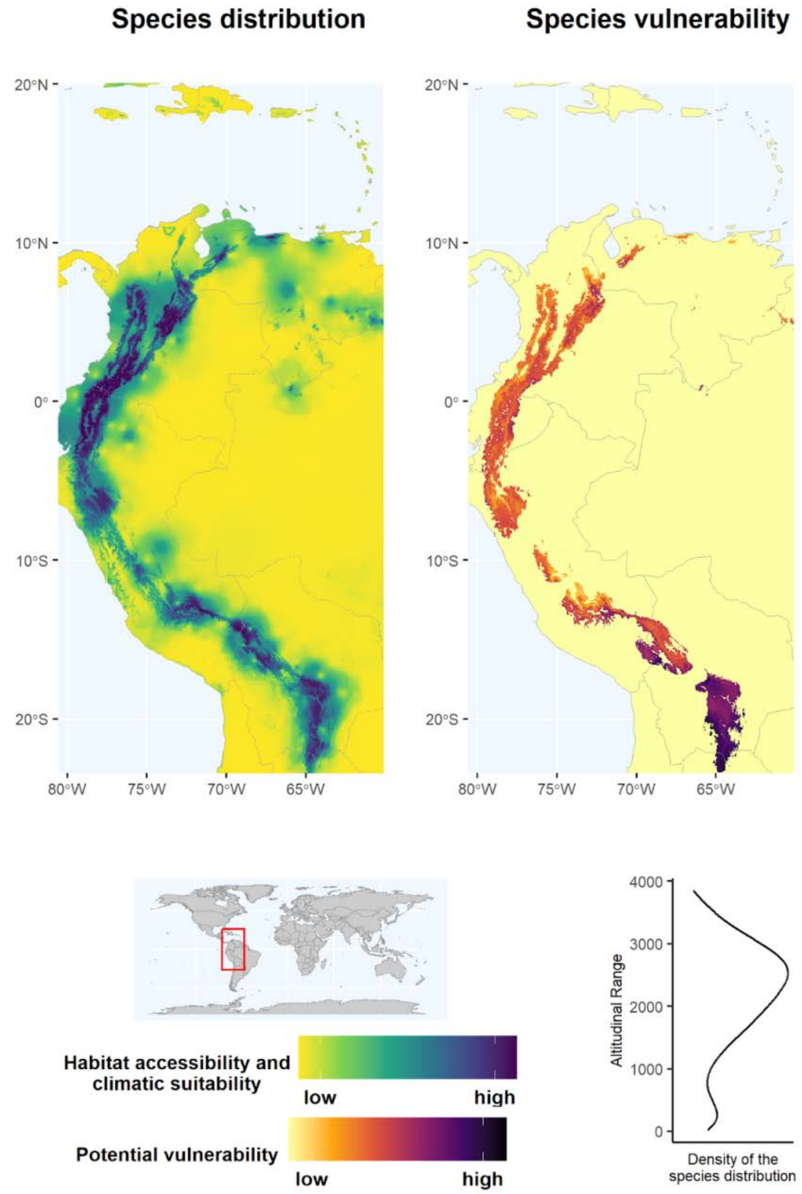
M. peruviana is a plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil Southeast and South, Colombia, Ecuador, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Peru. *M. peruviana* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 215 to 5115 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. peruviana* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Chile, Colombia, Ecuador, Peru. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

Microgramma piloselloides (L.) Copel.



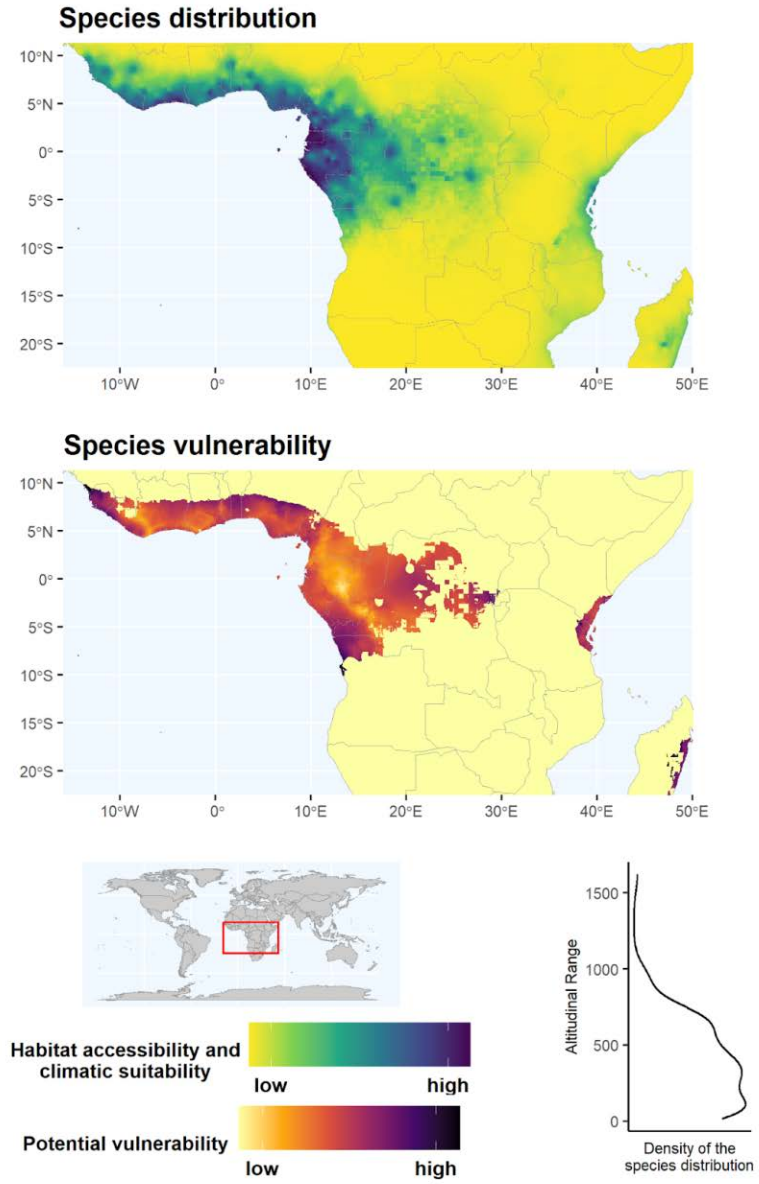
M. piloselloides is a plant whose distribution comprises Brazil North, Brazil Northeast, Costa Rica, Cuba, Dominican Republic, Ecuador, French Guiana, Guyana, Haiti, Honduras, Jamaica, Leeward Is., Mexico Southeast, Nicaragua, Peru, Puerto Rico, Windward Is. *M. piloselloides* individuals can be primarily found in equatorial and warm temperate climates, ranging from 3 to 1867 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *M. piloselloides* populations are expected to be potentially more vulnerable to climate change in parts of Colombia, Costa Rica, Ecuador, Honduras, Nicaragua, Peru, Panama. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

Pecluma eurybasis (C. Chr.) M.G. Price



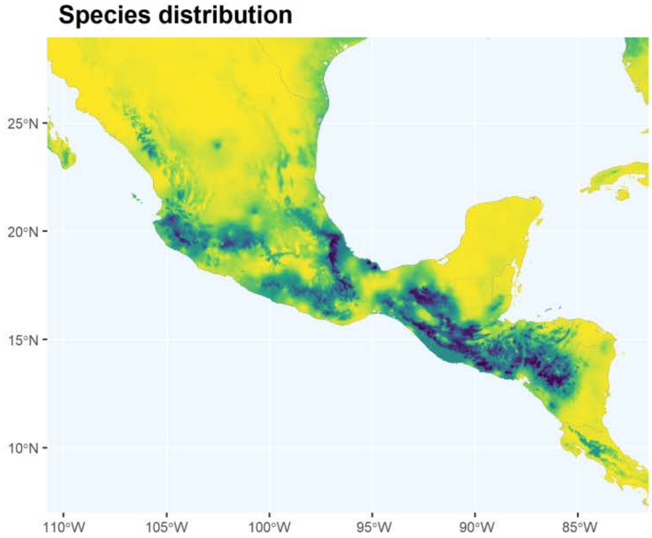
P. eurybasis is a plant whose distribution comprises Bolivia, Colombia, Cuba, Ecuador, Guyana, Peru, Venezuela. *P. eurybasis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 18 to 3858 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. eurybasis* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Peru. This species has not yet been assessed by IUCN, and only 28% of its distribution range is currently found within protected areas.

Platycerium stemaria (P. Beauv.) Desv.

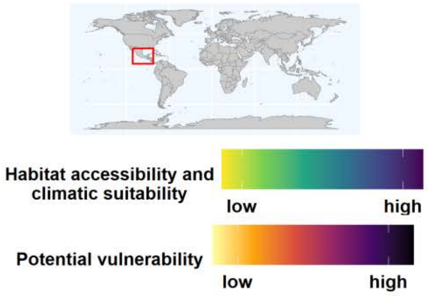


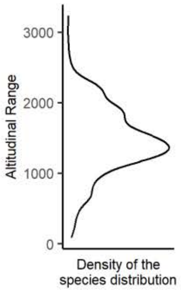
P. stemaria is a homoiochlorophyllous plant whose distribution comprises Angola, Benin, Cameroon, Comoros, Equatorial Guinea, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, Liberia, Madagascar, Mozambique, Nigeria, Senegal, Seychelles, Sierra Leone, Sudan, Tanzania, Uganda, Zaïre, Zimbabwe. *P. stemaria* individuals can be primarily found in equatorial and warm temperate climates, ranging from 16 to 1622 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. stemaria* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Democratic Republic of the Congo, Cameroon, Guinea, Liberia, Madagascar, Nigeria, Rwanda, Sierra Leone, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Pleopeltis angusta Humb. & Bonpl. ex Willd.

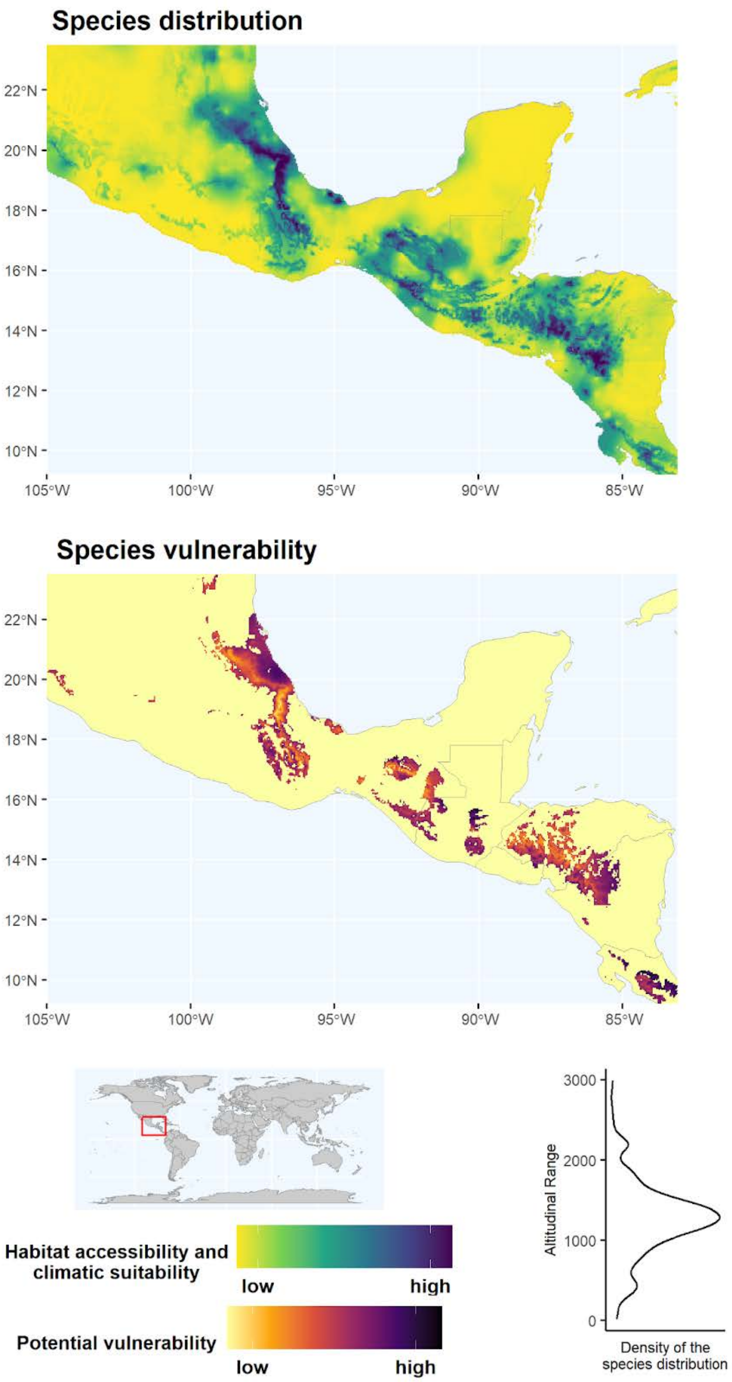


P. angusta is a plant whose distribution comprises El Salvador, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Nicaragua. *P. angusta* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 88 to 3235 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. angusta* populations are expected to be potentially more vulnerable to climate change in parts of Guatemala, Mexico. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.



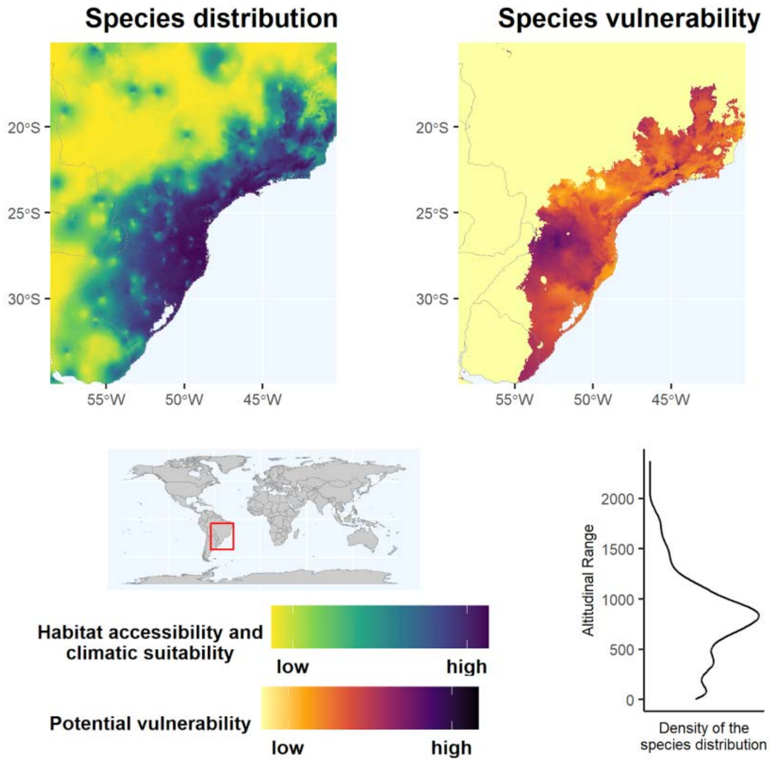


Pleopeltis crassinervata (Fée) T. Moore



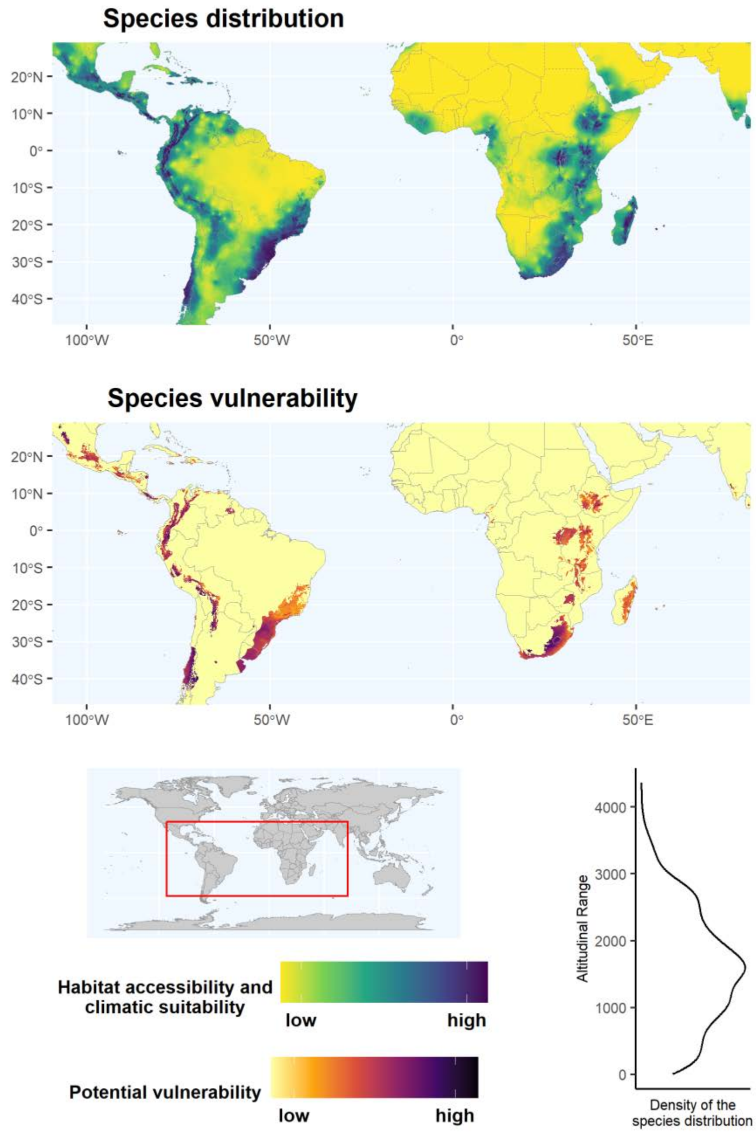
P. crassinervata is a plant whose distribution comprises Costa Rica, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua. *P. crassinervata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 21 to 2990 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. crassinervata* populations are expected to be potentially more vulnerable to climate change in parts of Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Pleopeltis hirsutissima (Raddi) de la Sota



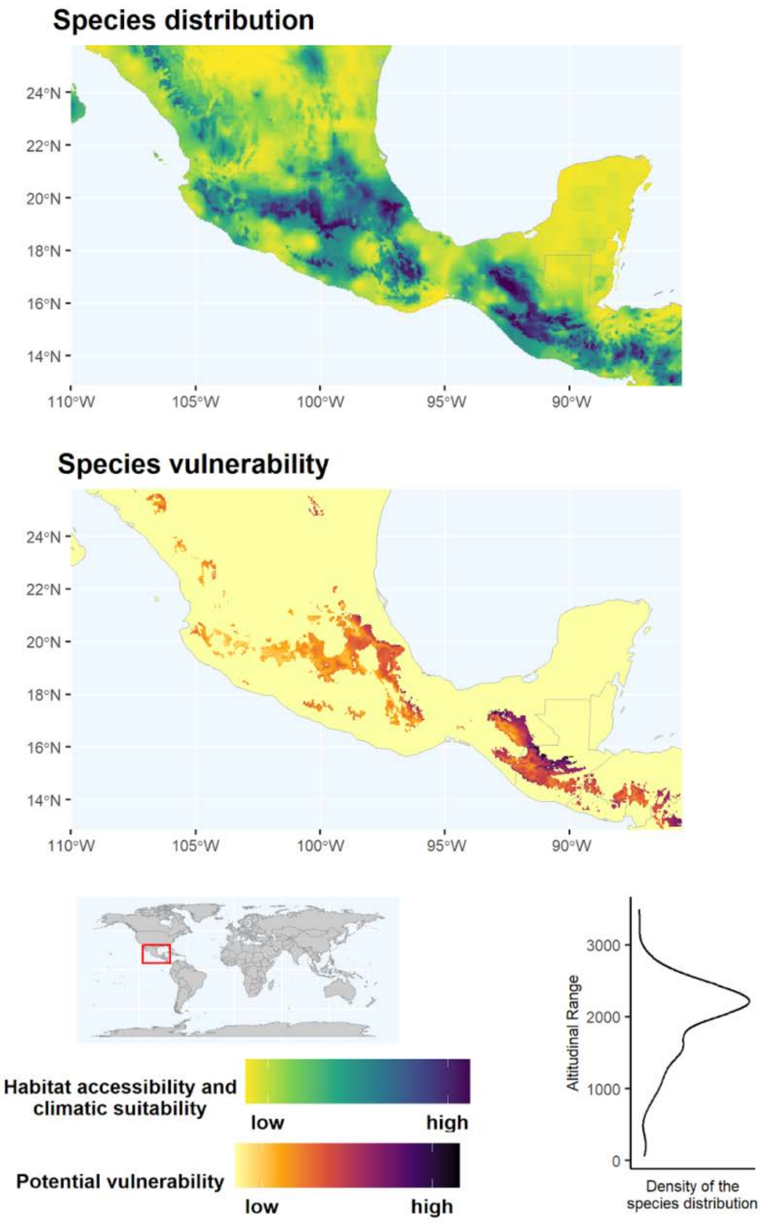
P. hirsutissima is a plant whose distribution comprises Argentina Northeast, Argentina Northwest, Brazil South, Brazil Southeast, Brazil West-Central, Paraguay, Uruguay. *P. hirsutissima* individuals can be primarily found in equatorial and warm temperate climates, ranging from 3 to 2375 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *P. hirsutissima* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

Pleopeltis macrocarpa (Bory ex Willd.) Kaulf.



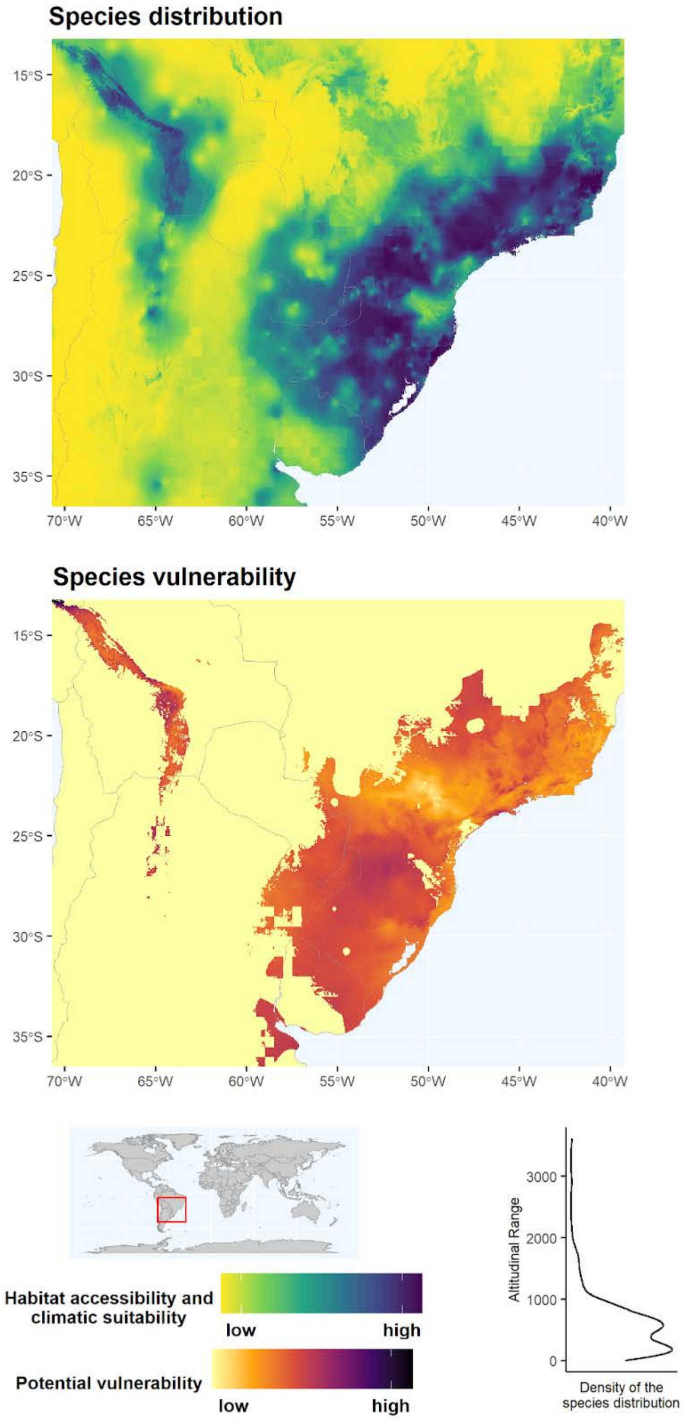
P. macrocarpa is a plant whose distribution comprises Angola, Argentina Northeast, Argentina Northwest, Bolivia, Brazil South, Brazil Southeast, Burundi, Cameroon, Cape Provinces, Central American Pac, Chile Central, Chile North, Chile South, Colombia, Comoros, Costa Rica, Cuba, Dominican Republic, Ecuador, Ethiopia, Free State, Guinea, Gulf of Guinea Is., Haiti, Honduras, India, Ivory Coast, Juan Fernández Is., Kenya, KwaZulu-Natal, Lesotho, Liberia, Madagascar, Malawi, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southwest, Mozambique, Nicaragua, Nigeria, Northern Provinces, Panamá, Peru, Puerto Rico, Rwanda, Réunion, Saudi Arabia, Sierra Leone, Socotra, Somalia, Sri Lanka, St.Helena, Swaziland, Tanzania, Uganda, Uruguay, Venezuela, Yemen, Zaïre, Zimbabwe. *P. macrocarpa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 4 to 4361 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. macrocarpa* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Sri Lanka, Democratic Republic of the Congo, Chile, Colombia, Costa Rica, Ecuador, Ethiopia, Guatemala, India, Kenya, Mexico, Nicaragua, Peru, Panama, South Africa, Lesotho, Uganda, Venezuela. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Pleopeltis mexicana (Fée) Mickel & Beitel



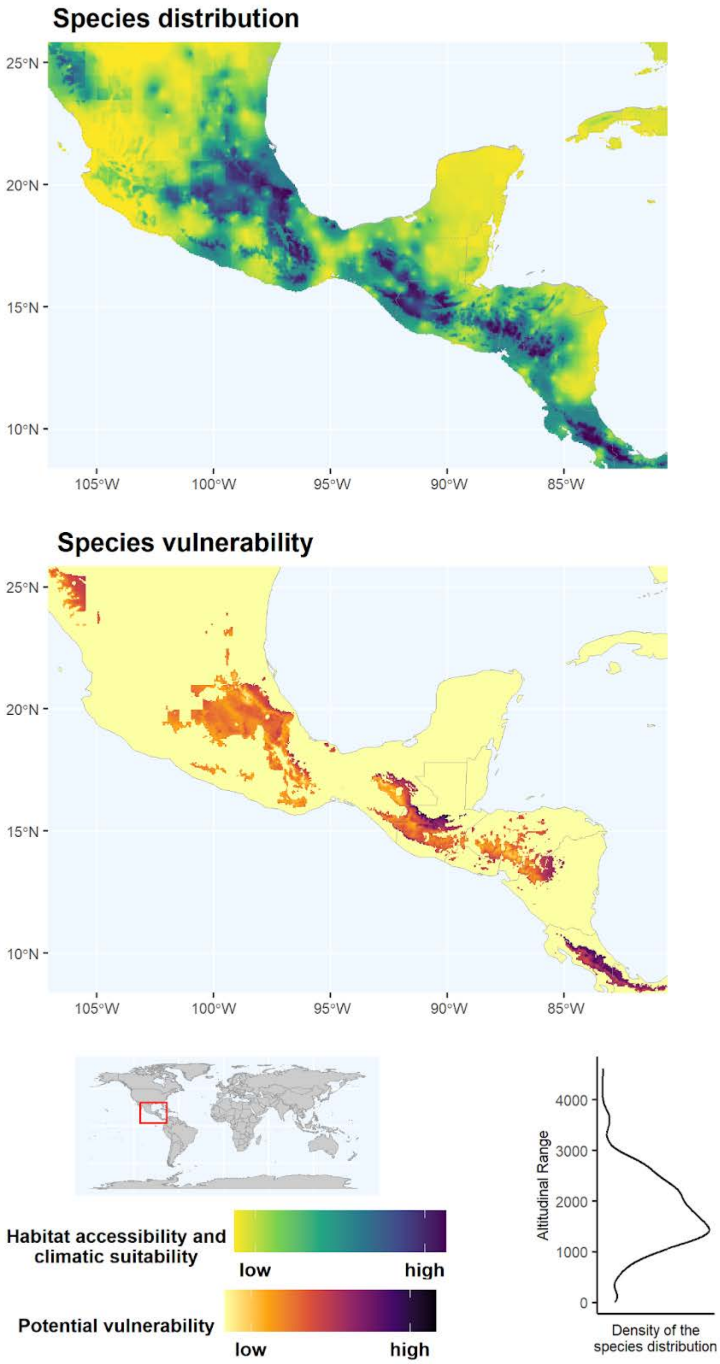
P. mexicana is a plant whose distribution comprises El Salvador, Guatemala, Honduras, Mexico Gulf, Mexico, Central, Northeast, Northwest, Southeast, and Southwest, Nicaragua. *P. mexicana* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 59 to 3494 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. mexicana* populations are expected to be potentially more vulnerable to climate change in parts of Guatemala, Mexico. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Pleopeltis minima (Bory) J. Prado & R.Y. Hirai (also cited as *Pleopeltis squalida*)



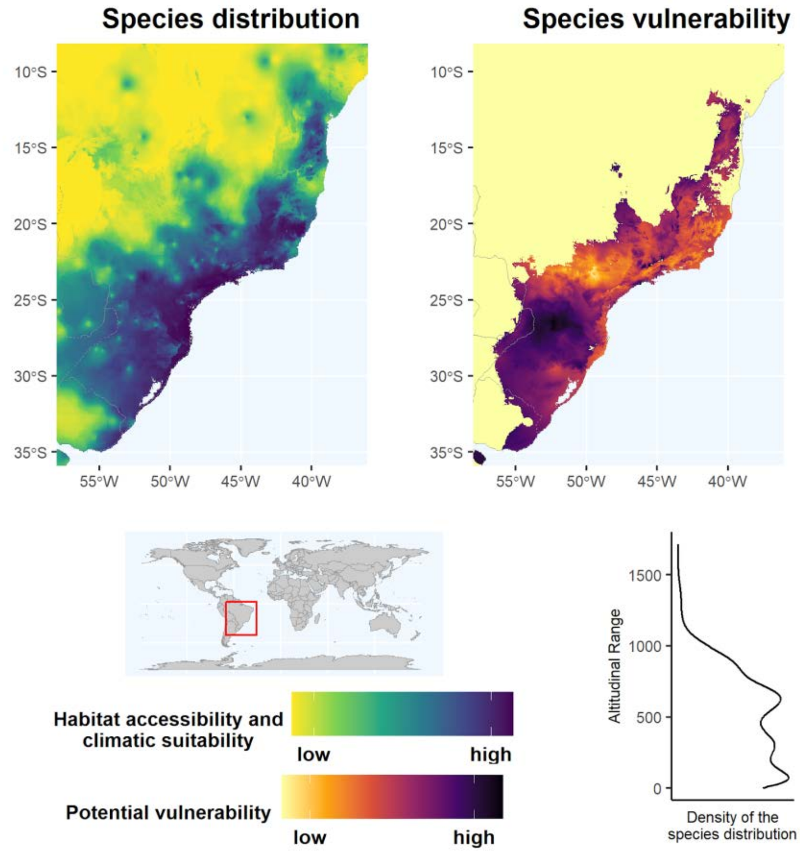
P. minima is a plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil South, Brazil Southeast, Paraguay, Uruguay. *P. minima* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 3616 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. minima* populations are expected to be potentially more vulnerable to climate change in parts of Peru. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

Pleopeltis plebeia (Schltdl. & Cham.) A.R. Sm. & Tejero



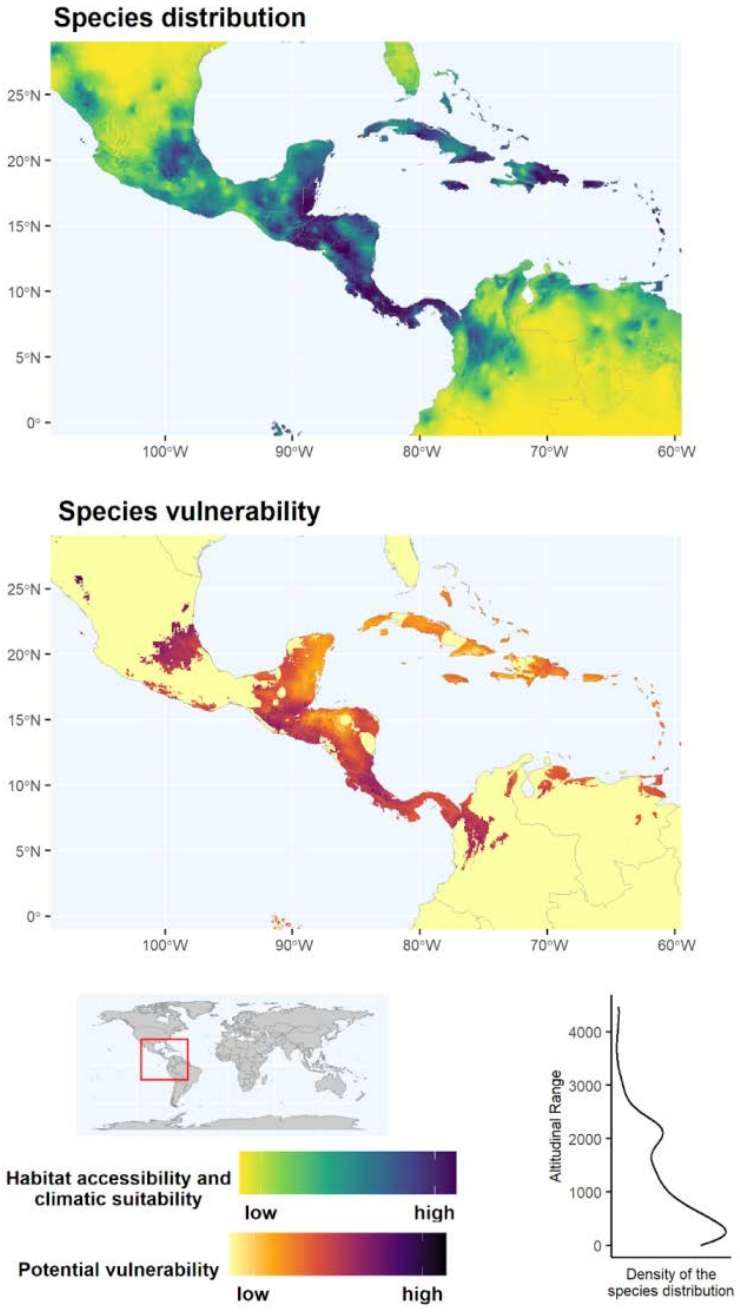
P. plebeia is a plant whose distribution comprises Costa Rica, El Salvador, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá. *P. plebeia* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 11 to 4618 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. plebeia* populations are expected to be potentially more vulnerable to climate change in parts of Costa Rica, Guatemala, Mexico, Panama. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Pleopeltis pleopeltifolia (Raddi) Alston



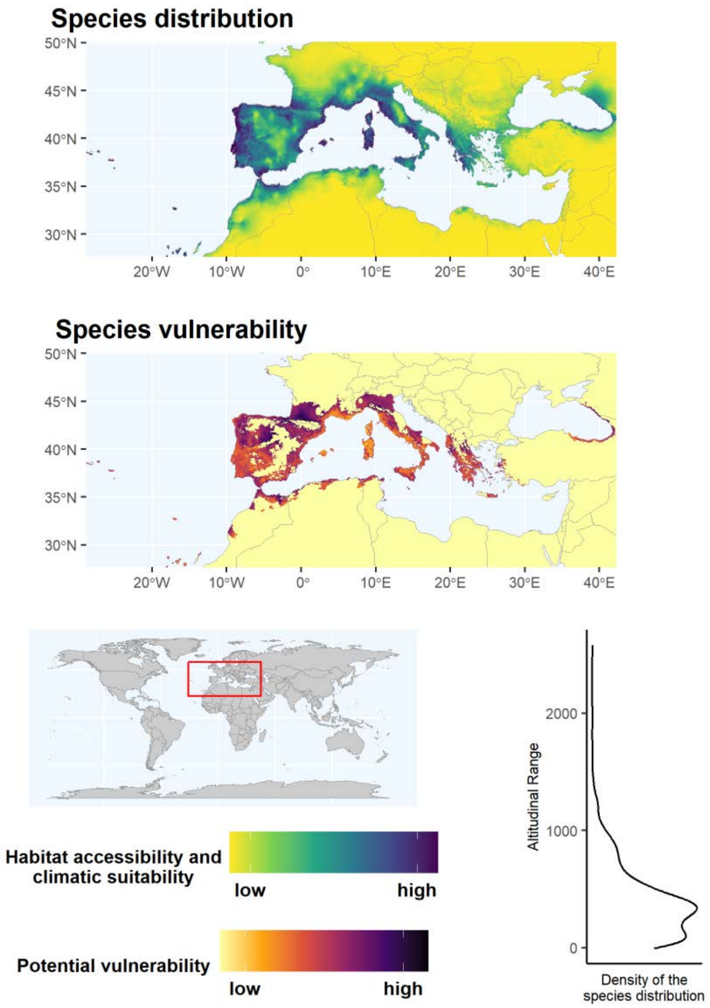
P. pleopeltifolia is a plant whose distribution comprises Argentina Northeast, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Paraguay, Uruguay. *P. pleopeltifolia* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 2 to 1716 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. pleopeltifolia* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Brazil, Paraguay, Uruguay. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

Pleopeltis polypodioides (L.) E.G. Andrews & Windham
(also cited as *Polypodium polypodioides* and *Acrostichum polypodioides*)



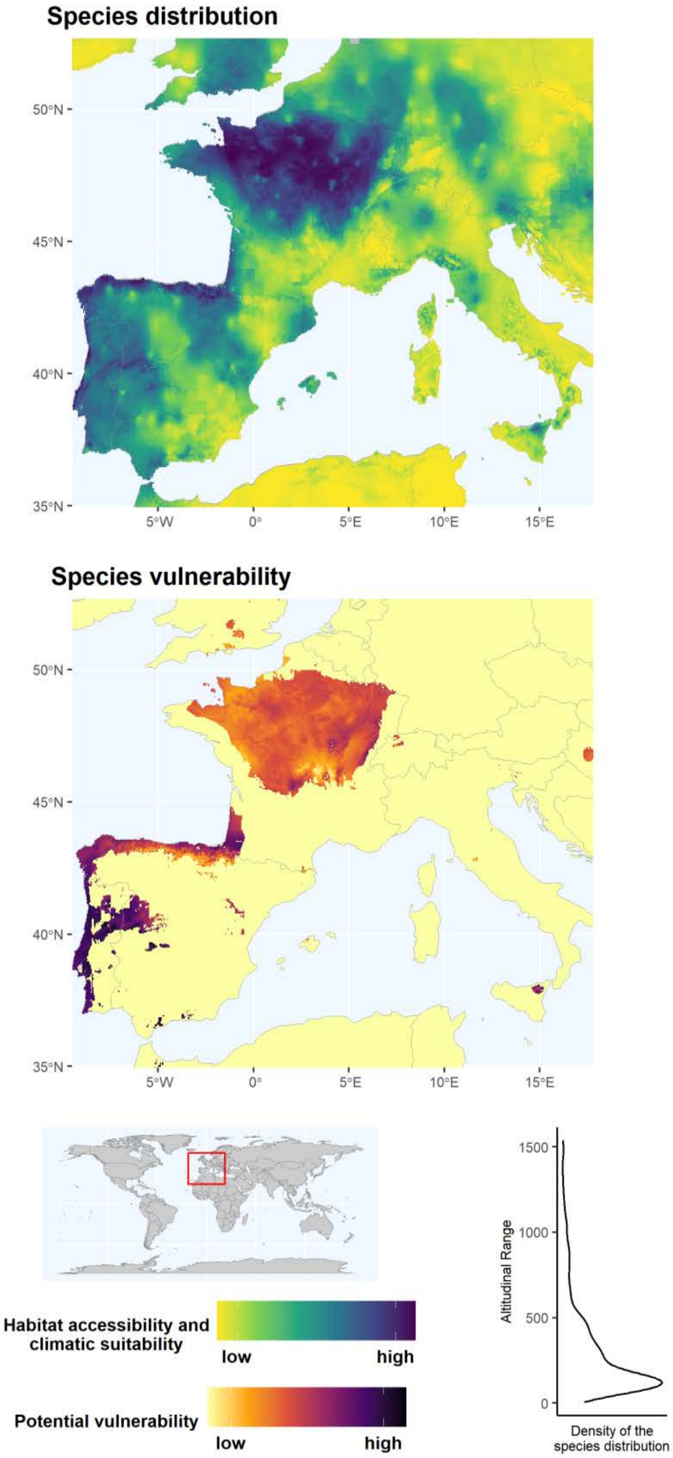
P. polypodioides is a homoiochlorophyllous plant whose distribution comprises Bahamas, Belize, Cayman Is., Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Galápagos, Guatemala, Guyana, Haiti, Honduras, Jamaica, Leeward Is., Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Puerto Rico, Trinidad-Tobago, Venezuela, Venezuelan Antilles, Windward Is. *P. polypodioides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 0 to 4476 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. polypodioides* populations are expected to be potentially more vulnerable to climate change in parts of Colombia, Costa Rica, Mexico. This species has not yet been assessed by IUCN, and only 30% of its distribution range is currently found within protected areas.

Polypodium cambricum L.



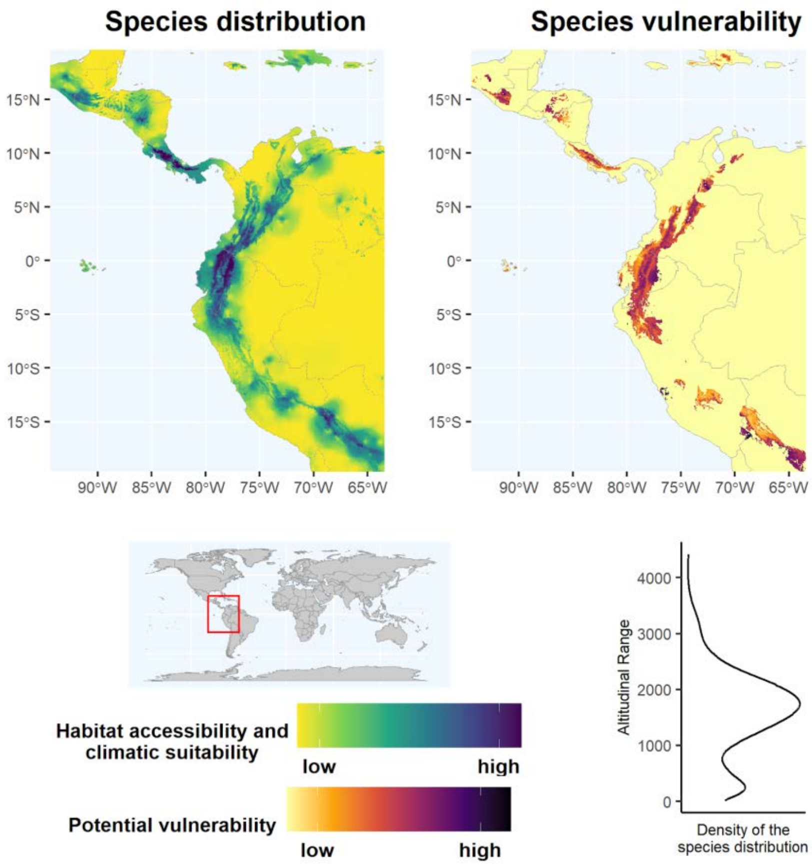
P. cambricum is a homoiochlorophyllous plant whose distribution comprises Albania, Algeria, Baleares, Bulgaria, Corse, Cyprus, East Aegean Is., France, Great Britain, Greece, Ireland, Italy, Kriti, Krym, Lebanon-Syria, Libya, Morocco, North Caucasus, Palestine, Portugal, Sardegna, Sicilia, Spain, Switzerland, Transcaucasus, Tunisia, Turkey, Yugoslavia. *P. cambricum* individuals can be primarily found in arid and warm temperate climates, ranging from -6 to 2580 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *P. cambricum* populations are expected to be potentially more vulnerable to climate change in parts of Algeria, Albania, France, Georgia, Greece, Italy, North Macedonia, Morocco, Portugal, Russia, Spain, Switzerland, Tunisia. This species is listed as Least concern by IUCN, although only 38% of its distribution range is currently found within protected areas.

Polypodium interjectum Shivas



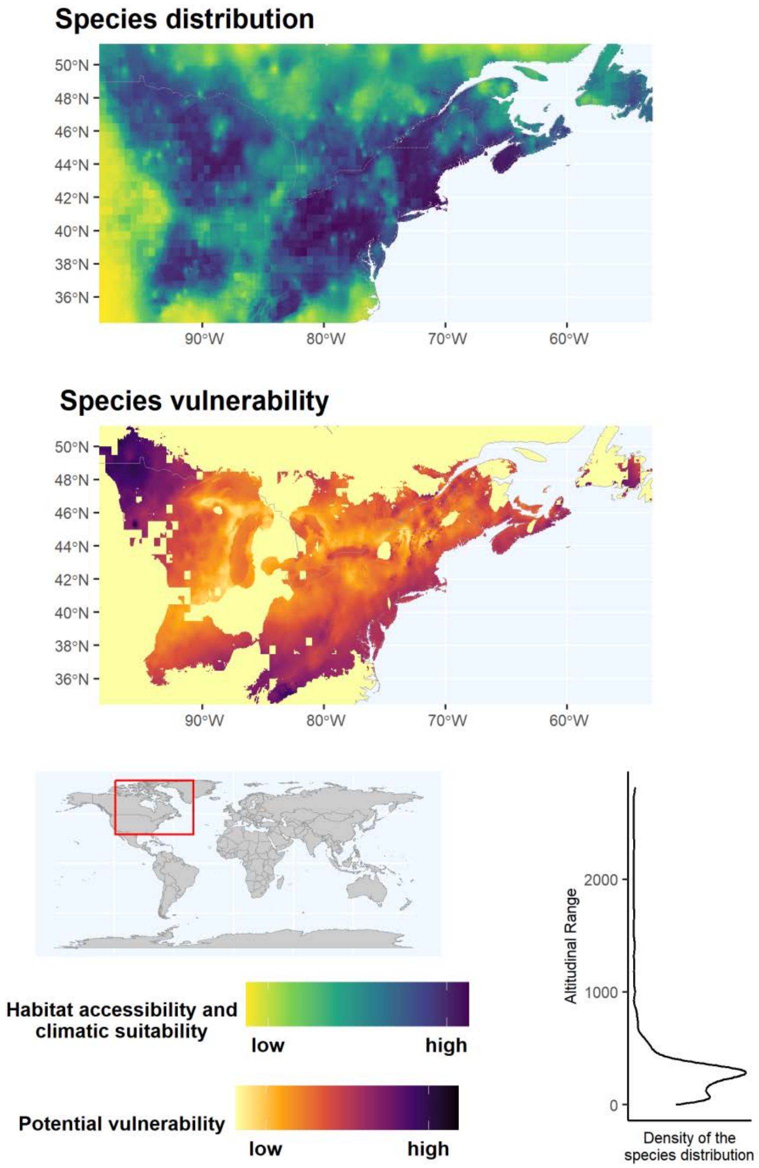
P. interjectum is a homoiochlorophyllous plant whose distribution comprises Baltic States, Belgium, Central European Rus, Corse, Denmark, France, Germany, Great Britain, Hungary, Iran, Ireland, Italy, Krym, Netherlands, North Caucasus, Portugal, Sardegna, Sicilia, Spain, Switzerland, Turkey, Ukraine. *P. interjectum* individuals can be primarily found in arid, and warm temperate climates, ranging from 5 to 1536 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *P. interjectum* populations are expected to be potentially more vulnerable to climate change in parts of France, Italy, Morocco, Portugal, Spain. This species is listed as Least concern by IUCN, although only 33% of its distribution range is currently found within protected areas.

Polypodium remotum Desv.
(also cited as *Pleopeltis remota*)



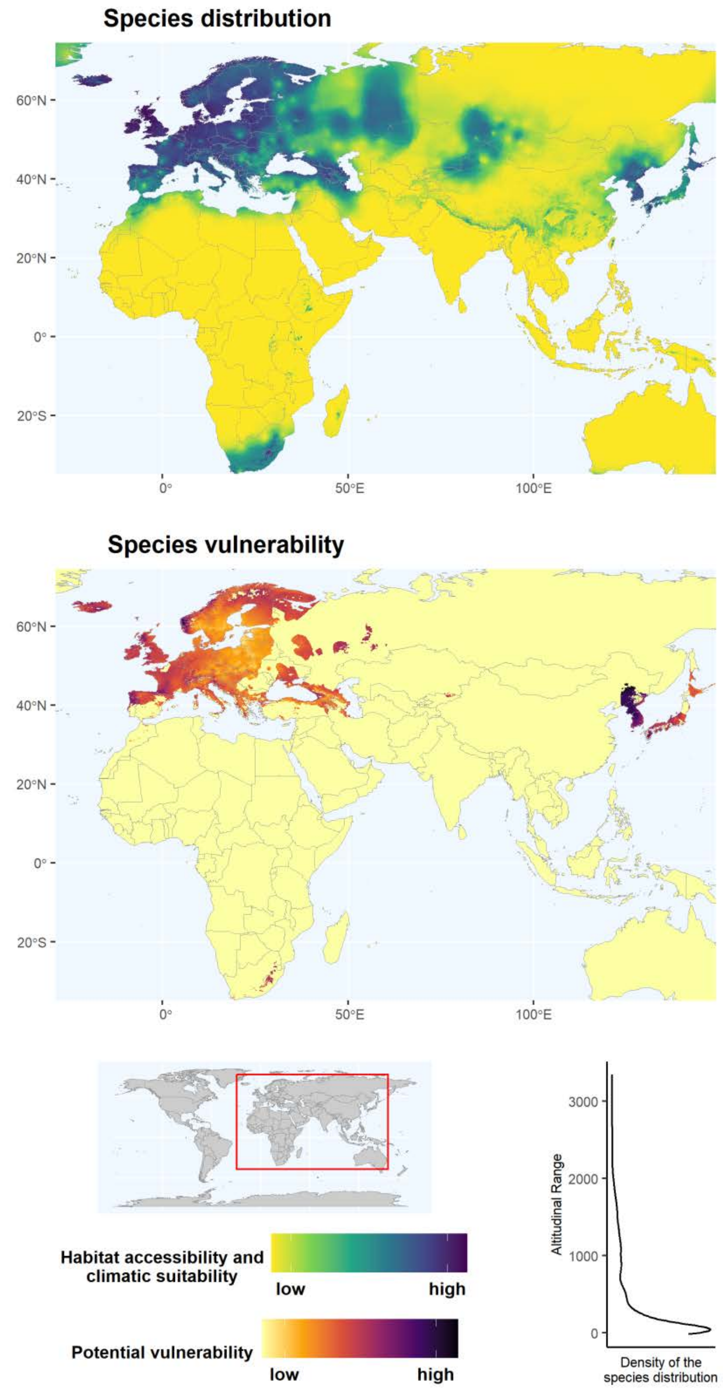
P. remotum is a plant whose distribution comprises Bolivia, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Jamaica, Mexico Southeast, Nicaragua, Panamá, Peru, Venezuela. *P. remotum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 21 to 4419 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. remotum* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Peru, Venezuela. This species has not yet been assessed by IUCN, and only 31% of its distribution range is currently found within protected areas.

Polypodium virginianum L.



P. virginianum is a homoiochlorophyllous plant whose distribution comprises Alabama, Alaska, Arkansas, Connecticut, Delaware, District of Columbia, Georgia, Greenland, Illinois, Indiana, Iowa, Kentucky, Labrador, Maine, Manitoba, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Brunswick, New Hampshire, New Jersey, New York, Newfoundland, North Carolina, Northwest Territorie, Nova Scotia, Ohio, Ontario, Pennsylvania, Prince Edward I., Québec, Rhode I., Saskatchewan, South Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin. *P. virginianum* individuals can be primarily found in warm temperate and snow climates, ranging from 2 to 2814 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the drier season is short). *P. virginianum* populations are expected to be potentially more vulnerable to climate change in parts of Canada, United States. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

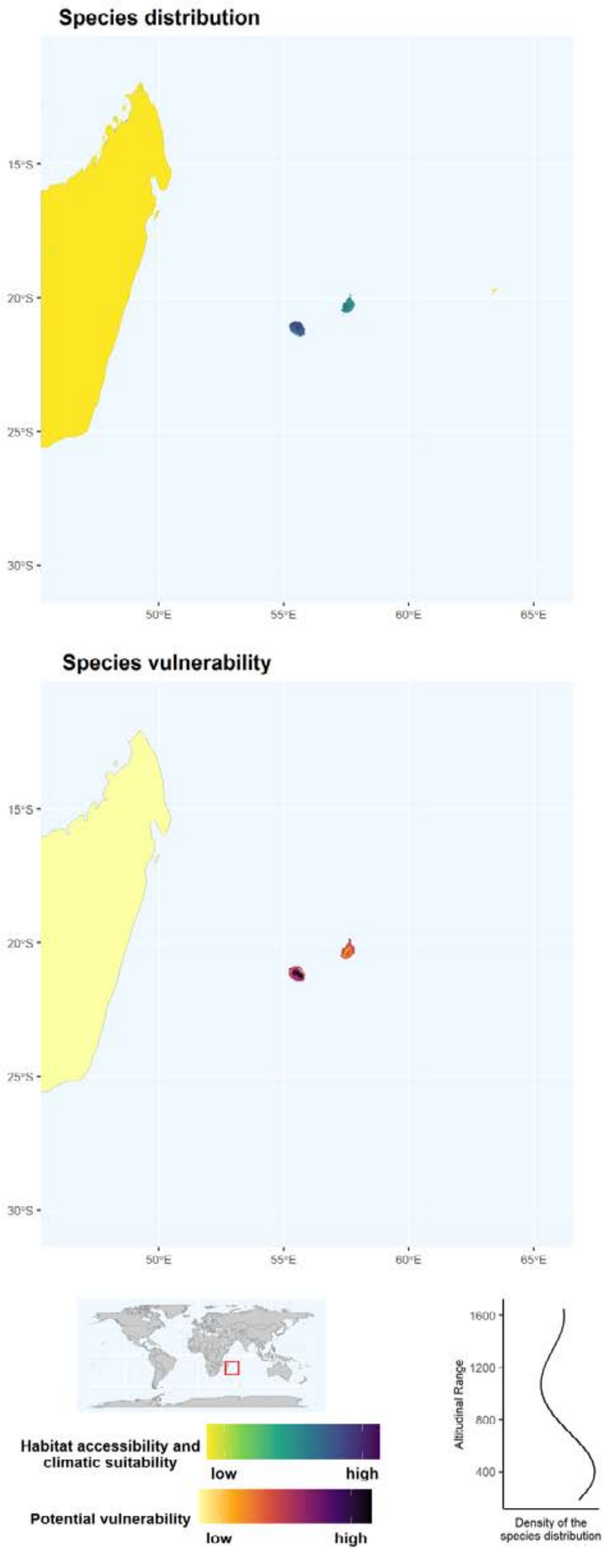
Polypodium vulgare L.



P. vulgare is a homoiochlorophyllous plant whose distribution comprises Albania, Altay, Austria, Baltic States, Belarus, Belgium, Bulgaria, Buryatiya, Cape Provinces, Central European Rus, Corse, Cyprus, Czechoslovakia, Denmark, East European Russia, Finland, France, Free State, Føroyar, Germany, Great Britain, Greece, Hungary, Iceland, Iran, Ireland, Italy, Kazakhstan, Korea, Krasnoyarsk, Krym, Kuril Is., KwaZulu-Natal, Lesotho, Morocco, Netherlands, North European Russi, Northern Provinces, Northwest European R, Norway, Poland, Portugal, Primorye, Romania, Sakhalin, Sardegna, Sicilia, Spain, Sweden, Switzerland, Transcaucasus, Turkey, Ukraine, West Siberia, Xinjiang, Yugoslavia. *P. vulgare* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from -15 to 3345 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. vulgare* populations are expected to be potentially more vulnerable to climate change in parts of China, Japan, Korea, Democratic People's Republic of, Korea, Republic of, Norway, Portugal, Spain, United Kingdom. This species is listed as Least concern by IUCN, although only 30% of its distribution range is currently found within protected areas.

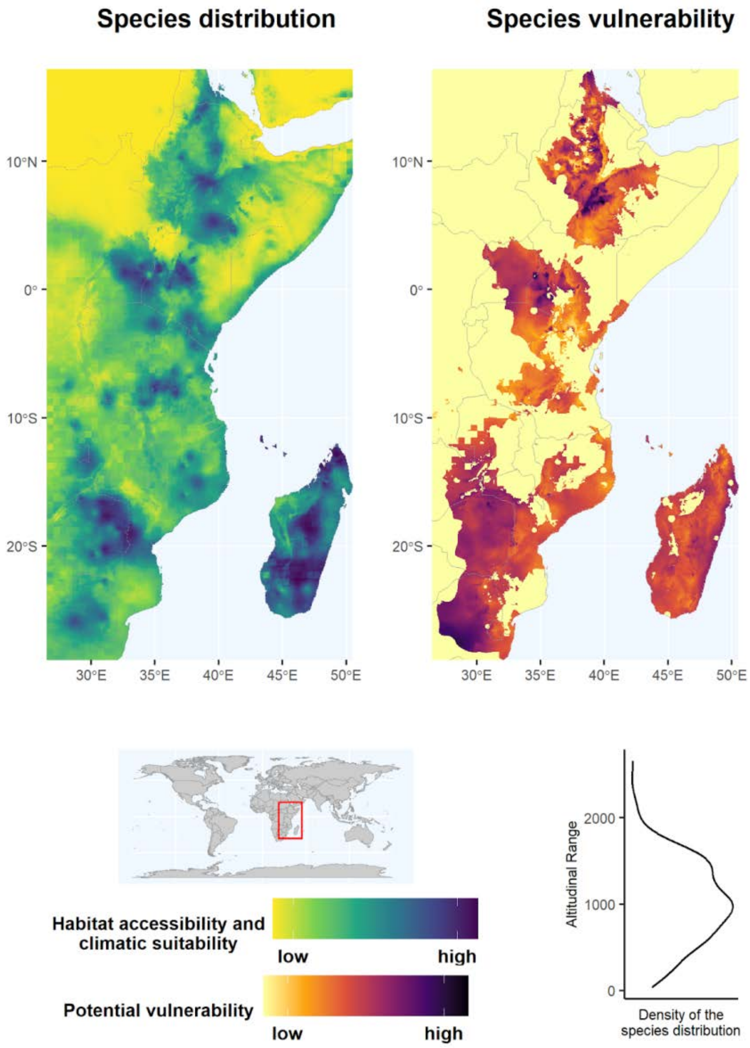
Pteridaceae

Actiniopteris australis (L. f.) Link



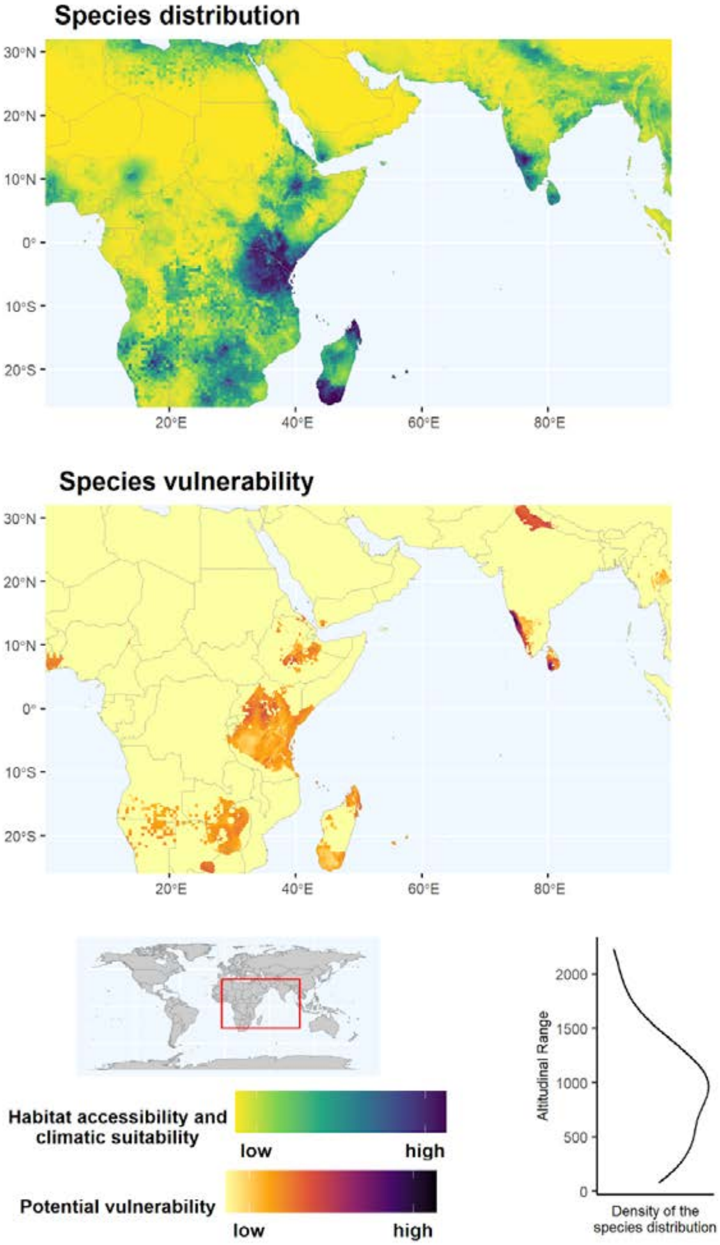
A. australis is a plant whose distribution comprises Mauritius, Réunion. *A. australis* individuals can be primarily found in equatorial climates, ranging from 187 to 1650 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). *A. australis* populations are expected to be potentially more vulnerable to climate change in parts of Reunion. This species has not yet been assessed by IUCN, and 43% of its distribution range is currently found within protected areas.

Actiniopteris dimorpha Pic. Serm.



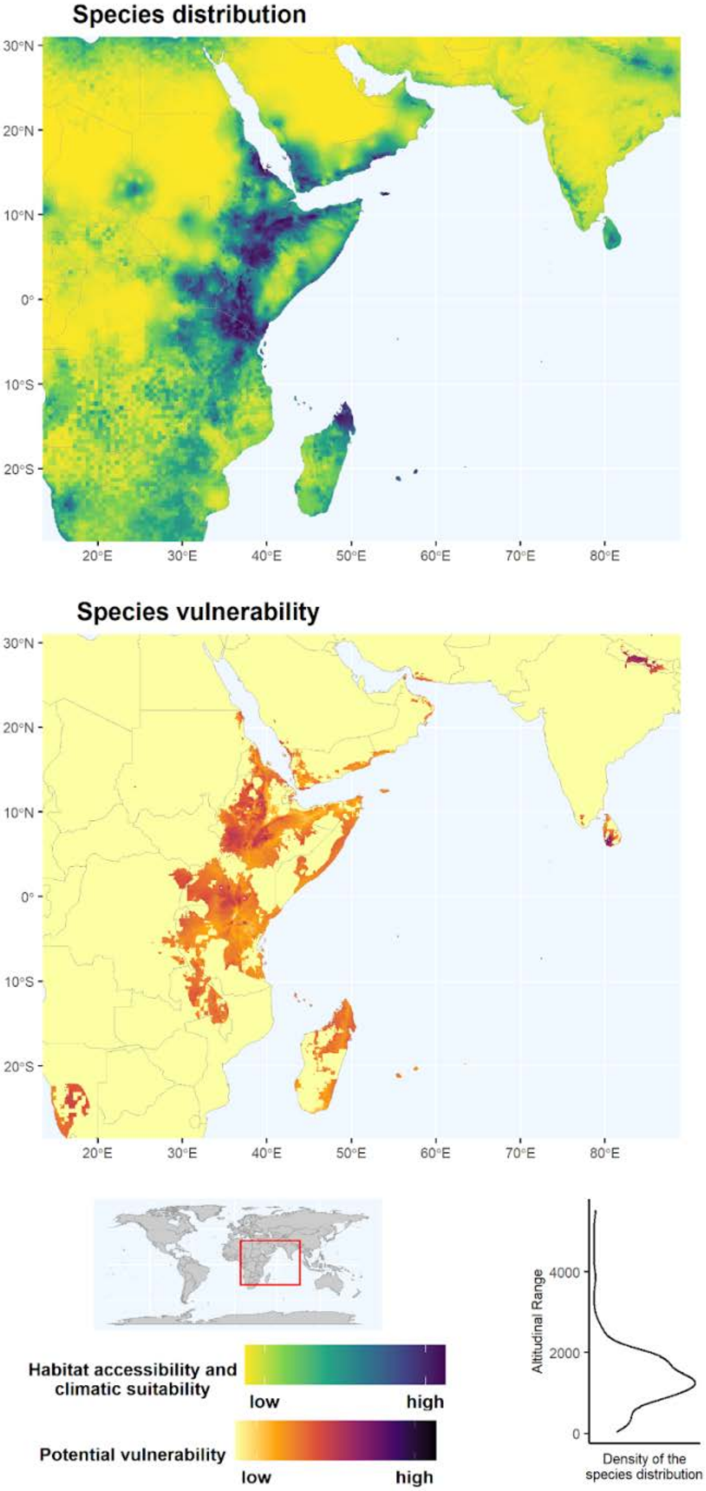
A. dimorpha is a homoiochlorophyllous plant whose distribution comprises Botswana, Burundi, Comoros, Ethiopia, Kenya, Madagascar, Mozambique, Northern Provinces, Réunion, Somalia, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *A. dimorpha* individuals can be primarily found inequatorial, arid, and warm temperate climates, ranging from 37 to 2660 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. dimorpha* populations are expected to be potentially more vulnerable to climate change in parts of Eritrea, Ethiopia, Kenya, Madagascar, South Africa, Tanzania, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

Actiniopteris radiata (Sw.) Link



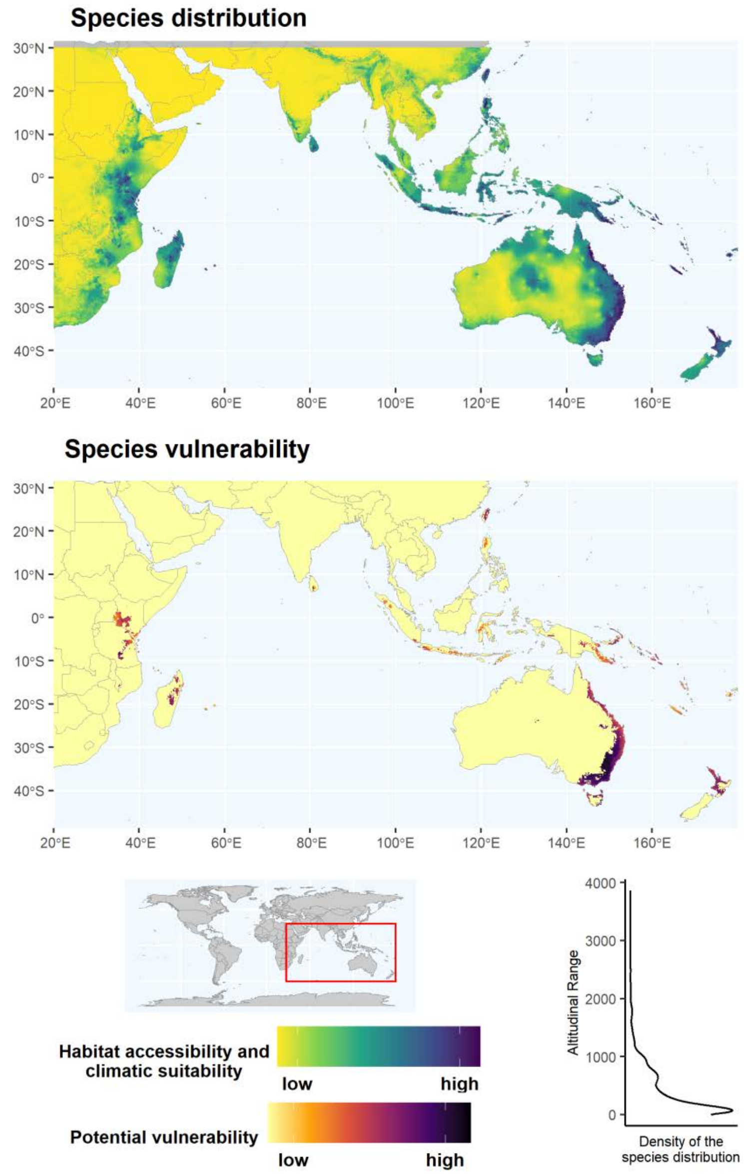
A. radiata is a homoiochlorophyllous lithophyte Hemicryptophytes with medicinal use, whose distribution comprises Afghanistan, Angola, Botswana, Cameroon, Cape Provinces, Cape Verde, Chad, Comoros, Djibouti, Ethiopia, India, Iran, Kenya, KwaZulu-Natal, Madagascar, Mali, Mozambique, Myanmar, Namibia, Nigeria, Northern Provinces, Oman, Pakistan, Saudi Arabia, Seychelles, Somalia, Sri Lanka, Sudan, Swaziland, Tanzania, Togo, Uganda, West Himalaya, Yemen, Zambia, Zaïre, Zimbabwe. *A. radiata* individuals can be primarily found inequatorial, arid, and warm temperate climates, ranging from 78 to 2232 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. radiata* populations are expected to be potentially more vulnerable to climate change in parts of Sri Lanka and Southwestern India. Although being considered extinct in Mauritius, this species has not yet been assessed by IUCN and only 28% of its distribution range is currently found within protected areas.

Actiniopteris semiflabellata Pic. Serm.



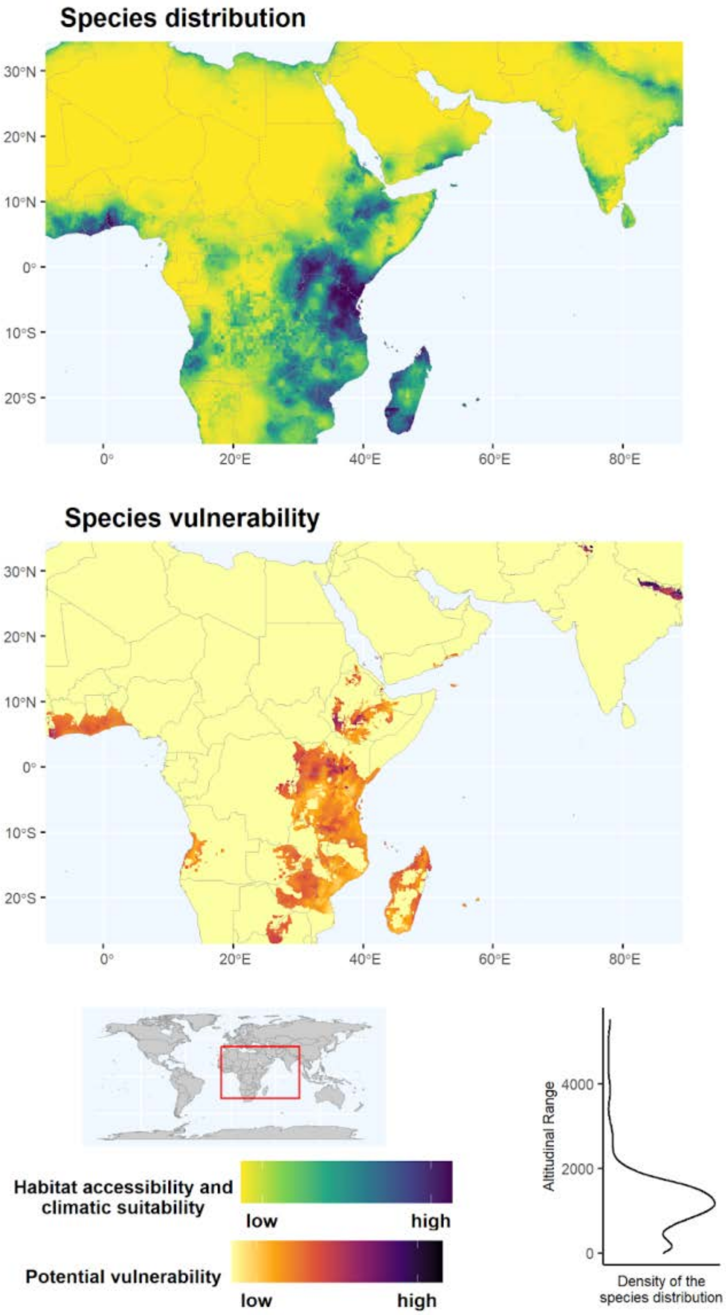
A. semiflabellata is a plant whose distribution comprises Burundi, Djibouti, Egypt, Ethiopia, Kenya, Madagascar, Mauritania, Mauritius, Namibia, Nepal, Oman, Rwanda, Réunion, Saudi Arabia, Socotra, Somalia, Sudan, Tanzania, Uganda, Yemen, Zaïre. *A. semiflabellata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 32 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to precipitation is extremely seasonal. *A. semiflabellata* populations are expected to be potentially more vulnerable to climate change in parts of Sri Lanka, China. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Adiantum hispidulum Sw.



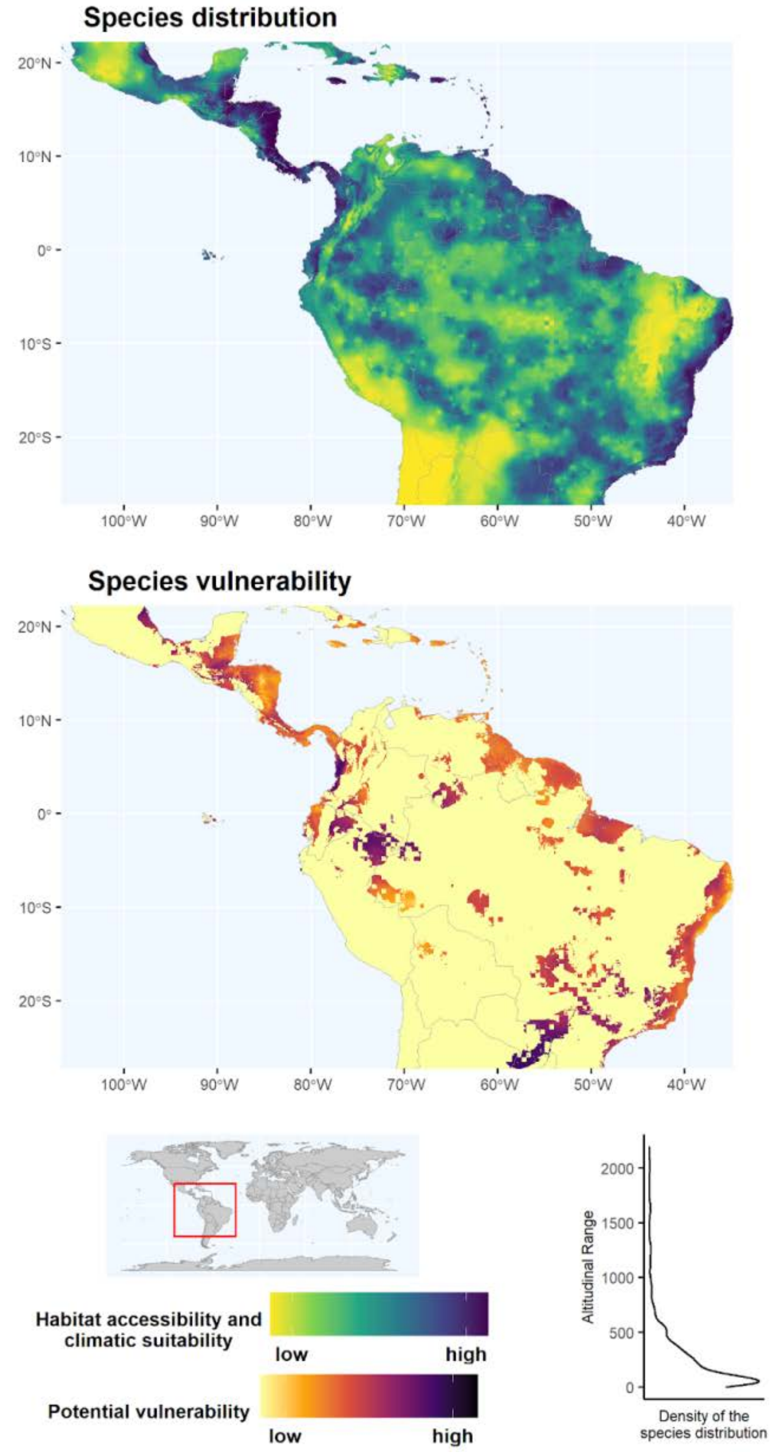
A. hispidulum is a plant whose distribution comprises Caroline Is., Chatham Is., China South-Central, China Southeast, Comoros, Cook Is., Ethiopia, Fiji, India, Jawa, Kenya, Kermadec Is., Lesser Sunda Is., Madagascar, Malawi, Malaya, Mozambique, New Caledonia, New South Wales, New Zealand North, Norfolk Is., Northern Provinces, Northern Territory, Philippines, Queensland, Society Is., South Australia, Sri Lanka, Sulawesi, Taiwan, Tanzania, Tonga, Tuamotu, Tubuai Is., Vanuatu, Victoria, Western Australia, Zimbabwe. *A. hispidulum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 1 to 3864 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. hispidulum* populations are expected to be potentially more vulnerable to climate change in parts of Australia, Sri Lanka, China, Kenya, Madagascar, Malawi, New Zealand, Papua New Guinea, Tanzania, United States, Indonesia, Taiwan. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Adiantum incisum Forssk.



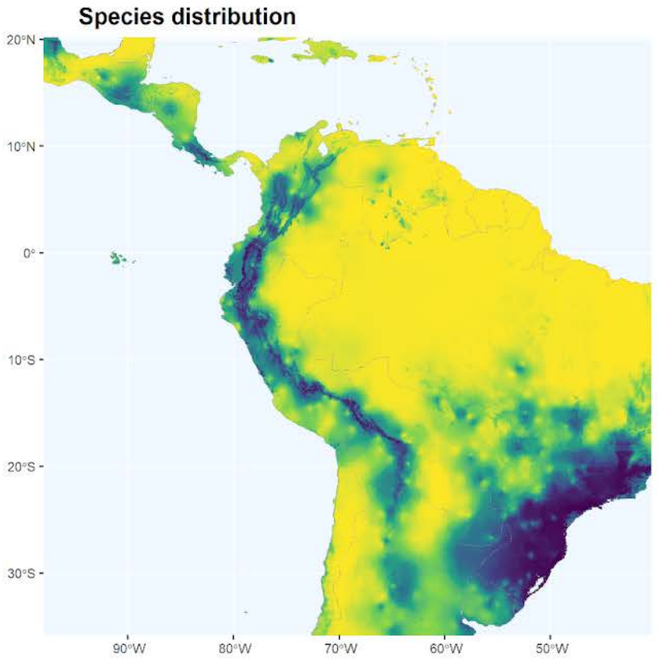
A. incisum is a homoiochlorophyllous plant whose distribution comprises Angola, Assam, Bangladesh, Burundi, Cameroon, Cape Verde, China South-Central, Comoros, East Himalaya, Ethiopia, Ghana, India, Ivory Coast, Kenya, Malawi, Mozambique, Myanmar, Namibia, Nepal, Nigeria, Northern Provinces, Oman, Pakistan, Rwanda, Saudi Arabia, Socotra, Somalia, Sri Lanka, Swaziland, Tanzania, Togo, Uganda, West Himalaya, Yemen, Zambia, Zimbabwe. *A. incisum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 5 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. incisum* populations are expected to be potentially more vulnerable to climate change in parts of Bangladesh, Ethiopia, India, Kenya, Nepal, Pakistan, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

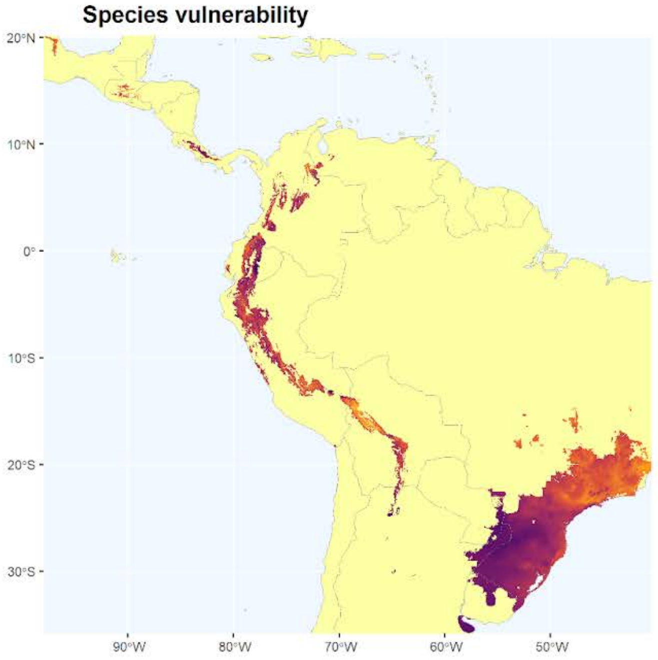
Adiantum latifolium Lam.

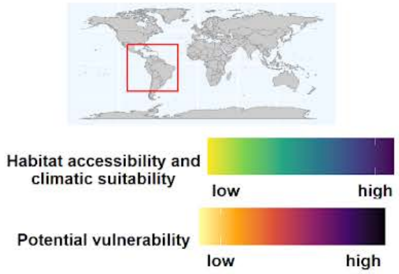


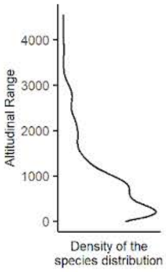
A. latifolium is a plant whose distribution comprises Argentina Northeast, Belize, Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Central American Pac, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Honduras, Jamaica, Leeward Is., Mexico Gulf, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Paraguay, Peru, Puerto Rico, Suriname, Trinidad-Tobago, Venezuela, Windward Is. *A. latifolium* individuals can be primarily found inequatorial, arid, and warm temperate climates, ranging from 1 to 2196 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. latifolium* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Brazil, Colombia, Ecuador, Guatemala, Mexico, Paraguay, Peru, Venezuela. This species has not yet been assessed by IUCN, and only 28% of its distribution range is currently found within protected areas.

Adiantum raddianum C. Presl



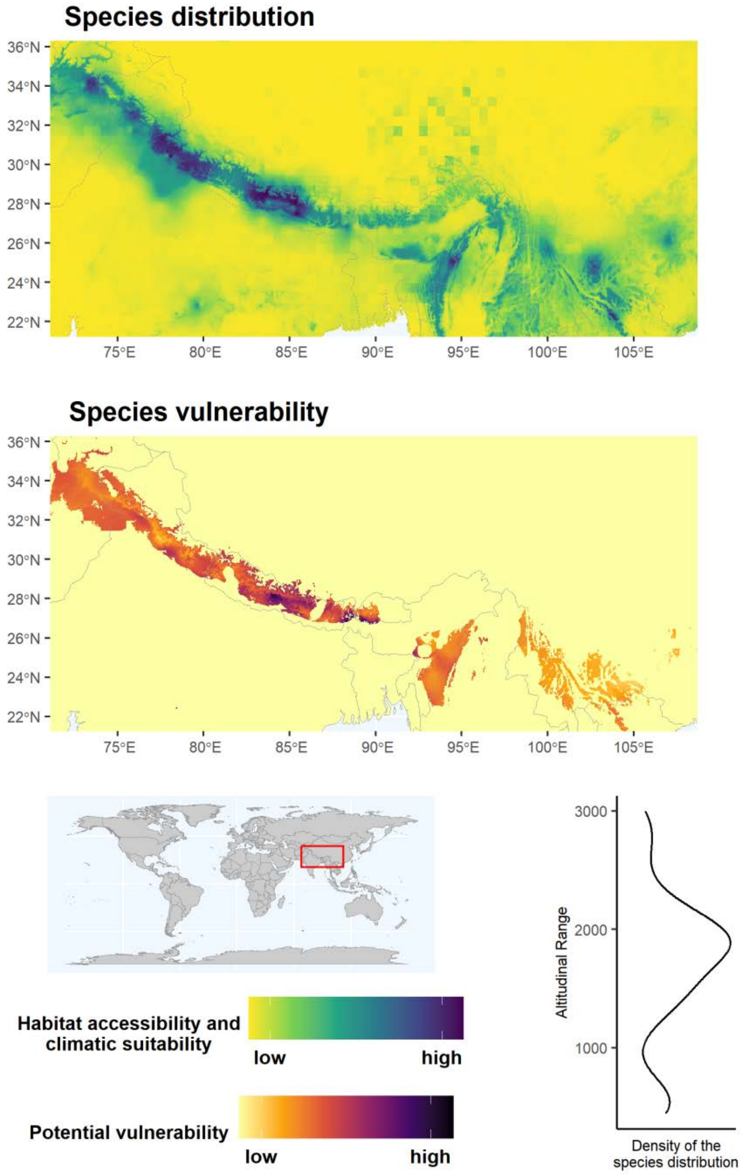






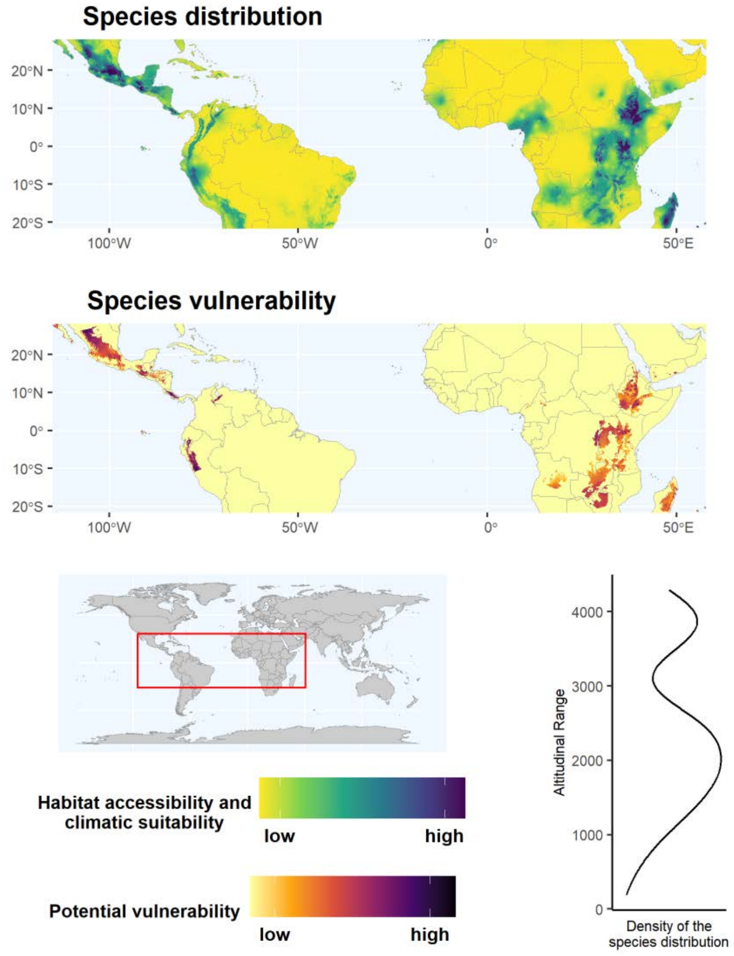
A. raddianum is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Costa Rica, Ecuador, Guatemala, Haiti, Mexico Central, Mexico Gulf, Mexico Southeast, Mexico Southwest, Nicaragua, Paraguay, Peru, Trinidad-Tobago, Uruguay, Venezuela, Windward Is. *A. raddianum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 4560 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. raddianum* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Brazil, Colombia, Costa Rica, Ecuador, Paraguay, Peru, Panama, Uruguay. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

***Aleuritopteris* albomarginata** (C.B. Clarke) Ching
(also cited as *Cheilanthes albomarginata* and *Hemionitis albomarginata*)



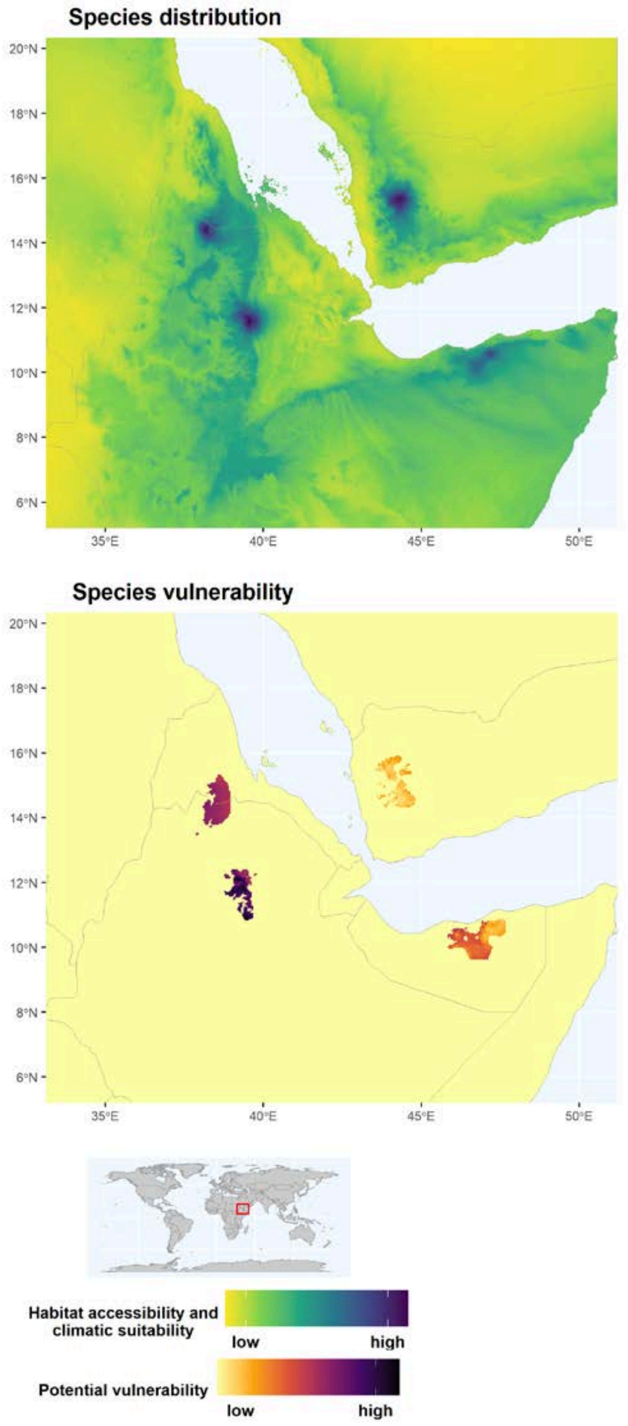
A. albomarginata is a homoiochlorophyllous plant whose distribution comprises Assam, Bangladesh, China South-Central, China Southeast, East Himalaya, India, Myanmar, Nepal, Pakistan, Philippines, Taiwan, Thailand, Tibet, Vietnam, West Himalaya. *A. albomarginata* individuals can be primarily found in warm equatorial climates, ranging from 443 to 2998 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. albomarginata* populations are expected to be potentially more vulnerable to climate change in parts of Bhutan, India, Nepal. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

Aleuritopteris farinosa (Forssk.) Fée
(also cited as *Cheilanthes farinosa* and *Hemionitis farinosa*)



A. farinosa is a homoiochlorophyllous plant whose distribution comprises Mexico (Aguascalientes, Chiapas, Chihuahua, Colima, Ciudad de Mexico, Durango, Guerrero, Hidalgo, Jalisco, Mexico State, Michoacan, Morelos, Nayarit, Oaxaca, Puebla, Queretaro, San Luis Potosi, Sinaloa, Tamaulipas, Veracruz, Zacatecas); Guatemala; Honduras; Costa Rica; Colombia (Cundinamarca); Ecuador; Peru; Venezuela (Tachira); N-Yemen; Saudi Arabia; Oman; Guinea; Sierra Leone; Nigeria; Cameroon; Bioko Isl. Fernando Poo.; D.R.Congo Zaire.; Sudan; Eritrea; Ethiopia; Djibouti; Somalia; Uganda; Rwanda; Burundi; Kenya; Tanzania; Angola; Zambia; Malawi; Zimbabwe; Botswana; Comores (Grande Comore, Anjouan, Mayotte); Madagascar; Mauritius; La Réunion; Soqotra. *A. farinosa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 192 to 4293 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to precipitation is extremely seasonal. *A. farinosa* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Democratic Republic of the Congo, Cameroon, Colombia, Costa Rica, Ecuador, Ethiopia, Guatemala, Kenya, Mexico, Nicaragua, Peru, Panama, Rwanda, Tanzania, Uganda, Venezuela, Yemen, Zimbabwe. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

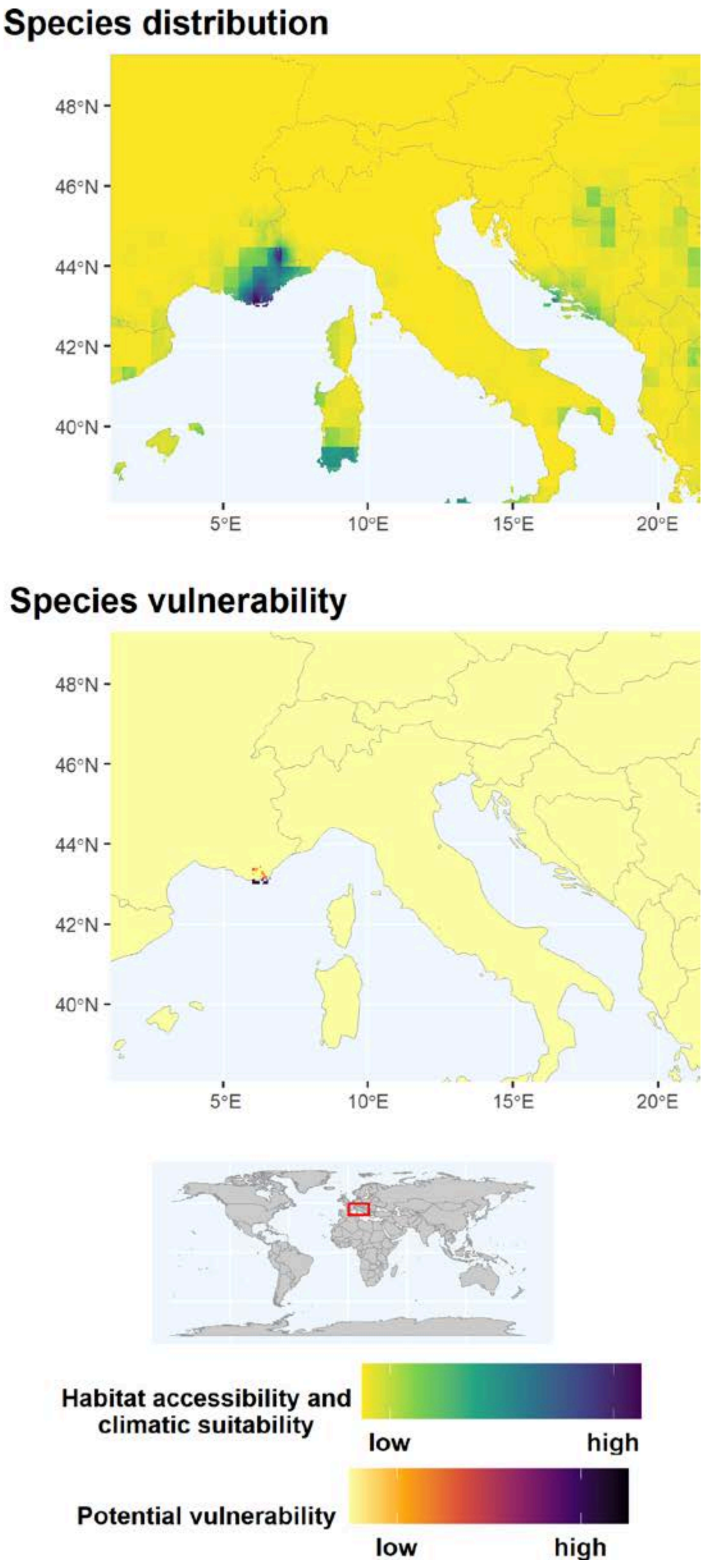
Allosorus coriaceus (Decne.) Christenh.
(also cited as *Cheilanthes coriacea* and *Hemionitis morla*)



A. coriaceus is a plant whose distribution comprises Chad, Djibouti, Ethiopia, Iran, Oman, Saudi Arabia, Somalia, Sudan, Tanzania, Yemen. More occurrence points are needed for a consistent evaluation of the ecological aspects of *A. coriaceus*. *A. coriaceus* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia. This species has not yet been assessed by IUCN, and none of its distribution range is currently found within protected areas.

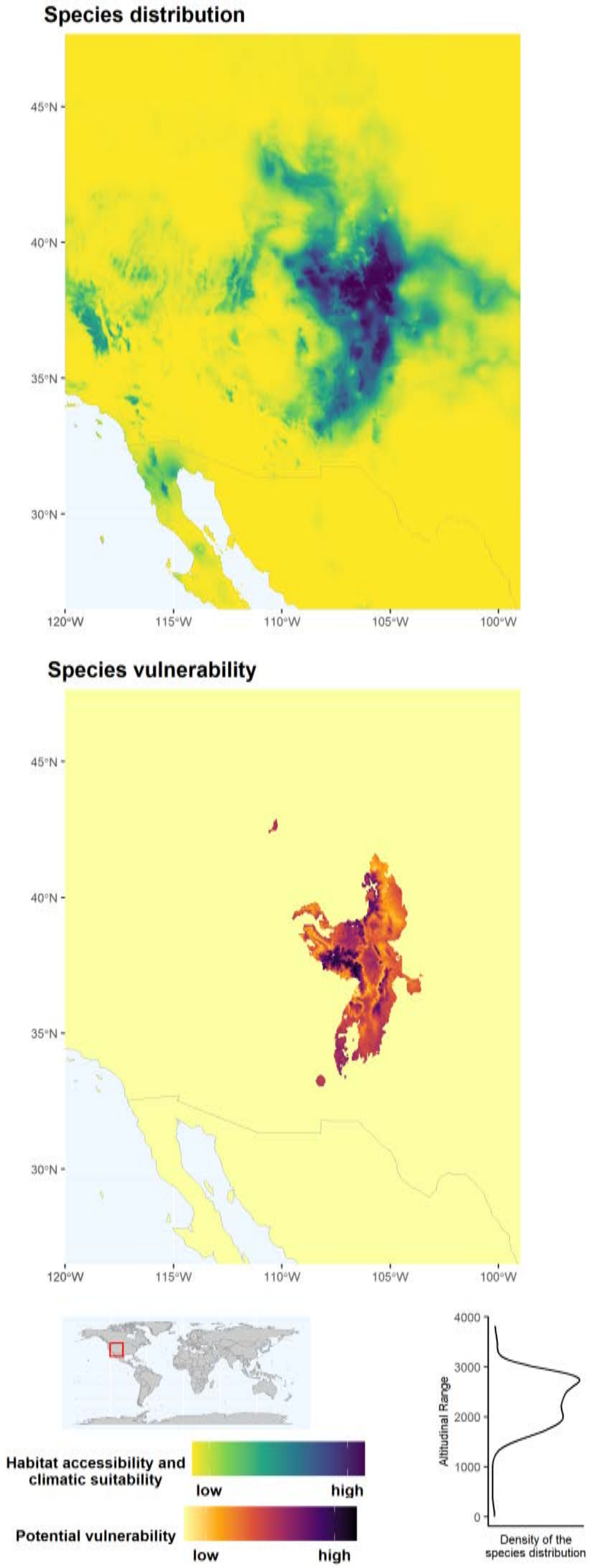
Allosorus pteridioides (Reichard) Christenh.

(also cited as *Cheilanthes pteridioides* and *Hemionitis pteridioides*)



A. pteridioides is a plant whose distribution comprises Albania, Algeria, Azores, Baleares, Bulgaria, Canary Is., Chad, Corse, Cyprus, East Aegean Is., France, Italy, Kriti, Lebanon-Syria, Madeira, Morocco, Palestine, Portugal, Sardegna, Sicilia, Spain, Turkey, Yugoslavia. *A. pteridioides* individuals can be primarily found in warm temperate climates, ranging circa 33 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas which precipitation is spread throughout the year. *A. pteridioides* populations are expected to be potentially more vulnerable to climate change in parts of France. This species is listed as Least concern by IUCN, although 78% of its distribution range is currently found within protected areas.

Argyrochosma fendleri (Kunze) Windham

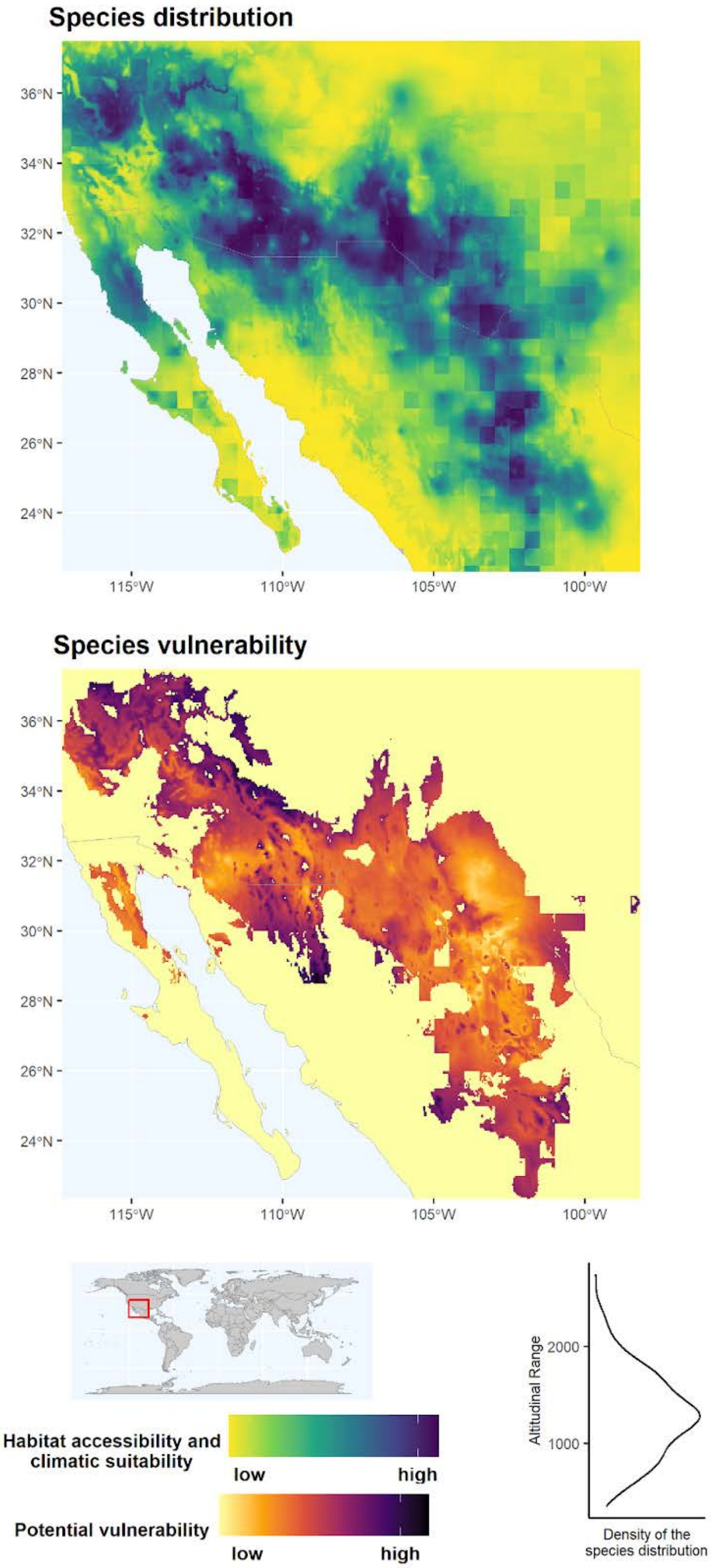


A. fendleri is a plant whose distribution comprises Colorado, Mexico Northeast, New Mexico, Wyoming. *A. fendleri* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 4 to 3820 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *A. fendleri* populations are expected to be potentially more vulnerable to climate change in parts of United States. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

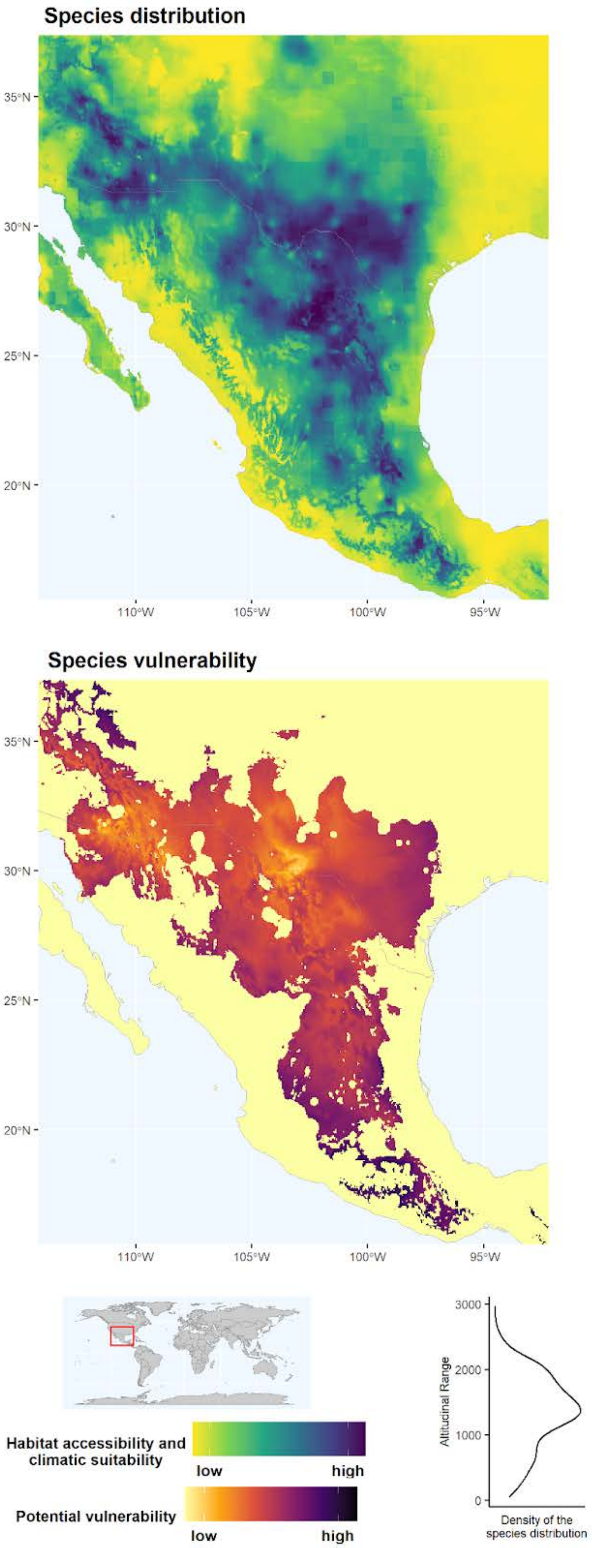
Astrolepis cochisensis (Goodd.) D.M. Benham & Windham

(also cited as *Hemionitis cochisensis* and *Notholaena sinuata* var. *cochisensis*)

A. cochisensis is a homoiochlorophyllous plant whose distribution comprises Arizona, California, Colorado, Mexico Northeast, Mexico Northwest, New Mexico, Texas. *A. cochisensis* individuals can be primarily found in arid and warm temperate climates, ranging from 352 to 2745 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *A. cochisensis* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

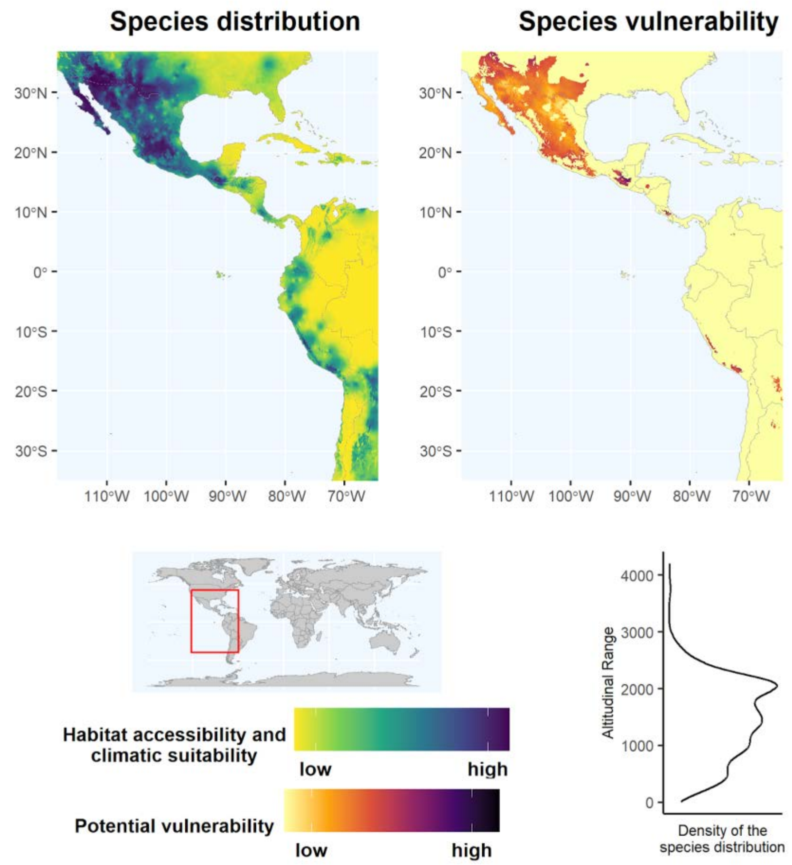


Astrolepis integerrima (Hook.) D.M. Benham & Windham
(also cited as *Cheilanthes integerrima*, *Astrolepis windhamii*, *Notholaena sinuata* var. *integerrima*, and *Hemionitis integerrima*)



A. integerrima is a homoiochlorophyllous plant whose distribution comprises Alabama, Arizona, Colorado, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nevada, New Mexico, Oklahoma, Texas. *A. integerrima* individuals can be primarily found in arid and warm temperate climates, ranging from 52 to 2971 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *A. integerrima* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 9% of its distribution range is currently found within protected areas.

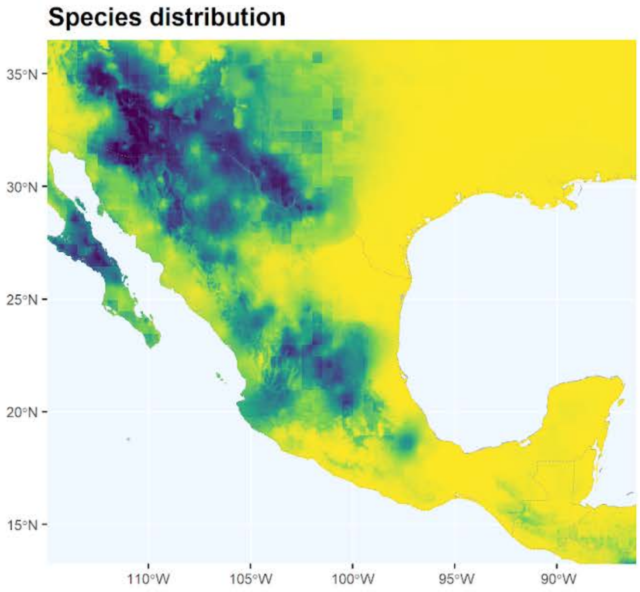
Astrolepis sinuata (Lag. ex Sw.) D.M. Benham & Windham

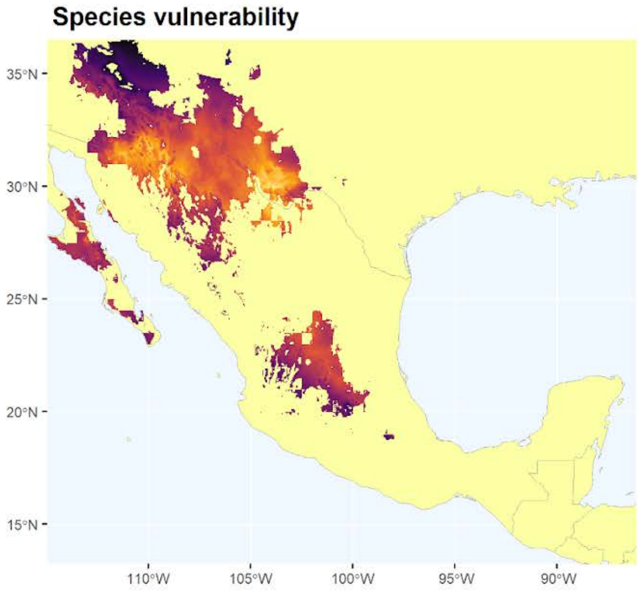


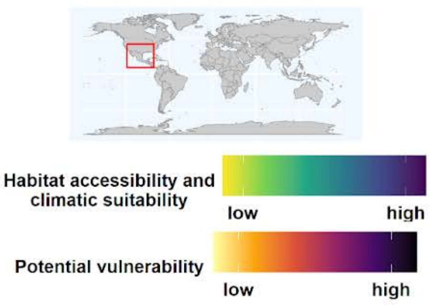
A. sinuata is a plant whose distribution comprises Argentina Northwest, Arizona, Bolivia, Chile North, Colombia, Costa Rica, Ecuador, Georgia, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, New Mexico, Oklahoma, Panamá, Peru, Puerto Rico, Texas, Venezuela. *A. sinuata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 9 to 4206 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *A. sinuata* populations are expected to be potentially more vulnerable to climate change in parts of Costa Rica, Guatemala, Mexico. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

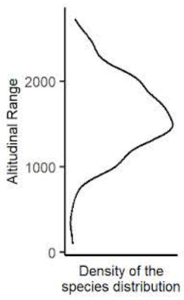
Bommeria hispida (Mett. ex Kuhn) Underw.

B. hispida is a plant whose distribution comprises Arizona, Mexico Central, Mexico Northeast, Mexico Northwest, Mexico Southwest, New Mexico, Nicaragua, Texas. *B. hispida* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 101 to 2736 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *B. hispida* populations are expected to be potentially more vulnerable to climate change in parts of Honduras, Mexico, Nicaragua, United States. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.



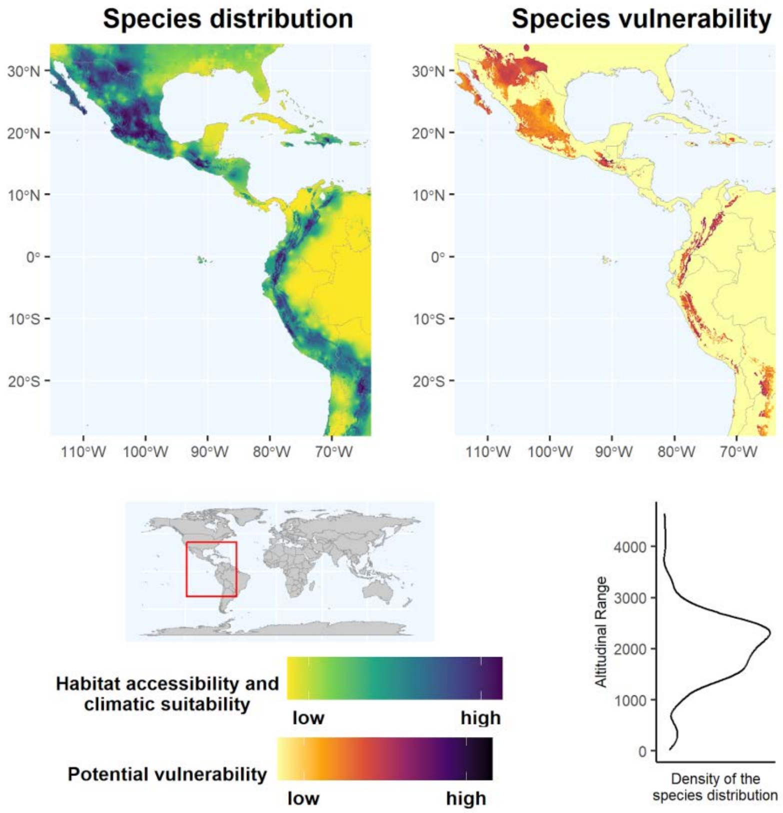






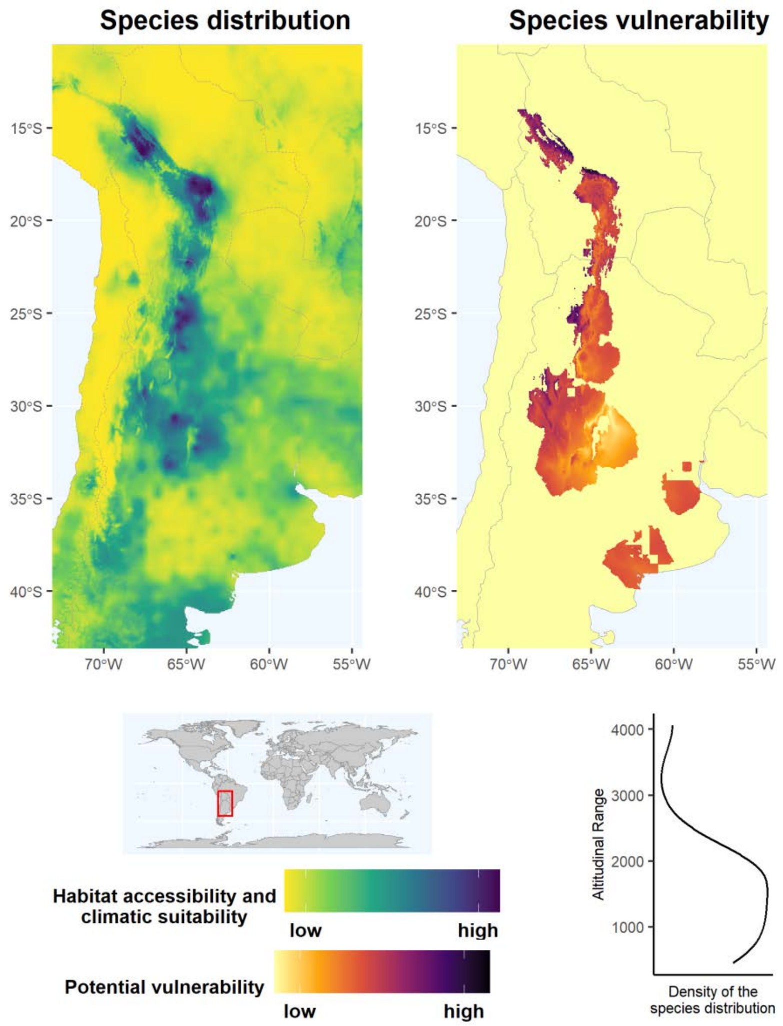
Cheilanthes bonariensis (Willd.) Proctor

(also cited as *Hemionitis bonariensis*)



C. bonariensis is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Arizona, Belize, Bolivia, Chile North, Colombia, Costa Rica, Dominican Republic, Ecuador, Galápagos, Guatemala, Haiti, Jamaica, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, New Mexico, Nicaragua, Panamá, Peru, Texas, Venezuela. *C. bonariensis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 17 to 4644 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *C. bonariensis* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Colombia, Ecuador, Guatemala, Mexico. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

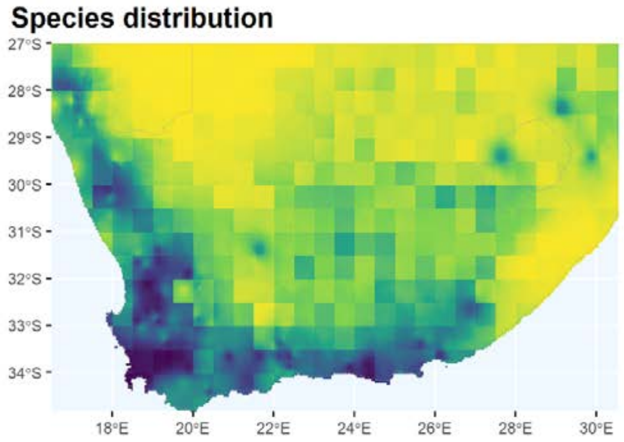
Cheilanthes buchtienii (Rosenst.) R.M. Tryon
(also cited as *Hemionitis buchtienii*)

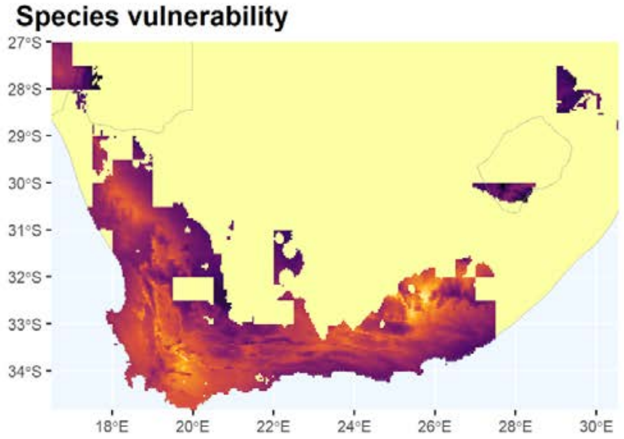


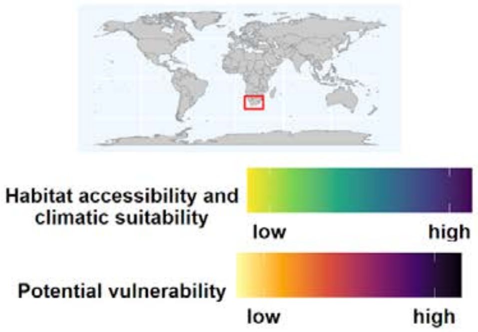
C. buchtienii is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia. *C. buchtienii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 453 to 4061 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. buchtienii* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Peru. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

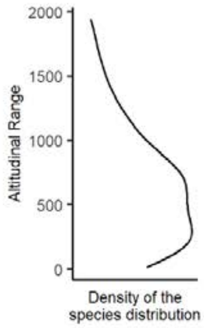
Cheilanthes capensis (Thunb.) Sw.
(also cited as *Hemionitis capensis*)

C. capensis is a homoiochlorophyllous plant whose distribution comprises Cape Provinces, Free State, KwaZulu-Natal, Lesotho, Namibia. *C. capensis* individuals can be primarily found in arid and warm temperate climates, ranging from 13 to 1942 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *C. capensis* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho, Namibia. This species has not yet been assessed by IUCN, and 32% of its distribution range is currently found within protected areas.

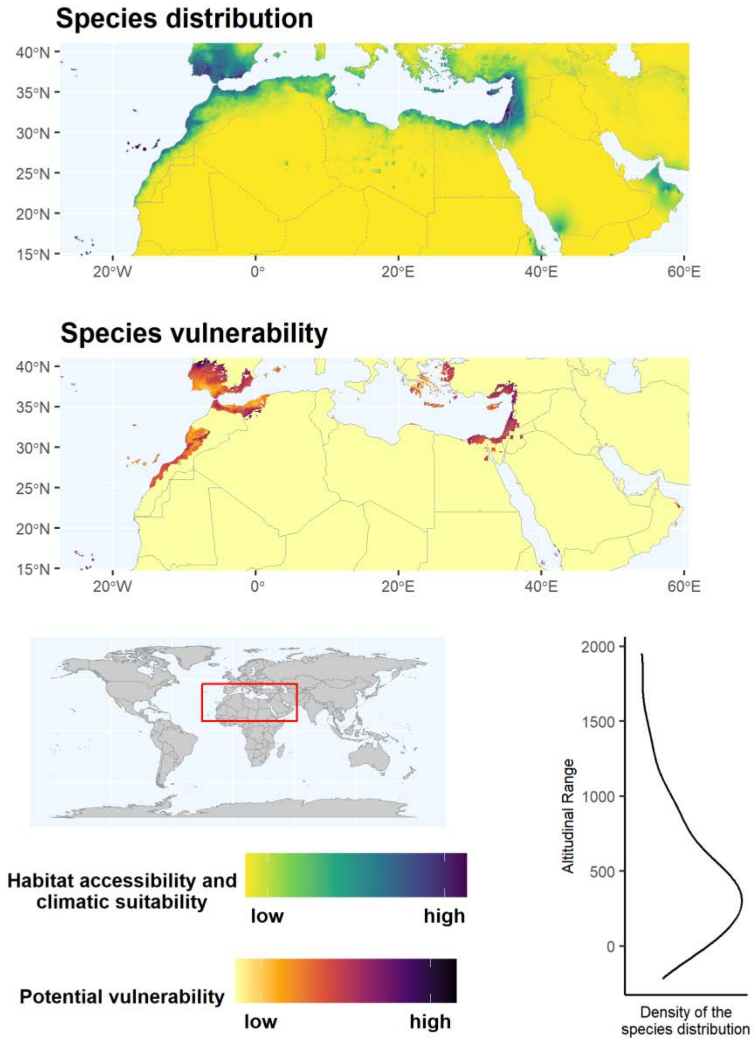






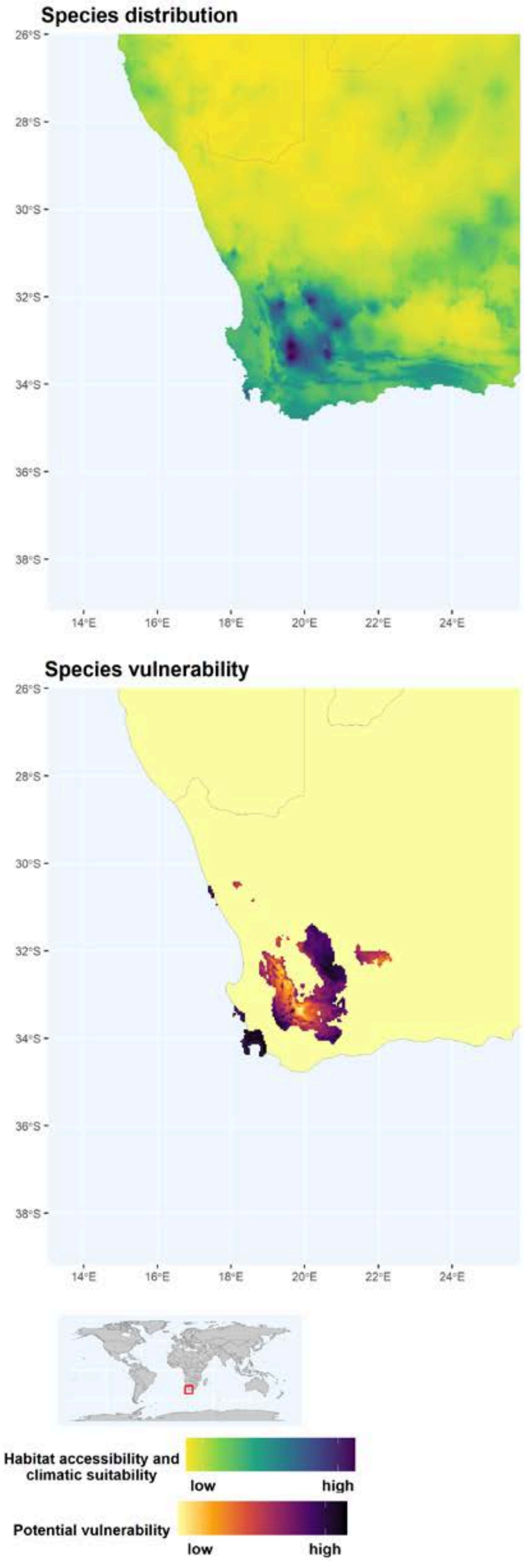


Cheilanthes catanensis (Cosent.) H.P. Fuchs



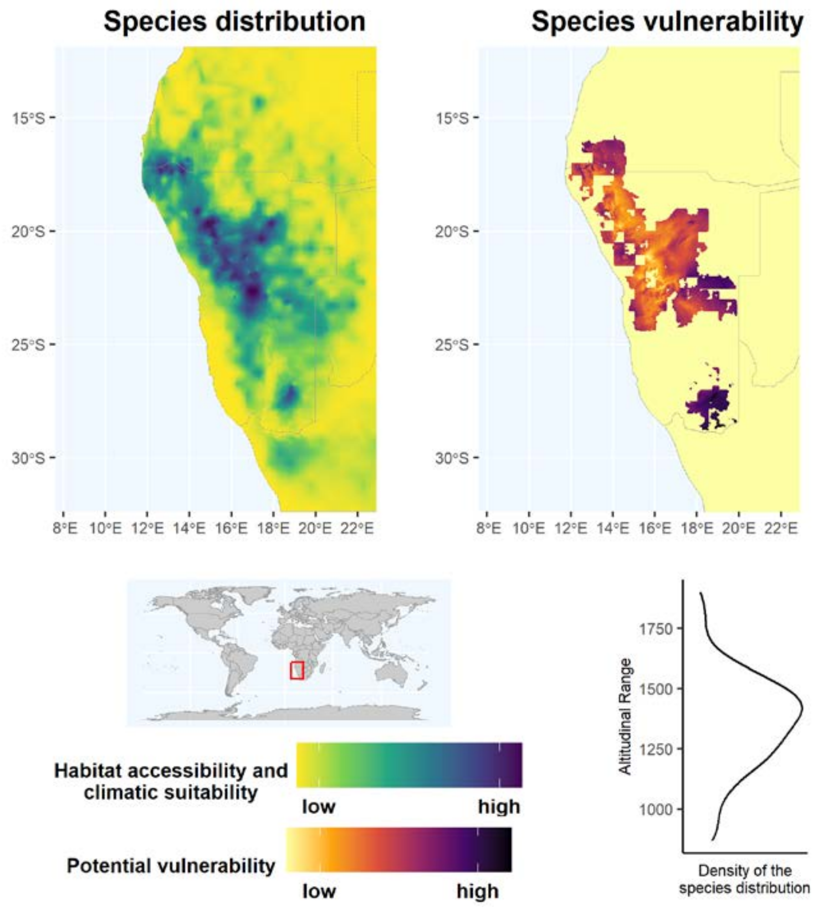
C. catanensis is a plant whose distribution comprises Algeria, Baleares, Corse, Cyprus, Egypt, Ethiopia, France, Greece, Iran, Italy, Kriti, Lebanon-Syria, Libya, Morocco, Oman, Palestine, Portugal, Sardegna, Saudi Arabia, Sicilia, Sinai, Somalia, Spain, Sudan, Tunisia, Turkey, Yemen. *C. catanensis* individuals can be primarily found in arid and warm temperate climates, ranging from -216 to 1953 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. catanensis* populations are expected to be potentially more vulnerable to climate change in parts of Cape Verde, Lebanon, Morocco, Portugal, Spain, Syrian Arab Republic, Turkey. This species has not yet been assessed by IUCN, and 32% of its distribution range is currently found within protected areas.

Cheilanthes depauperata Baker
(also cited as *Hemionitis depauperata*)



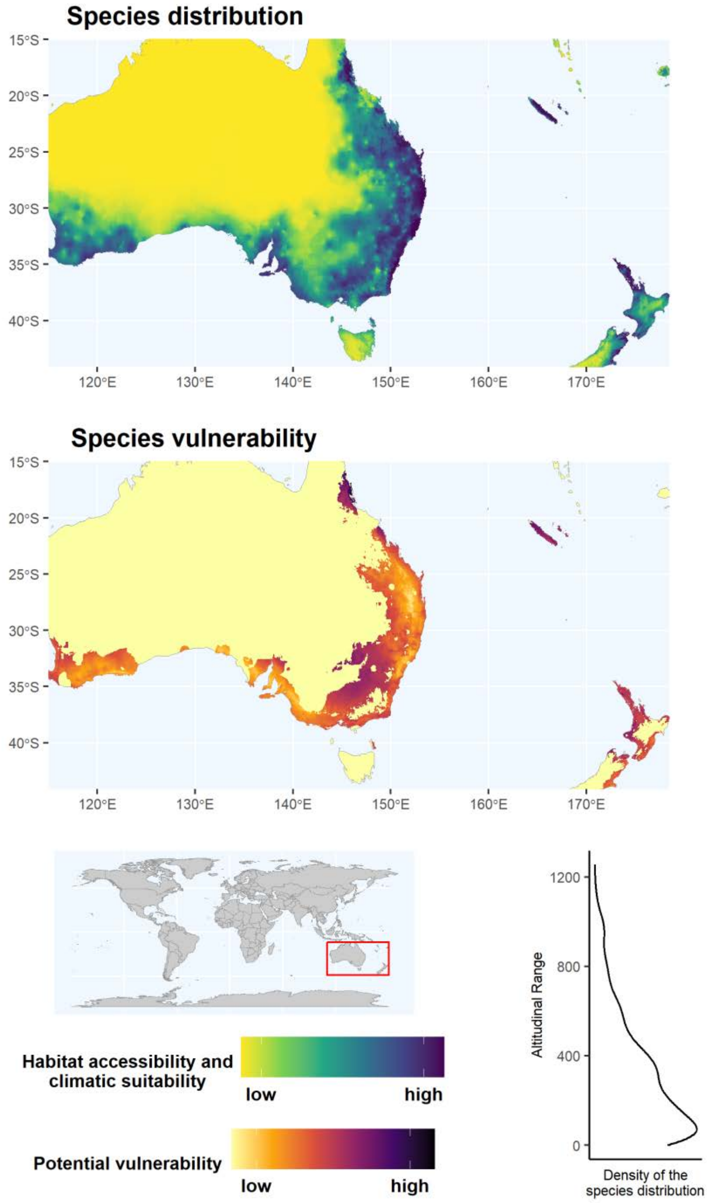
C. depauperata is a homoiochlorophyllous plant whose distribution is restricted to Cape Provinces. More occurrence points are needed for a consistent evaluation of the ecological aspects of *C. depauperata*. Its populations are expected to be potentially more vulnerable to climate change in parts of South Africa. This species has not yet been assessed by IUCN, and 36% of its distribution range is currently found within protected areas.

Cheilanthes dinteri Brause
(also cited as *Hemionitis dinteri*)



C. dinteri is a homoiochlorophyllous plant whose distribution comprises Angola, Namibia. *C. dinteri* individuals can be primarily found in arid climates, ranging from 869 to 1901 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. dinteri* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Namibia. This species has not yet been assessed by IUCN, and 33% of its distribution range is currently found within protected areas.

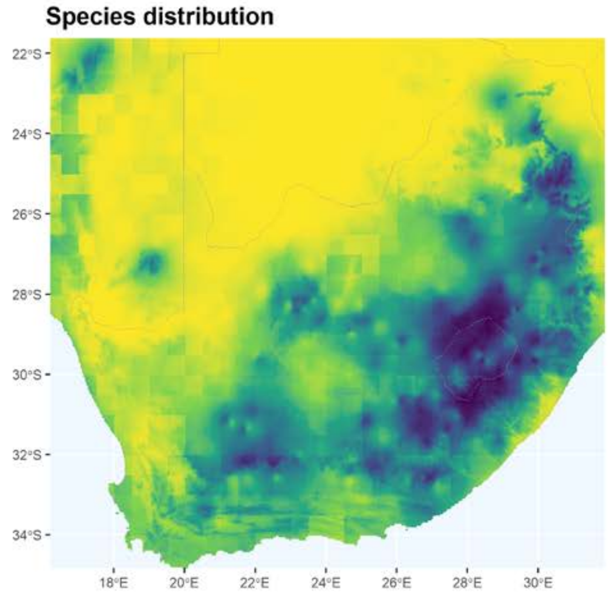
Cheilanthes distans (R. Br.) Mett.
(also cited as *Hemionitis distans*)

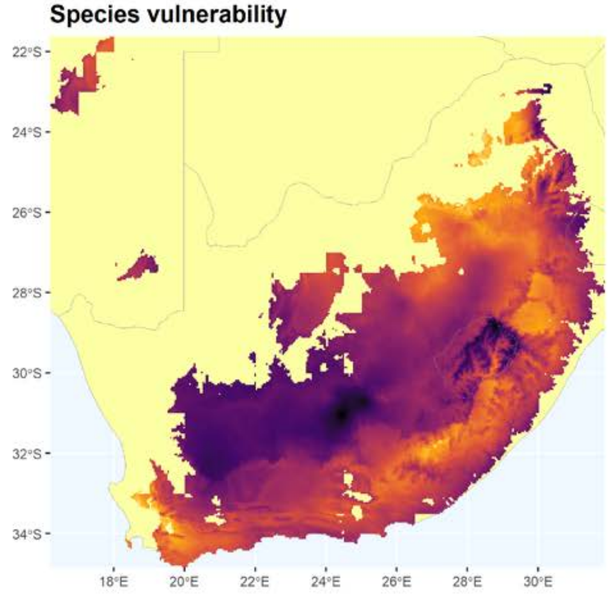


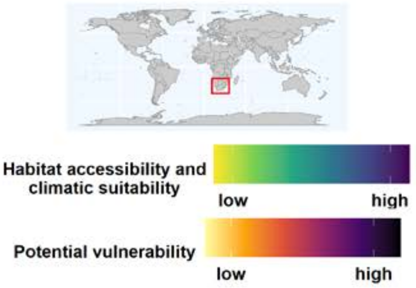
C. distans is a homoiochlorophyllous plant whose distribution comprises Australia (New South Wales, South Australia, Queensland, Victoria, Western Australia), New Zealand (North Isl., South Isl.), Norfolk Isl., New Caledonia, Lord Howe Isl., Sulawesi, Lesser Sunda Isl. (Lombok, Alor). *C. distans* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 0 to 1255 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *C. distans* populations are expected to be potentially more vulnerable to climate change in parts of Australia, New Caledonia, New Zealand. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

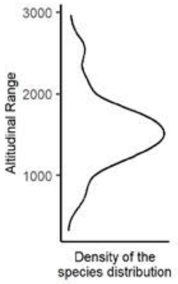
Cheilanthes eckloniana Mett.
(also cited as *Hemionitis eckloniana*)

C. eckloniana is a homoiochlorophyllous plant whose distribution comprises Cape Provinces, Free State, KwaZulu-Natal, Lesotho, Namibia, Northern Provinces, Swaziland, Zimbabwe. *C. eckloniana* individuals can be primarily found in arid and warm temperate climates, ranging from 321 to 2966 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *C. eckloniana* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho, Namibia, Swaziland. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.



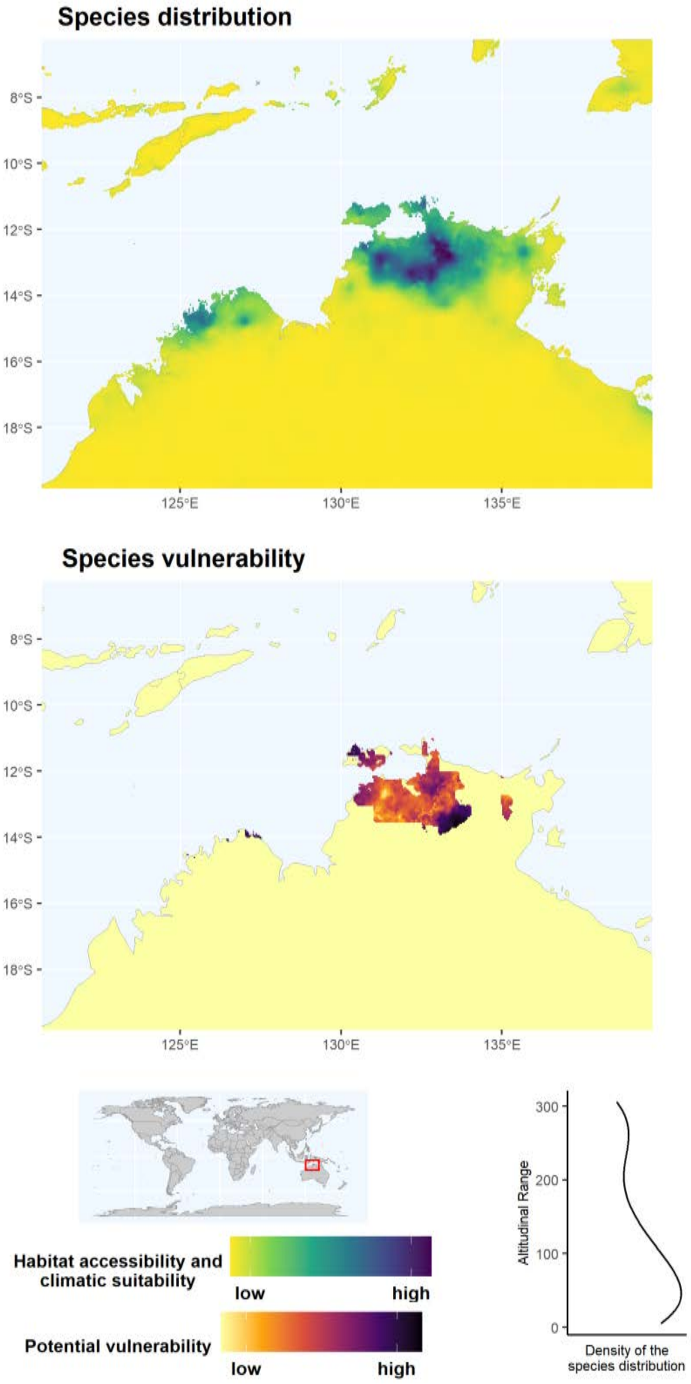






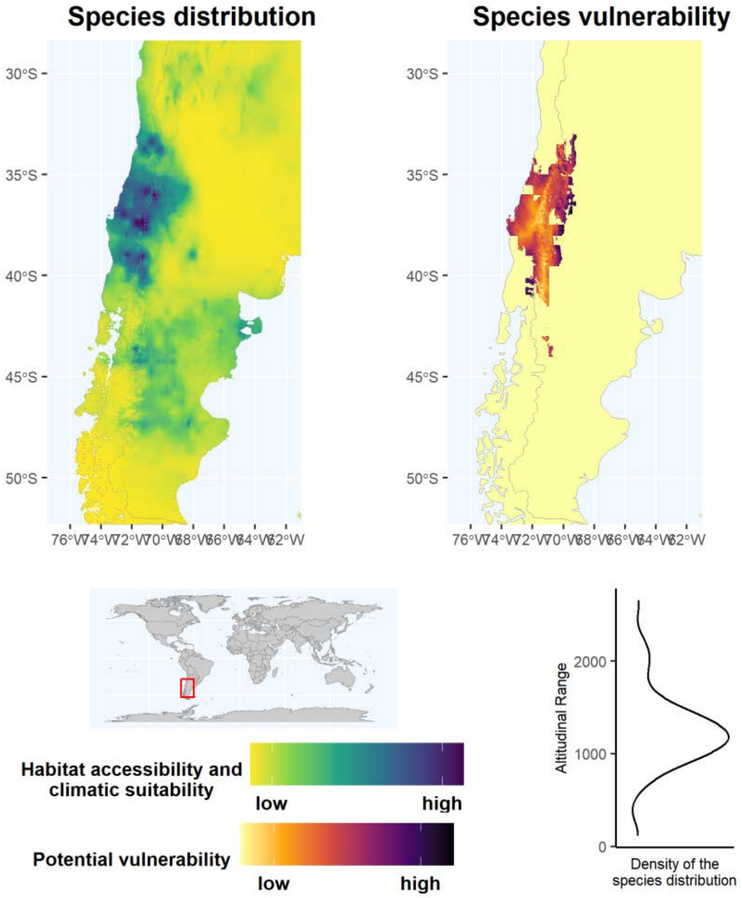
Cheilanthes fragillima F. Muell.

(also cited as *Hemionitis fragillima*)



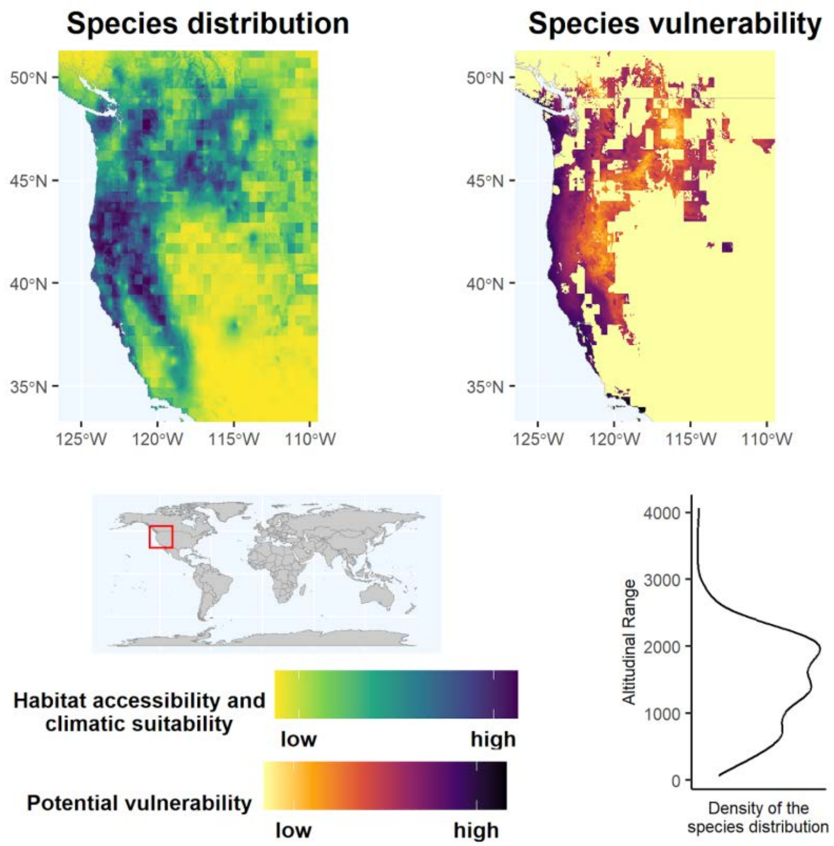
C. fragillima is a homoiochlorophyllous plant whose distribution comprises Northern Territory, Western Australia. *C. fragillima* individuals can be primarily found in equatorial climates, ranging from 5 to 306 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. fragillima* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 46% of its distribution range is currently found within protected areas.

Cheilanthes glauca (Cav.) Mett.
(also cited as *Hemionitis glauca*)



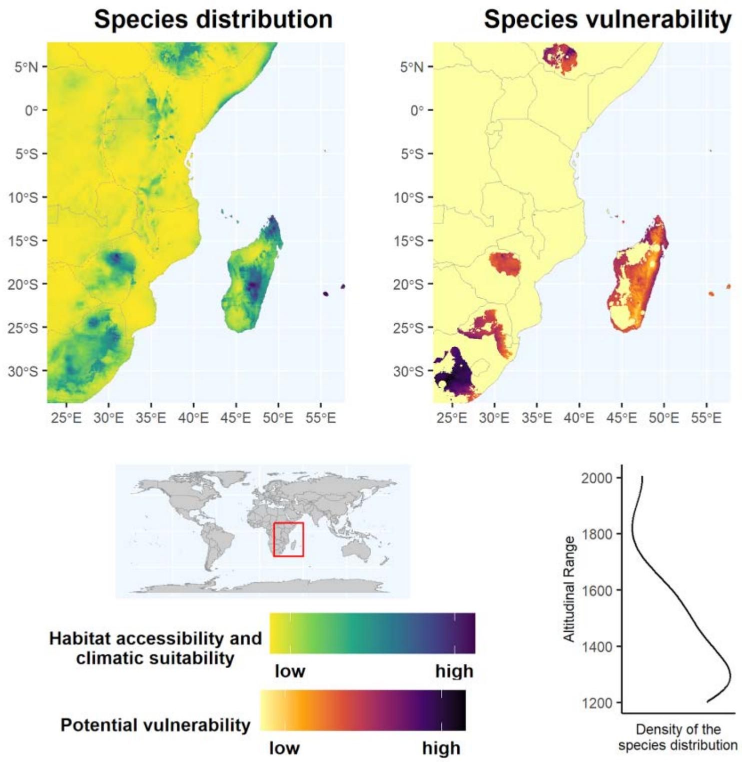
C. glauca is a homoiochlorophyllous plant whose distribution comprises Argentina South, Chile Central, Chile South. *C. glauca* individuals can be primarily found in arid and warm temperate climates, ranging from 118 to 2656 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *C. glauca* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Chile. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Cheilanthes gracillima D.C. Eaton



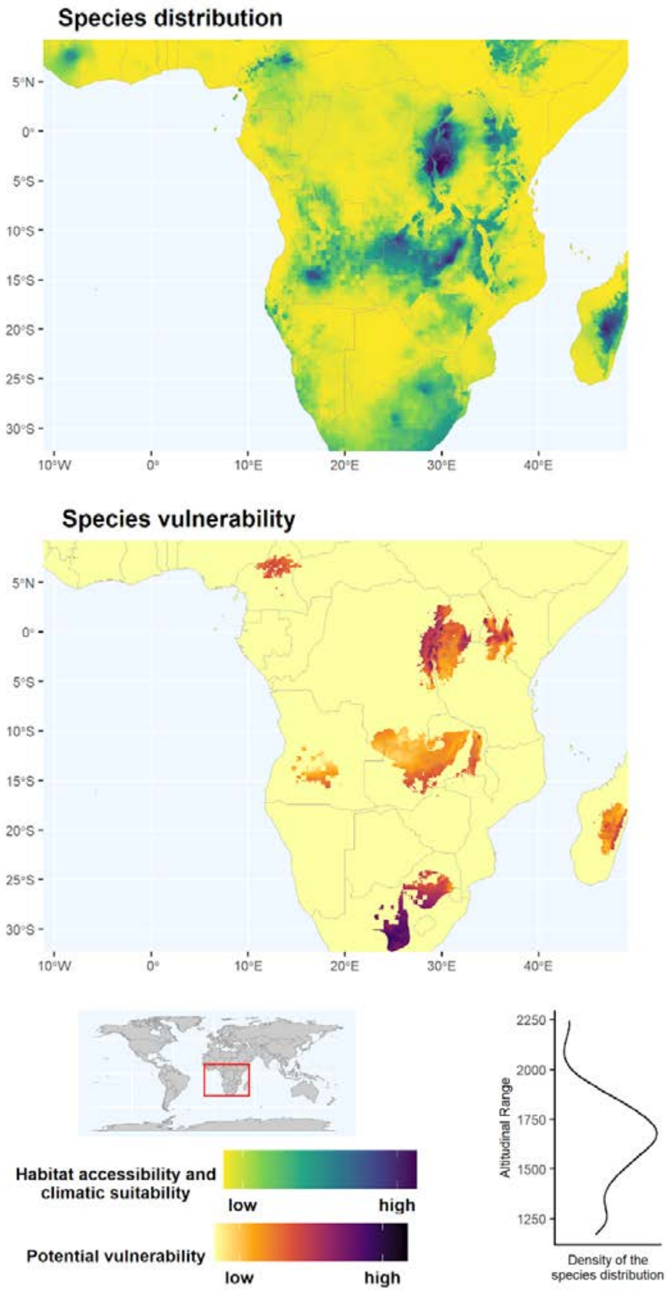
C. gracillima is a plant whose distribution comprises Alberta, British Columbia, California, Guatemala, Idaho, Montana, Nevada, Oregon, Utah, Washington. *C. gracillima* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 66 to 4067 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *C. gracillima* populations are expected to be potentially more vulnerable to climate change in parts of Canada, United States. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Cheilanthes hirta Sw.
(also cited as *Hemionitis hirta*)



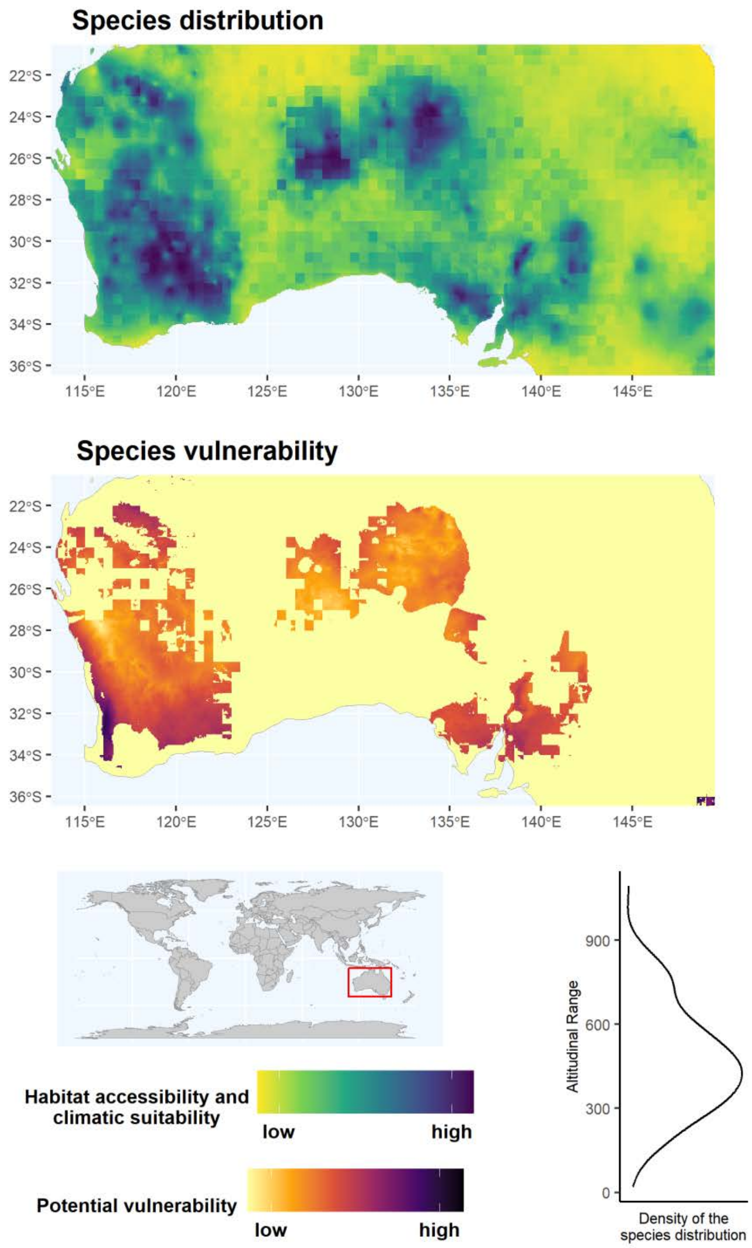
C. hirta is a homoiochlorophyllous plant whose distribution is restricted to Ethiopia; Uganda; Kenya; Tanzania; Angola; Mozambique; Zimbabwe; Namibia; S-Botswana; South Africa (widespread); Lesotho; Eswatini Swaziland.; Madagascar; Mauritius; La Réunion. *C. hirta* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 1202 to 2006 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. hirta* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Madagascar, Seychelles, South Africa, Zimbabwe. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

Cheilanthes inaequalis (Kunze) Mett.
(also cited as *Hemionitis inaequalis*)



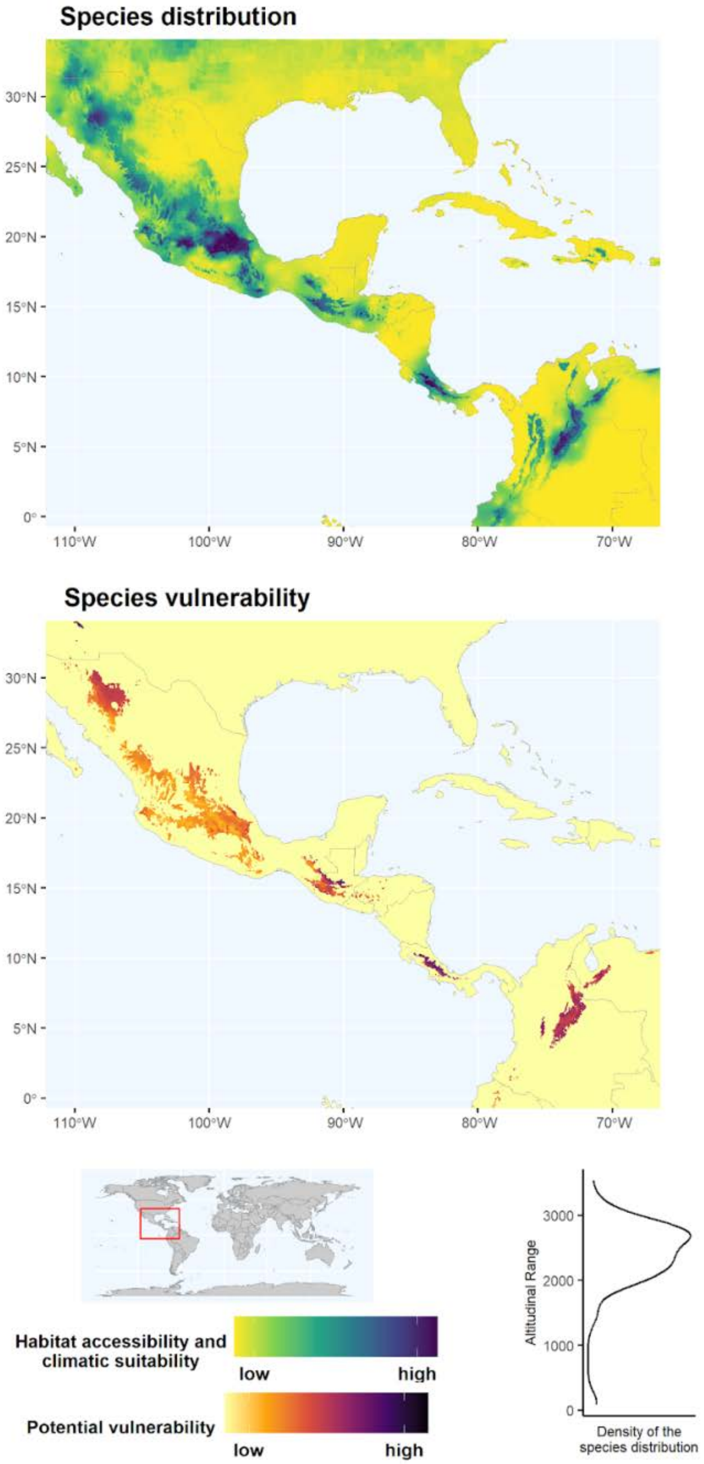
C. inaequalis is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Burundi, Cameroon, Ethiopia, Guinea, Kenya, KwaZulu-Natal, Madagascar, Malawi, Namibia, Nigeria, Northern Provinces, Rwanda, Sudan, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *C. inaequalis* individuals can be primarily found in equatorial and warm temperate climates, ranging from 1172 to 2244 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. inaequalis* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Kenya, Rwanda, South Africa, Uganda. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Cheilanthes lasiophylla Pic. Serm.



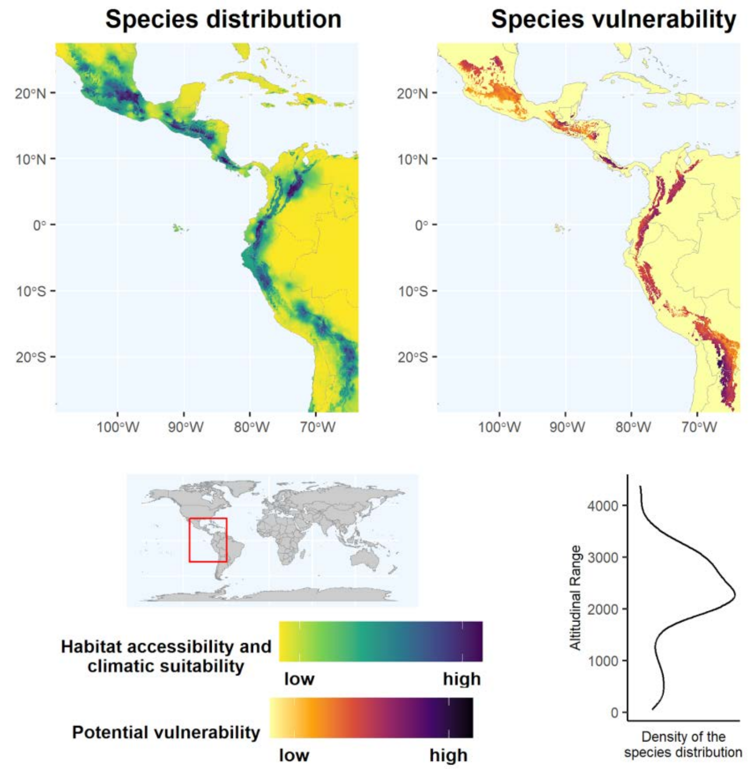
C. lasiophylla is a homoiochlorophyllous plant whose distribution comprises Australia (Northern Territory, W-New South Wales, NW-Victoria, Western Australia). *C. lasiophylla* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 21 to 1093 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. lasiophylla* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

Cheilanthes lendigera (Cav.) Sw.
(also cited as *Hemionitis lendigera*)



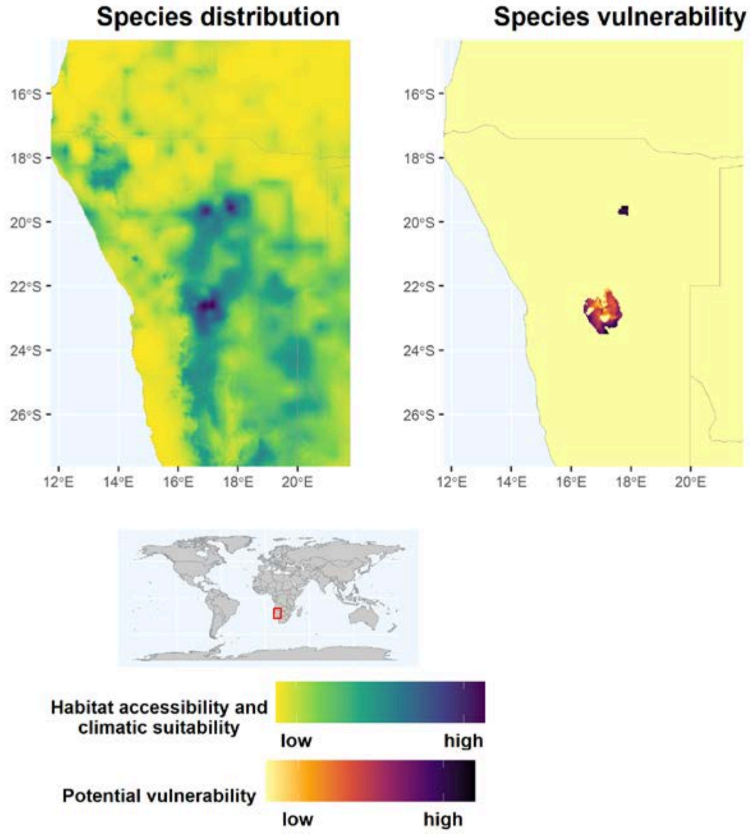
C. lendigera is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Panamá, Peru, Venezuela. *C. lendigera* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 88 to 3536 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. lendigera* populations are expected to be potentially more vulnerable to climate change in parts of Colombia, Costa Rica, Guatemala, Mexico, Panama, United States. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Cheilanthes marginata Kunth
(also cited as *Hemionitis marginata*)



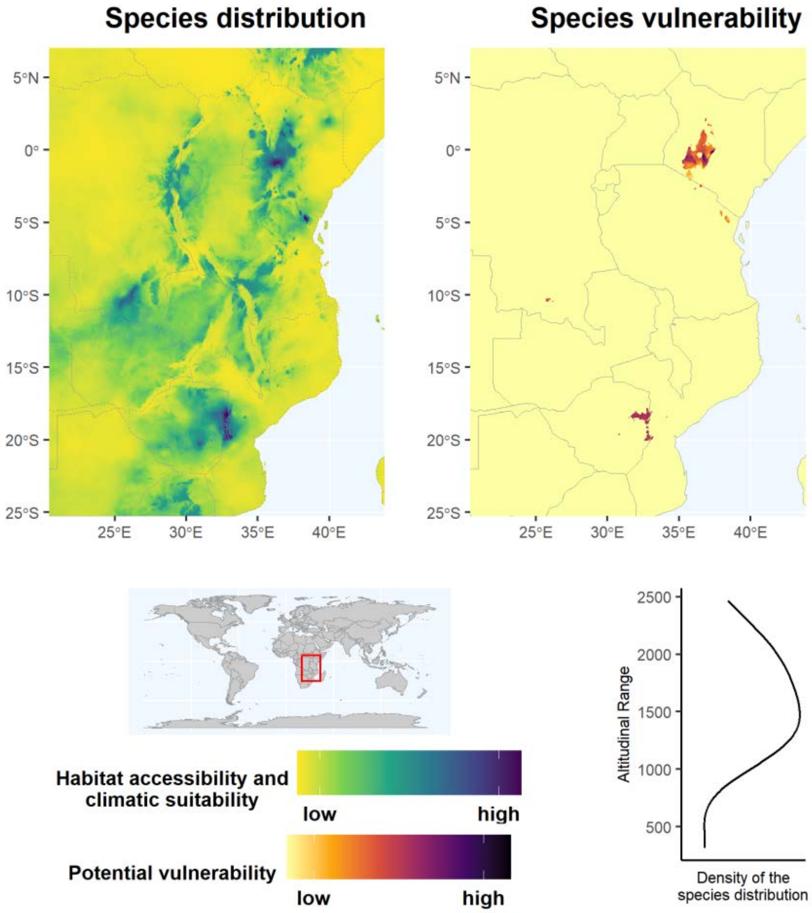
C. marginata is a homoiochlorophyllous plant whose distribution comprises Costa Rica; Mexico (Aguascalientes, Baja California Sur, Chiapas, Chihuahua, Coahuila, Colima, Ciudad de Mexico, Guanajuato, Guerrero, Hidalgo, Jalisco, Mexico State, Michoacan, Morelos, Nayarit, Nuevo Leon, Oaxaca, Puebla, Queretaro, San Luis Potosi, Sonora, Tamaulipas, Veracruz, Zacatecas); El Salvador; Honduras; Nicaragua; Panama; Guatemala; Colombia (Antioquia, Boyacá, Cauca, Cundinamarca, Nariño); Venezuela (Aragua, Barinas, Guarico, Merida, Monagas, Sucre, Tachira, Trujillo); Ecuador; Peru; Bolivia (Chuquisaca, Cochabamba, La Paz, Santa Cruz, Tarija); Argentina (Catamarca, Cordoba, Jujuy, La Rioja, Salta, Santiago del Estero, Tucuman). *C. marginata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 52 to 4385 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *C. marginata* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Belize, Bolivia, Colombia, Costa Rica, Ecuador, Guatemala, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Cheilanthes marlothii (Hieron.) Domin
(also cited as *Hemionitis marlothii*)



C. marlothii is a homoiochlorophyllous plant whose distribution comprises South Africa (Limpopo, Gauteng, North West); Namibia; S-Angola. *C. marlothii* individuals can be primarily found in arid climates, circa 1709 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). *C. marlothii* populations are expected to be potentially more vulnerable to climate change in parts of Namibia. This species has not yet been assessed by IUCN, and 3% of its distribution range is currently found within protected areas.

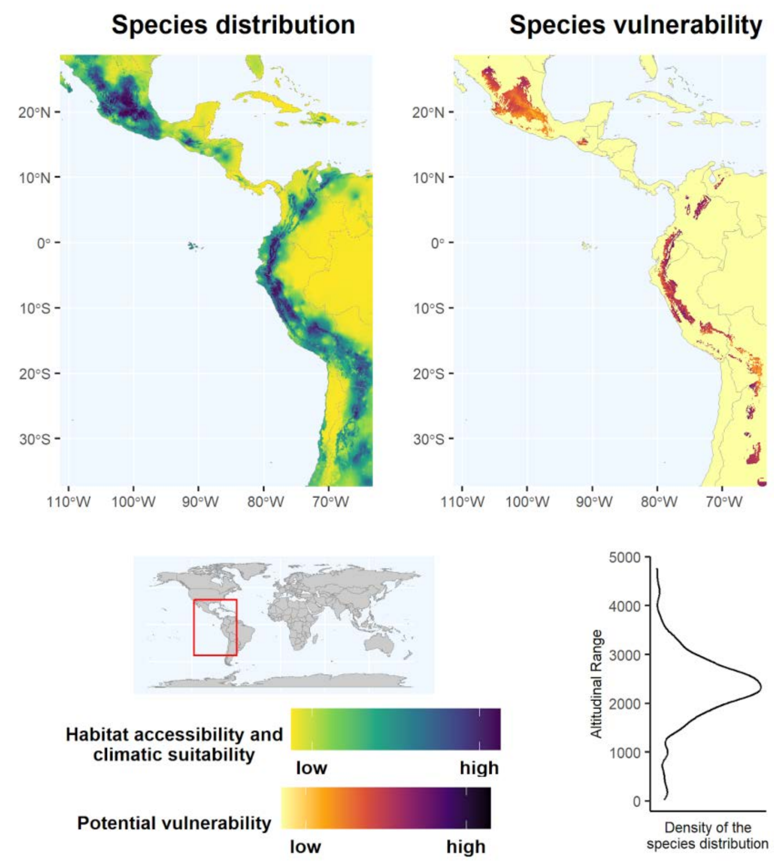
Cheilanthes multifida (Sw.) Sw.
(also cited as *Hemionitis multifida*)



C. multifida is a homoiochlorophyllous plant whose distribution comprises South Africa (N-Cape Prov., W-Cape Prov., E-Cape Prov.), Namibia, St. Helena, Zambia, Zimbabwe, Malawi, Mozambique, Angola, Madagascar. *C. multifida* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 316 to 2467 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *C. multifida* populations are expected to be potentially more vulnerable to climate change in parts of Kenya. This species has not yet been assessed by IUCN, and only 29% of its distribution range is currently found within protected areas.

Cheilanthes myriophylla Desv.

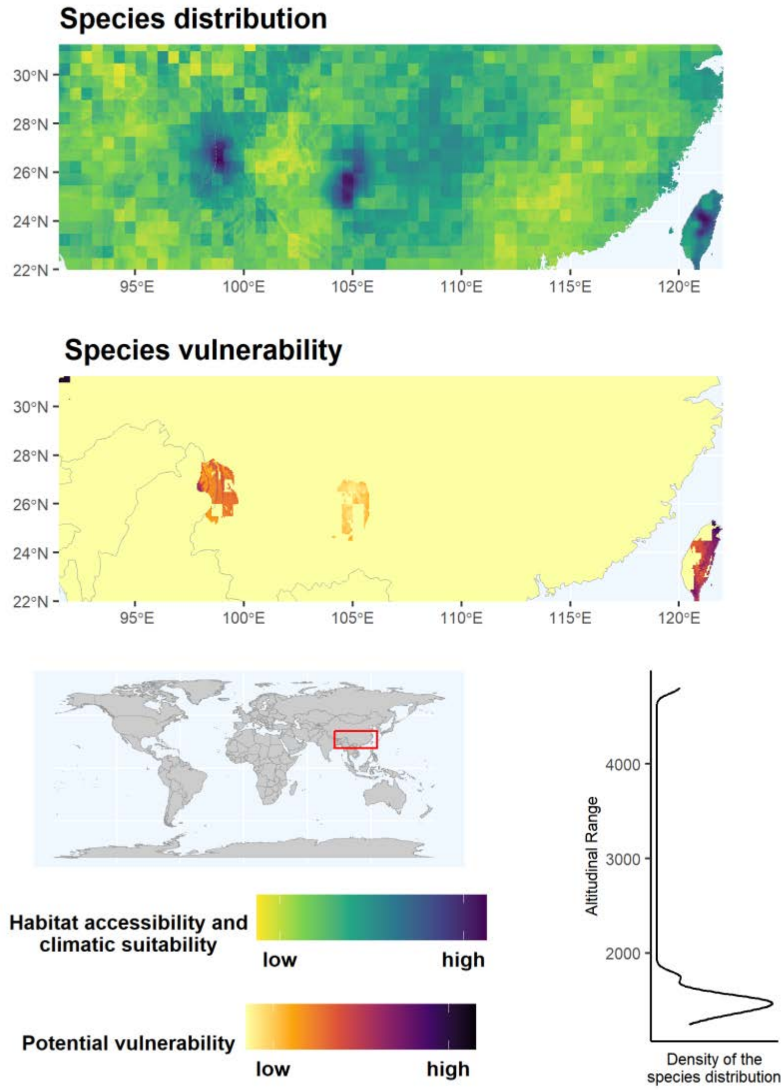
(also cited as *Hemionitis myriophylla*)



C. myriophylla is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Chile North, Colombia, Dominican Republic, Ecuador, El Salvador, Galápagos, Guatemala, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southwest, Nicaragua, Peru, Venezuela. *C. myriophylla* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 30 to 4771 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *C. myriophylla* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Colombia, Ecuador, Guatemala, Mexico, Peru, Venezuela. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

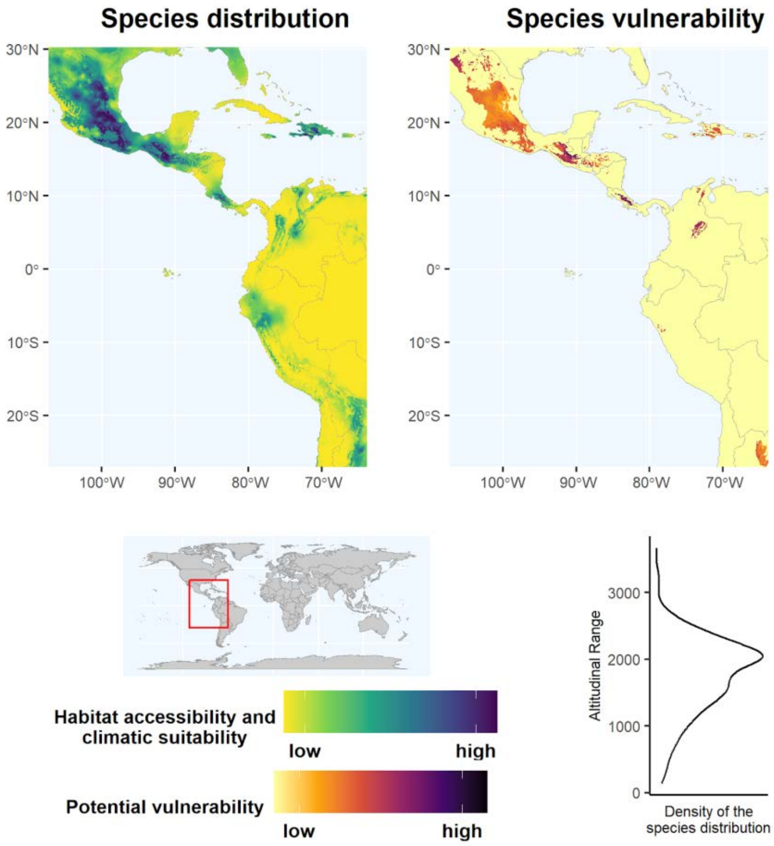
Cheilanthes nitidula Wall. ex Hook.

(also cited as *Pellaea nitidula* and *Hemionitis nitidula*)



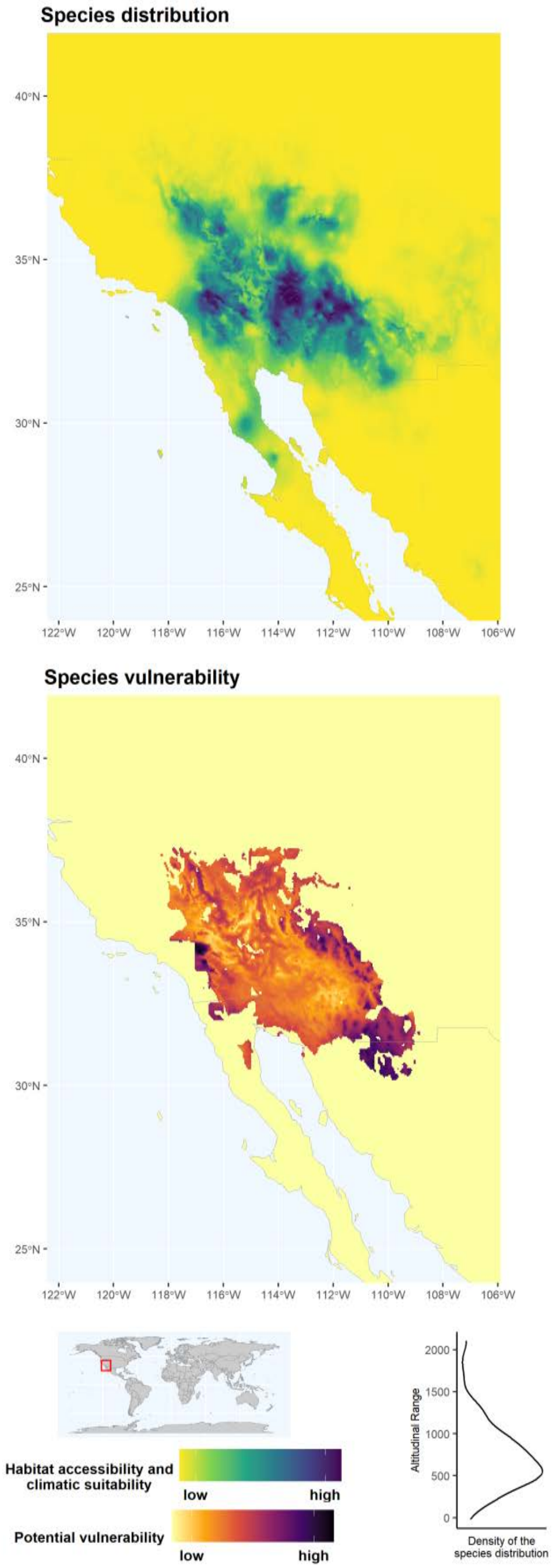
C. nitidula is a plant whose distribution comprises China North-Central, China South-Central, China Southeast, East Himalaya, Nepal, Pakistan, Taiwan, Tibet, Vietnam, West Himalaya. *C. nitidula* individuals can be primarily found in arid and warm temperate climates, ranging from 1246 to 4809 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. nitidula* populations are expected to be potentially more vulnerable to climate change in parts of China, Taiwan. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Cheilanthes notholaenoides (Desv.) Maxon ex Weath.
(also cited as *Doryopteris ornithopus*, *Hemionitis ornithopus*, and *Hemionitis notholaenoides*)



C. notholaenoides is a plant whose distribution comprises Argentina Northwest, Belize, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Jamaica, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Southeast, Mexico Southwest, Panamá, Peru, Venezuela. *C. notholaenoides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 145 to 3667 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *C. notholaenoides* populations are expected to be potentially more vulnerable to climate change in parts of Costa Rica, Guatemala, Mexico, Panama. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

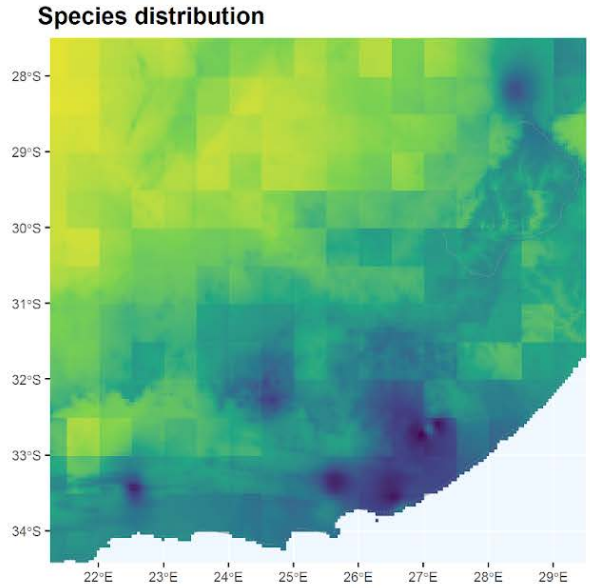
Cheilanthes parryi (D.C. Eaton) Domin
(also cited as *Notholaena parryi* and *Hemionitis parryi*)

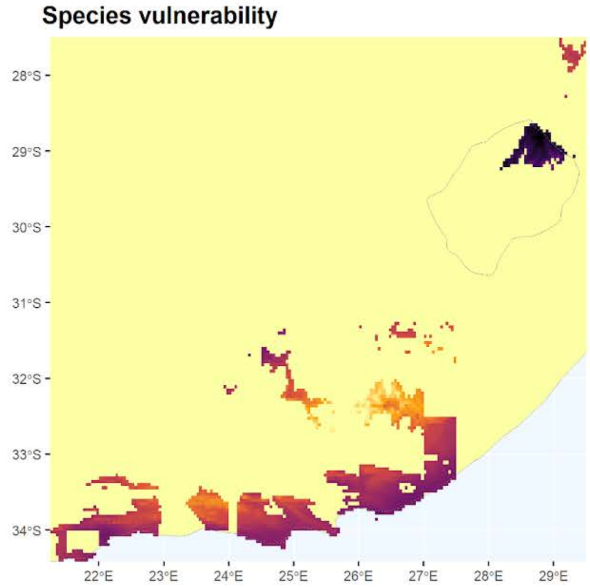


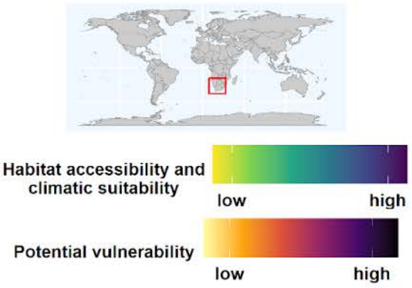
C. parryi is a homoiochlorophyllous plant whose distribution comprises Arizona, California, Mexico Northwest, Nevada, Utah. *C. parryi* individuals can be primarily found in arid, and warm temperate climates, ranging from -20 to 2106 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *C. parryi* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 8.91% of its distribution range is currently found within protected areas.

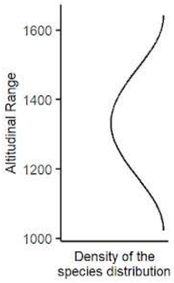
Cheilanthes parviloba Sw.
(also cited as *Hemionitis parviloba*)

C. parviloba is a homoiochlorophyllous plant whose distribution comprises Cape Provinces, Free State, KwaZulu-Natal, Namibia, Northern Provinces, Zimbabwe. *C. parviloba* individuals can be primarily found in warm temperate climates, ranging from 1023 to 1643 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *C. parviloba* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho. This species has not yet been assessed by IUCN, and only 50% of its distribution range is currently found within protected areas.

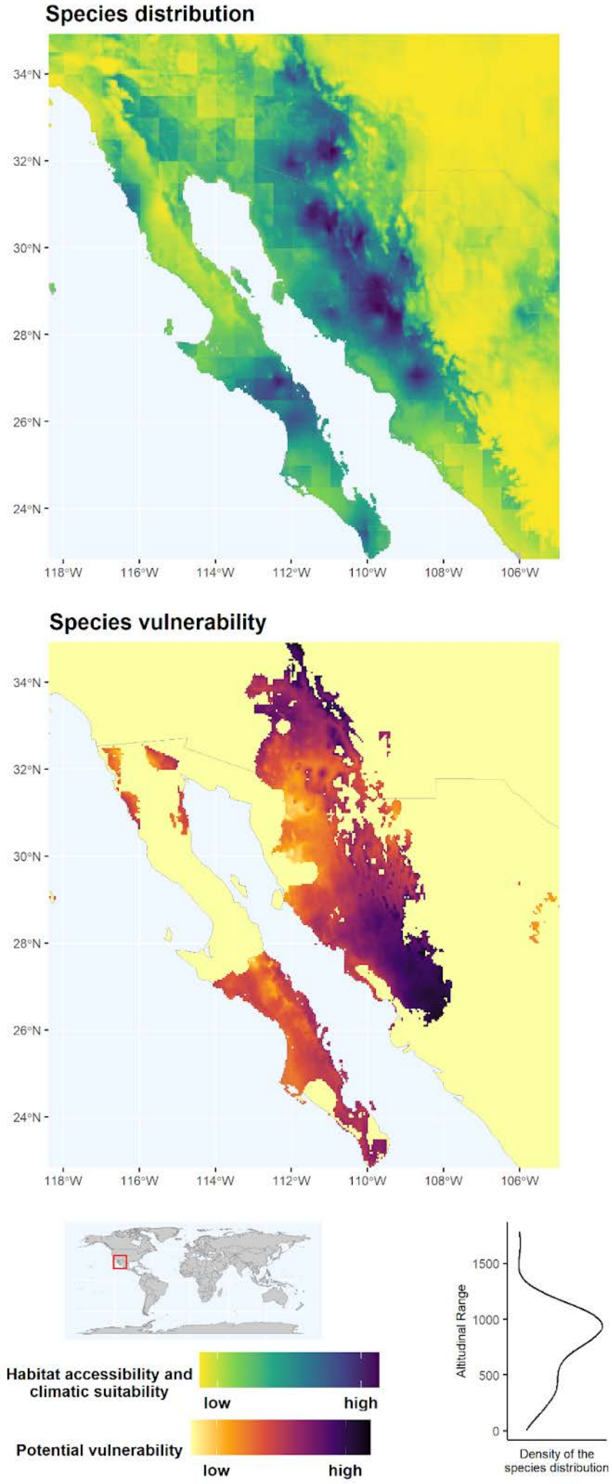






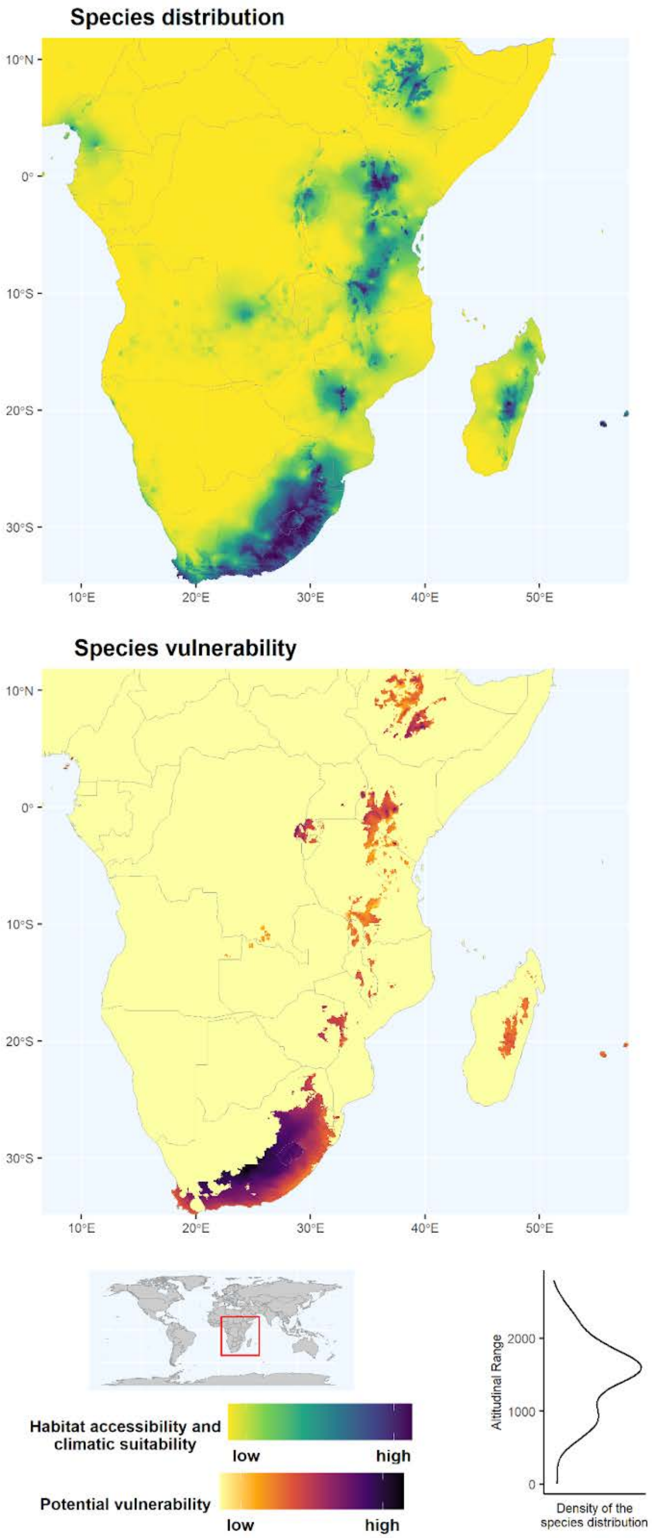


Cheilanthes pringlei Davenp.
(also cited as *Hemionitis pringlei*)



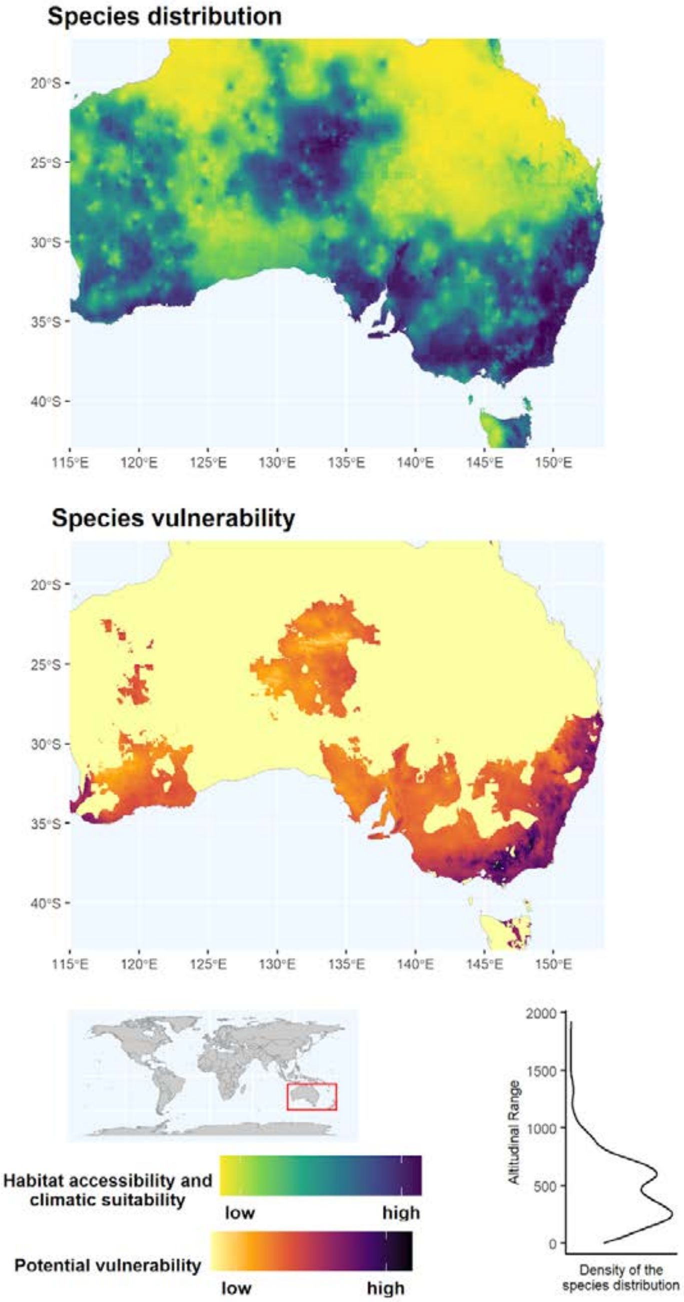
C. pringlei is a homoiochlorophyllous plant whose distribution comprises Arizona, Mexico Northeast, Mexico Northwest. *C. pringlei* individuals can be primarily found in arid and warm temperate climates, ranging from 8 to 1783 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. pringlei* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Cheilanthes quadripinnata (Forssk.) Kuhn
(also cited as *Pellaea quadripinnata* and *Hemionitis quadripinnata*)



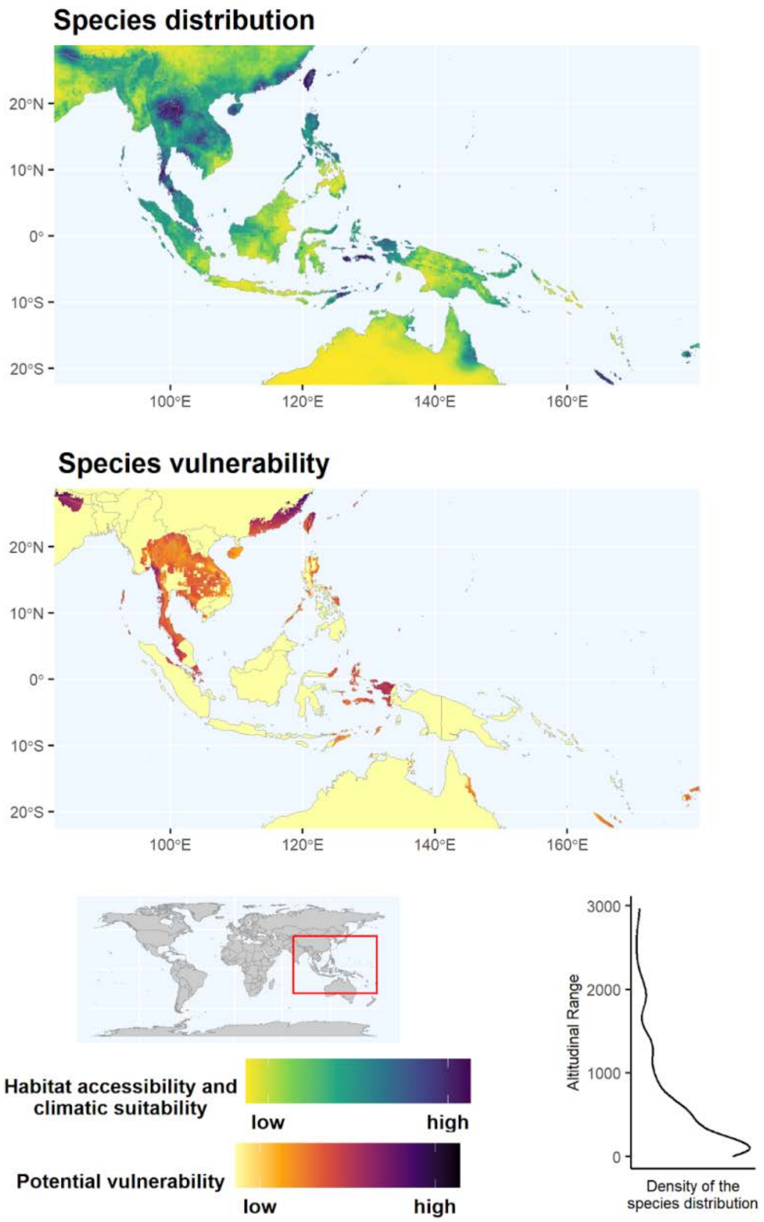
C. quadripinnata is a homoiochlorophyllous plant whose distribution comprises Cameroon, Sudan, Ethiopia, Uganda, Rwanda, Kenya, Tanzania, Malawi, Mozambique, Zimbabwe, South Africa (Limpopo, Gauteng, Mpulamanga, Free State, KwaZulu-Natal, E-Cape Prov., W-Cape Prov.), Lesotho, Swaziland, Comoros, Madagascar, Mauritius, N-Yemen. *C. quadripinnata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 7 to 2795 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *C. quadripinnata* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Kenya, South Africa, Lesotho, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Cheilanthes sieberi Kunze
(also cited as *Hemionitis sieberi*)



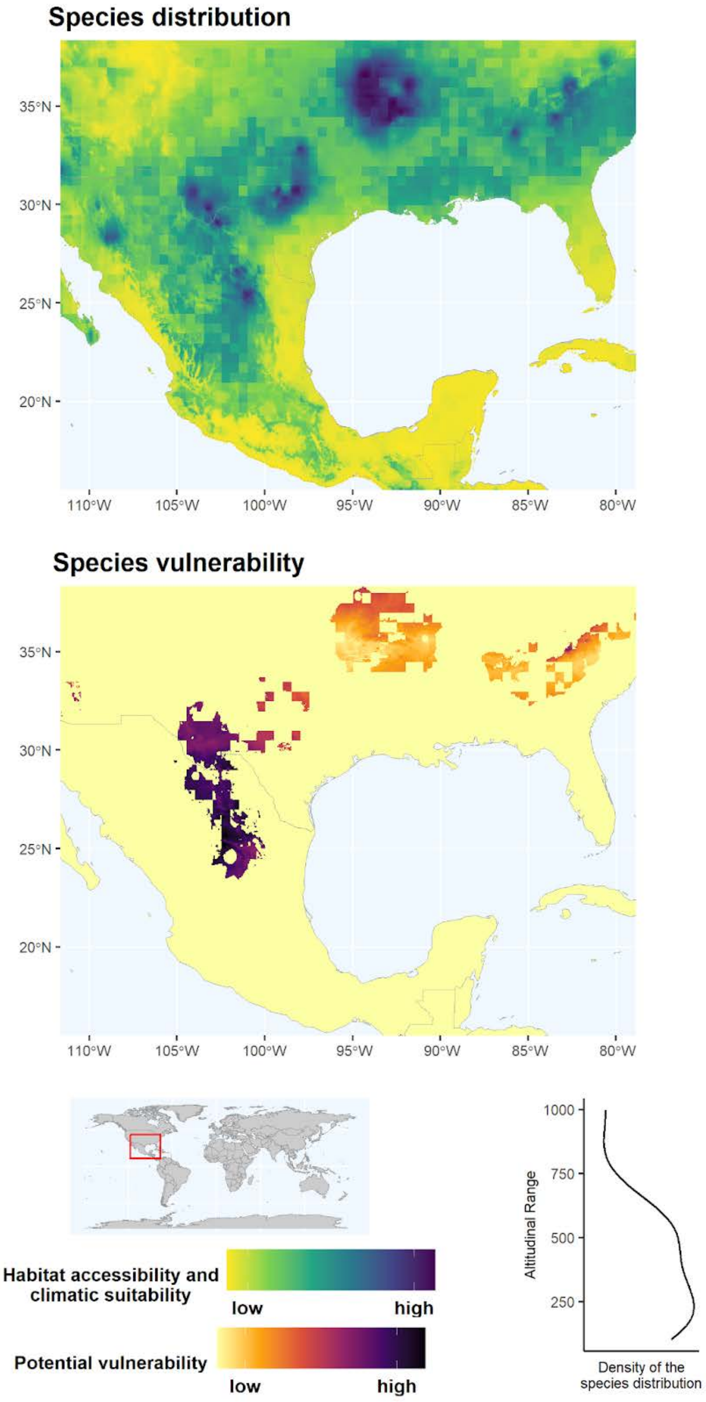
C. sieberi is a homoiochlorophyllous plant whose distribution comprises Australia (Northern Territory, South Australia, Western Australia, Victoria, New South Wales, Tasmania), New Zealand (North Isl., South Isl., Three Kings Isl.), Norfolk Isl., New Caledonia, Isle of Pines, Lord Howe Isl. *C. sieberi* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 2 to 1928 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *C. sieberi* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and 22% of its distribution range is currently found within protected areas.

Cheilanthes tenuifolia (Burm. f.) Sw.
(also cited as *Hemionitis tenuifolia*)



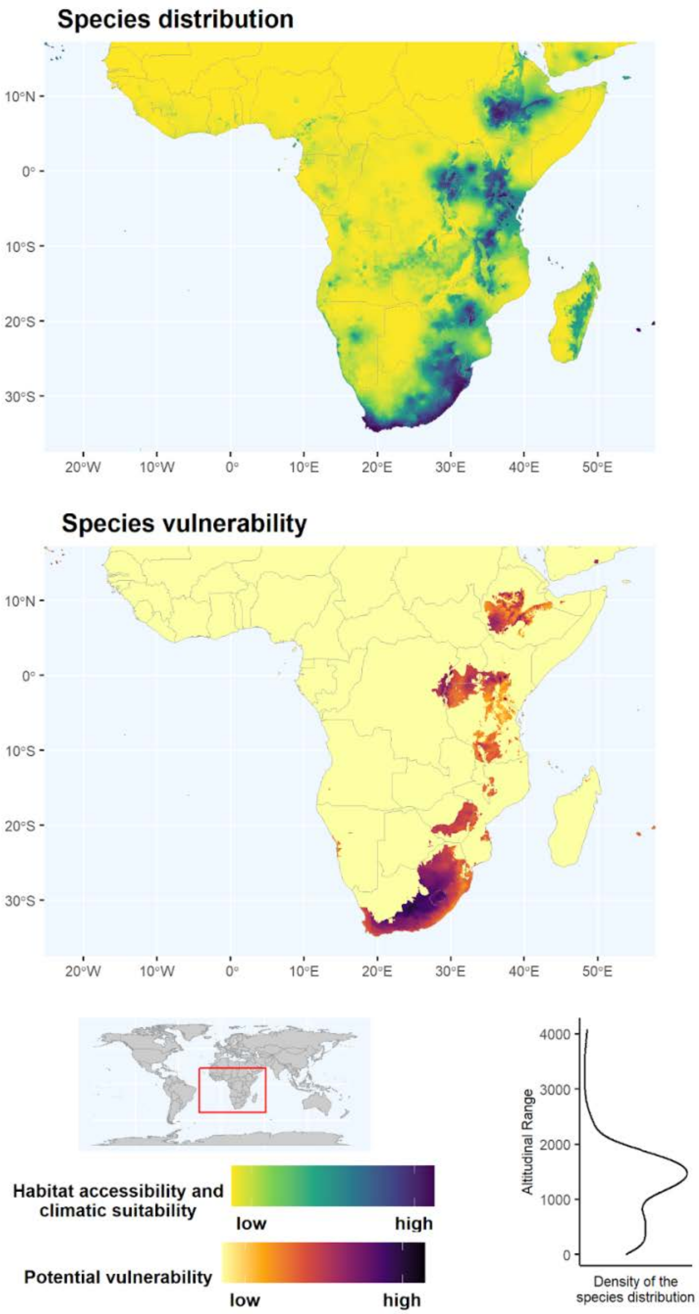
C. tenuifolia is a homoiochlorophyllous plant whose distribution comprises Andaman Is., Assam, Bangladesh, Borneo, Cambodia, Caroline Is., China South-Central, China Southeast, East Himalaya, Fiji, Hainan, India, Laos, Lesser Sunda Is., Malaya, Maluku, Marianas, Marquesas, Myanmar, Nepal, New Caledonia, New Guinea, Northern Territory, Philippines, Queensland, Samoa, Society Is., Solomon Is., Sri Lanka, Taiwan, Thailand, Tonga, Tubuai Is., Vanuatu, Vietnam, West Himalaya. *C. tenuifolia* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 5 to 2968 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. tenuifolia* populations are expected to be potentially more vulnerable to climate change in parts of China, Nepal, Taiwan. This species has not yet been assessed by IUCN, and 20% of its distribution range is currently found within protected areas.

Cheilanthes tomentosa Link
(also cited as *Hemionitis bradburyi*)



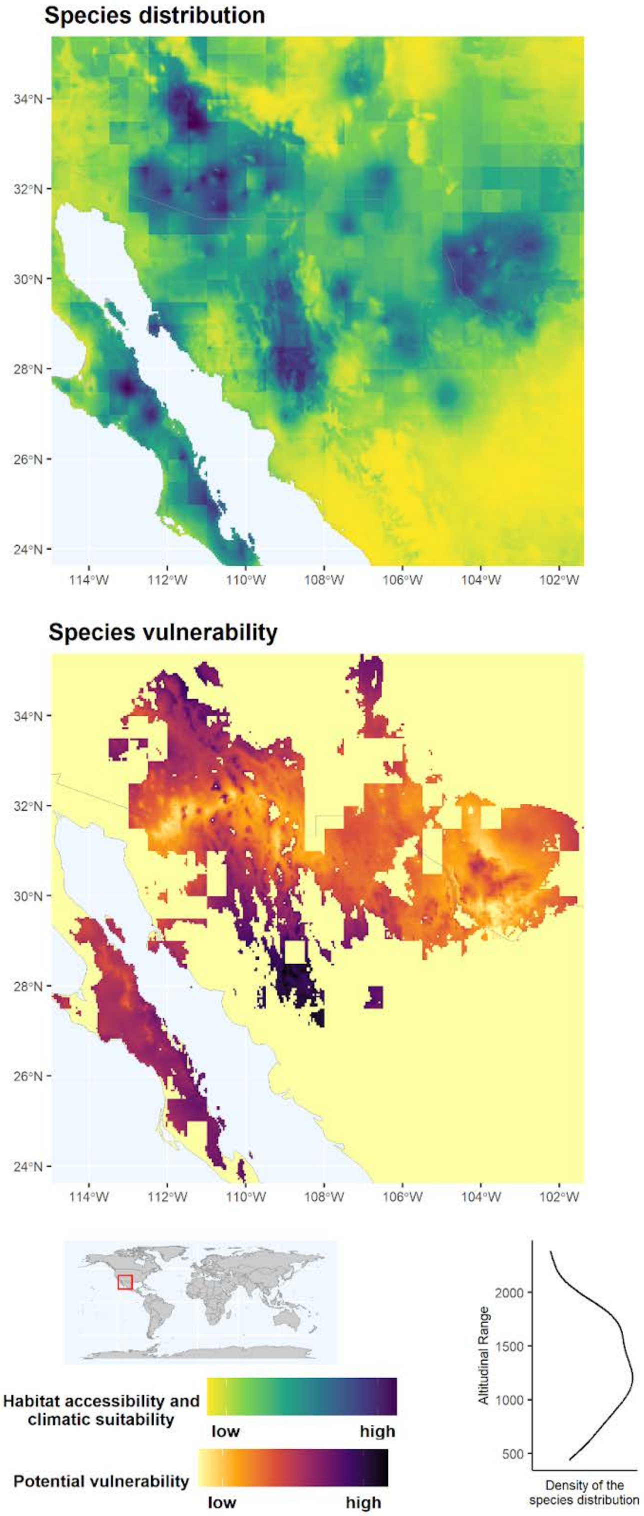
C. tomentosa is a homoiochlorophyllous plant whose distribution comprises Alabama, Arizona, Arkansas, Georgia, Kansas, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Missouri, New Mexico, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia. *C. tomentosa* individuals can be primarily found in arid and warm temperate climates, ranging from 102 to 998 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the drier season is short). *C. tomentosa* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 9% of its distribution range is currently found within protected areas.

Cheilanthes viridis (Forssk.) Sw.
(also cited as *Pellaea viridis* and *Hemionitis viridis*)



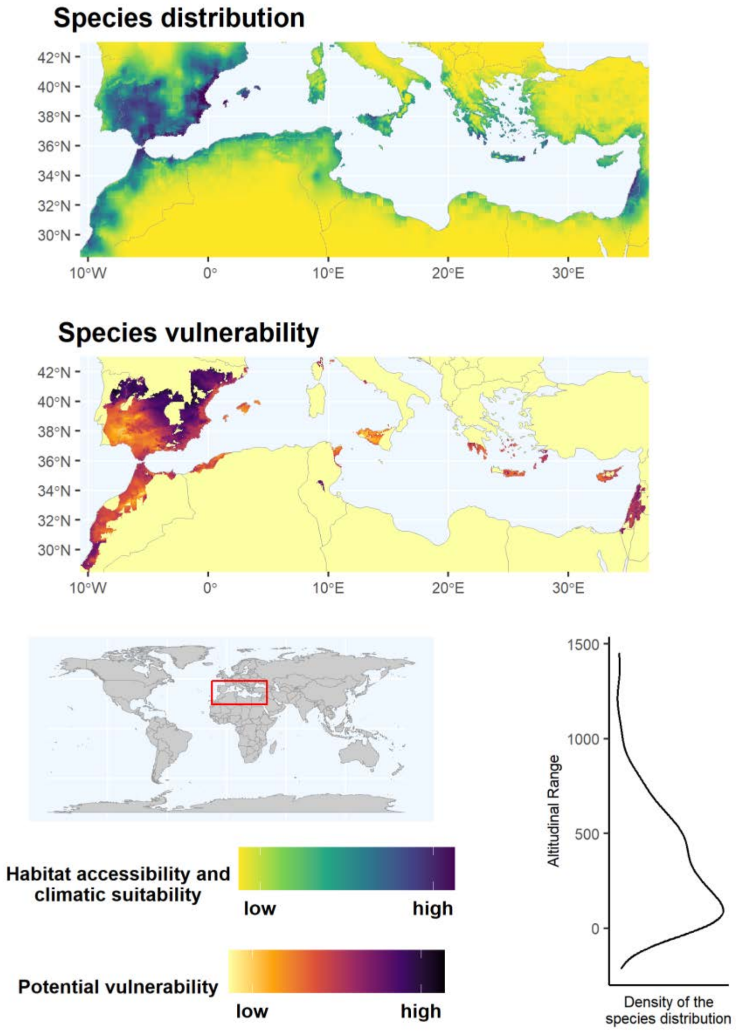
C. viridis is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Burundi, Cape Provinces, Comoros, Ethiopia, Free State, Kenya, KwaZulu-Natal, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Northern Provinces, Rodrigues, Rwanda, Réunion, Saudi Arabia, Seychelles, Socotra, Somalia, Sudan, Swaziland, Tanzania, Uganda, Yemen, Zaïre, Zimbabwe. *C. viridis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 6 to 4086 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is extremely seasonal. *C. viridis* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, South Africa, Lesotho, Tanzania, Uganda. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Cheilanthes wrightii Hook.
(also cited as *Hemionitis wrightii*)



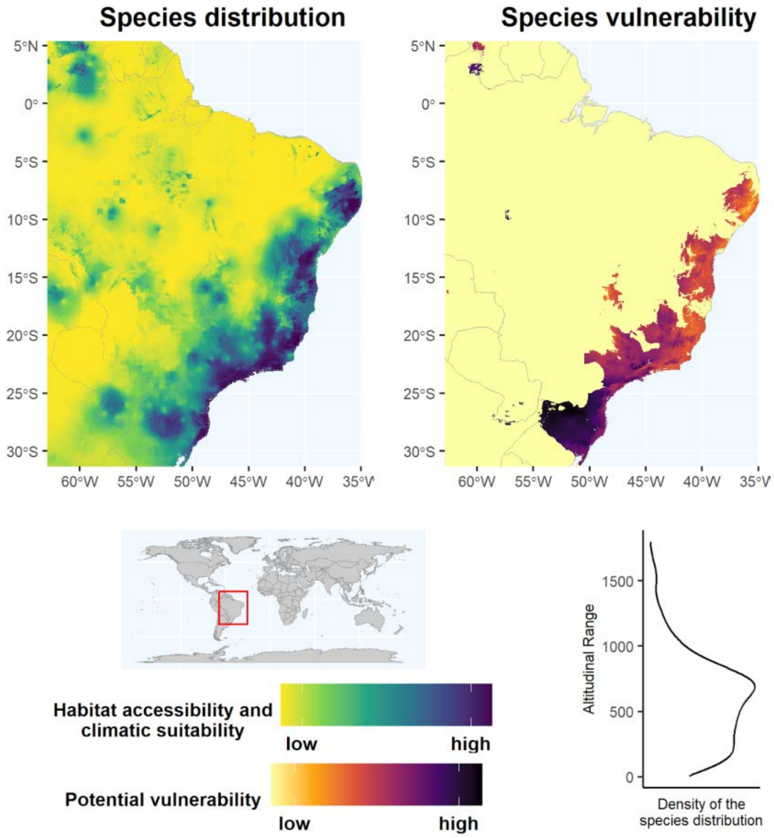
C. wrightii is a homoiochlorophyllous plant whose distribution comprises Arizona, Mexico Northeast, Mexico Northwest, New Mexico, Texas. *C. wrightii* individuals can be primarily found in arid climates, ranging from 439 to 2387 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *C. wrightii* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

Cosentinia vellea (Aiton) Tod.
(also cited as *Cheilanthes vellea*)



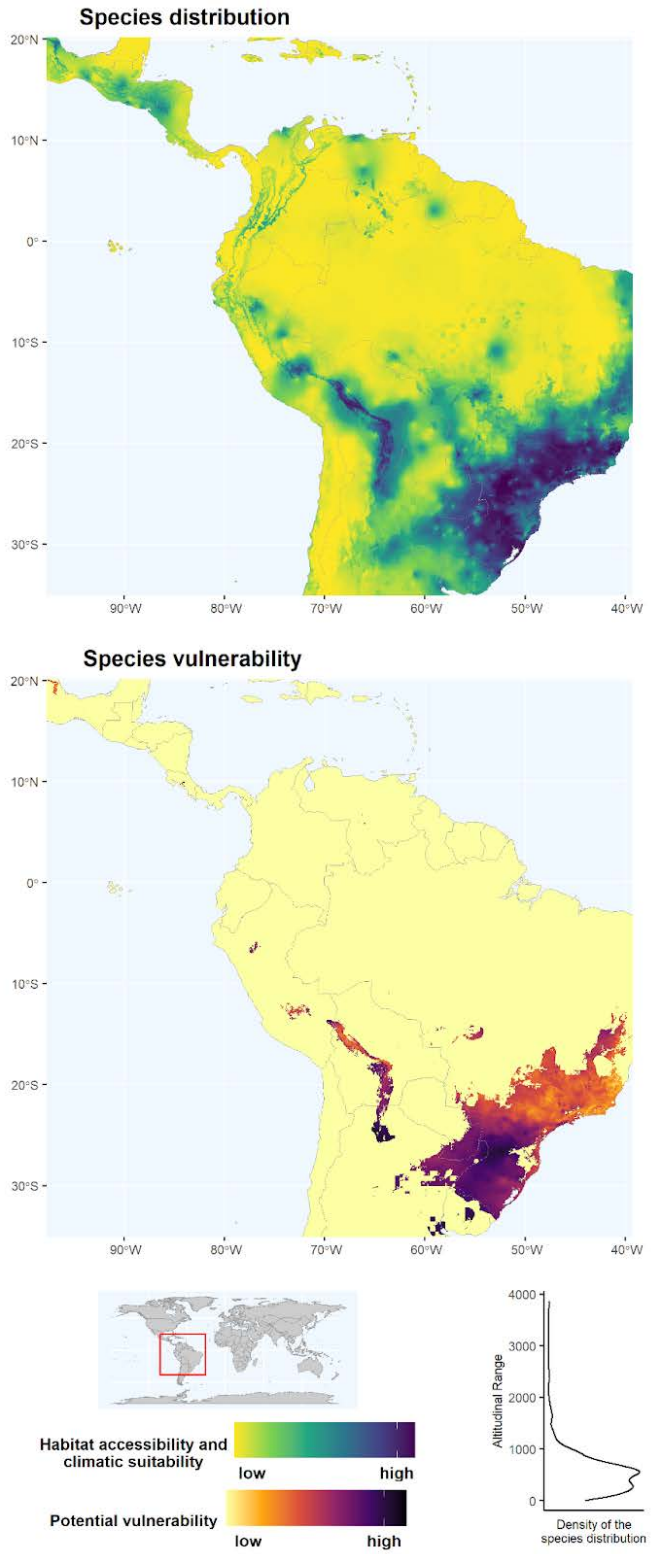
C. vellea is a homoiochlorophyllous plant whose distribution comprises Afghanistan, Algeria, Baleares, Canary Is., Cape Verde, Chad, Corse, Cyprus, Egypt, Ethiopia, France, Greece, Iran, Italy, Kriti, Lebanon-Syria, Libya, Madeira, Morocco, Oman, Pakistan, Palestine, Portugal, Sardegna, Saudi Arabia, Sicilia, Sinai, Somalia, Spain, Sudan, Tunisia, Turkey, West Himalaya, Yemen. *C. vellea* individuals can be primarily found in arid and warm temperate climates, ranging from -216 to 1453 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *C. vellea* populations are expected to be potentially more vulnerable to climate change in parts of Lebanon, Portugal, Spain, Tunisia. This species is listed as Least concern by IUCN, although 41% of its distribution range is currently found within protected areas.

Doryopteris collina (Raddi) J. Sm.



D. collina is a homoiochlorophyllous plant whose distribution comprises Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Guyana, Paraguay, Suriname, Trinidad-Tobago. *D. collina* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 8 to 1798 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *D. collina* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Brazil, Guyana, Paraguay. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

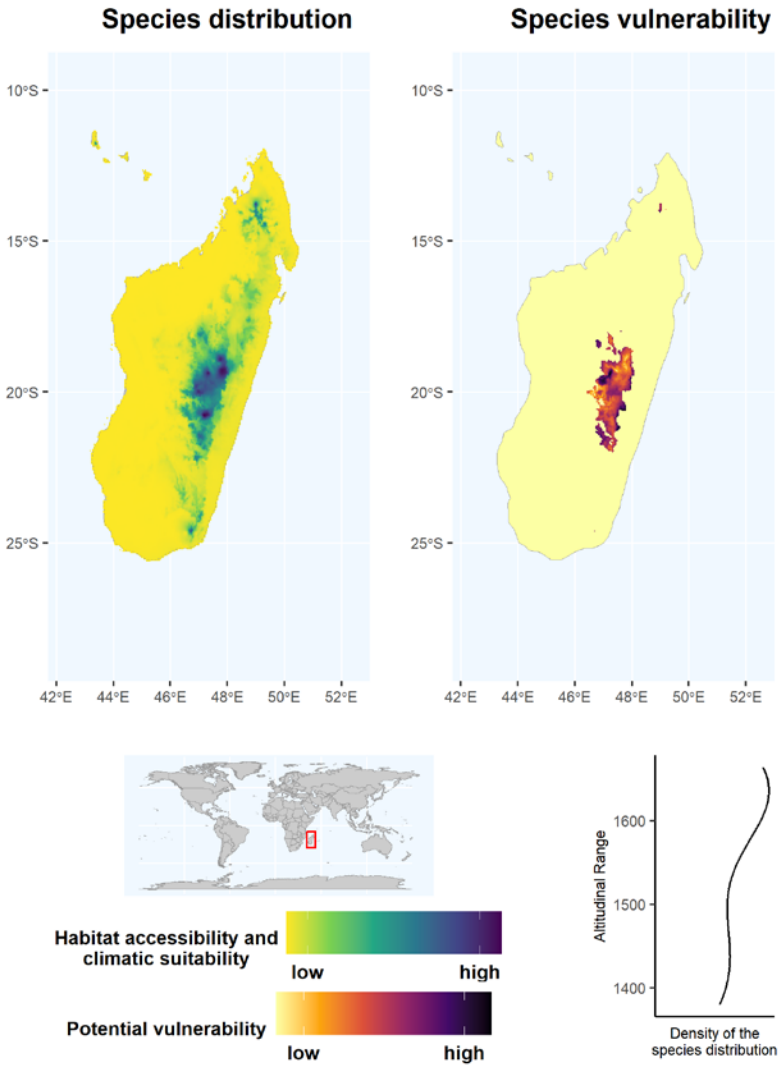
Doryopteris concolor (Langsd. & Fisch.) Kuhn (also cited as *Hemionitis concolor*)



D. concolor is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Argentina South, Bolivia, Brazil North, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Cuba, Ecuador, El Salvador, Galápagos, Guatemala, Honduras, Jamaica, Leeward Is., Mexico Gulf, Mexico Southeast, Mexico Southwest, Netherlands Antilles, Nicaragua, Paraguay, Peru, Uruguay, Venezuela, Windward Is. *D. concolor* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 4 to 3865 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *D. concolor* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Brazil, Costa Rica, Paraguay, Peru, Uruguay, Venezuela. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

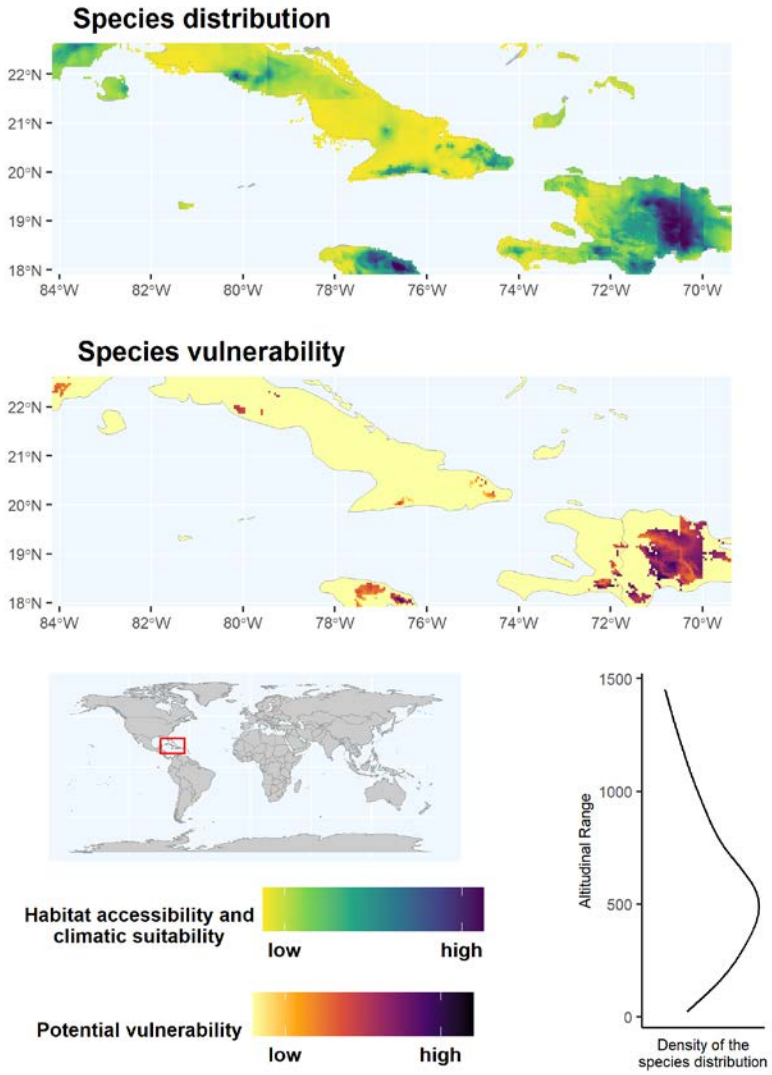
Doryopteris kitchingii (Baker) Bonap.

(also cited as *Hemionitis kitchingii*)



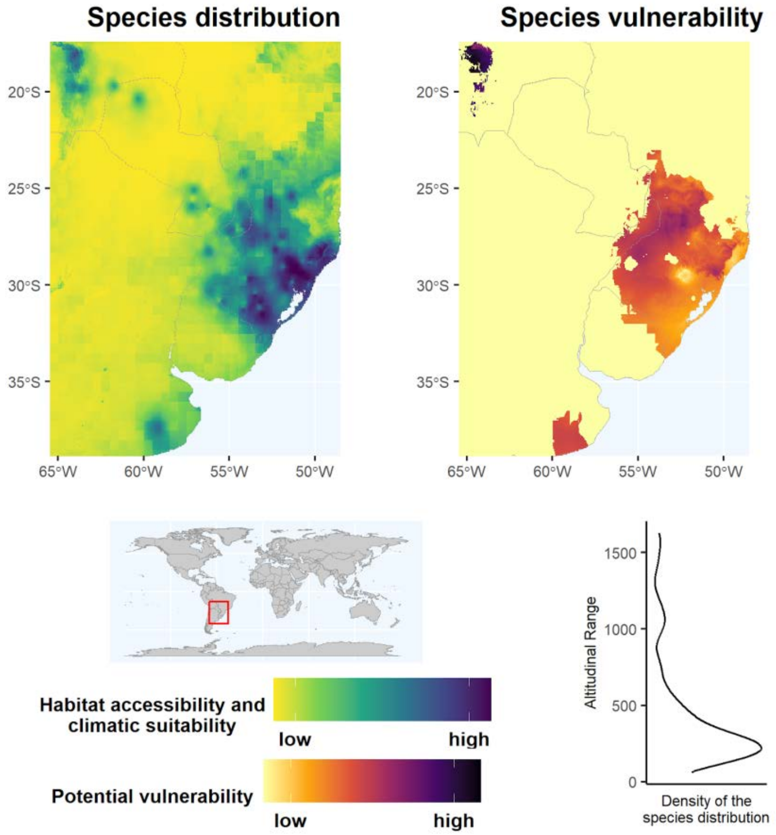
D. kitchingii is a homoiochlorophyllous plant whose distribution is restricted to Madagascar. *D. kitchingii* individuals can be primarily found in warm temperate climates, ranging from 1380 to 1664 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *D. kitchingii* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 11% of its distribution range is currently found within protected areas.

Doryopteris pedata (L.) Fée
(also cited as *Hemionitis pedata*)



D. pedata is a homoiochlorophyllous plant whose distribution comprises Cuba, Dominican Republic, Ecuador, Haiti, Jamaica, Leeward Is., Puerto Rico, Venezuela, Windward Is. *D. pedata* individuals can be primarily found in equatorial and warm temperate climates, ranging from 24 to 1451 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *D. pedata* populations are expected to be potentially more vulnerable to climate change in parts of Dominican Republic, Haiti, Jamaica. This species has not yet been assessed by IUCN, and 45% of its distribution range is currently found within protected areas.

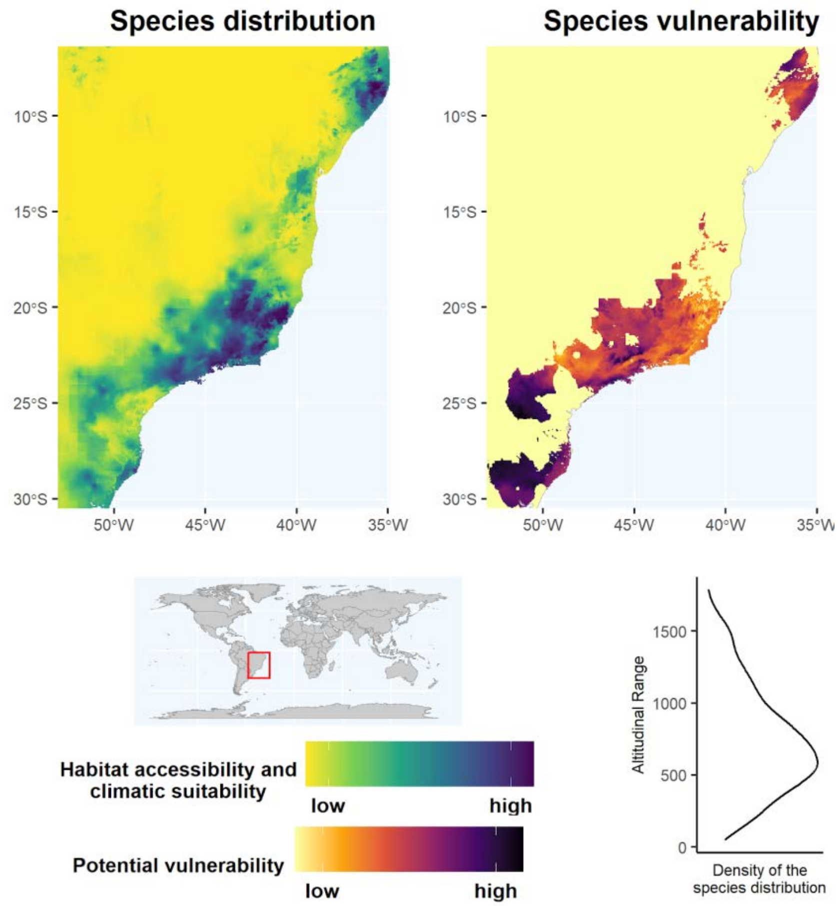
Doryopteris triphylla (Lam.) Christ
(also cited as *Hemionitis triphylla*)



D. triphylla is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil South, Paraguay, Uruguay. *D. triphylla* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 64 to 1628 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *D. triphylla* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia. This species has not yet been assessed by IUCN, and only 9% of its distribution range is currently found within protected areas.

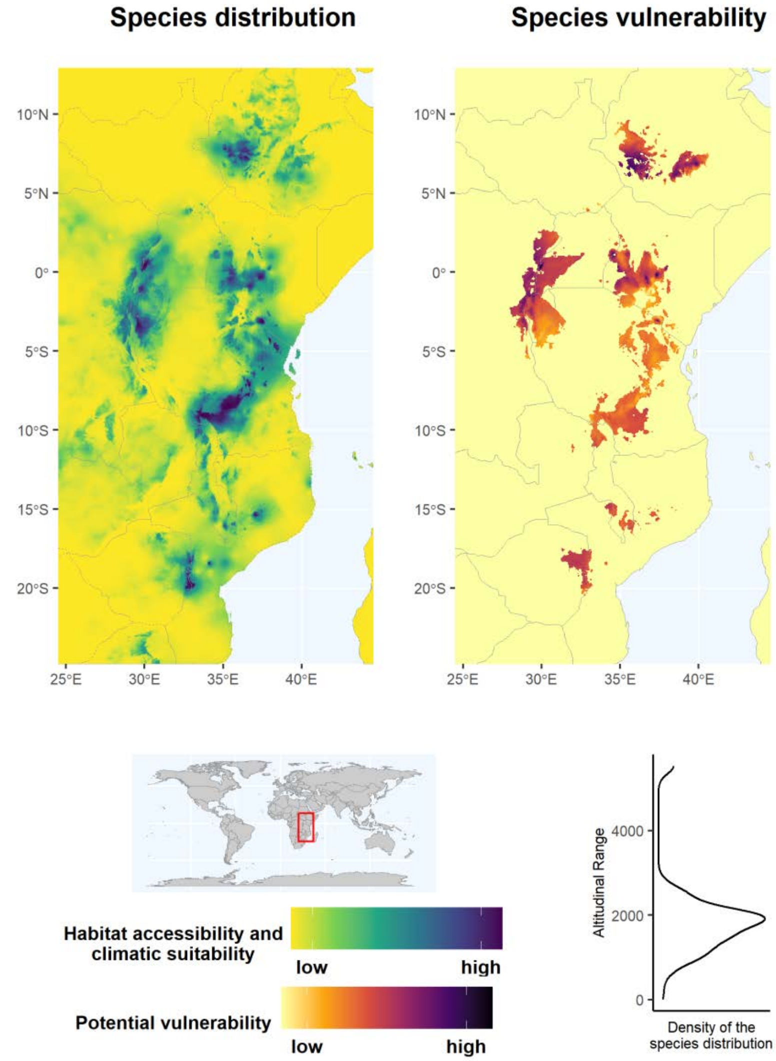
Doryopteris varians (Raddi) Sm.

(also cited as *Hemionitis varians*)



D. varians is a homoiochlorophyllous plant whose distribution comprises Brazil Northeast, Brazil Southeast, Guyana. *D. varians* individuals can be primarily found in equatorial and warm temperate climates, ranging from 50 to 1789 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *D. varians* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

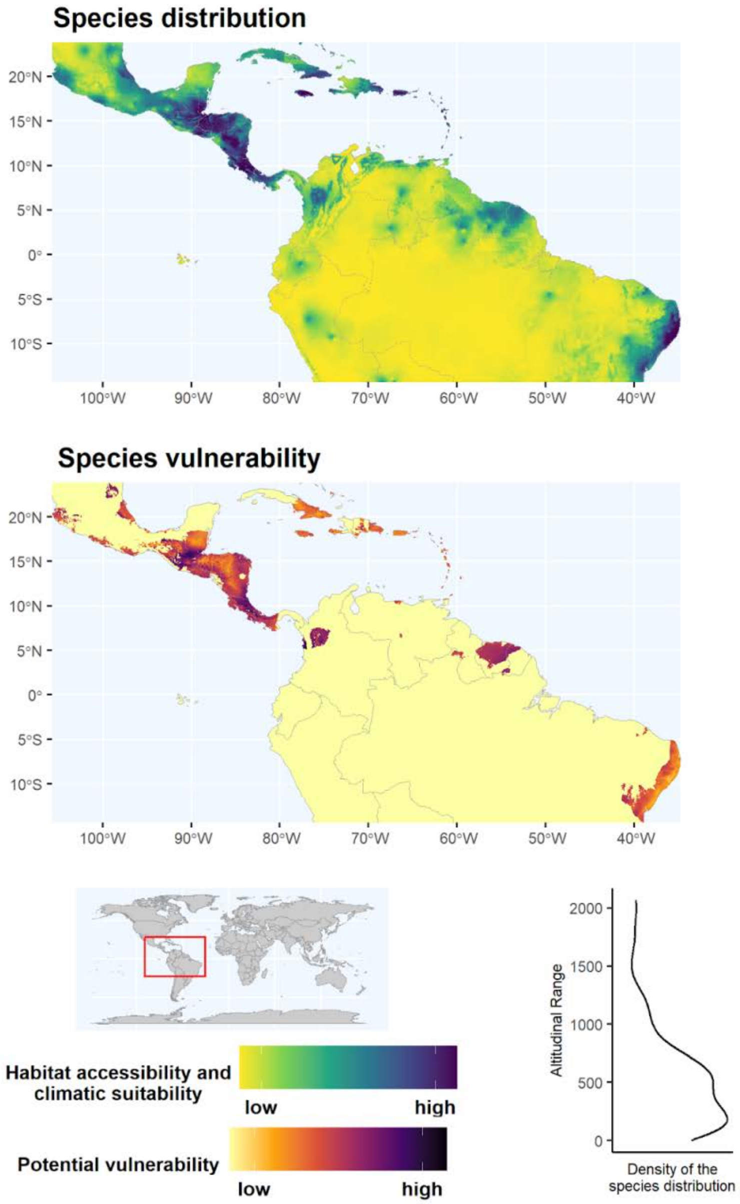
Haplopteris volkensii (Hieron.) E.H. Crane
(also cited as *Vittaria volkensii*)



H. volkensii is a plant whose distribution comprises Ethiopia, Kenya, Malawi, Mozambique, Sudan, Tanzania, Uganda, Zaïre, Zimbabwe. *H. volkensii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 13 to 5529 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *H. volkensii* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Ethiopia, Kenya, Tanzania, Uganda. This species has not yet been assessed by IUCN, and 30% of its distribution range is currently found within protected areas.

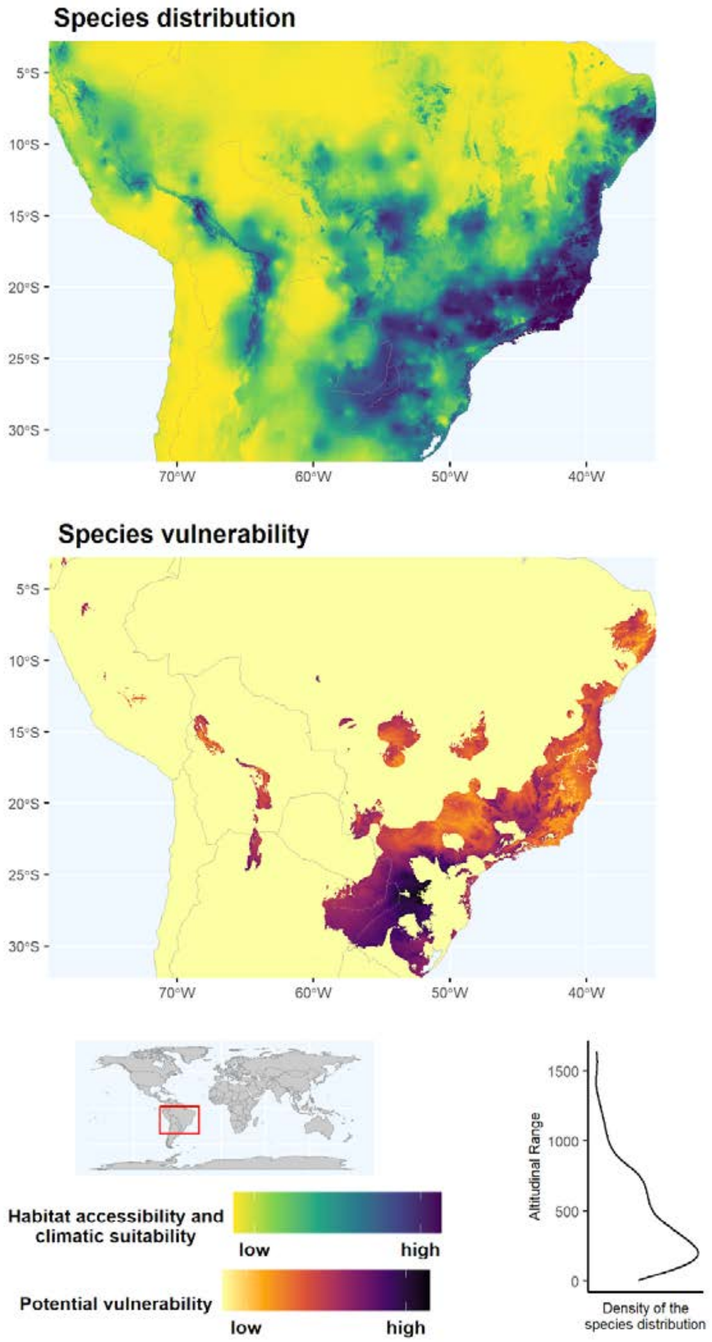
Hemionitis palmata L.

(also cited as *Pellaea cordata* and *Hemionitis paradoxa*)



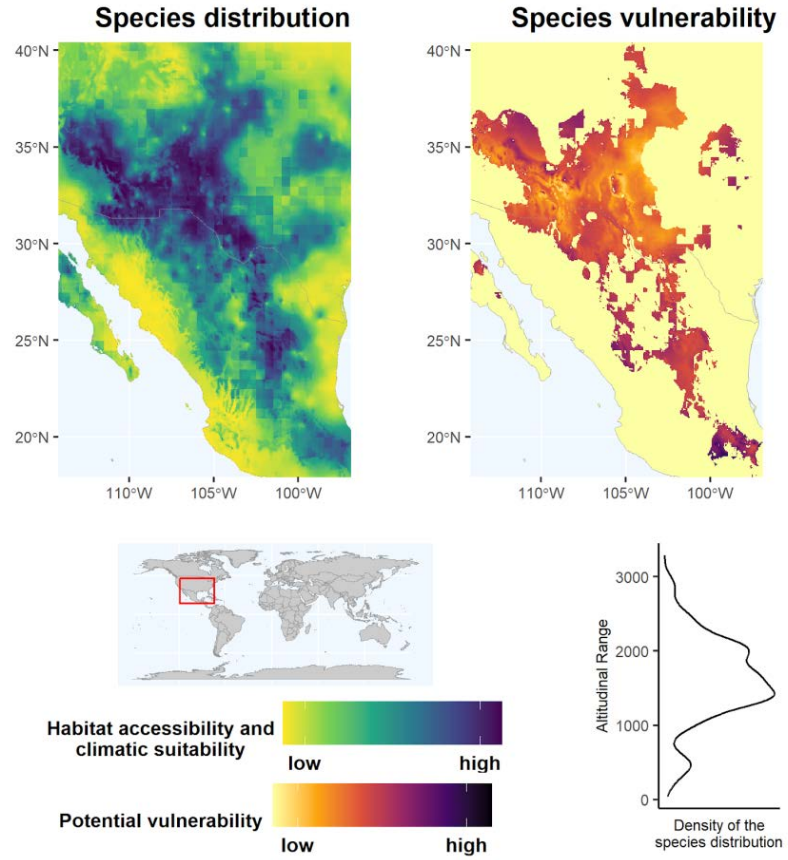
H. palmata is a plant whose distribution comprises Belize, Bolivia, Brazil Northeast, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, French Guiana, Galápagos, Guatemala, Guyana, Honduras, Jamaica, Leeward Is., Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Peru, Puerto Rico, Suriname, Venezuela, Windward Is. *H. palmata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 2 to 2068 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *H. palmata* populations are expected to be potentially more vulnerable to climate change in parts of Belize, Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

Hemionitis tomentosa (Lam.) Raddi



H. tomentosa is a plant whose distribution comprises Argentina (Chaco, Corrientes, Entre Rios, Formosa, Jujuy, Misiones, Salta, Santa Fe, Tucuman), S-Brazil (Parana, Rio Grande do Sul, Santa Catarina), Paraguay (Amambay, Canindeyu, Guaira, Pres. Hayes), Peru, Bolivia (Beni, Chuquisaca, La Paz, Santa Cruz, Tarija), WC-Brazil (Distrito Federal), SE-Brazil (Minas Gerais, Espirito Santo, Sao Paulo, Rio de Janeiro), Sri Lanka (I). *H. tomentosa individuals can be primarily found* in equatorial, arid, and warm temperate climates, ranging from 3 to 1637 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *H. tomentosa* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Brazil, Paraguay, Peru. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

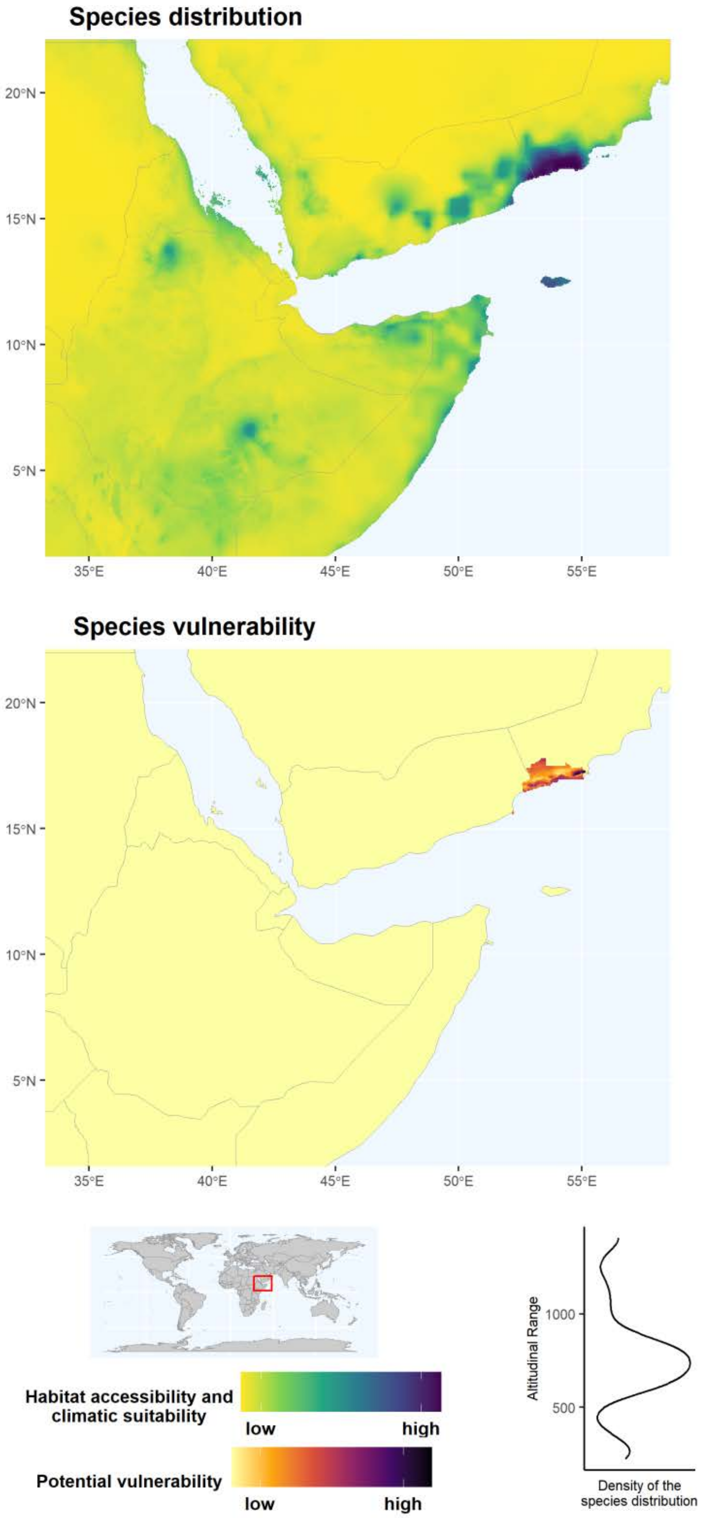
Myriopteris rufa Fée
(also cited as *Cheilanthes eatonii*)



M. rufa is a plant whose distribution comprises Arizona, Arkansas, Colorado, Costa Rica, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, New Mexico, Oklahoma, Texas, Utah, Virginia, West Virginia. *M. rufa* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 46 to 3290 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *M. rufa* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

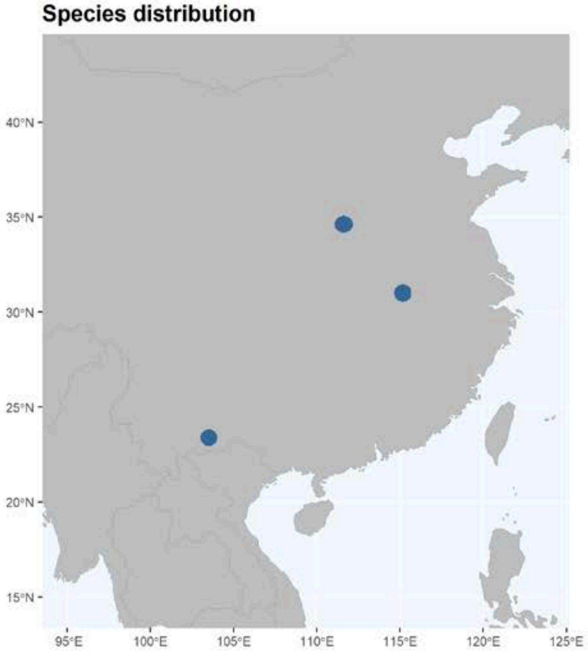
Negripteris scioana (Chiov.) Pic. Serm.

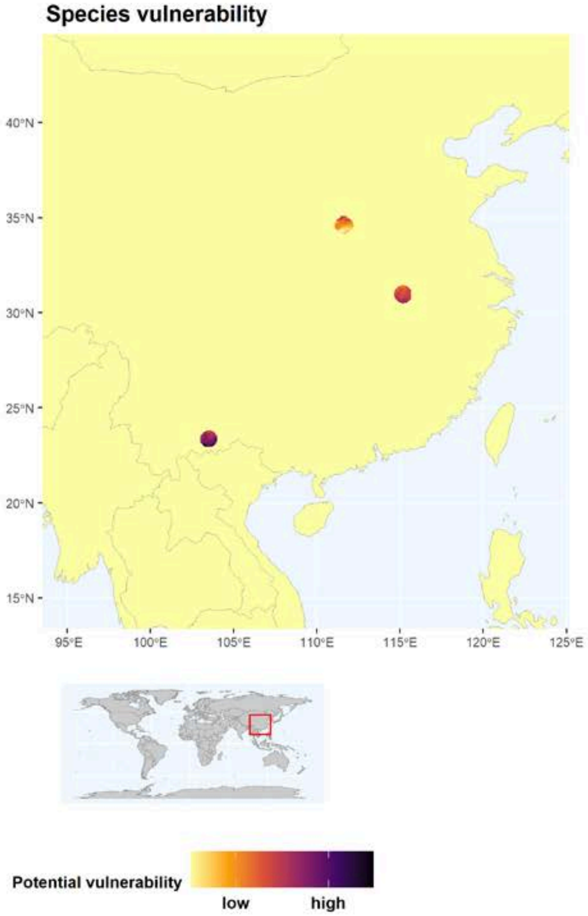
N. scioana is a plant whose distribution comprises Ethiopia, India, Kenya, Oman, Socotra, Somalia, Sudan, Yemen. *N. scioana* individuals can be primarily found in equatorial and arid climates, ranging from 224 to 1407 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *N. scioana* populations are expected to be potentially more vulnerable to climate change in parts of Oman, Yemen. This species has not yet been assessed by IUCN, and 6% of its distribution range is currently found within protected areas.



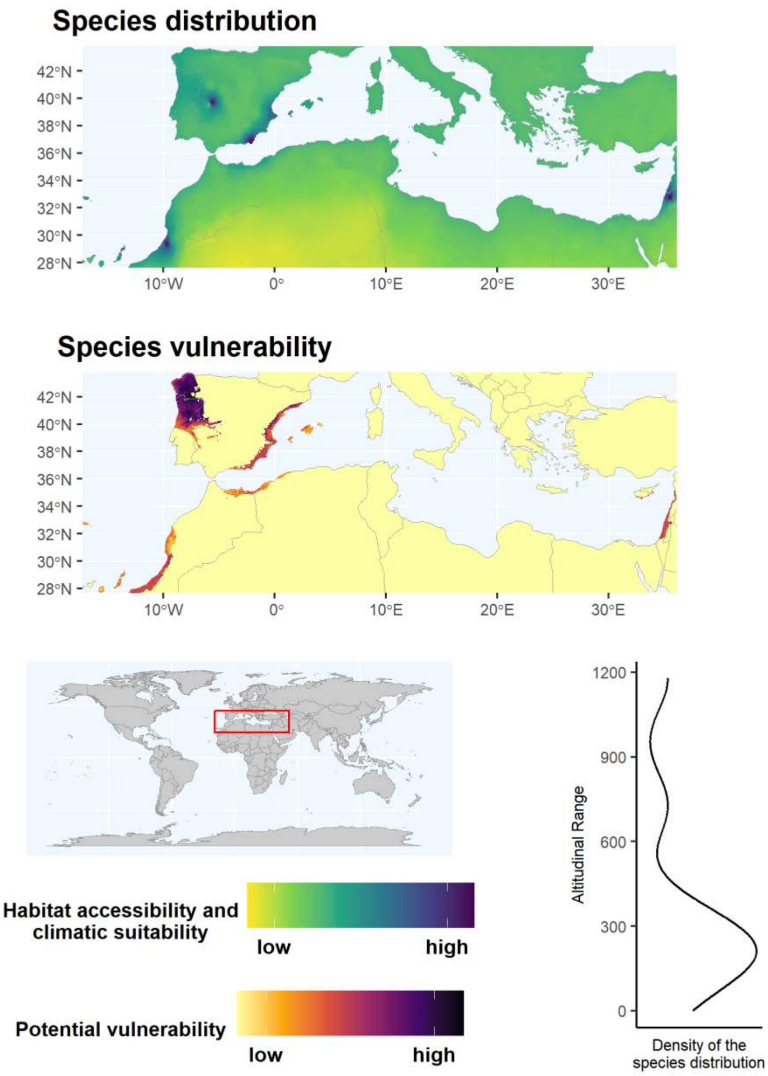
Notholaena dipinnata Fraser-Jenk.

N. dipinnata is a plant whose distribution comprises China North-Central, China South-Central, East Himalaya, Nepal, Tibet. *N. dipinnata* individuals can be primarily found in warm temperate climates, circa 1803 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime. More occurrence points are needed for a consistent evaluation of the conservation of *N. dipinnata* populations. This species has not yet been assessed by IUCN, and none of its distribution range is currently found within protected areas.


Species distribution


Species vulnerability

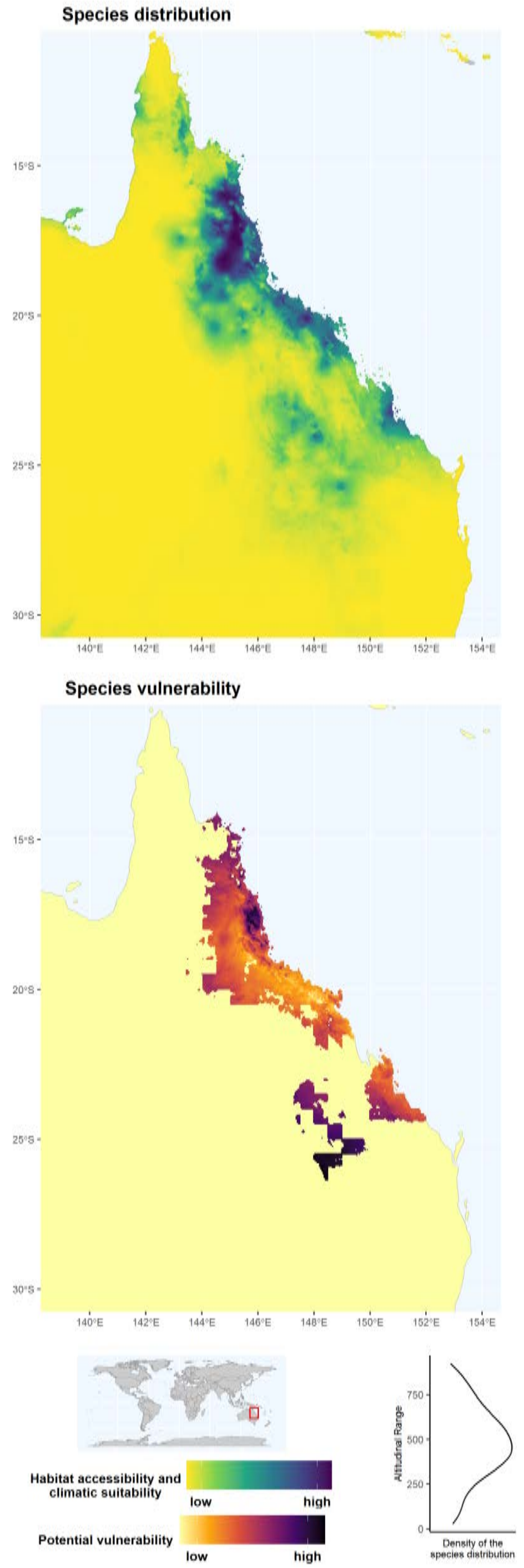
Notholaena lanuginosa Desv. ex Poir.



N. lanuginosa is a plant whose distribution comprises Algeria, Baleares, Corse, Cyprus, Egypt, Ethiopia, France, Greece, Iran, Italy, Kriti, Lebanon-Syria, Libya, Morocco, Oman, Palestine, Portugal, Sardegna, Saudi Arabia, Sicilia, Sinai, Somalia, Spain, Sudan, Tunisia, Turkey, Yemen. *N. lanuginosa* individuals can be primarily found in arid and warm temperate climates, ranging from 0 to 1179 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *N. lanuginosa* populations are expected to be potentially more vulnerable to climate change in parts of Portugal, Spain. This species has not yet been assessed by IUCN, and only 42% of its distribution range is currently found within protected areas.

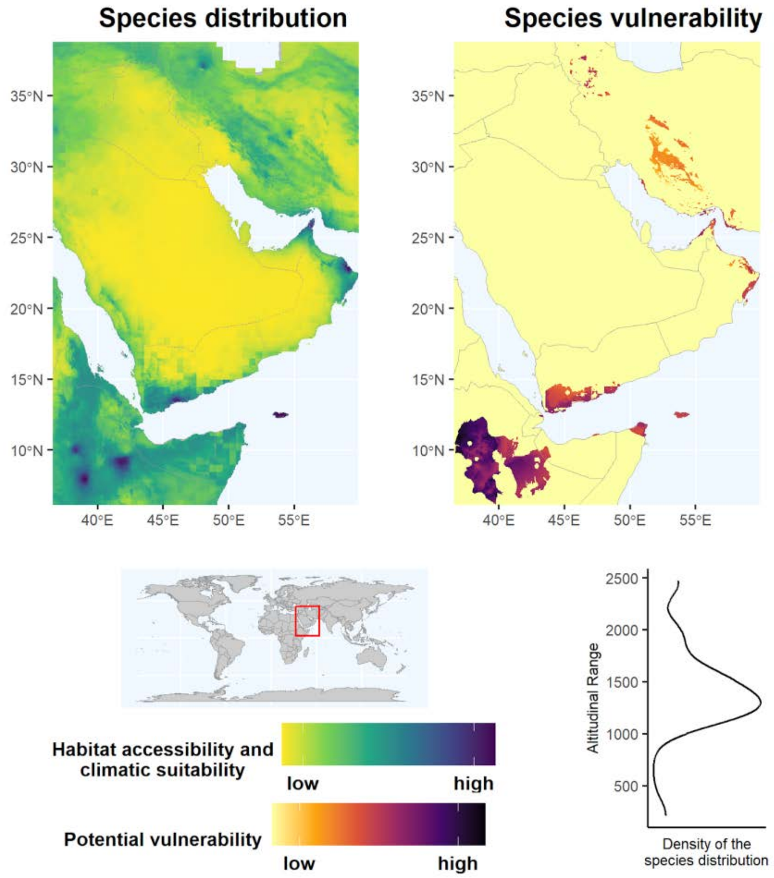
Notholaena muelleri (Hook.) Fraser-Jenk.

(also cited as *Paraceterach muelleri* and *Hemionitis muelleri*)



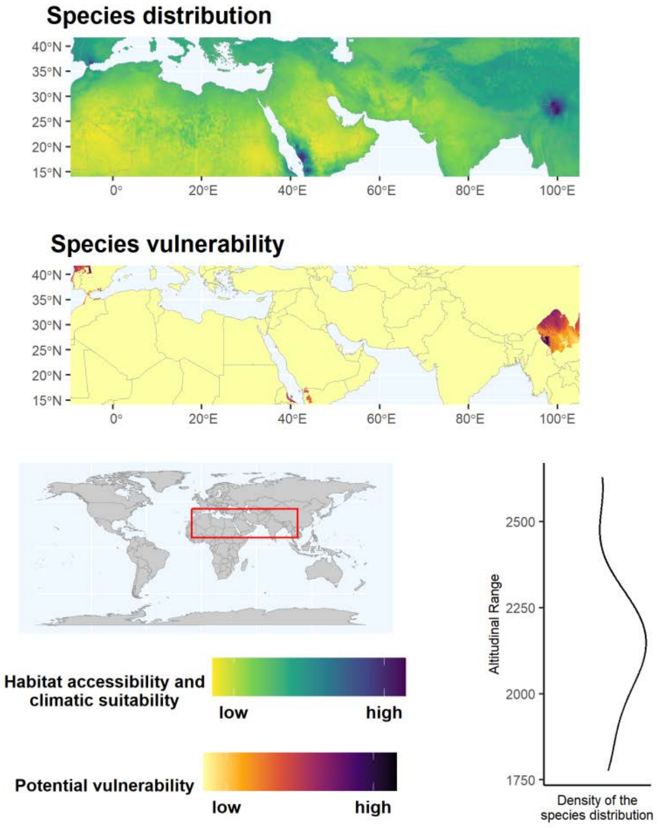
N. muelleri is a homoiochlorophyllous plant whose distribution is restricted to Australia. *N. muelleri* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 28 to 924 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *N. muelleri* populations are expected to be potentially more vulnerable to climate change in parts of Australia. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Onychium divaricatum (Poir.) Alston



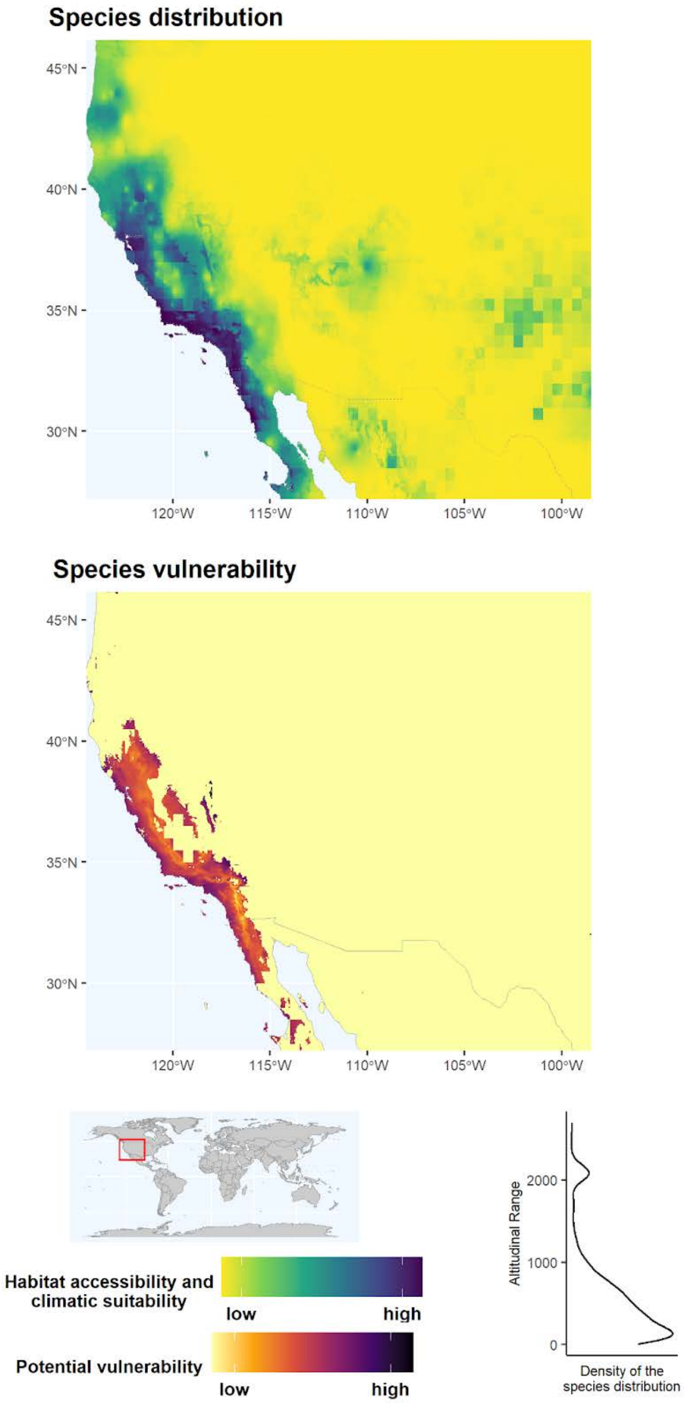
O. divaricatum is a plant whose distribution comprises Djibouti, Ethiopia, Gulf States, Iran, Oman, Saudi Arabia, Socotra, Somalia, Sudan, Yemen. *O. divaricatum* individuals can be primarily found in arid and warm temperate climates, ranging from 213 to 2475 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *O. divaricatum* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Oman. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

Paragymnopteris marantae (L.) K.H. Shing
(also cited as *Paraceterach marantae*, *Notholaena marantae*, and *Hemionitis marantae*)



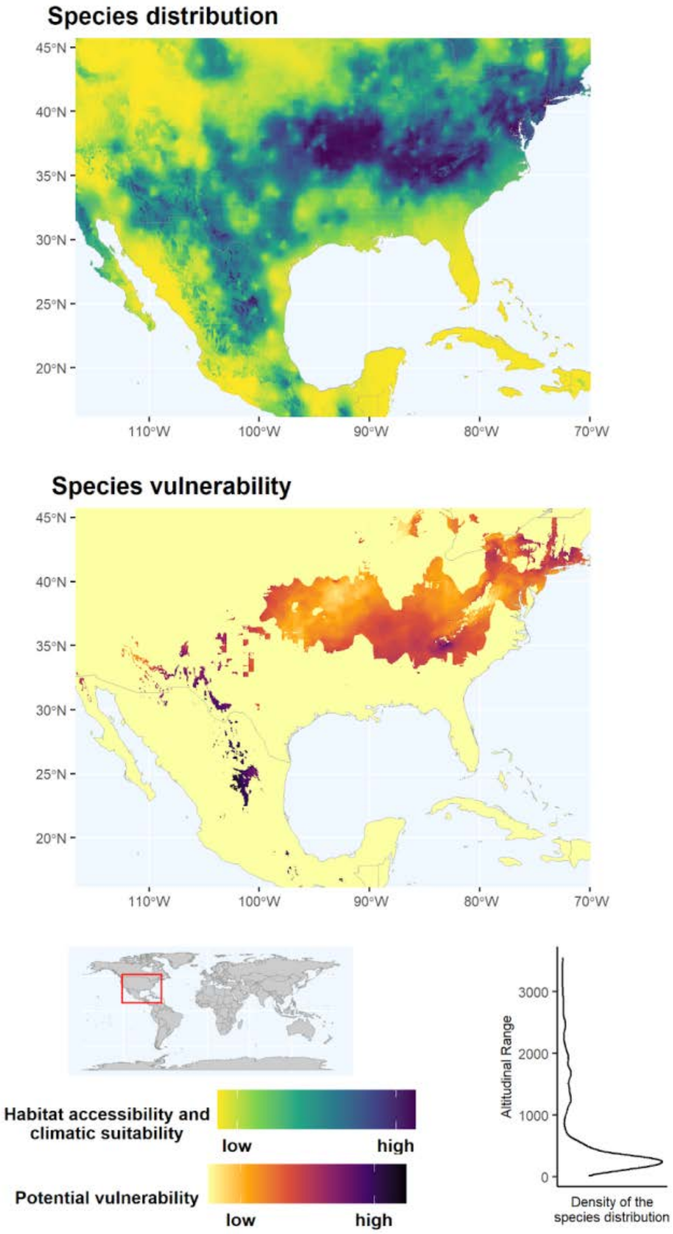
P. marantae is a homoiochlorophyllous plant whose distribution comprises Albania, Algeria, Austria, Bulgaria, China South-Central, Corse, Cyprus, East Himalaya, Eritrea, Ethiopia, France, Greece, Hungary, Iran, Italy, Kenya, Krym, Lebanon-Syria, Morocco, Nepal, Portugal, Romania, Saudi Arabia, Spain, Switzerland, Tanzania, Tibet, Transcaucasus, Turkey, West Himalaya, Yemen, Yugoslavia. *P. marantae* individuals can be primarily found in arid climates, ranging from 1777 to 2628 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *P. marantae* populations are expected to be potentially more vulnerable to climate change in parts of Burma, India, Spain. This species is listed as Near Threatened by IUCN, and only 13% of its distribution range is currently found within protected areas.

Pellaea andromedifolia (Kaulf.) Fée
(also cited as *Hemionitis andromedifolia*)



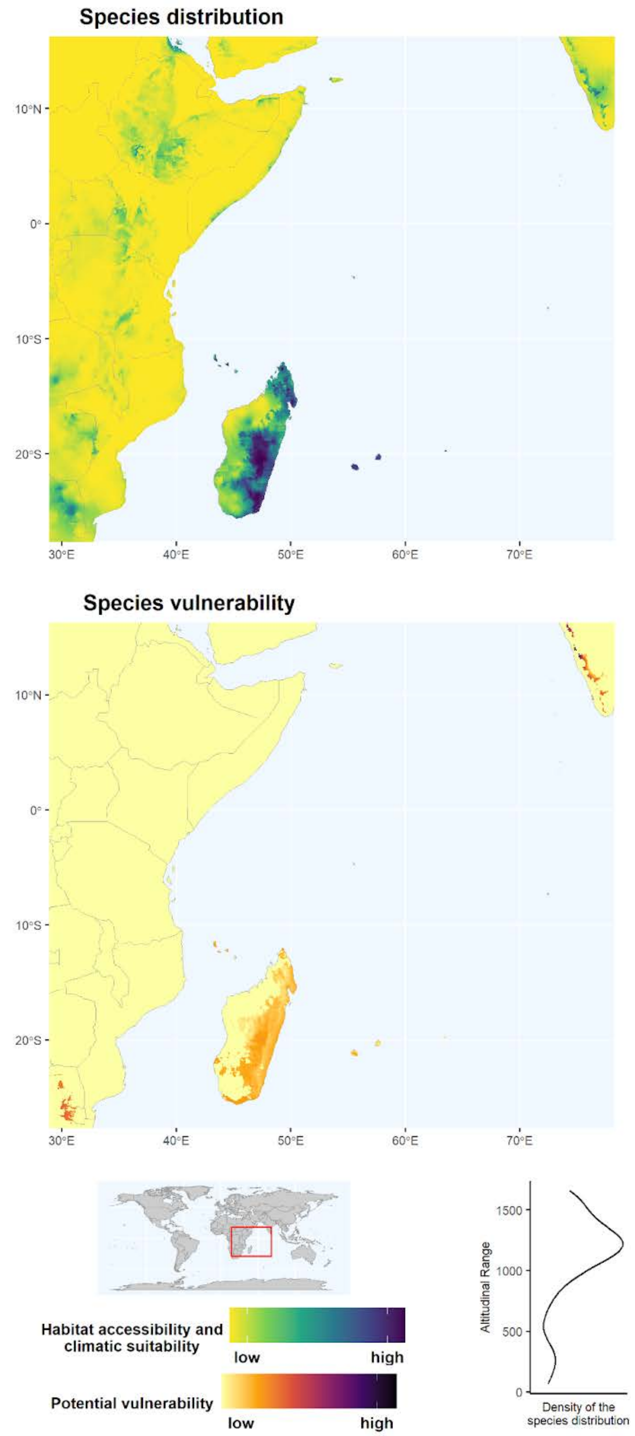
P. andromedifolia is a plant whose distribution comprises California, Mexico Northwest, Oregon. *P. andromedifolia* individuals can be primarily found in arid and warm temperate climates, ranging from 3 to 2702 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. andromedifolia* populations are expected to be potentially more vulnerable to climate change in parts of United States. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Pellaea atropurpurea (L.) Link
(also cited as *Hemionitis atropurpurea*)



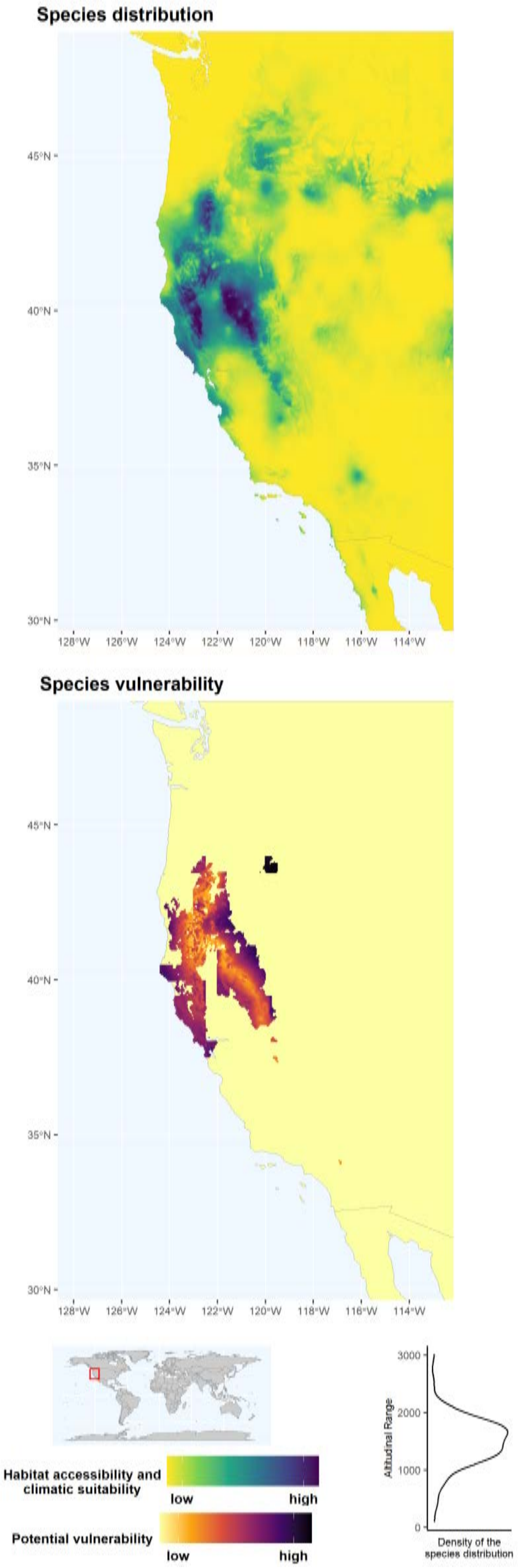
P. atropurpurea is a homoiochlorophyllous plant whose distribution comprises Alabama, Arizona, Arkansas, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Guatemala, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Ontario, Pennsylvania, Québec, Rhode I., South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, West Virginia, Wisconsin, Wyoming. *P. atropurpurea* individuals can be primarily found in equatorial, arid, warm temperate, and snow climates, ranging from 18 to 3555 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. atropurpurea* populations are expected to be potentially more vulnerable to climate change in parts of Canada, Mexico, United States. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

Pellaea boivinii Hook.
(also cited as *Hemionitis boivinii*)



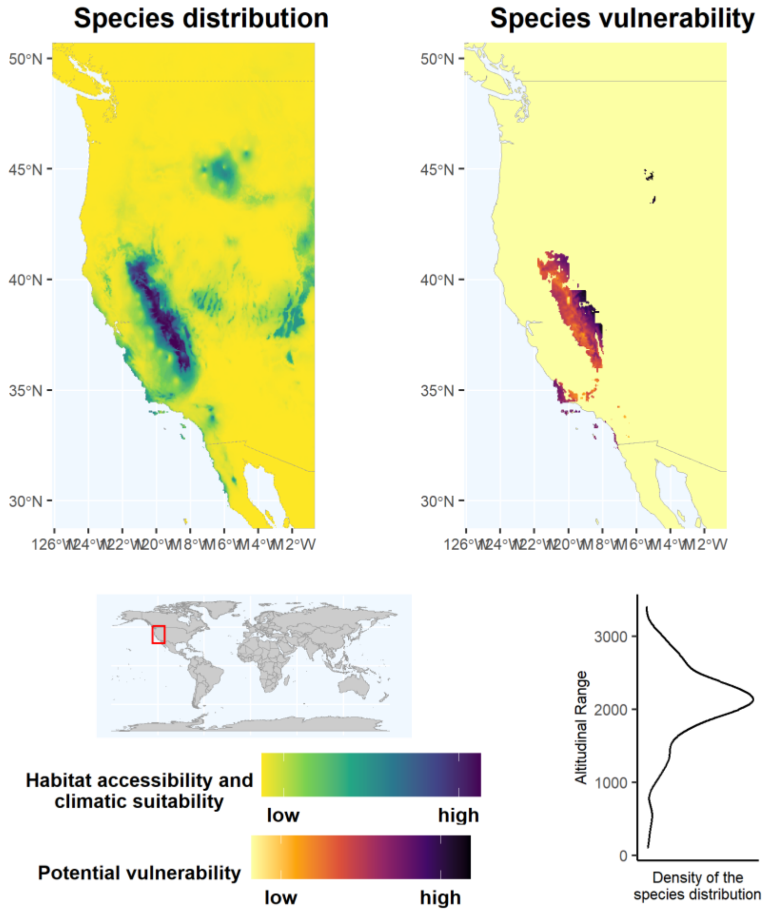
P. boivinii is a homoiochlorophyllous plant whose distribution comprises Botswana, Comoros, India, Kenya, Madagascar, Mauritius, Northern Provinces, Sri Lanka, Tanzania, Zambia, Zimbabwe. *P. boivinii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 68 to 1661 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. boivinii* populations are expected to be potentially more vulnerable to climate change in parts of India. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Pellaea brachyptera (T. Moore) Baker



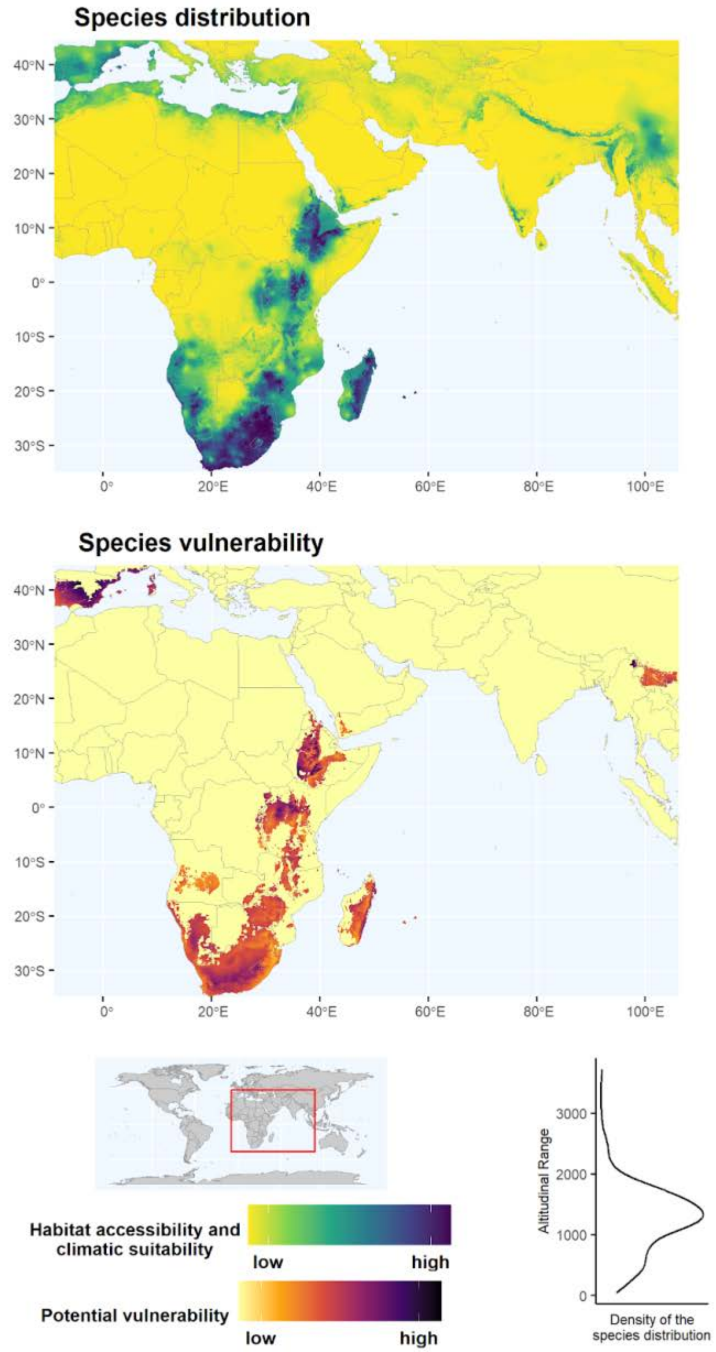
P. brachyptera is a plant whose distribution comprises California, Oregon, Washington. *P. brachyptera* individuals can be primarily found in arid and warm temperate climates, ranging from 96 to 3018 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. brachyptera* populations are expected to be potentially more vulnerable to climate change in parts of United States. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Pellaea bridgesii Hook.



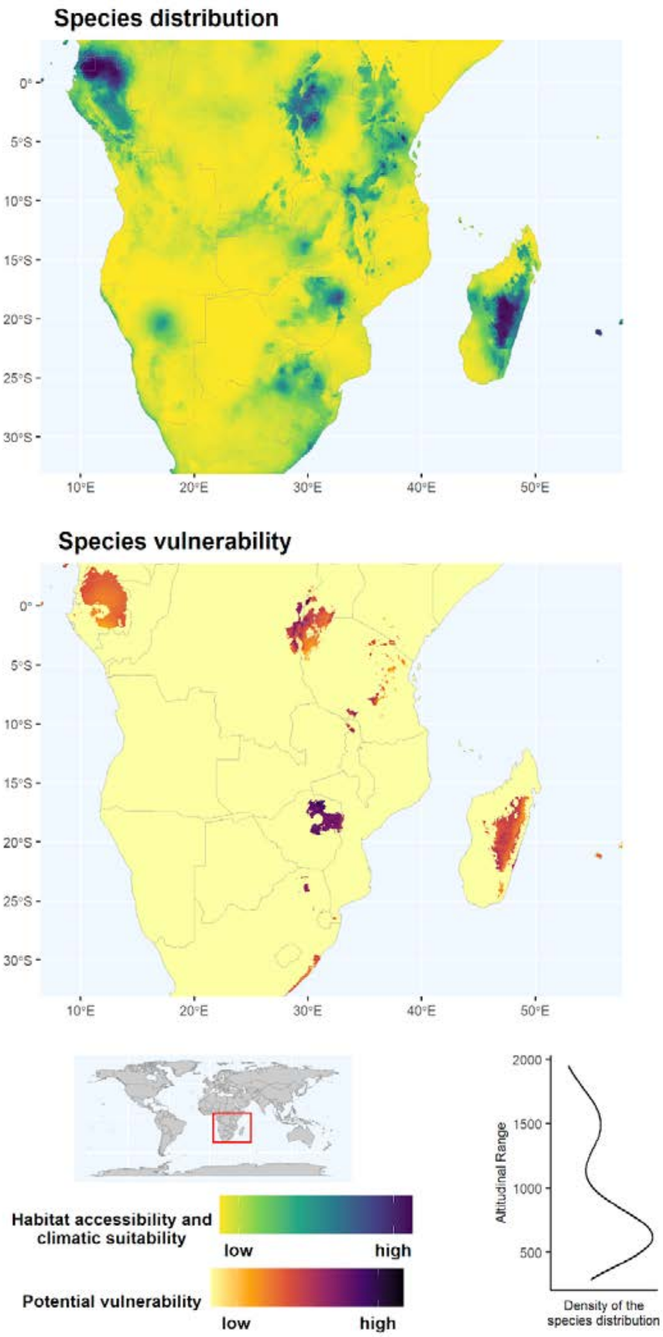
P. bridgesii is a plant whose distribution comprises California, Idaho, Nevada, Oregon. *P. bridgesii* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 96 to 3406 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *P. bridgesii* populations are expected to be potentially more vulnerable to climate change in parts of United States. This species has not yet been assessed by IUCN, and only 35% of its distribution range is currently found within protected areas.

Pellaea calomelanos (Sw.) Link
(also cited as *Hemionitis calomelanos*)



P. calomelanos is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Burundi, Cape Provinces, China South-Central, Comoros, Ethiopia, Free State, Kenya, KwaZulu-Natal, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Nepal, Pakistan, Rwanda, Réunion, Somalia, Spain, Sudan, Swaziland, Tanzania, Uganda, West Himalaya, Zaïre, Zimbabwe. *P. calomelanos* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 46 to 3728 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. calomelanos* populations are expected to be potentially more vulnerable to climate change in parts of Burma, Ethiopia, France, Italy, Kenya, Portugal, South Africa, Lesotho, Spain, Tanzania, Uganda. This species is listed as Endangered by IUCN, and only 22% of its distribution range is currently found within protected areas.

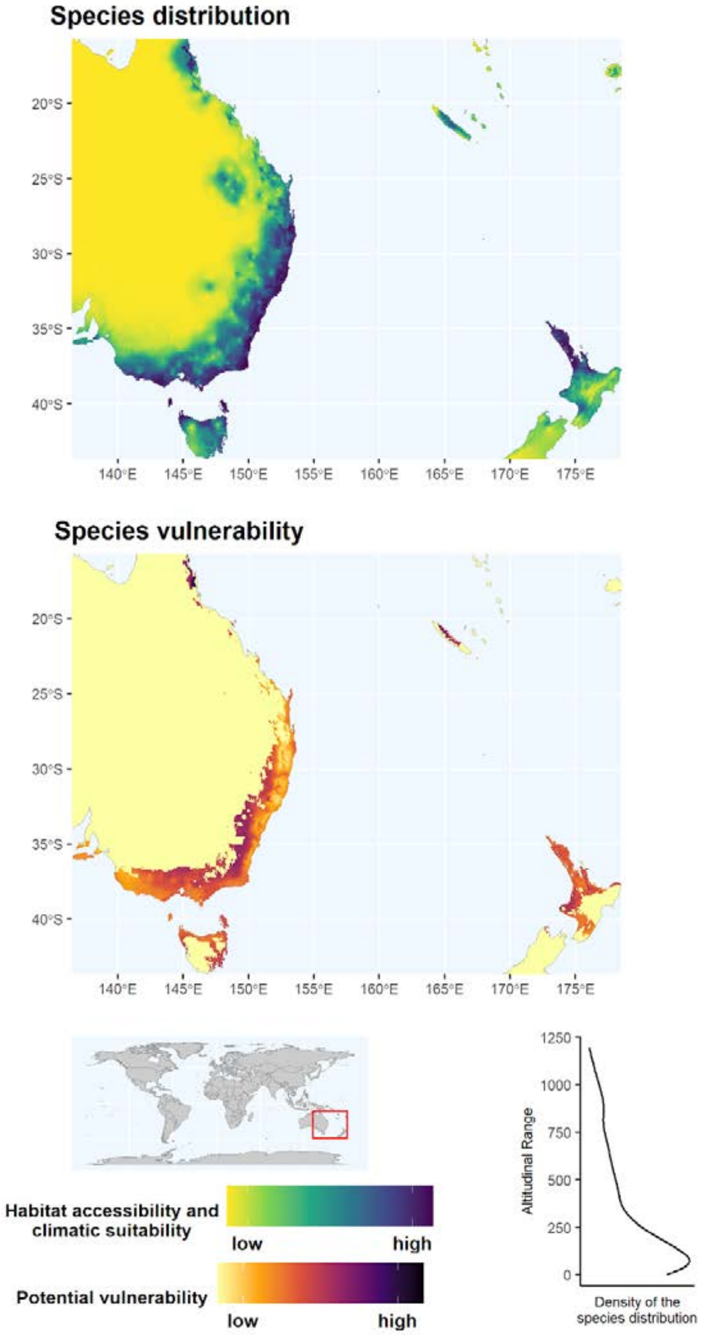
Pellaea dura (Willd.) Hook.
(also cited as *Pellaea schweinfurthii* and *Pellaea doniana*)


Species distribution

Species vulnerability

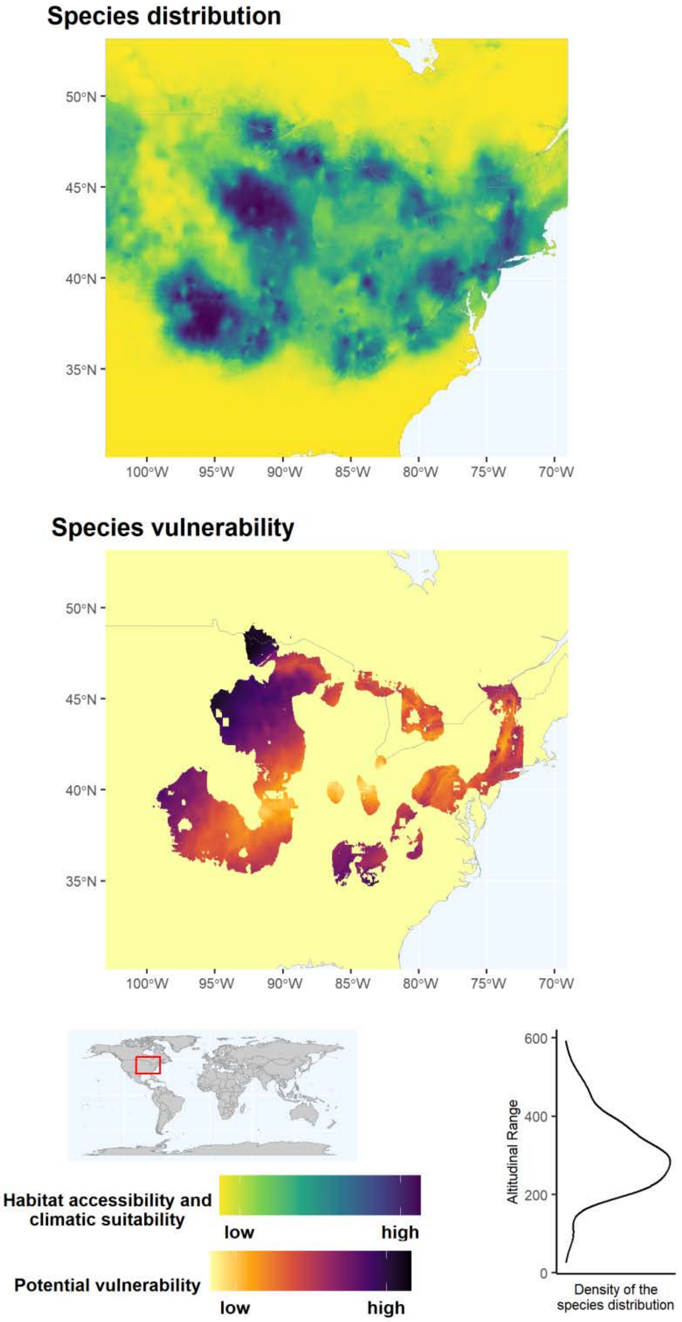
P. dura is a plant whose distribution comprises Angola, Burundi, Cape Provinces, Central African Republic, Equatorial Guinea, Gabon, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Namibia, Northern Provinces, Réunion, Tanzania, Uganda, Zambia, Zimbabwe. *P. dura* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 288 to 1952 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. dura* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Rwanda, South Africa, Uganda, Zimbabwe. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Pellaea falcata Fée



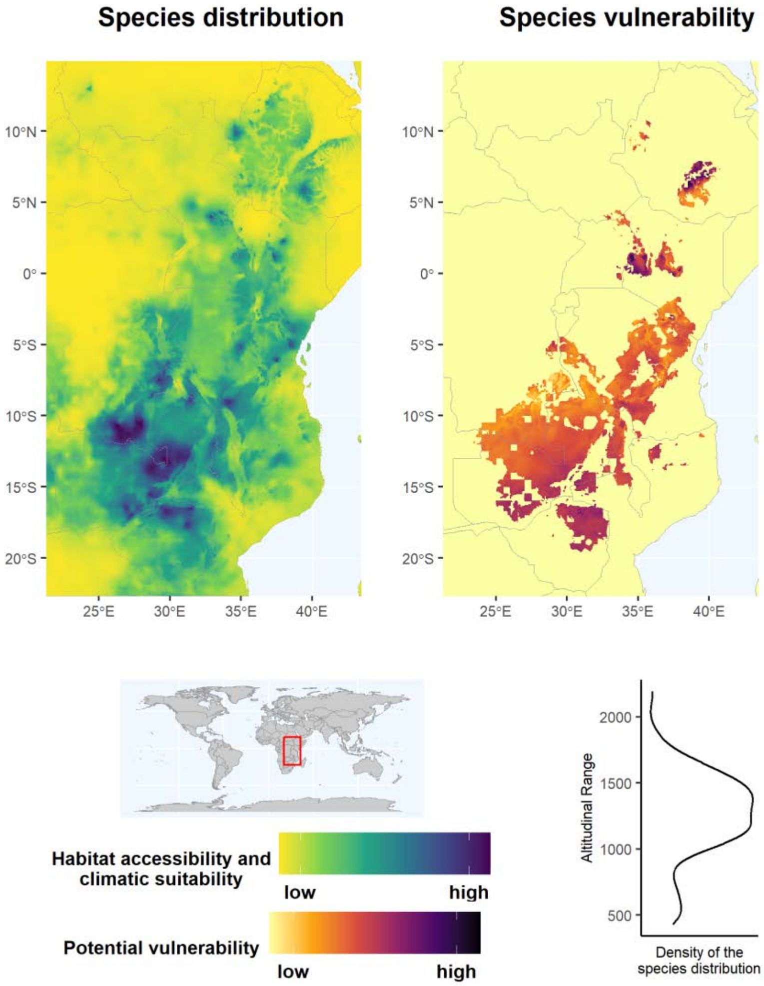
P. falcata is a homoiochlorophyllous plant whose distribution comprises India, Kermadec Is., Lesser Sunda Is., Malaya, New Caledonia, New South Wales, New Zealand North, New Zealand South, Norfolk Is., Queensland, Sri Lanka, Sulawesi, Tasmania, Victori. *P. falcata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 1 to 1196 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. falcata* populations are expected to be potentially more vulnerable to climate change in parts of Australia, New Caledonia, Vanuatu, New Zealand. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

Pellaea glabella Mett. ex Kuhn
(also cited as *Hemionitis glabella*)



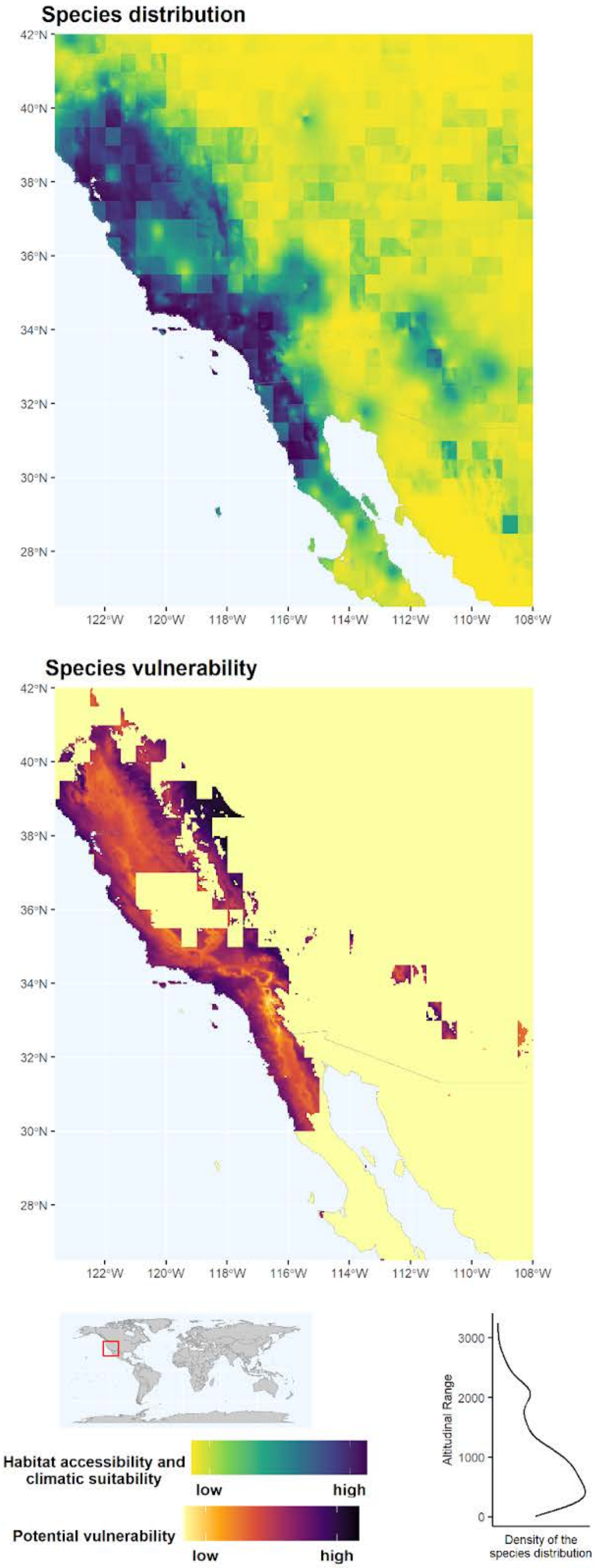
P. glabella is a homoiochlorophyllous plant whose distribution comprises Arkansas, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, Ohio, Oklahoma, Ontario, Pennsylvania, Québec, Tennessee, Texas, Vermont, Virginia, West Virginia, Wisconsin. *P. glabella* individuals can be primarily found in warm temperate and snow climates, ranging from 26 to 593 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the drier season is short). *P. glabella* populations are expected to be potentially more vulnerable to climate change in parts of Canada, United States. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

Pellaea longipilosa Bonap.



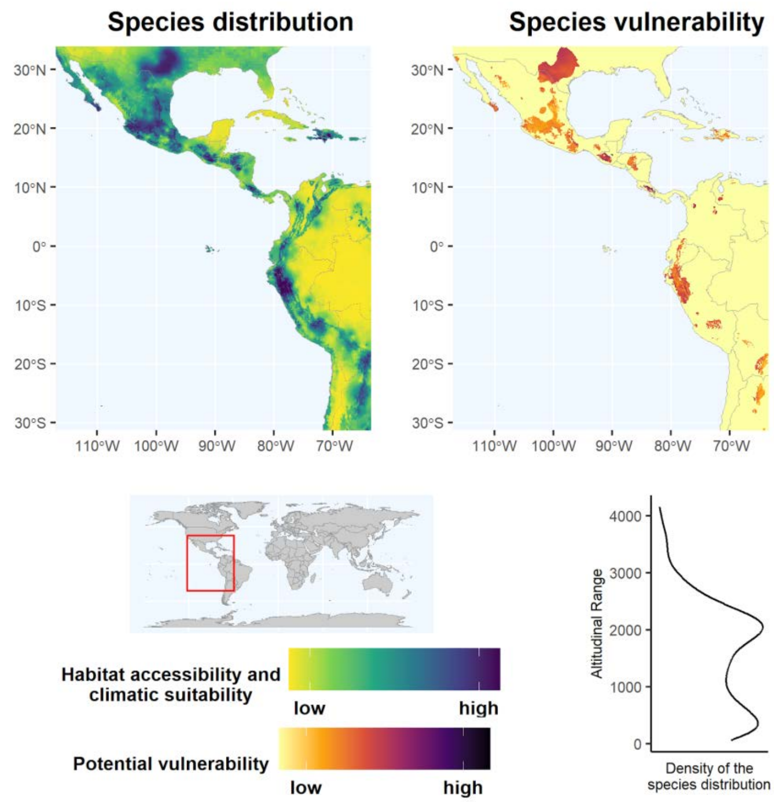
P. longipilosa is a plant whose distribution comprises Burundi, Ethiopia, India, Kenya, Malawi, Mozambique, Somalia, Sudan, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *P. longipilosa* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 432 to 2192 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. longipilosa* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Kenya, Tanzania, Uganda. This species has not yet been assessed by IUCN, and 30% of its distribution range is currently found within protected areas.

Pellaea mucronata (D.C. Eaton) D.C. Eaton



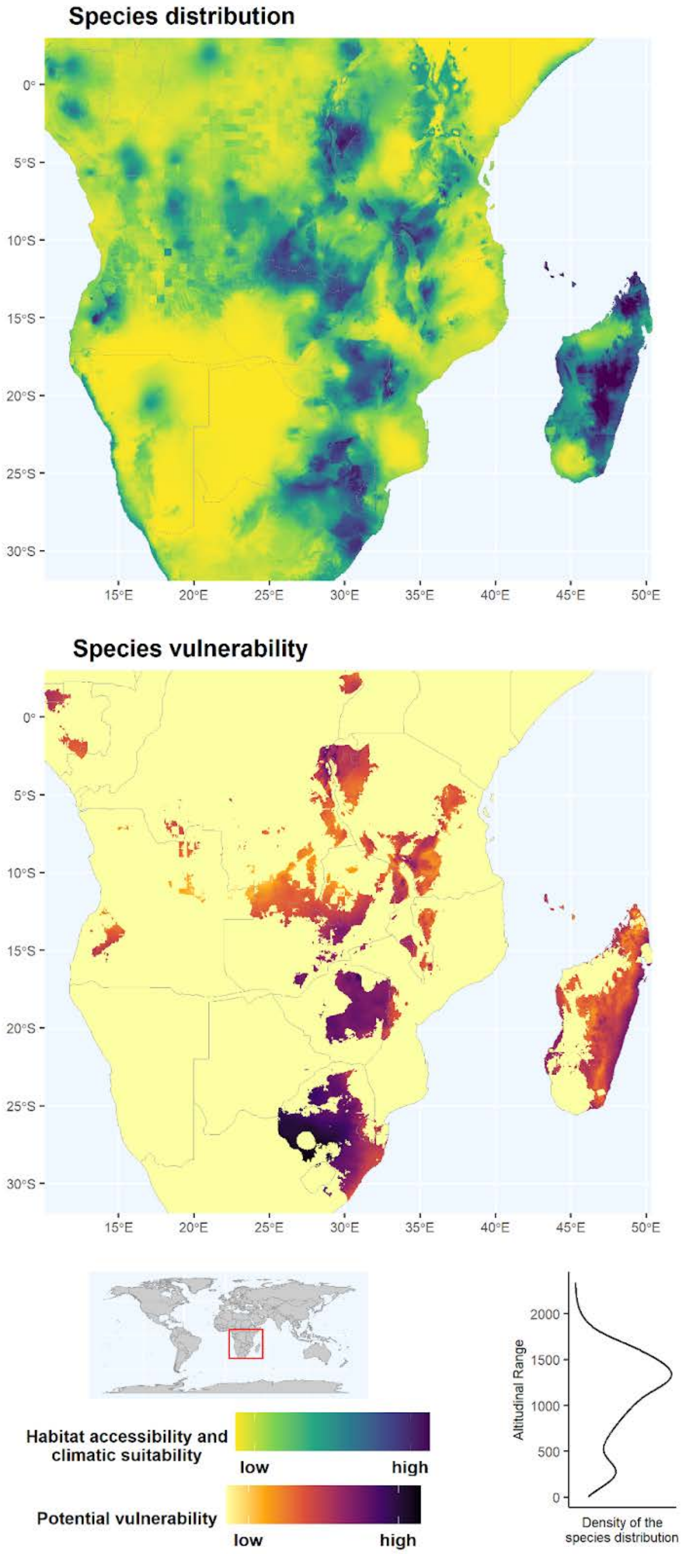
P. mucronata is a plant whose distribution comprises Arizona, California, Mexican Pacific Is., Mexico Northwest, Nevada, Oregon. *P. mucronata* individuals can be primarily found in arid and warm temperate climates, ranging from 8 to 3251 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. mucronata* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Pellaea ovata (Desv.) Weath.
(also cited as *Hemionitis ovata*)



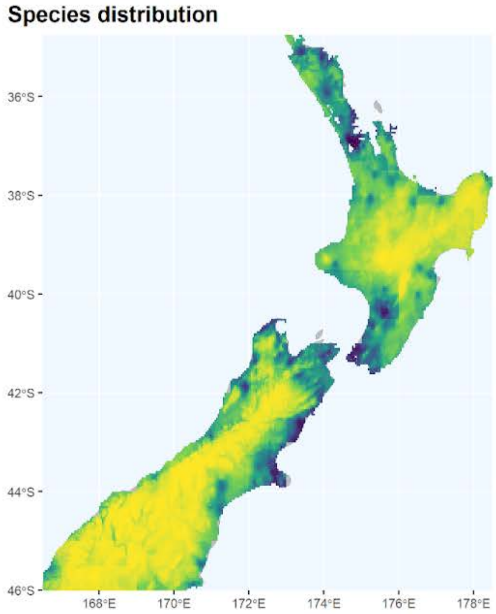
P. ovata is a homoiochlorophyllous plant whose distribution comprises Argentina Northwest, Bolivia, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Haiti, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Peru, Texas, Venezuela. *P. ovata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 66 to 4156 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to precipitation is extremely seasonal. *P. ovata* populations are expected to be potentially more vulnerable to climate change in parts of Colombia, Costa Rica, Guatemala, Mexico, Panama. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

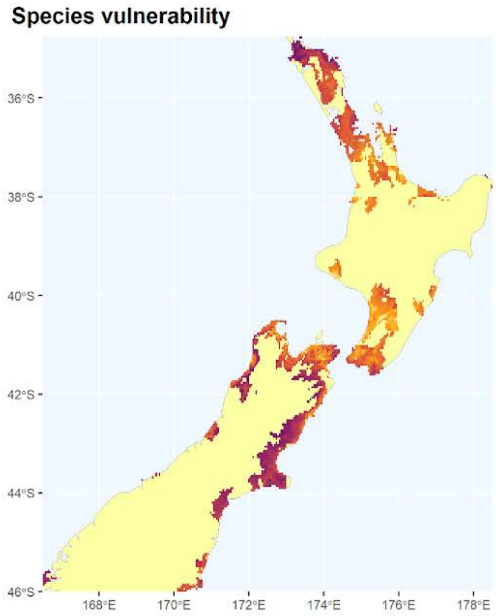
Pellaea pectiniformis Baker

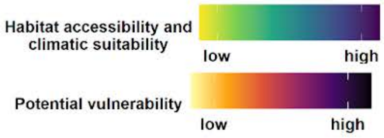


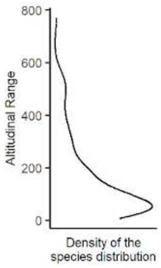
P. pectiniformis is a plant whose distribution comprises Angola, Burundi, Comoros, Gabon, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Namibia, Northern Provinces, Seychelles, Swaziland, Tanzania, Zambia, Zaïre, Zimbabwe. *P. pectiniformis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 6 to 2340 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. pectiniformis* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Madagascar, Rwanda, South Africa, Lesotho, Botswana, Zimbabwe. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Pellaea rotundifolia (G. Forst.) Hook. (also cited as *Hemionitis rotundifolia*)



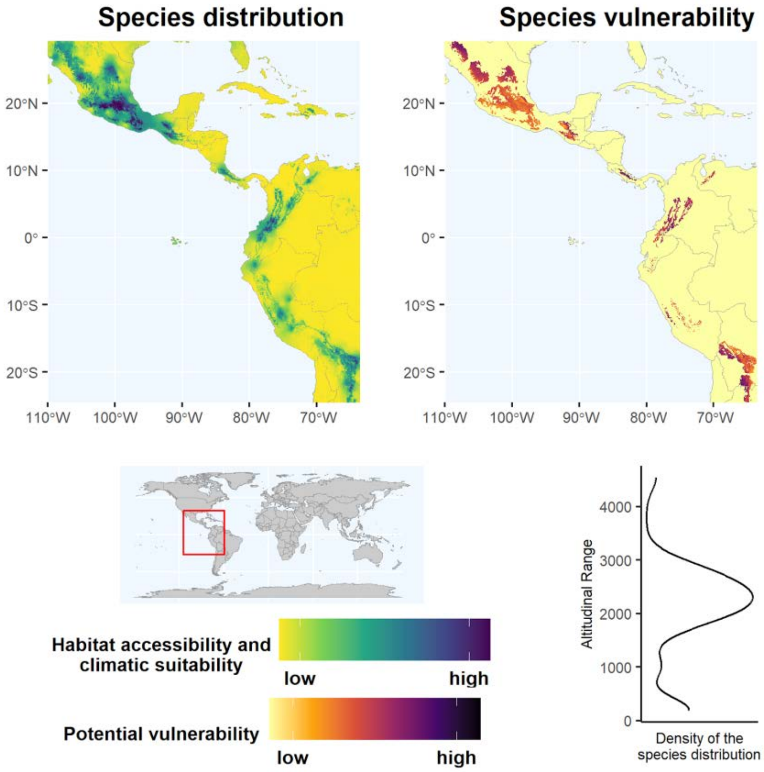






P. rotundifolia is a homoiochlorophyllous plant whose distribution comprises Chatham Is., New Zealand North, New Zealand South. *P. rotundifolia* individuals can be primarily found in warm temperate climates, ranging from 8 to 770 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *P. rotundifolia* populations are expected to be potentially more vulnerable to climate change in parts of New Zealand. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

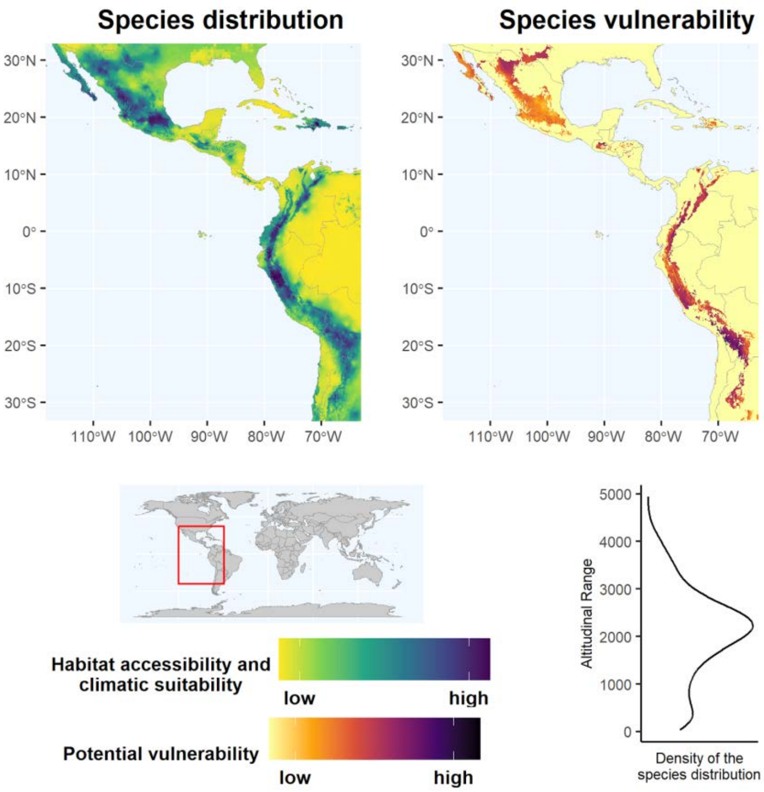
Pellaea sagittata (Cav.) Link
(also cited as *Hemionitis emperatricella*)



P. sagittata is a homoiochlorophyllous plant whose distribution comprises Argentina Northwest, Bolivia, Colombia, Ecuador, Guatemala, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Peru. *P. sagittata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 195 to 4544 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. sagittata* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Colombia, Costa Rica, Guatemala, Mexico, Panama. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

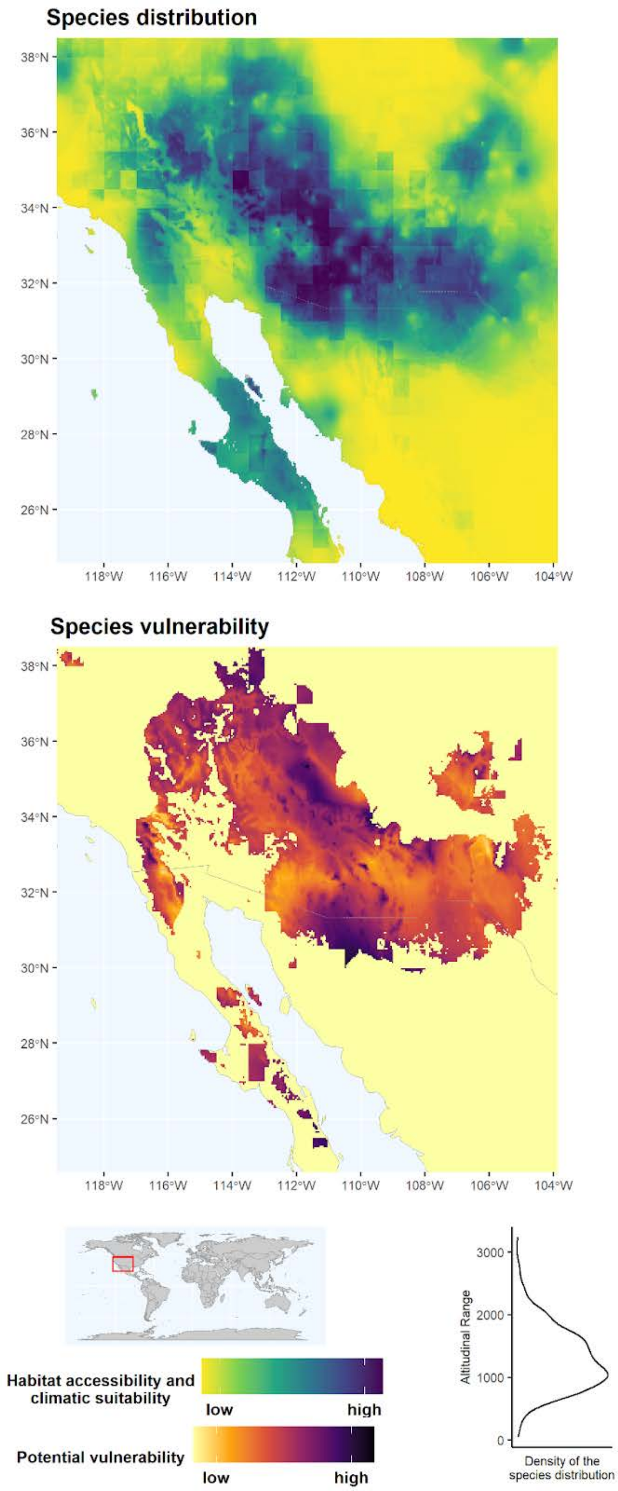
Pellaea ternifolia (Cav.) Link

(also cited as *Hemionitis ternifolia*)



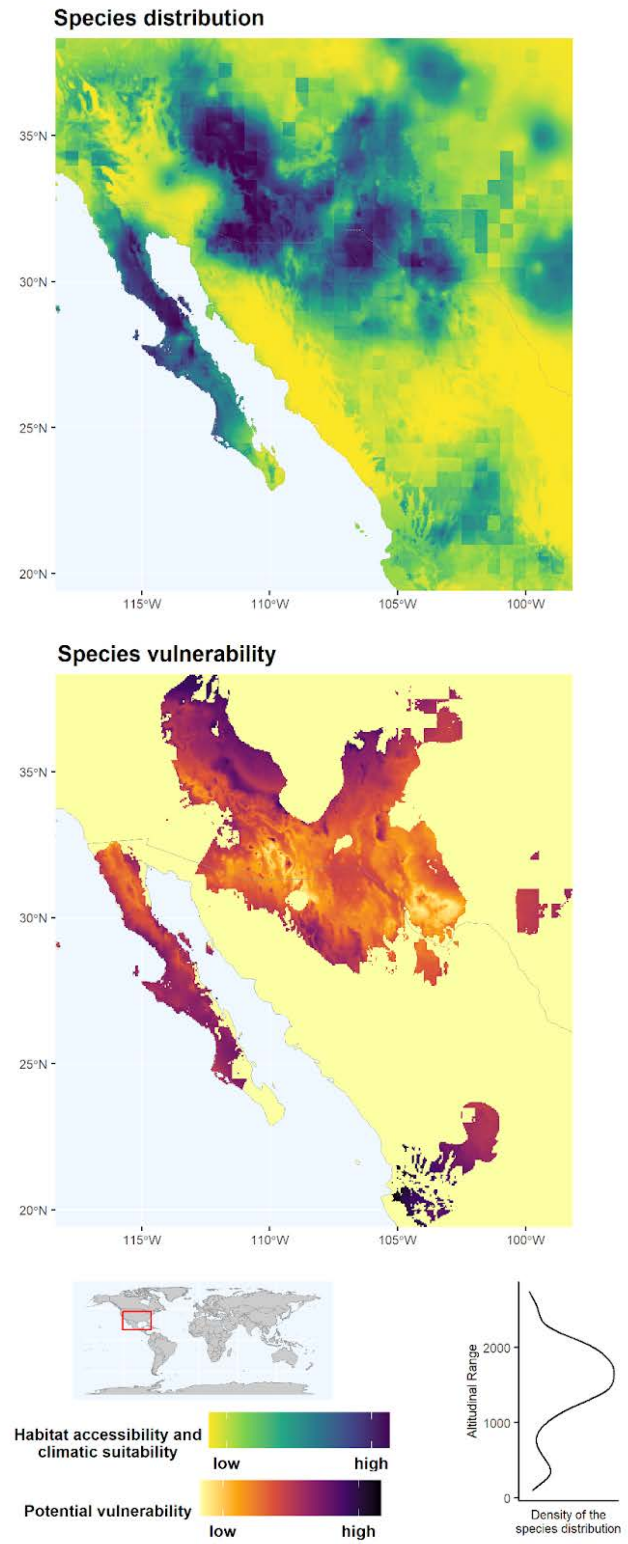
P. ternifolia is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Chile Central, Chile North, Chile South, Colombia, Costa Rica, Dominican Republic, Ecuador, Guatemala, Hawaii, Honduras, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Nicaragua, Peru, Texas, Venezuela. *P. ternifolia* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 32 to 4941 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. ternifolia* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Chile, Colombia, Ecuador, Guatemala, Peru. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Pellaea truncata Goodd.



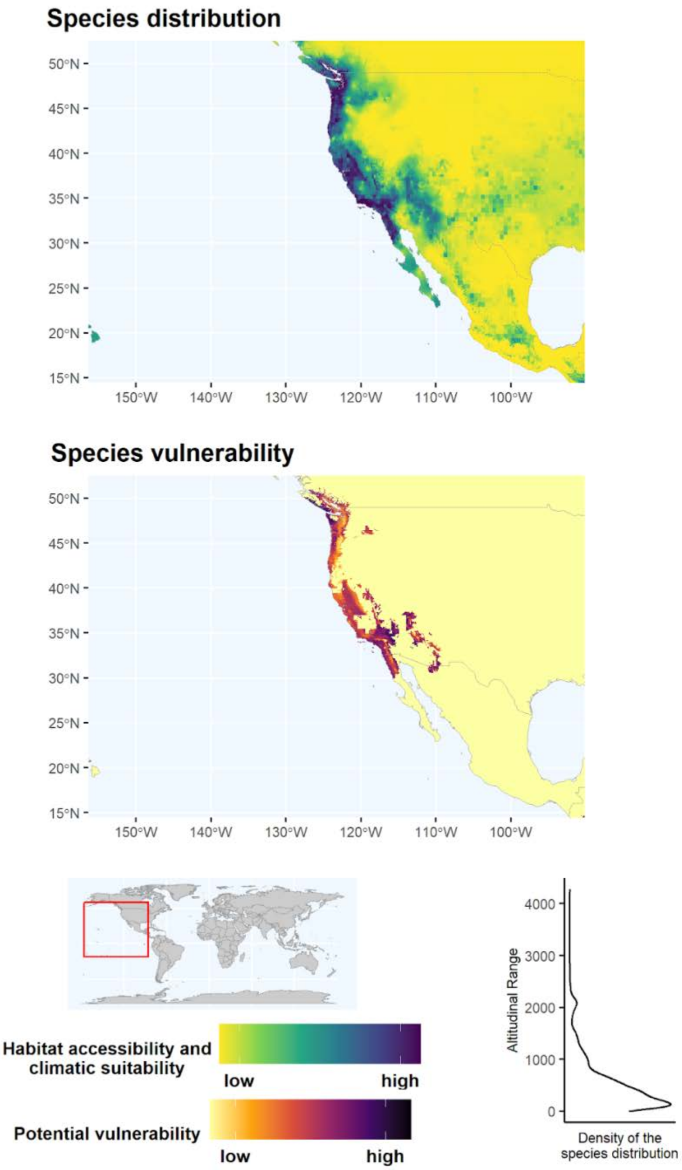
P. truncata is a plant whose distribution comprises Arizona, California, Colorado, Mexico Northwest, Nevada, New Mexico, Texas, Utah. *P. truncata* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 48 to 3243 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *P. truncata* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

Pellaea wrightiana Hook.



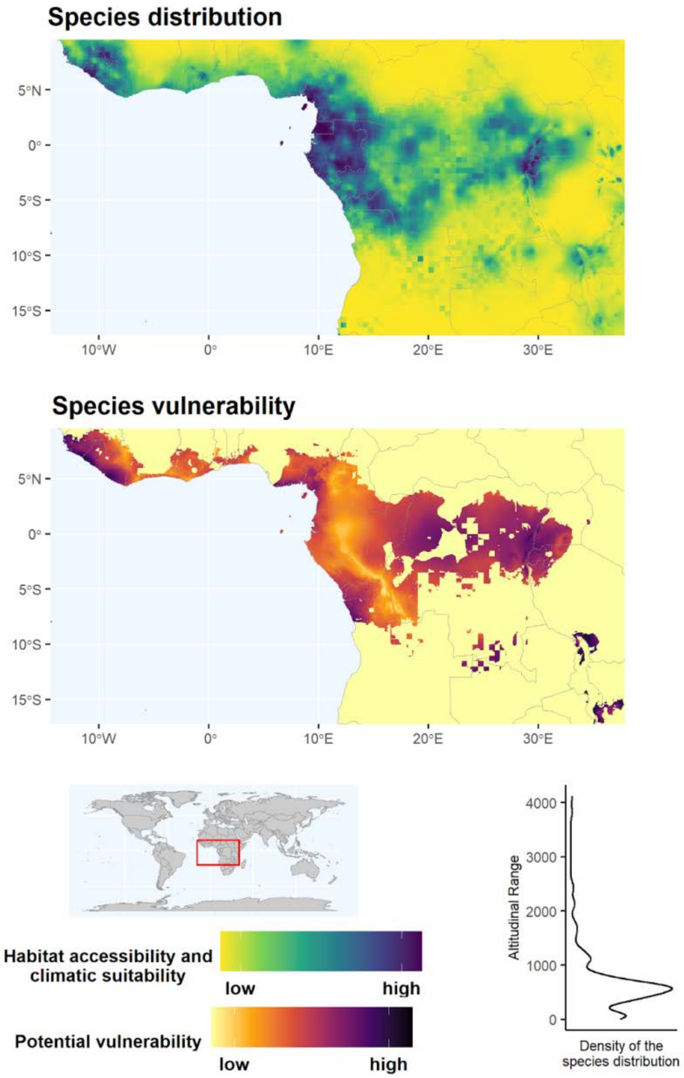
P. wrightiana is a plant whose distribution comprises Arizona, Colorado, Mexico Northeast, Mexico Northwest, New Mexico, North Carolina, Oklahoma, South Carolina, Texas, Utah. *P. wrightiana* individuals can be primarily found in arid and warm temperate climates, ranging from 95 to 2749 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *P. wrightiana* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Pentagramma triangularis (Kaulf.) Yatsk., Windham & E. Wollenw.
(also cited as *Hemionitis triangularis*)



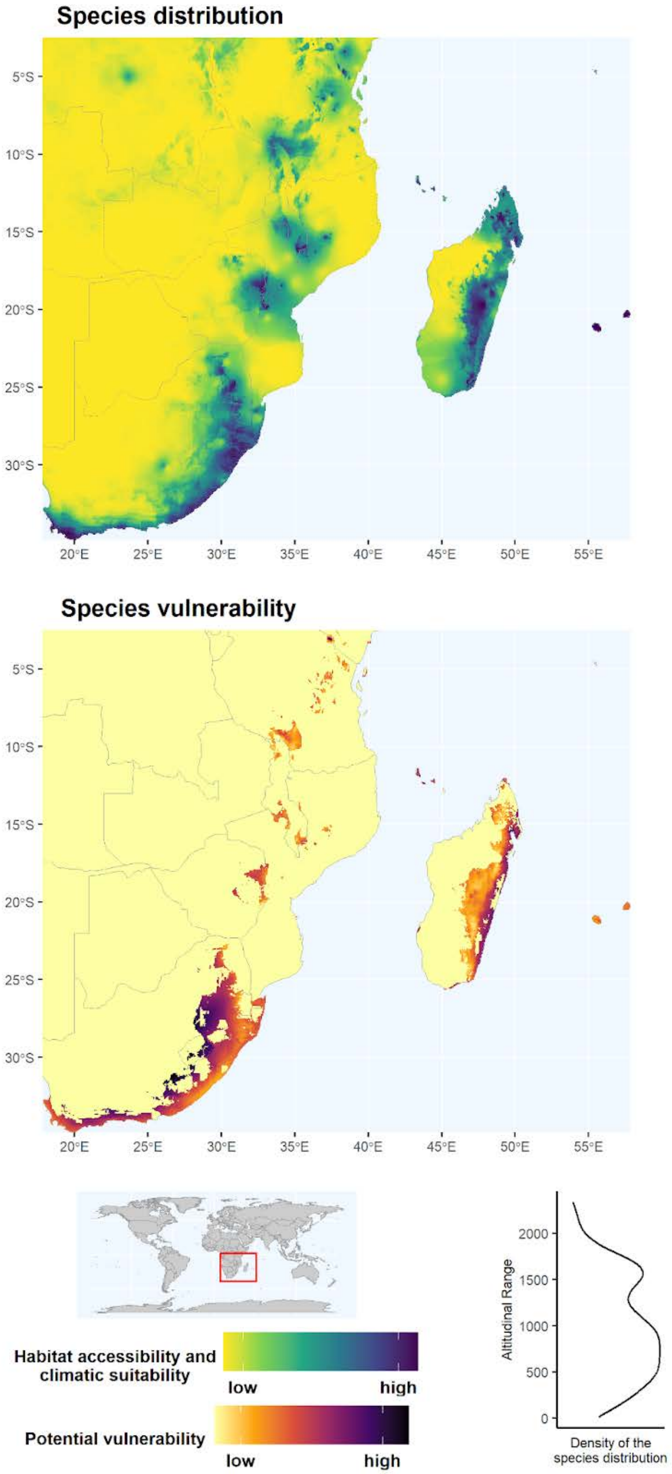
P. triangularis is a plant whose distribution comprises British Columbia, California, Idaho, Mexican Pacific Is., Mexico Northwest, Oregon, Washington. *P. triangularis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 3 to 4276 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *P. triangularis* populations are expected to be potentially more vulnerable to climate change in parts of Canada, Guatemala, Mexico, United States. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Vittaria guineensis Desv.



V. guineensis is a plant whose distribution comprises Angola, Burundi, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Liberia, Nigeria, Rwanda, Sierra Leone, Togo, Uganda, Zaïre. *V. guineensis* individuals can be primarily found in equatorial and warm temperate climates, ranging from 11 to 4121 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *V. guineensis* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Democratic Republic of the Congo, Cameroon, Equatorial Guinea, Kenya, Liberia, Mozambique, Malawi, Nigeria, Rwanda, Sierra Leone, Tanzania, Uganda, Zambia. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

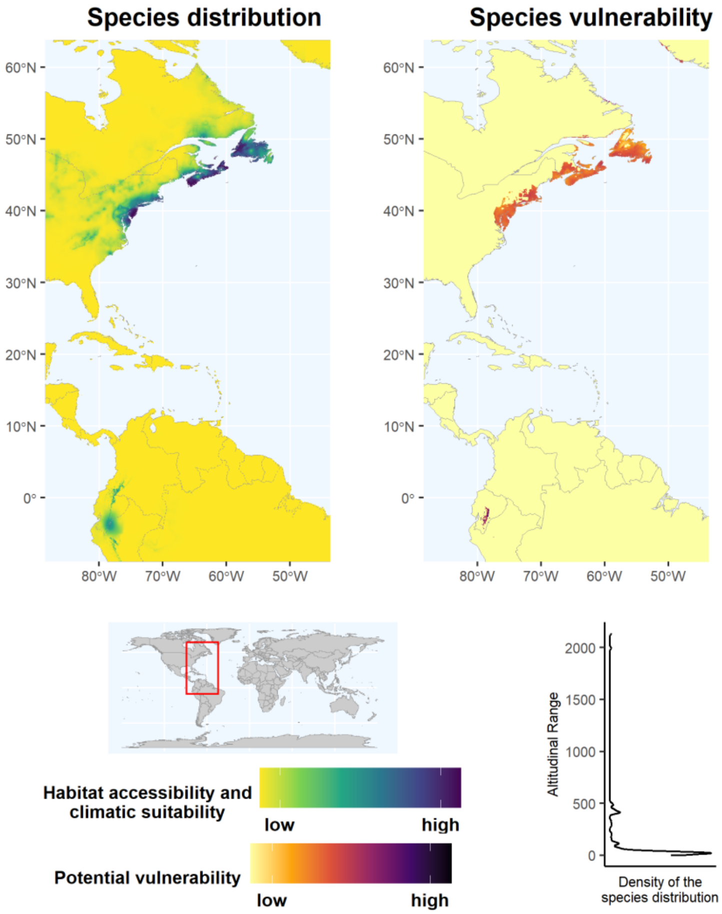
Vittaria isoetifolia Bory



V. isoetifolia is a plant whose distribution comprises Cape Provinces, Comoros, Kenya, KwaZulu-Natal, Madagascar, Malawi, Mozambique, Northern Provinces, Réunion, Seychelles, Tanzania, Zimbabwe. *V. isoetifolia* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 13 to 2340 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *V. isoetifolia* populations are expected to be potentially more vulnerable to climate change in parts of Comoros, Madagascar, South Africa, Lesotho, Tanzania. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

Schizaeaceae

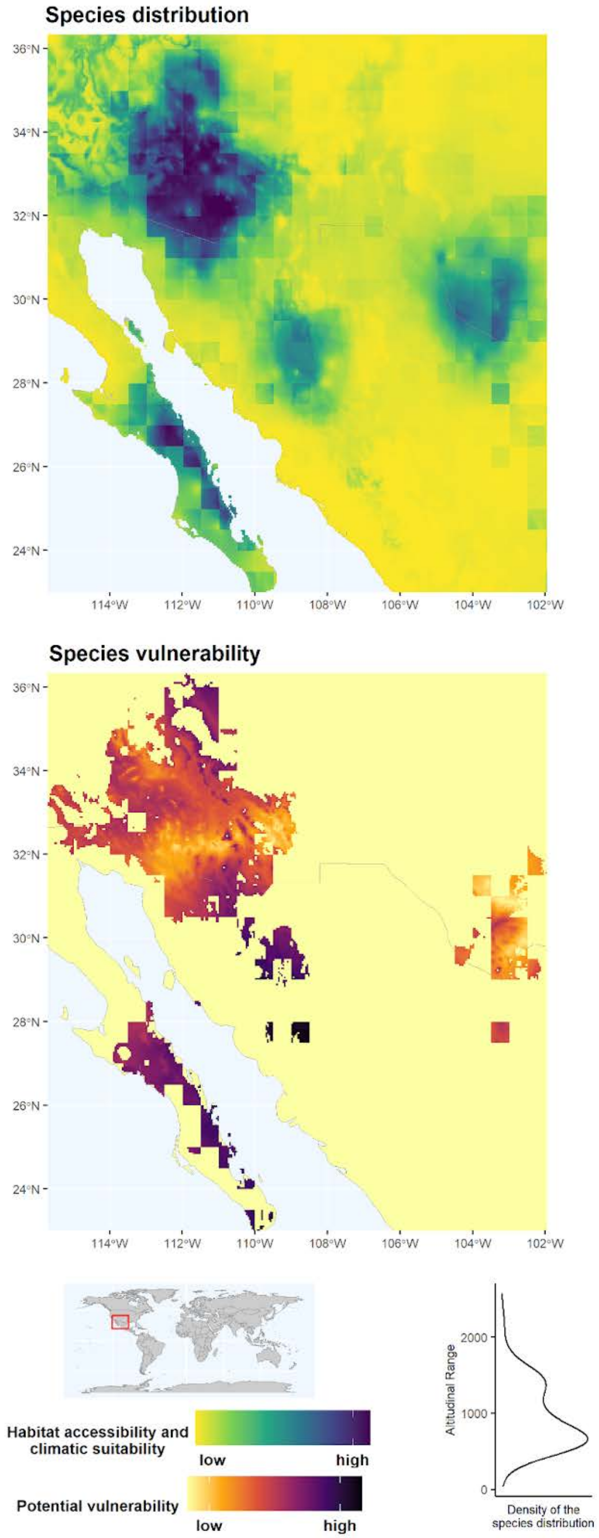
Schizaea pusilla Pursh



S. pusilla is a plant whose distribution comprises Delaware, Ecuador, New Brunswick, New Jersey, New York, Newfoundland, Nova Scotia, Peru. *S. pusilla* individuals can be primarily found in warm temperate and snow climates, ranging from 1 to 2138 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to precipitation is spread throughout the year. *S. pusilla* populations are expected to be potentially more vulnerable to climate change in parts of Ecuador, Peru. This species is listed as Least concern by IUCN, although only 12% of its distribution range is currently found within protected areas.

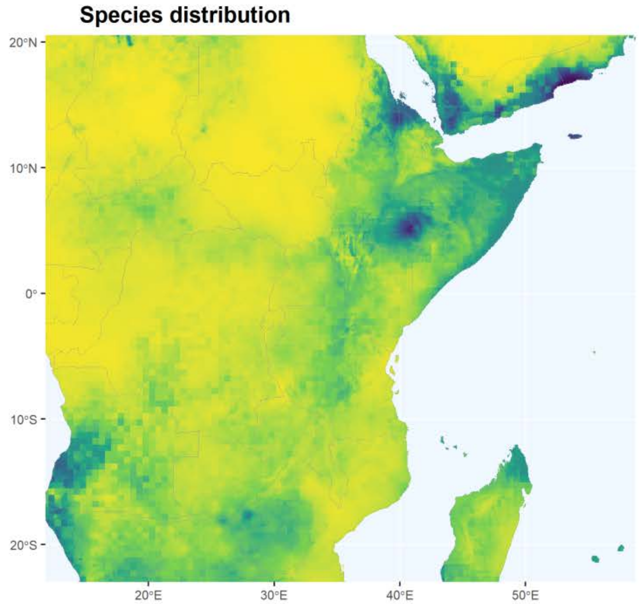
Selaginellaceae

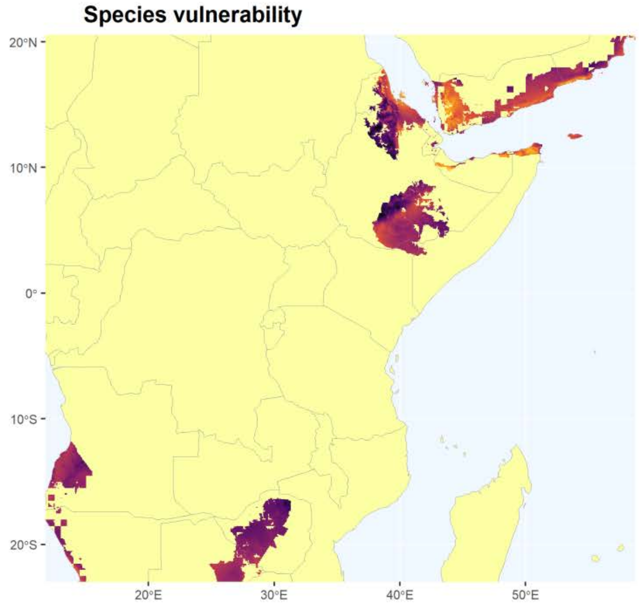
Selaginella arizonica Maxon

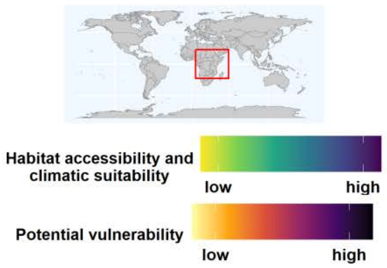


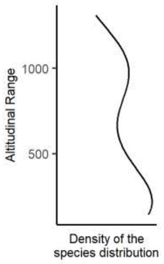
S. arizonica is a plant whose distribution comprises Arizona, Mexico Northeast, Mexico Northwest, New Mexico, Texas. *S. arizonica* individuals can be primarily found in arid and warm temperate climates, ranging from 39 to 2578 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *S. arizonica* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Selaginella bryopteris Baker



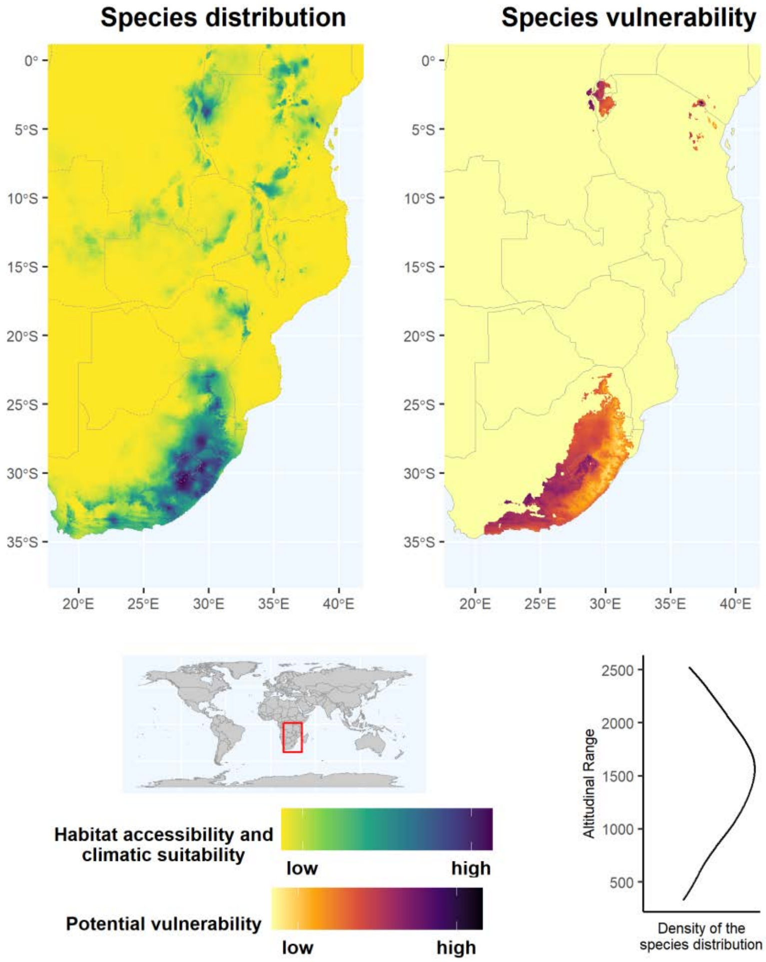






S. bryopteris is a homoiochlorophyllous plant whose distribution comprises India (Andhra Pradesh, Assam State, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Uttarakhand, Uttar Pradesh, West Bengal); Nepal; Bhutan; Sudan; Eritrea; Ethiopia; Somalia; Kenya; Zambia; Mozambique; N-Zimbabwe; NW-Namibia; N-Yemen; S-Yemen; Saudi Arabia; Oman (Dhofar). *S. bryopteris* individuals can be primarily found in arid climates, ranging from 144 to 1311 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. bryopteris* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Eritrea, Ethiopia, Oman, Somalia, Namibia, Yemen, Zimbabwe. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

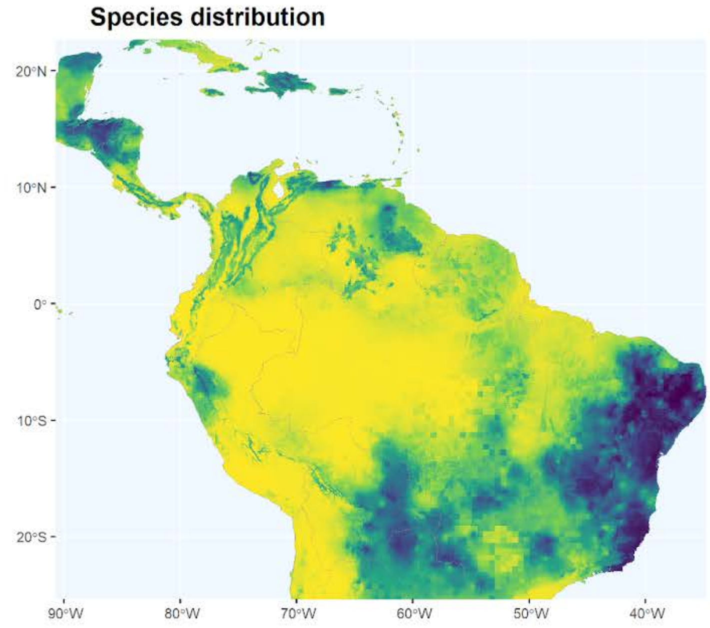
Selaginella caffrorum (Milde) Hieron.

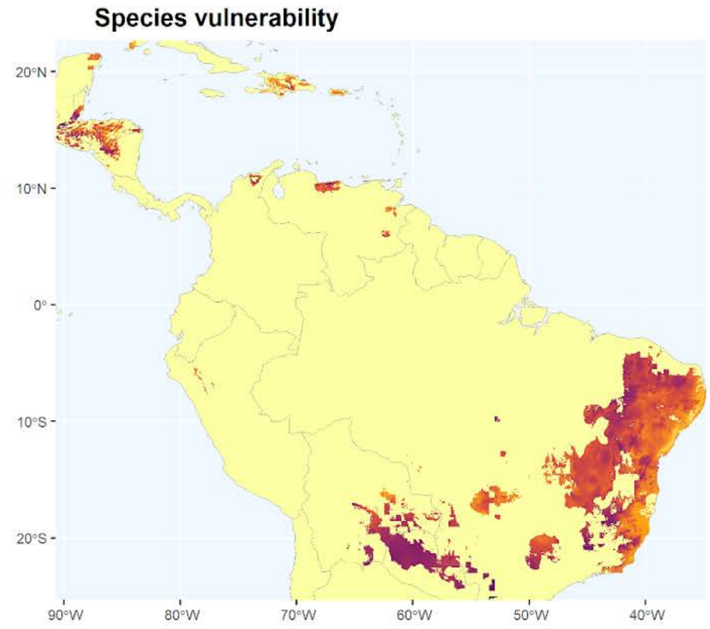


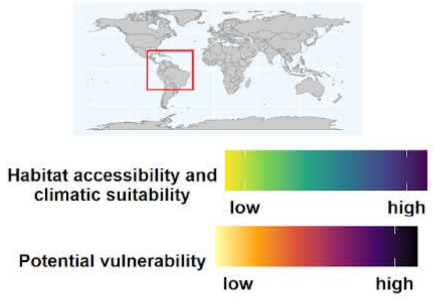
S. caffrorum is a homoiochlorophyllous plant whose distribution comprises Angola, Burundi, Cape Provinces, Free State, Kenya, KwaZulu-Natal, Lesotho, Namibia, Northern Provinces, Rwanda, Sudan, Tanzania, Uganda, Zaïre, Zimbabwe. *S. caffrorum* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 330 to 2527 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *S. caffrorum* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Rwanda, South Africa, Lesotho, Tanzania. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

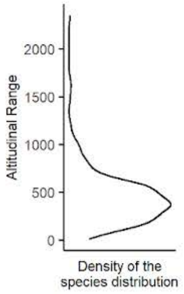
Selaginella convoluta (Arn.) Spring

S. convoluta is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Belize, Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Cuba, Dominican Republic, Guatemala, Guyana, Honduras, Mexico Southeast, Nicaragua, Paraguay, Peru, Venezuela. *S. convoluta* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 10 to 2351 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *S. convoluta* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Brazil, Colombia, El Salvador, Guatemala, Honduras, Nicaragua, Venezuela. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.



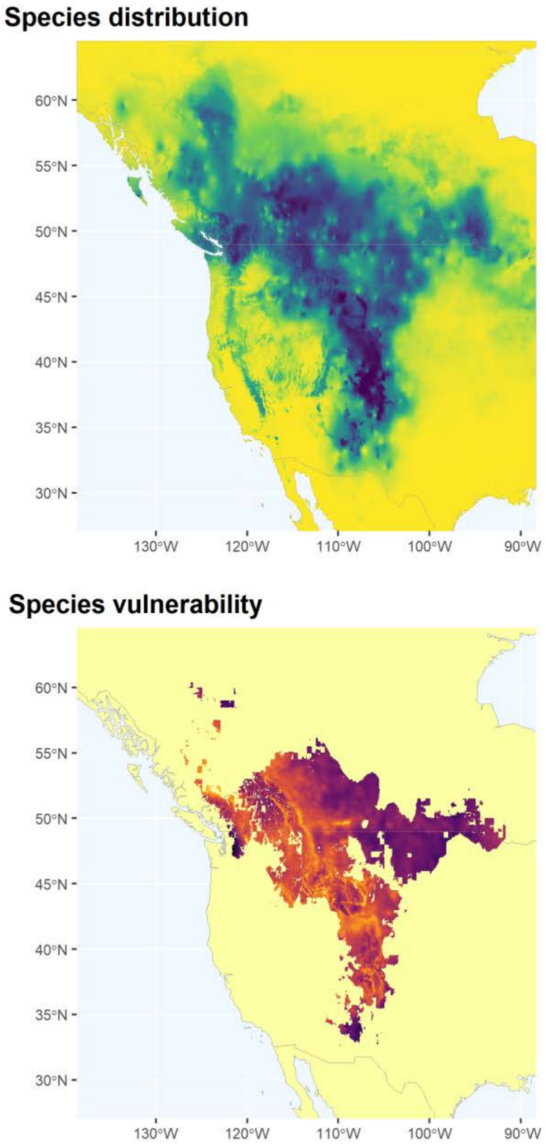


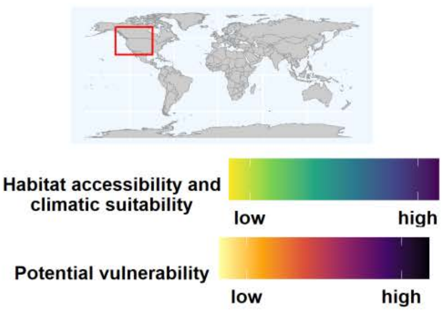


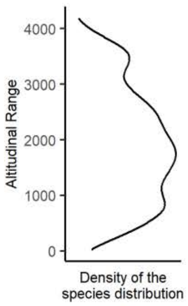


Selaginella densa Rydb.

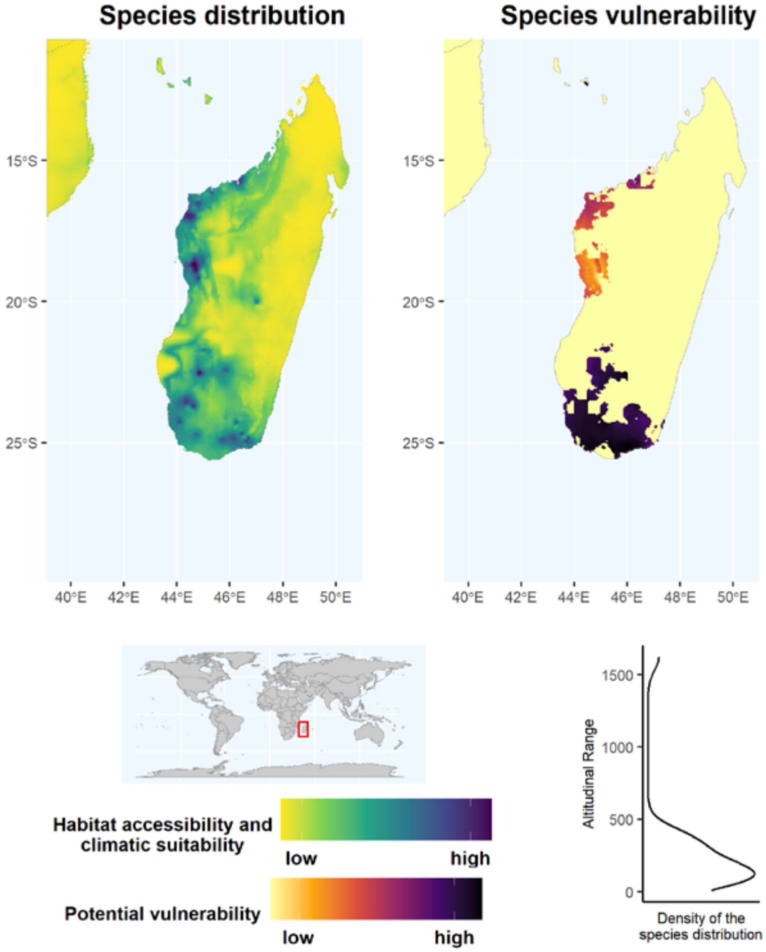
S. densa is a plant whose distribution comprises Alberta, Arizona, British Columbia, Colorado, Idaho, Manitoba, Montana, New Mexico, North Dakota, Oklahoma, Ontario, Saskatchewan, South Dakota, Wyoming. *S. densa* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 27 to 4188 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *S. densa* populations are expected to be potentially more vulnerable to climate change in parts of Canada, United States. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.





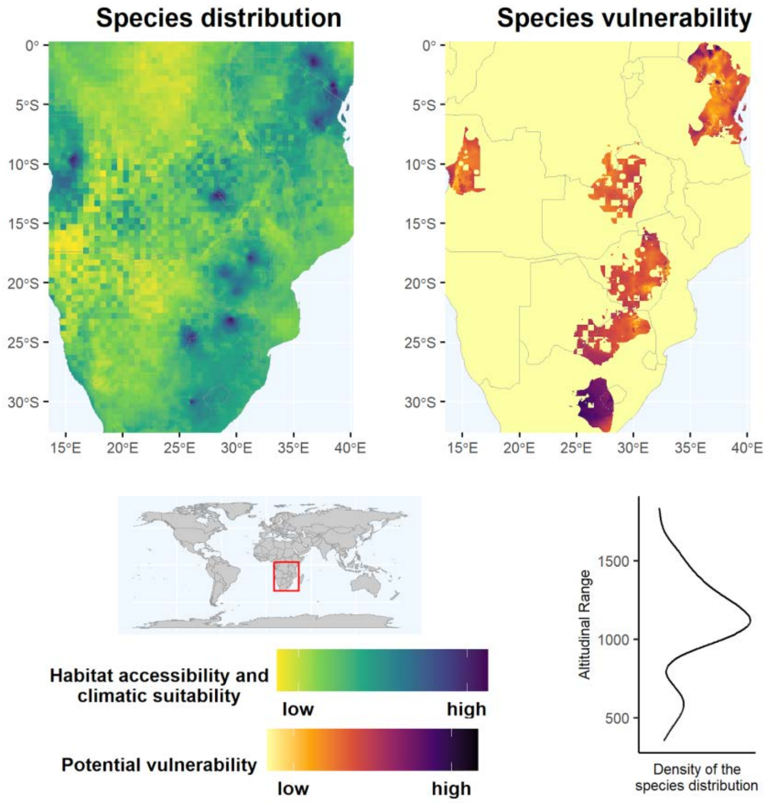


Selaginella digitata Spring



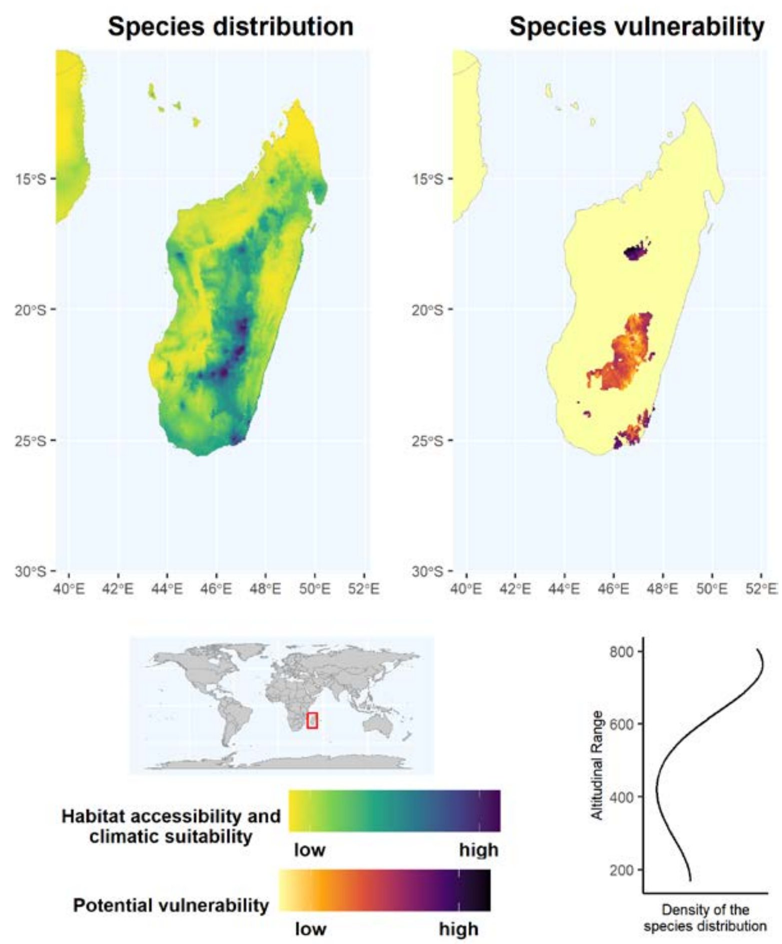
S. digitata is a homoiochlorophyllous plant whose distribution is restricted to Madagascar. *S. digitata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 11 to 1622 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. digitata* populations are expected to be potentially more vulnerable to climate change in parts of Comoros, Madagascar. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Selaginella dregei (C. Presl) Hieron.



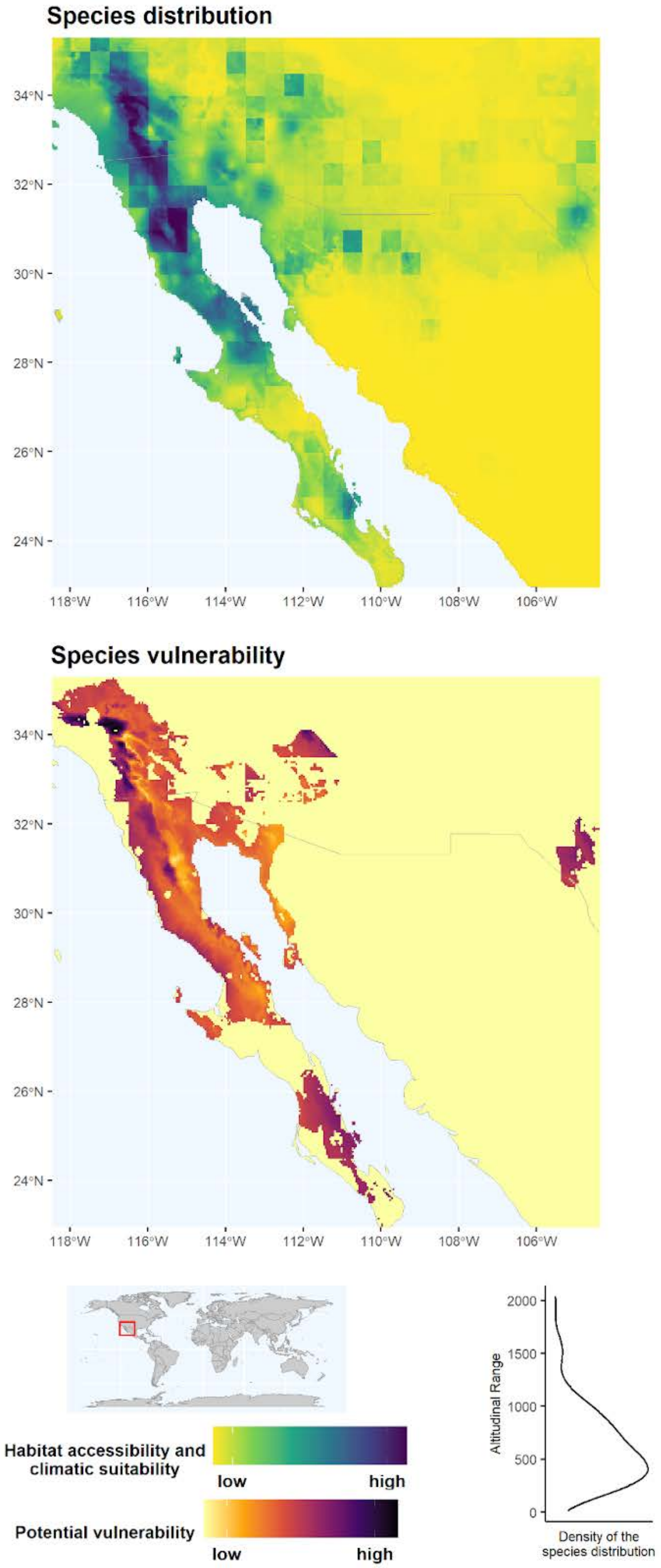
S. dregei is a homoiochlorophyllous plant whose distribution comprises Angola, Botswana, Cape Provinces, Free State, Kenya, KwaZulu-Natal, Lesotho, Malawi, Mozambique, Northern Provinces, Swaziland, Tanzania, Uganda, Zambia, Zaïre, Zimbabwe. *S. dregei* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 352 to 1838 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. dregei* populations are expected to be potentially more vulnerable to climate change in parts of Kenya, South Africa, Lesotho, Tanzania. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Selaginella echinata Baker



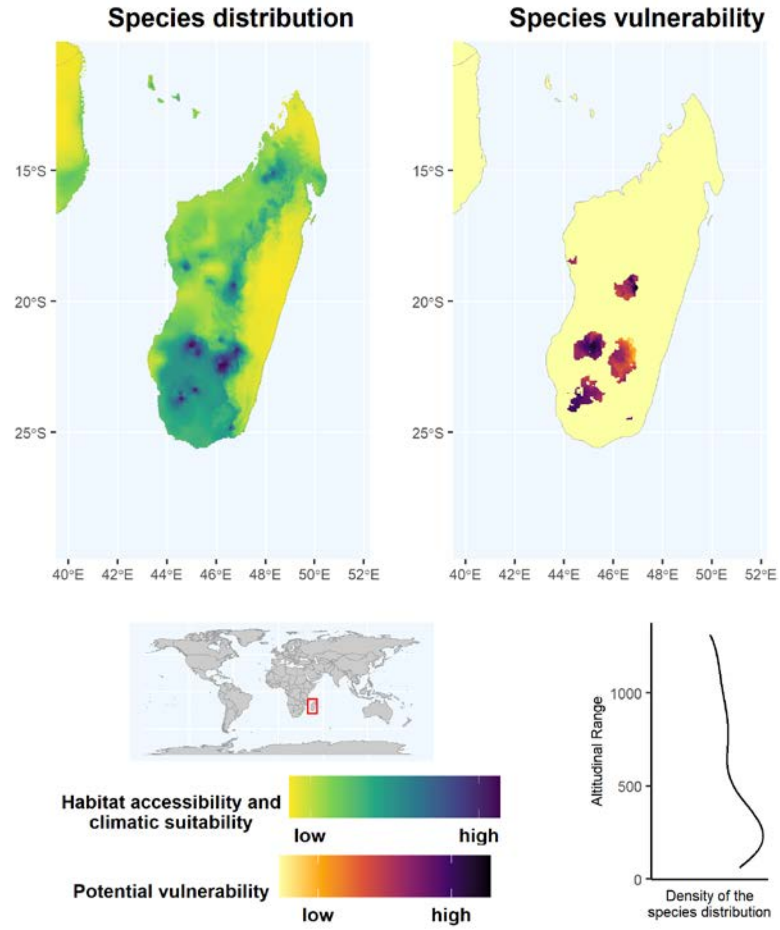
S. echinata is a homoiochlorophyllous plant whose distribution is restricted to Madagascar. *S. echinata* individuals can be primarily found in arid and warm temperate climates, ranging from 167 to 807 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). *S. echinata* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

Selaginella eremophila Maxon



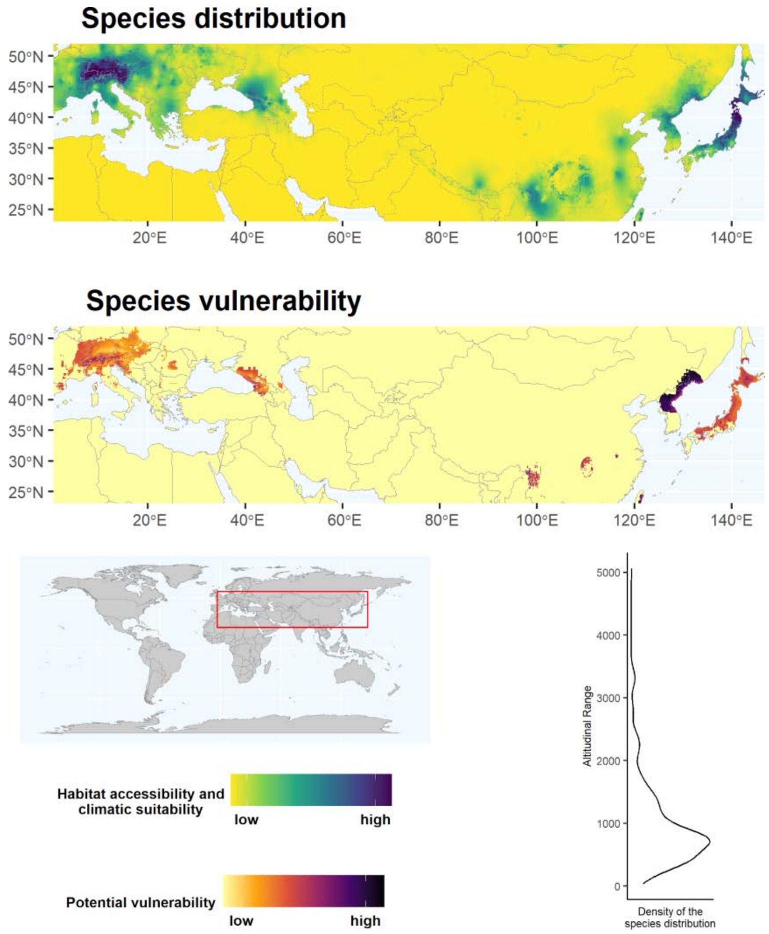
S. eremophila is a plant whose distribution comprises Arizona, California, Mexico Northeast, Mexico Northwest. *S. eremophila* individuals can be primarily found in arid and warm temperate climates, ranging from 15 to 2038 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *S. eremophila* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 42% of its distribution range is currently found within protected areas.

Selaginella helicoclada Alston



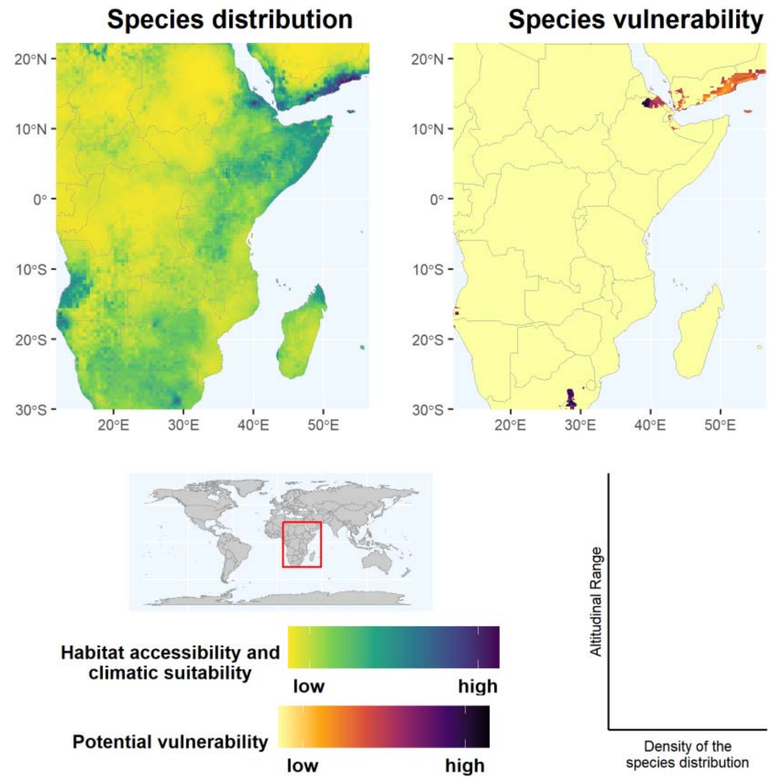
S. helicoclada is a plant whose distribution is restricted to Madagascar. *S. helicoclada* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 62 to 1314 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. helicoclada* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 1% of its distribution range is currently found within protected areas.

Selaginella helvetica (L.) Spring



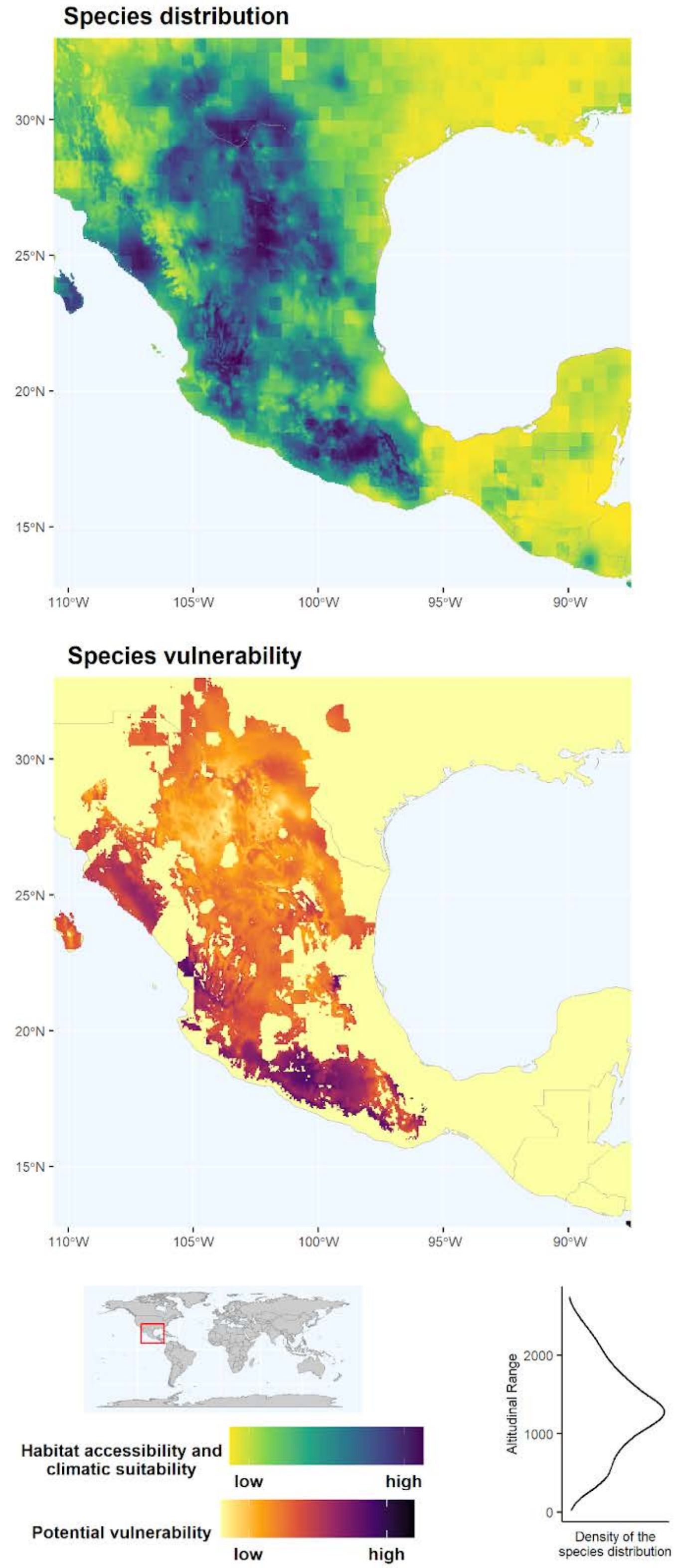
S. helvetica is a plant whose distribution comprises Albania, Amur, Austria, Bulgaria, Buryatiya, China North-Central, China South-Central, Chita, Czechoslovakia, East Himalaya, France, Germany, Greece, Hungary, Inner Mongolia, Iran, Italy, Japan, Khabarovsk, Korea, Krasnoyarsk, Kuril Is., Manchuria, Mongolia, Nepal, Poland, Primorye, Qinghai, Romania, Switzerland, Tibet, Transcaucasus, Turkey, Ukraine, West Himalaya, Yugoslavia. *S. helvetica* individuals can be primarily found in warm temperate and snow climates, ranging from 39 to 5062 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *S. helvetica* populations are expected to be potentially more vulnerable to climate change in parts of Burma, China, Austria, Japan, Korea, Democratic People's Republic of, Korea, Republic of, Russia, Switzerland, Taiwan. This species is listed as Least concern by IUCN, although only 35% of its distribution range is currently found within protected areas.

Selaginella imbricata (Forssk.) Spring ex Decne.



S. imbricata is a homoiochlorophyllous plant whose distribution comprises Ethiopia, Kenya, Mozambique, Namibia, Oman, Saudi Arabia, Somalia, Sudan, Yemen, Zambia, Zimbabwe. *S. imbricata* individuals can be primarily found in arid climates, circa 788 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas which precipitation is spread throughout the year. *S. imbricata* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Ethiopia, South Africa, Lesotho, Namibia, Yemen. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

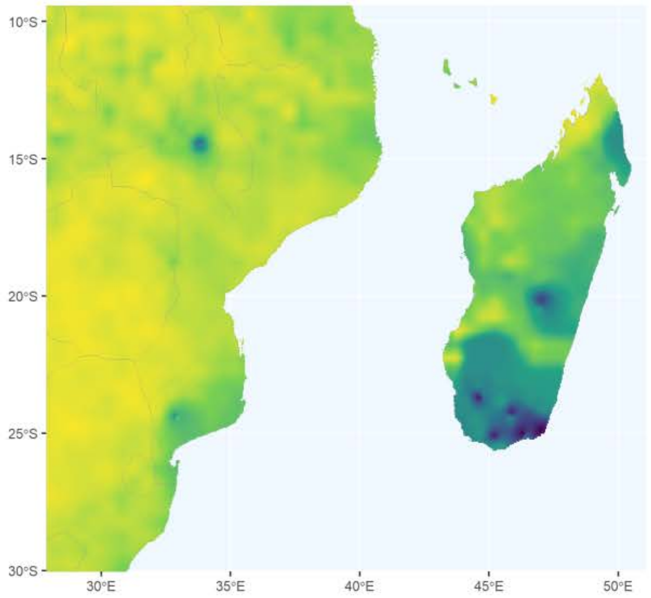
Selaginella lepidophylla (Hook. & Grev.) Spring



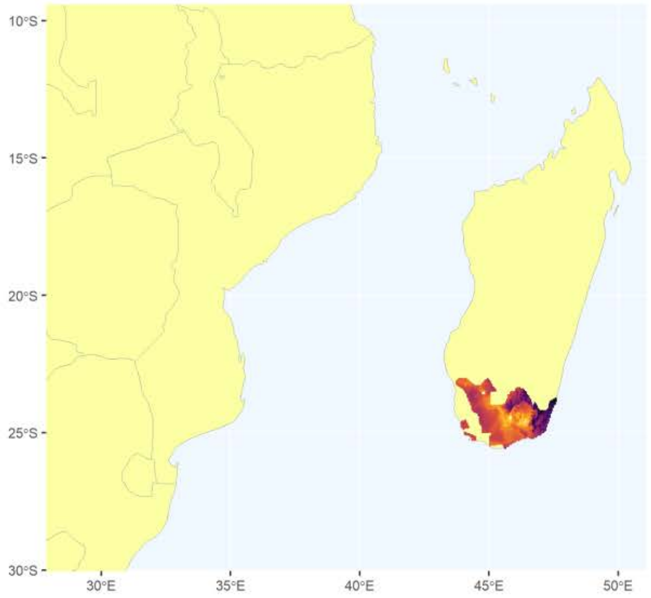
S. lepidophylla is a homoiochlorophyllous plant whose distribution comprises Costa Rica, El Salvador, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, New Mexico, Texas. *S. lepidophylla* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 18 to 2746 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. lepidophylla* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, Nicaragua. This species has not yet been assessed by IUCN, and only 11% of its distribution range is currently found within protected areas.

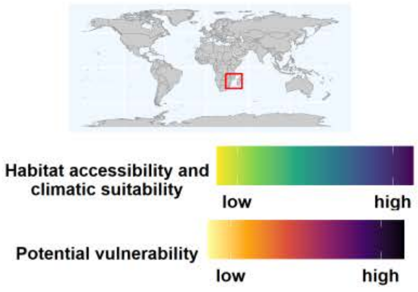
Selaginella nivea **Alston**

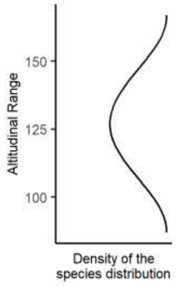
Species distribution



Species vulnerability

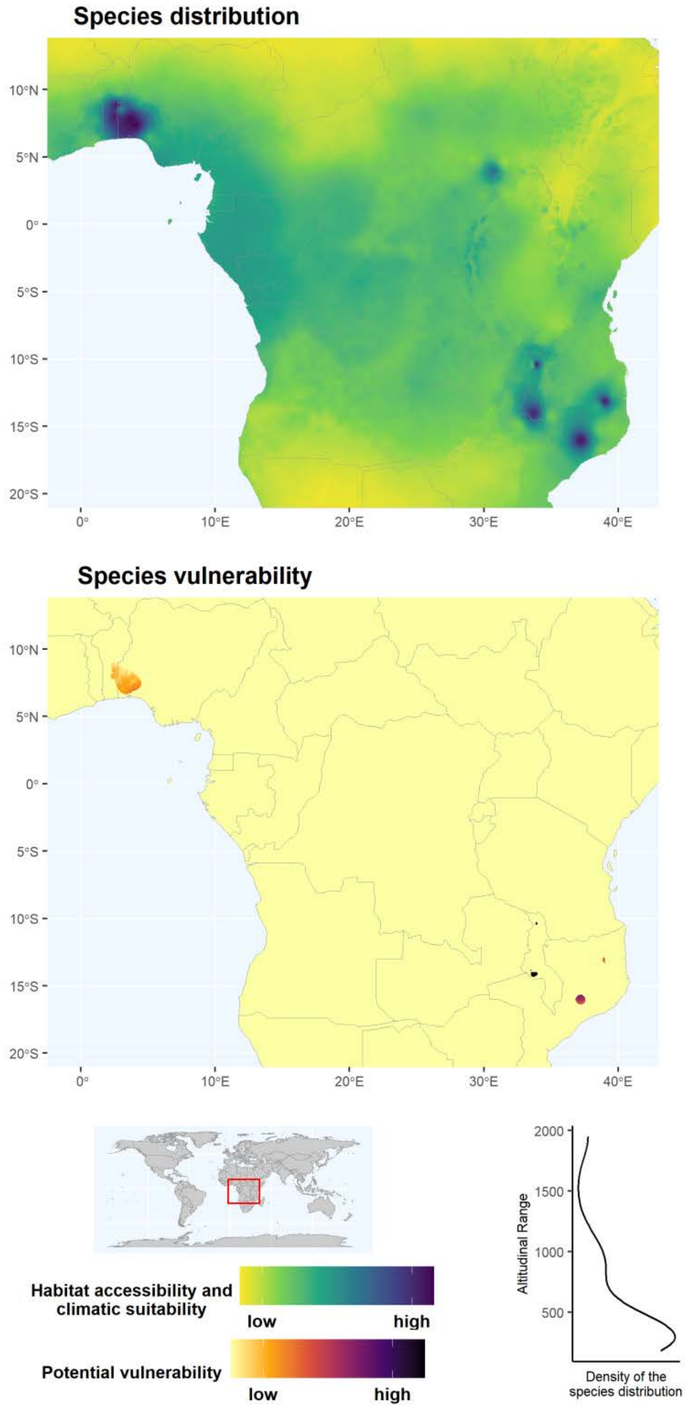






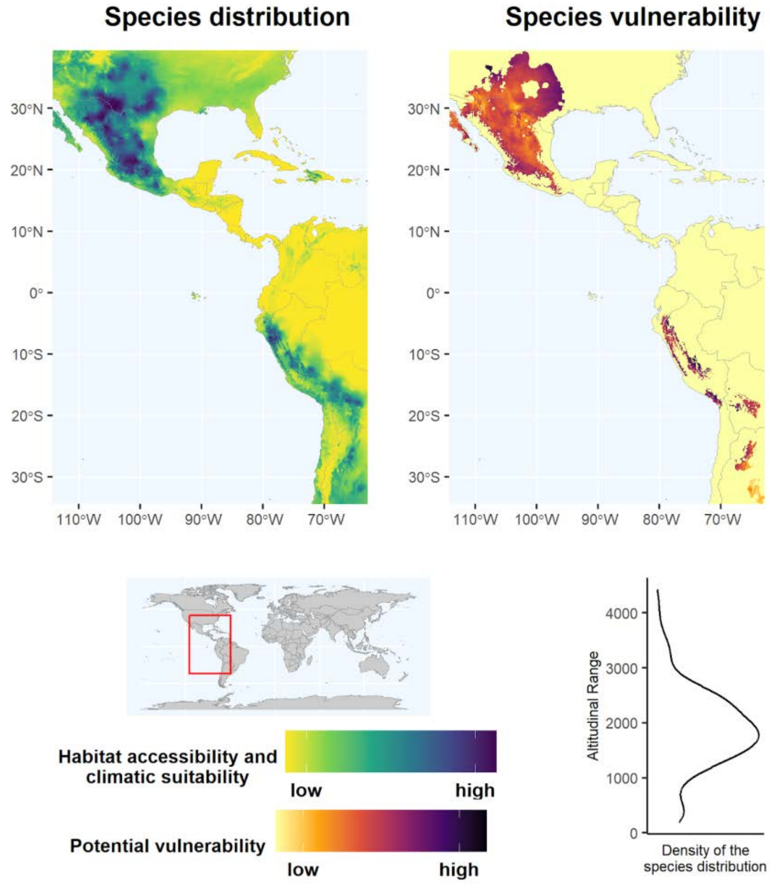
S. nivea is a homoiochlorophyllous plant whose distribution comprises Botswana, Madagascar, Mozambique, Northern Provinces, Zimbabwe. *S. nivea* individuals can be primarily found in equatorial and arid climates, ranging from 87 to 167 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *S. nivea* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

Selaginella njamnjamensis Hieron.



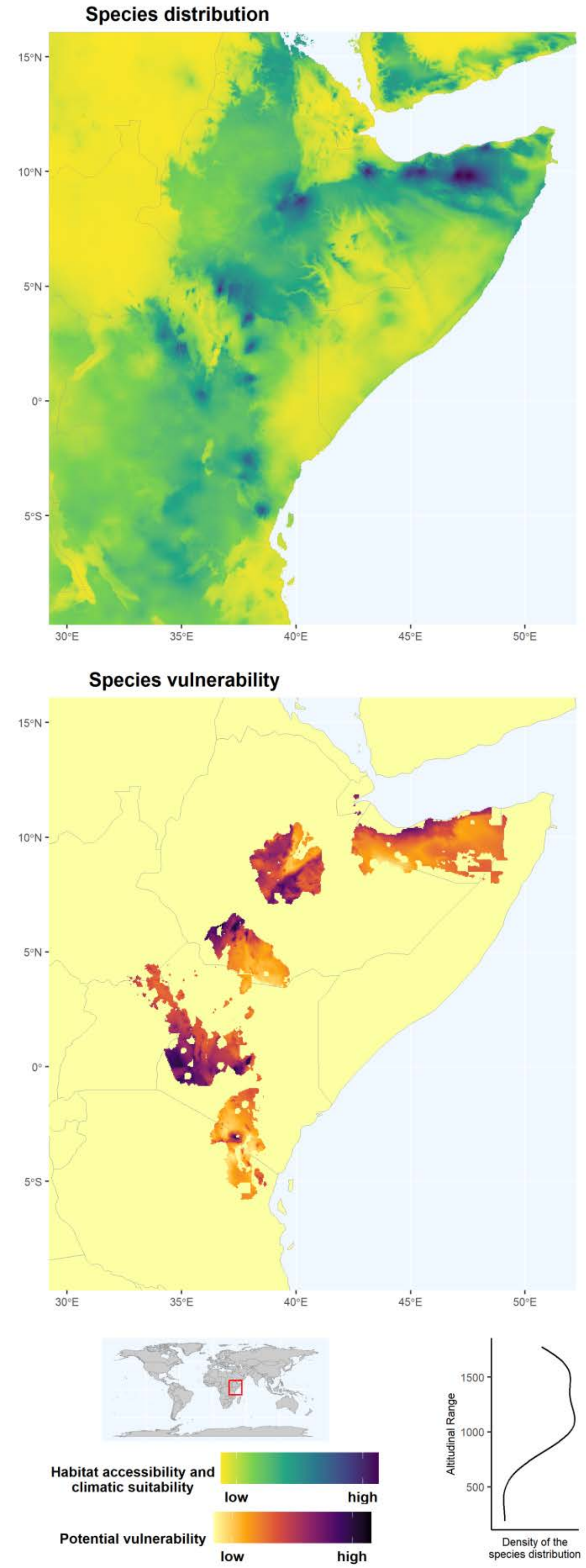
S. njamnjamensis is a homoiochlorophyllous plant whose distribution comprises Angola, Benin, Cameroon, Central African Republic, Malawi, Mali, Mozambique, Nigeria, Sudan, Tanzania, Uganda, Zambia, Zaïre. *S. njamnjamensis* individuals can be primarily found in equatorial and warm temperate climates, ranging from 182 to 1950 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. njamnjamensis* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, Malawi. This species has not yet been assessed by IUCN, and 14% of its distribution range is currently found within protected areas.

Selaginella peruviana (Milde) Hieron.



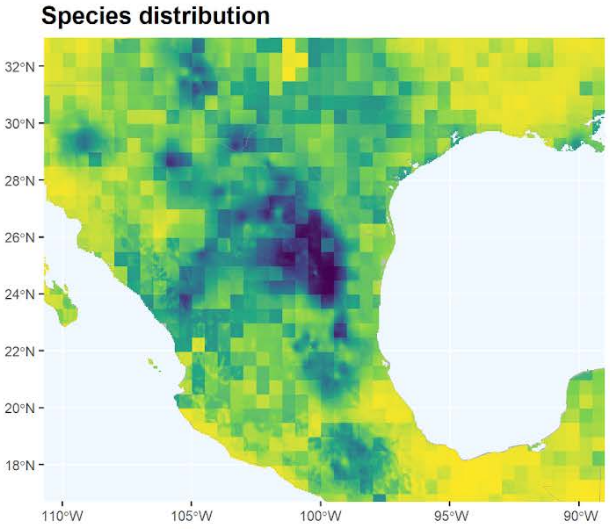
S. peruviana is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southwest, New Mexico, Oklahoma, Peru, Texas. *S. peruviana* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 195 to 4427 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. peruviana* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Chile, Ecuador, Mexico, Peru, United States. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

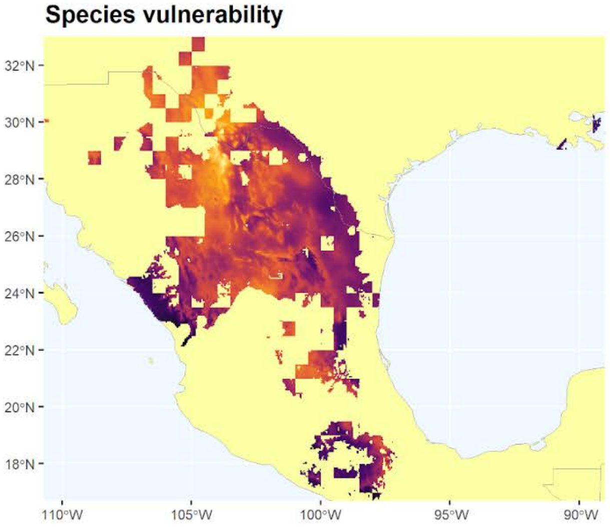
Selaginella phillipsiana (Hieron.) Alston

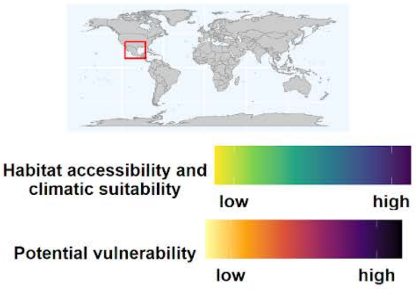


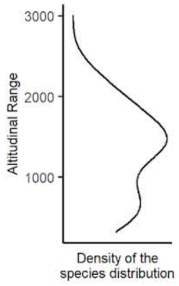
S. phillipsiana is a plant whose distribution comprises Ethiopia, Kenya, Somalia, Tanzania, Uganda. *S. phillipsiana* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 189 to 1776 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *S. phillipsiana* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia, Kenya, Somalia, Tanzania, Uganda. This species has not yet been assessed by IUCN, and 26% of its distribution range is currently found within protected areas.

Selaginella pilifera A. Braun
(also cited as *Selaginella pringlei*)



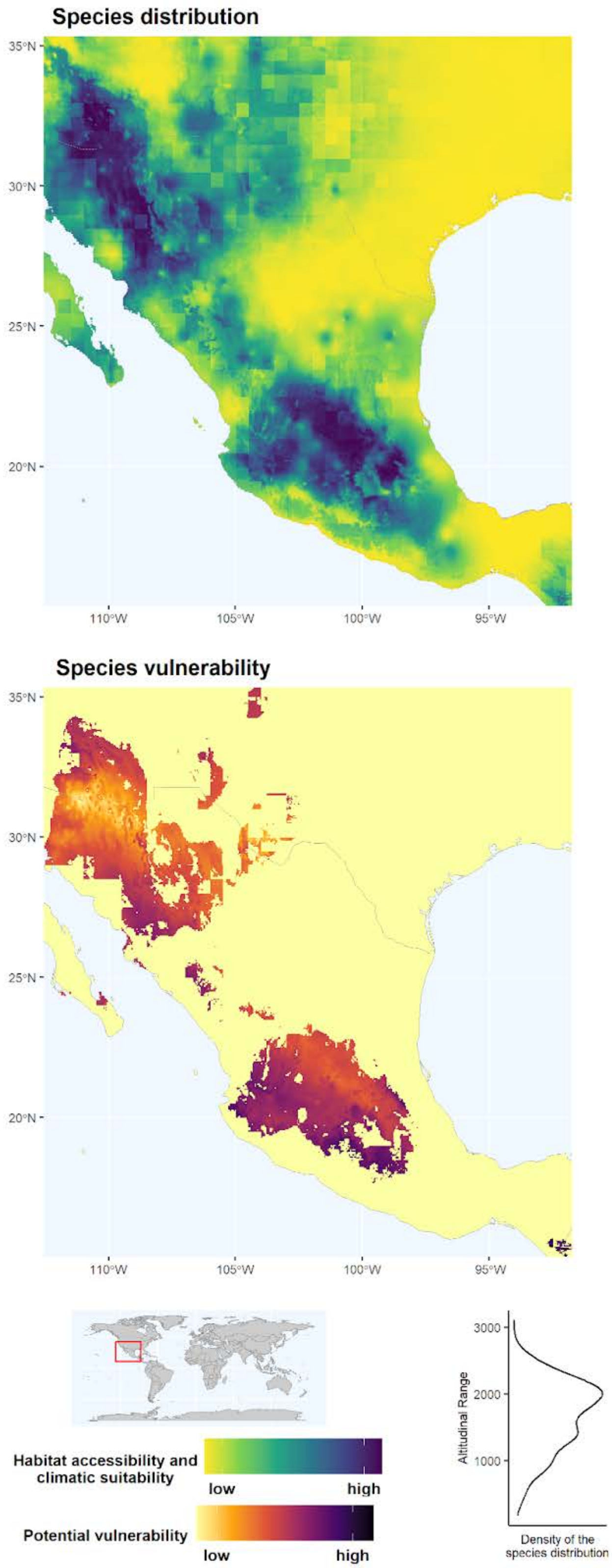






S. pilifera is a homoiochlorophyllous plant whose distribution comprises Mexico Northeast, Mexico Northwest, New Mexico, Texas. *S. pilifera* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 321 to 3010 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *S. pilifera* populations are expected to be potentially more vulnerable to climate change in parts of Mexico, United States. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

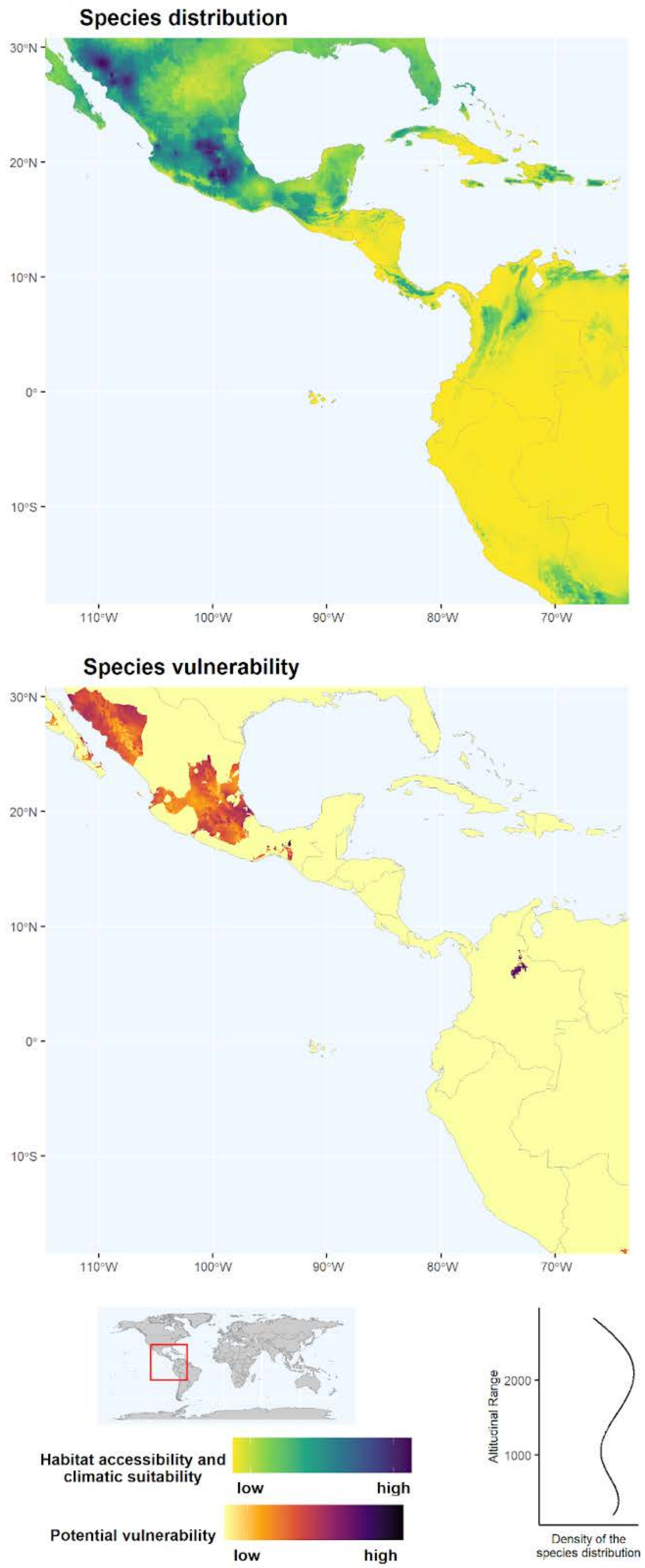
Selaginella rupincola Underw.



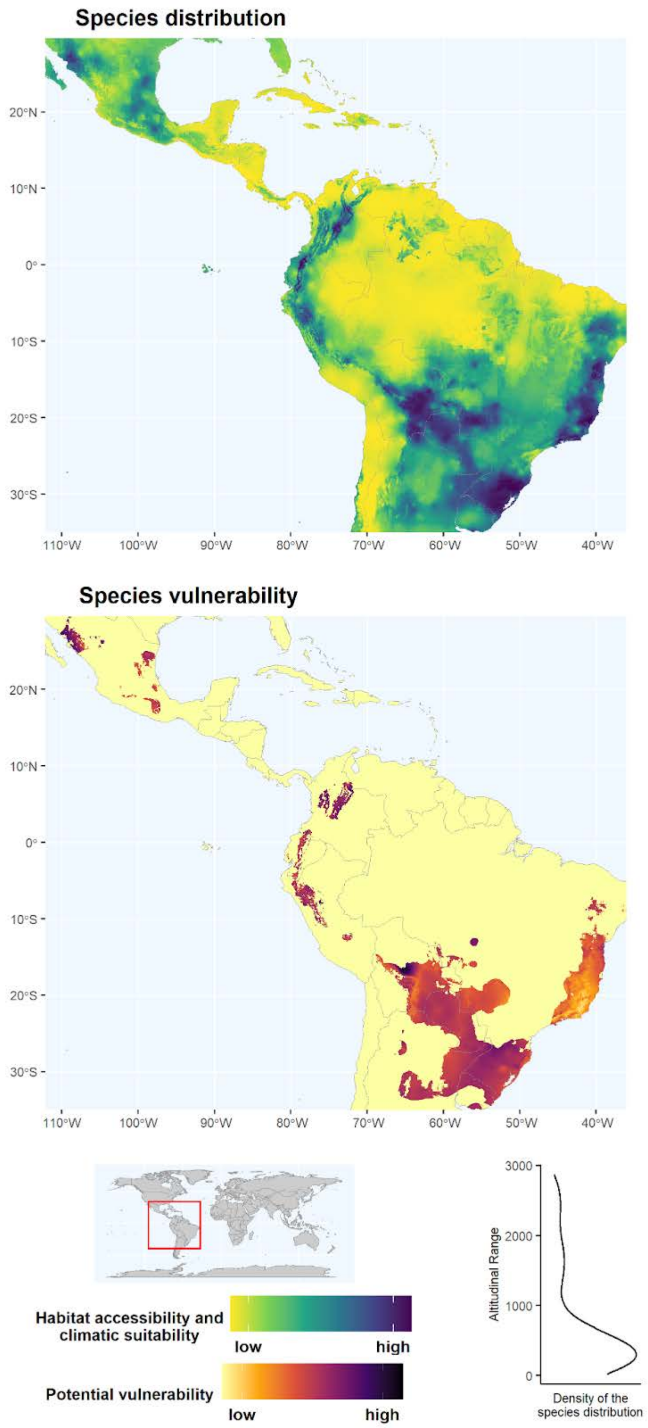
S. rupincola is a plant whose distribution comprises Arizona, Mexico Central, Mexico Northeast, Mexico Northwest, Mexico Southwest, New Mexico, Texas. *S. rupincola* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 176 to 3112 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. rupincola* populations are expected to be potentially more vulnerable to climate change in parts of Guatemala, Mexico. This species has not yet been assessed by IUCN, and only 11% of its distribution range is currently found within protected areas.

Selaginella sartorii Hieron.

S. sartorii is a homoiochlorophyllous plant whose distribution comprises Colombia, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southeast, Mexico Southwest, Venezuela. *S. sartorii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 195 to 2840 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. sartorii* populations are expected to be potentially more vulnerable to climate change in parts of Colombia, Mexico. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

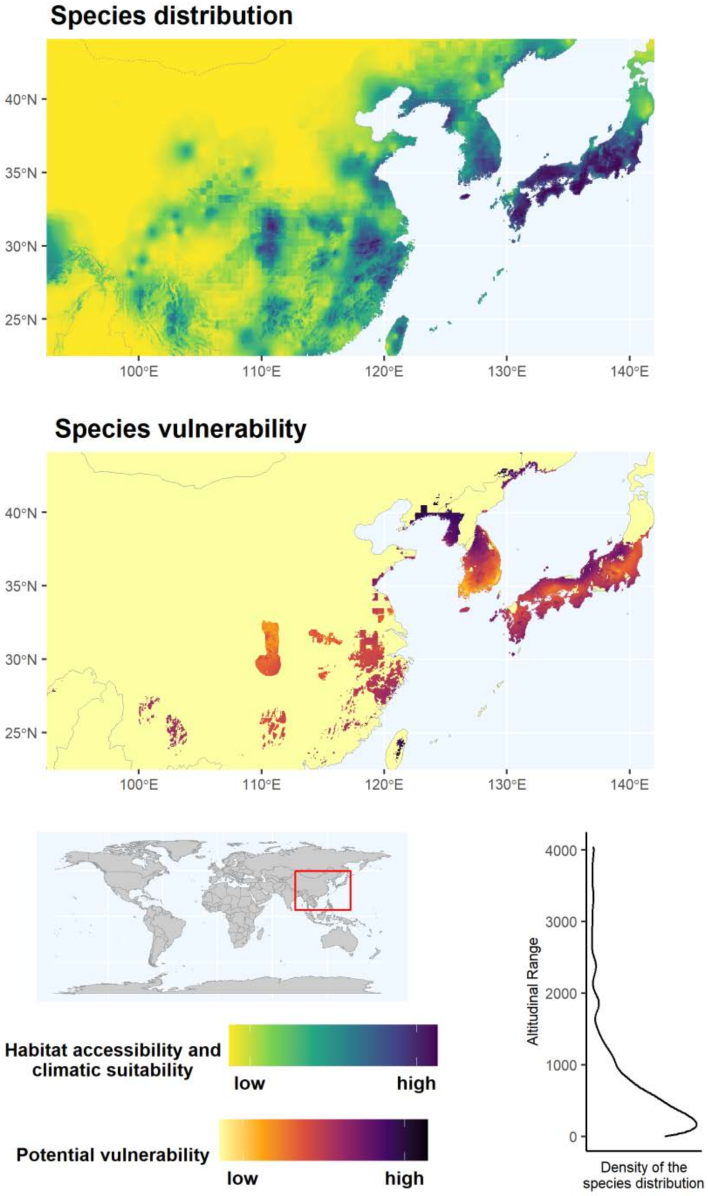


Selaginella sellowii Hieron.



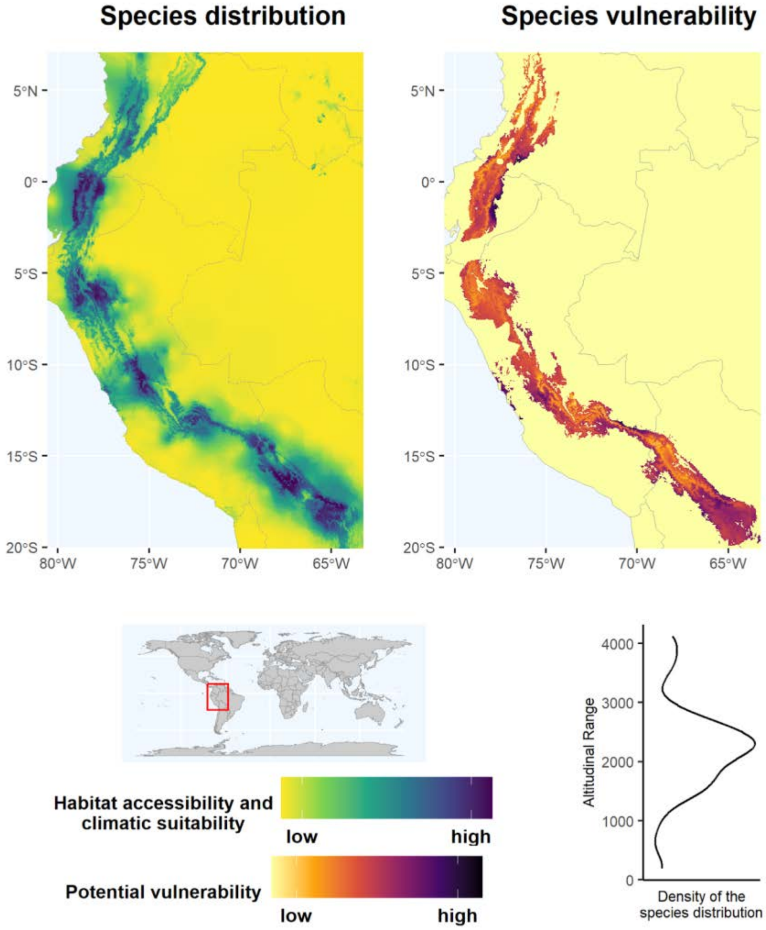
S. sellowii is a homoiochlorophyllous plant whose distribution comprises Argentina Northeast, Argentina Northwest, Bolivia, Brazil Northeast, Brazil South, Brazil Southeast, Brazil West-Central, Colombia, Cuba, Ecuador, Mexico Central, Mexico Gulf, Mexico Northeast, Mexico Northwest, Mexico Southwest, Paraguay, Peru, Uruguay, Venezuela. *S. sellowii* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 21 to 2874 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. sellowii* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Brazil, Colombia, Ecuador, Mexico, Peru, Venezuela. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

Selaginella tamariscina (P. Beauv.) Spring



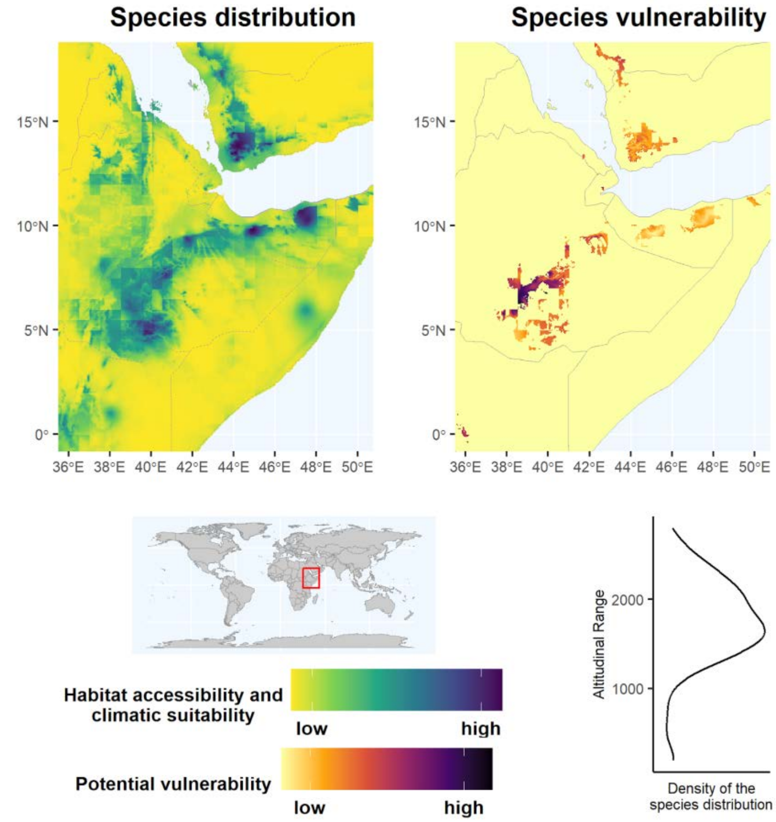
S. tamariscina is a homoiochlorophyllous plant whose distribution comprises Amur, China North-Central, China South-Central, China Southeast, Hainan, Inner Mongolia, Japan, Jawa, Khabarovsk, Korea, Lesser Sunda Is., Manchuria, Nansei-shoto, Ogasawara-shoto, Philippines, Primorye, Qinghai, Sulawesi, Taiwan, Thailand, Vietnam. *S. tamariscina* individuals can be primarily found in equatorial, arid, warm temperate, and snow climates, ranging from 1 to 4044 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. tamariscina* populations are expected to be potentially more vulnerable to climate change in parts of China, Japan, Korea, Democratic People's Republic of, Korea, Republic of, Russia, Taiwan. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

Selaginella trisulcata Aspl.



S. trisulcata is a plant whose distribution comprises Bolivia, Brazil North, Colombia, Ecuador, Peru. *S. trisulcata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 195 to 4123 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *S. trisulcata* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia, Colombia, Ecuador, Peru. This species has not yet been assessed by IUCN, and only 27% of its distribution range is currently found within protected areas.

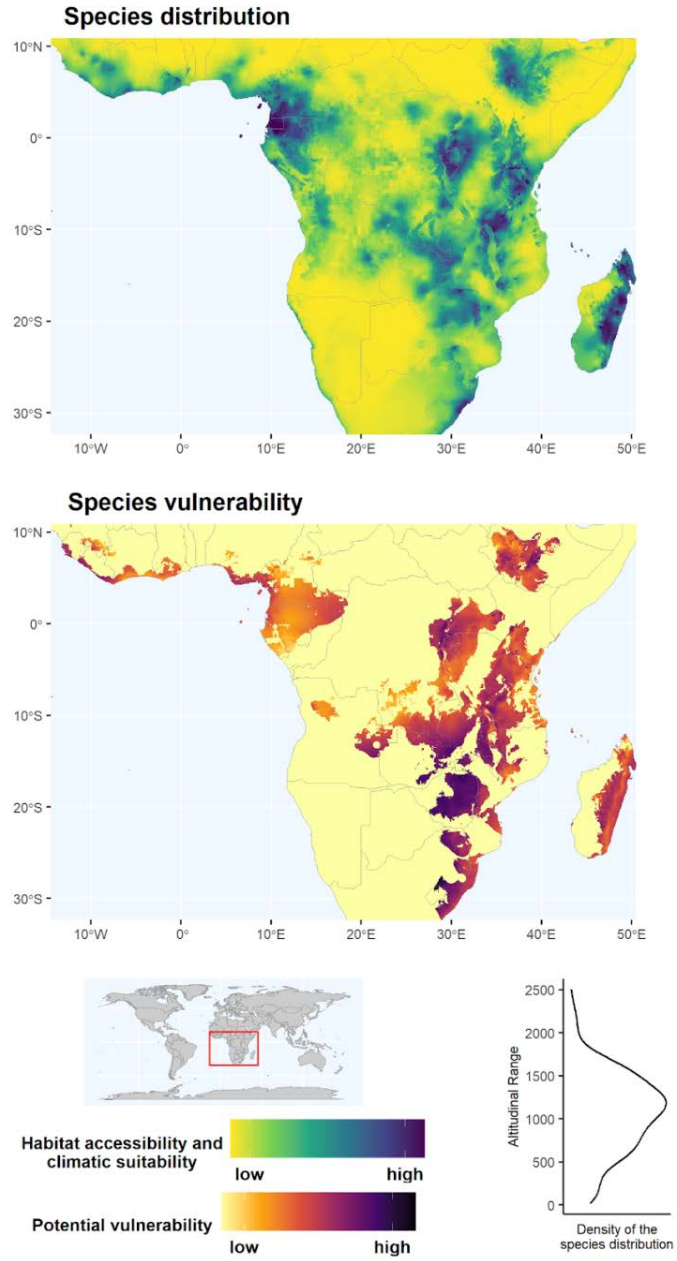
Selaginella yemensis (Sw.) Spring



S. yemensis is a plant whose distribution comprises Ethiopia, Kenya, Saudi Arabia, Somalia, Yemen. *S. yemensis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 196 to 2797 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *S. yemensis* populations are expected to be potentially more vulnerable to climate change in parts of Ethiopia. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

Tectariaceae

Arthropteris orientalis (J.F. Gmel.) Posth.

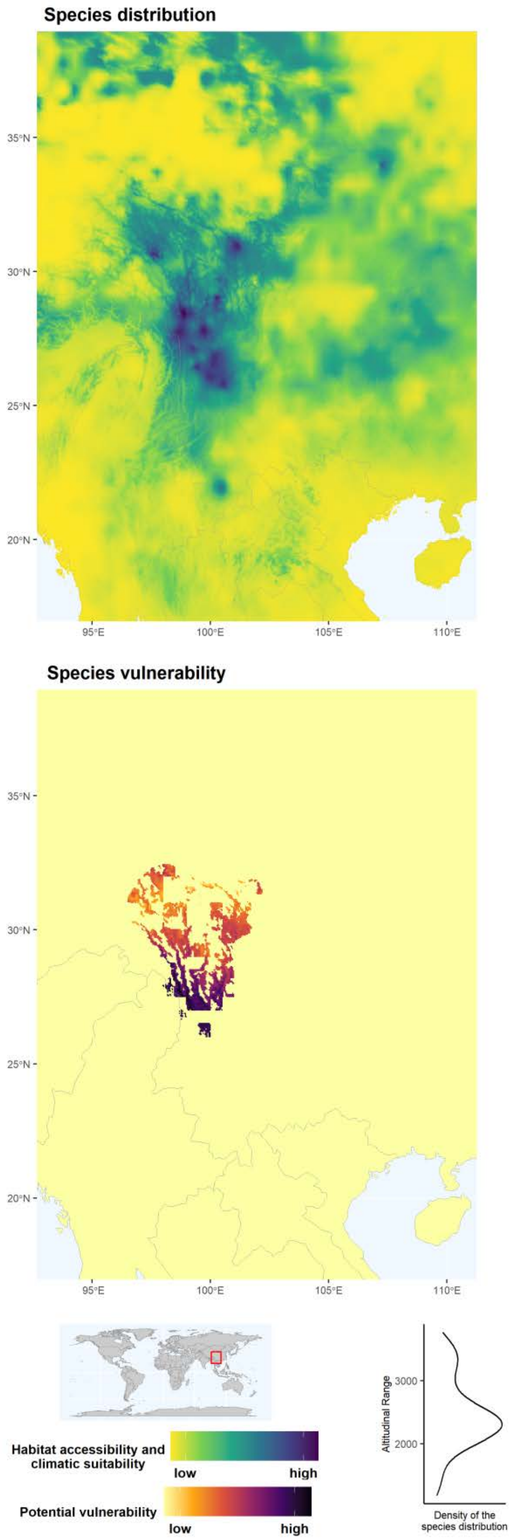


A. orientalis is a homoiochlorophyllous plant whose distribution comprises Angola, Burundi, Cameroon, Central African Republic, Comoros, Ethiopia, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Rwanda, Réunion, Sierra Leone, Sudan, Tanzania, Uganda, Yemen, Zambia, Zaïre, Zimbabwe. *A. orientalis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 17 to 2506 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *A. orientalis* populations are expected to be potentially more vulnerable to climate change in parts of Democratic Republic of the Congo, Cameroon, Ethiopia, Kenya, Mozambique, Malawi, Rwanda, South Africa, Lesotho, Botswana, Tanzania, Uganda, Zambia, Zimbabwe. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.

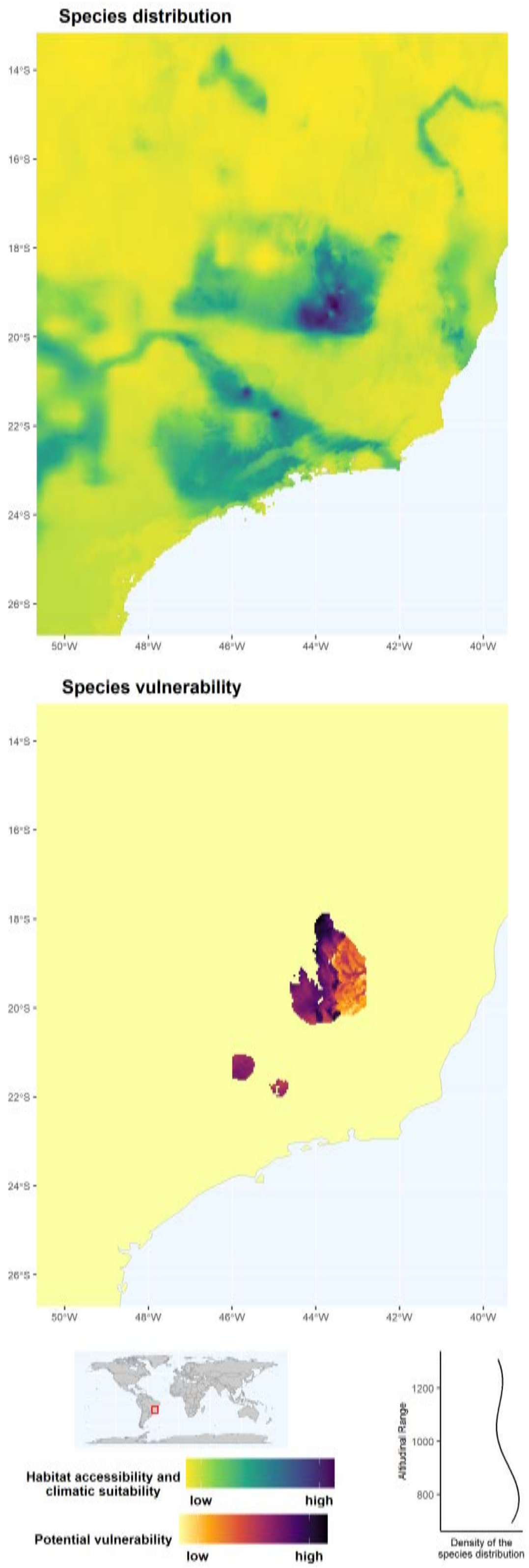
Velloziaceae

Acanthochlamys bracteata P.C. Kao

A. bracteata is a DT plant whose distribution comprises China South-Central, Tibet. *A. bracteata* individuals can be primarily found in arid and warm temperate climates, ranging from 1180 to 3765 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *A. bracteata* populations are expected to be potentially more vulnerable to climate change in parts of the southern parts of its distribution. This species is listed as Vulnerable by IUCN, and only 13% of its distribution range is currently found within protected areas.



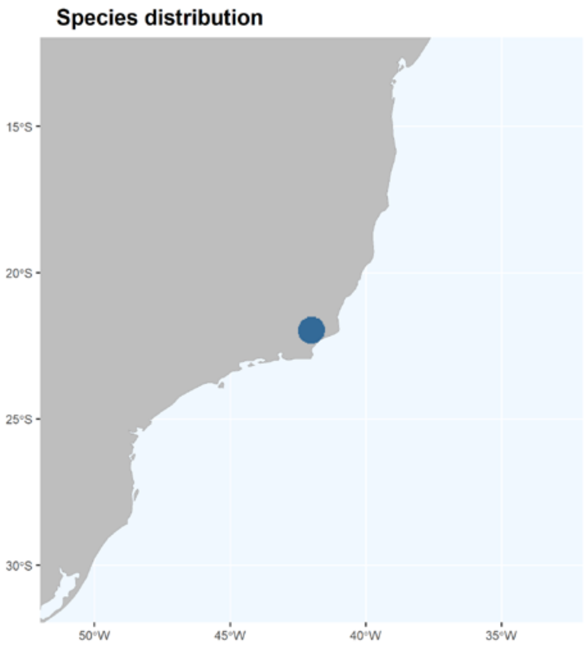
Barbacenia blackii L.B. Sm. (also cited as *Aylthonia blackii*)

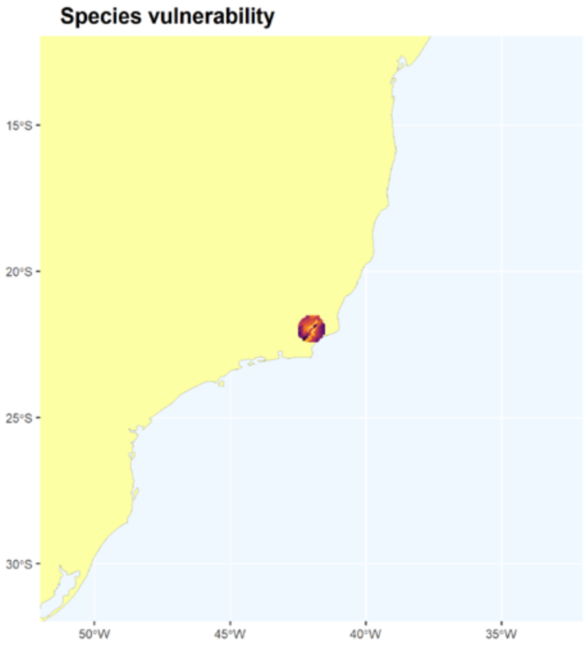


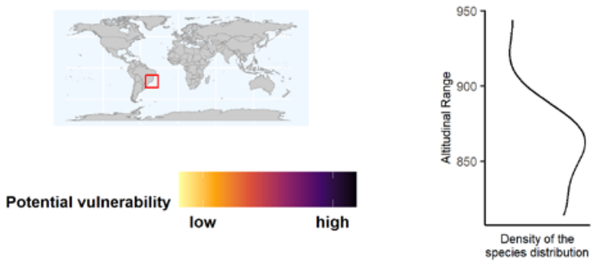
B. blackii is a DT plant whose distribution is restricted to Brazil Southeast. *B. blackii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 693 to 1308 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. blackii* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Barbacenia fanniae (N.L. Menezes) Mello-Silva (also cited as *Pleurostima fanniae*)

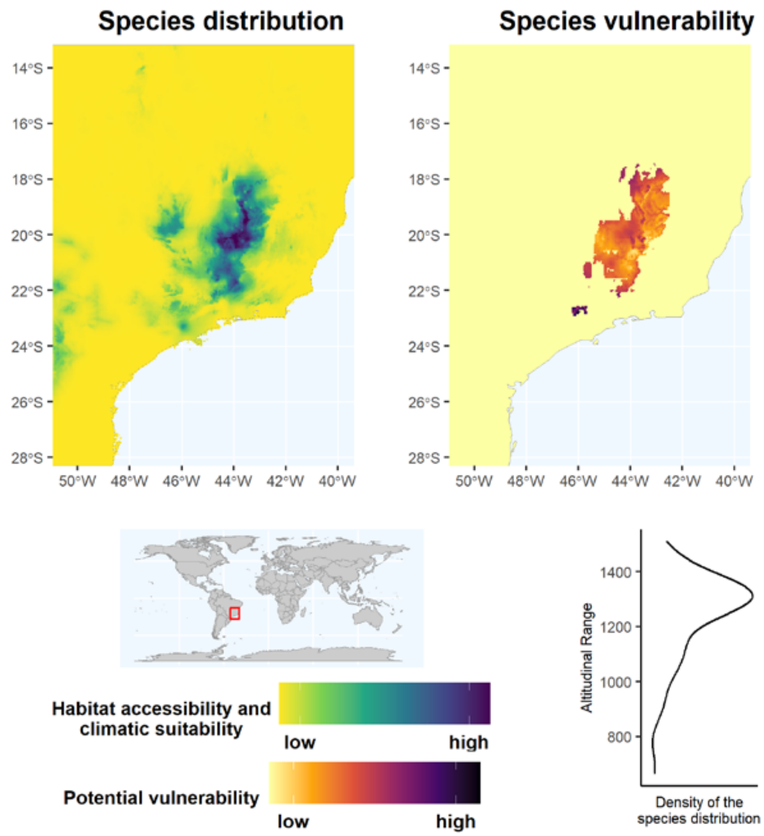
B. fanniae is a DT plant whose distribution is restricted to Brazil Southeast. *B. fanniae* individuals can be primarily found in equatorial and warm temperate climates, ranging from 814 to 944 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). More occurrence points are needed for a consistent evaluation of the conservation of *B. fanniae* populations. This species has not yet been assessed by IUCN, and only 7% of its distribution range is currently found within protected areas.







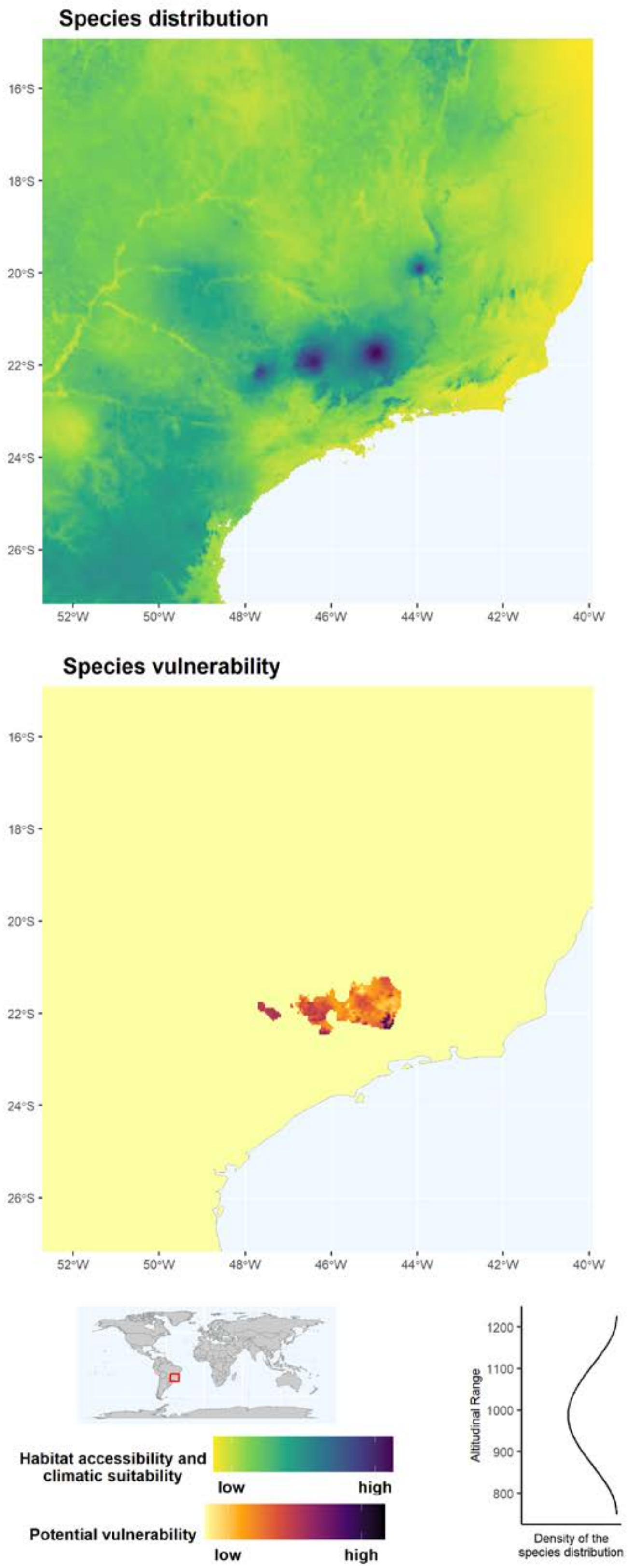
Barbacenia flava Mart. ex Schult. F.
(also cited as *Barbacenia sellovii*)



B. flava is a DT plant whose distribution is restricted to Brazil Southeast. *B. flava* individuals can be primarily found in equatorial and warm temperate climates, ranging from 663 to 1512 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. flava* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

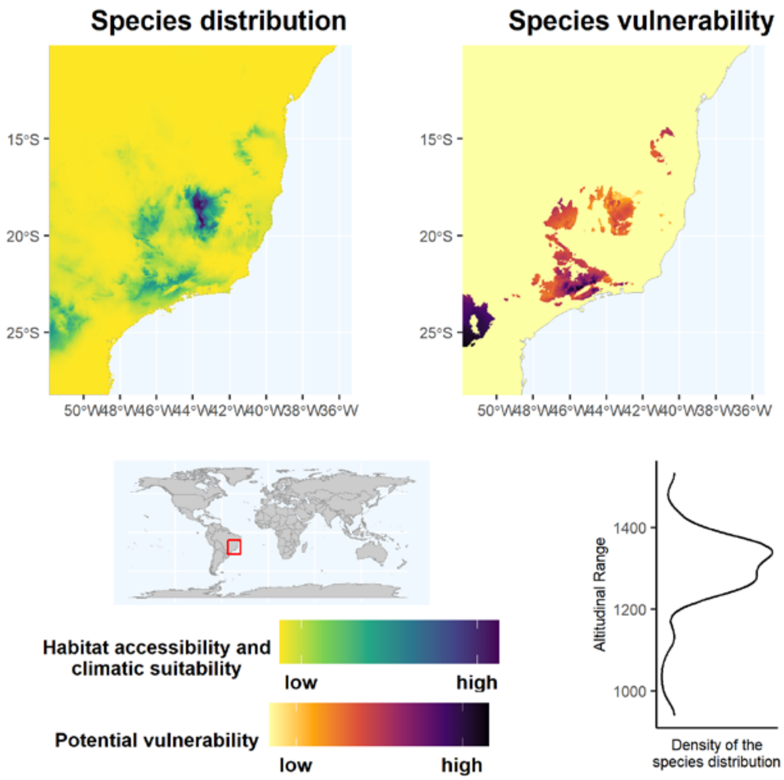
Barbacenia fragrans Goethart & Henrard

B. fragrans is a DT plant whose distribution is restricted to Brazil Southeast. *B. fragrans* individuals can be primarily found in warm temperate climates, ranging from 749 to 1227 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime. *B. fragrans* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.



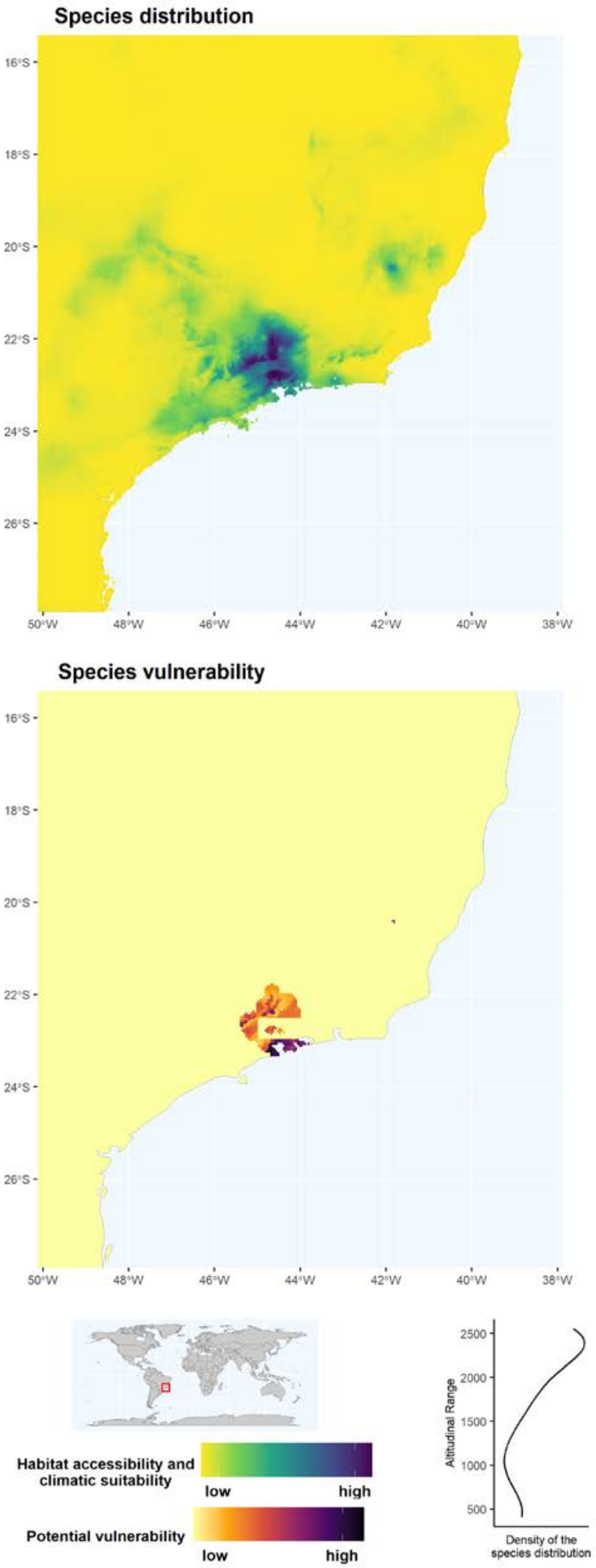
Barbacenia gentianoides Goethart & Henrard

(also cited as *Aylthonia gentianoides*)



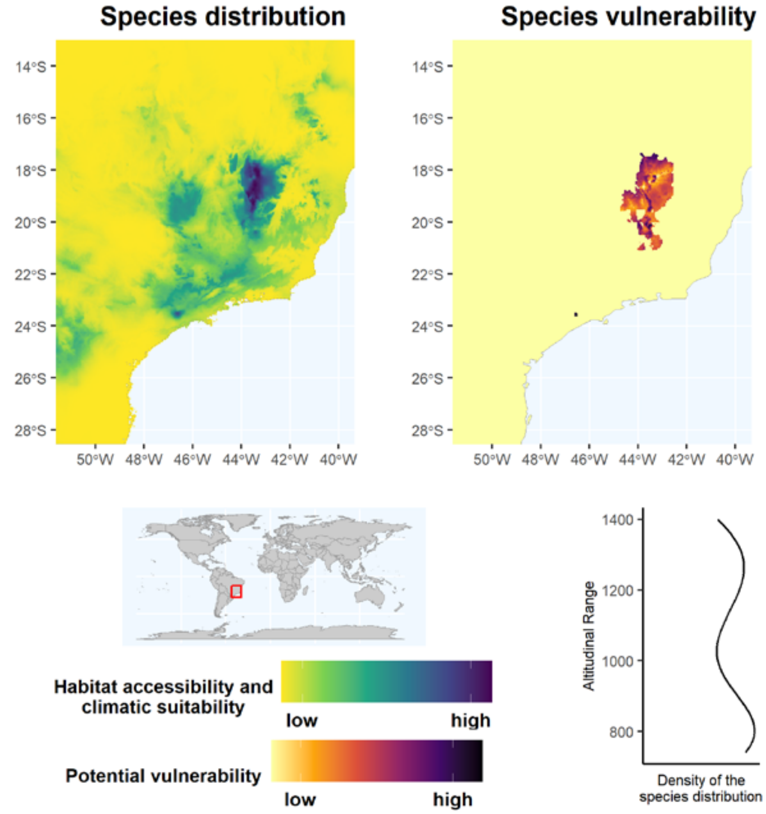
B. gentianoides is a DT plant whose distribution is restricted to Brazil Southeast. *B. gentianoides* individuals can be primarily found in warm temperate climates, ranging from 940 to 1533 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. More occurrence points are needed for a consistent evaluation of the conservation of *B. gentianoides* populations. This species has not yet been assessed by IUCN, and only 30% of its distribution range is currently found within protected areas.

Barbacenia gounelleana Beauverd
(also cited as *Pleurostima gounelleana*)



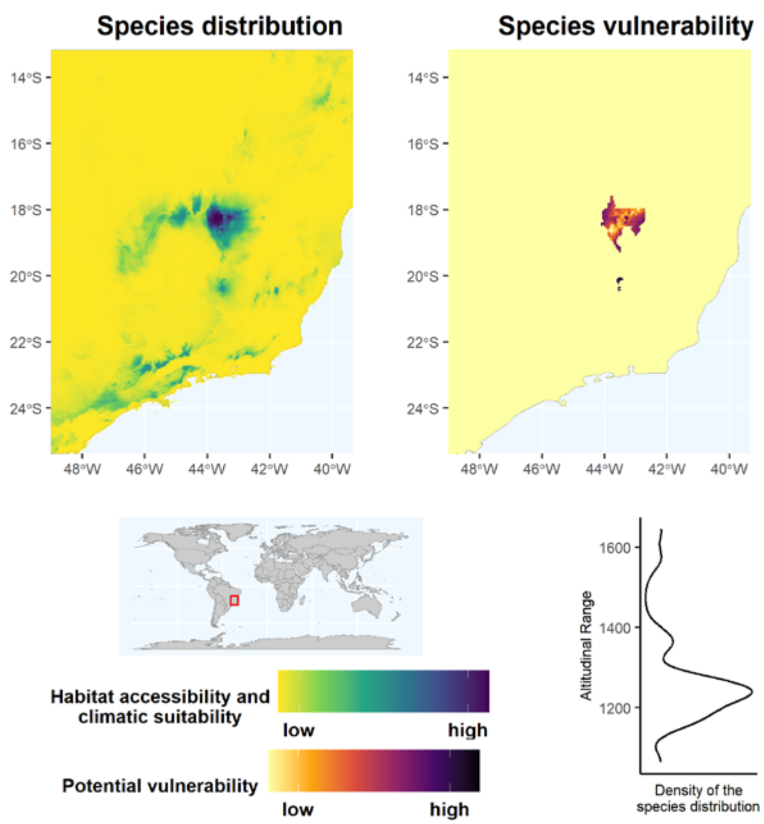
B. gounelleana is a DT plant whose distribution is restricted to Brazil Southeast. *B. gounelleana* individuals can be primarily found in equatorial and warm temperate climates, ranging from 410 to 2555 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime. *B. gounelleana* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, although 52% of its distribution range is currently found within protected areas.

Barbacenia graminifolia L.B. Sm.



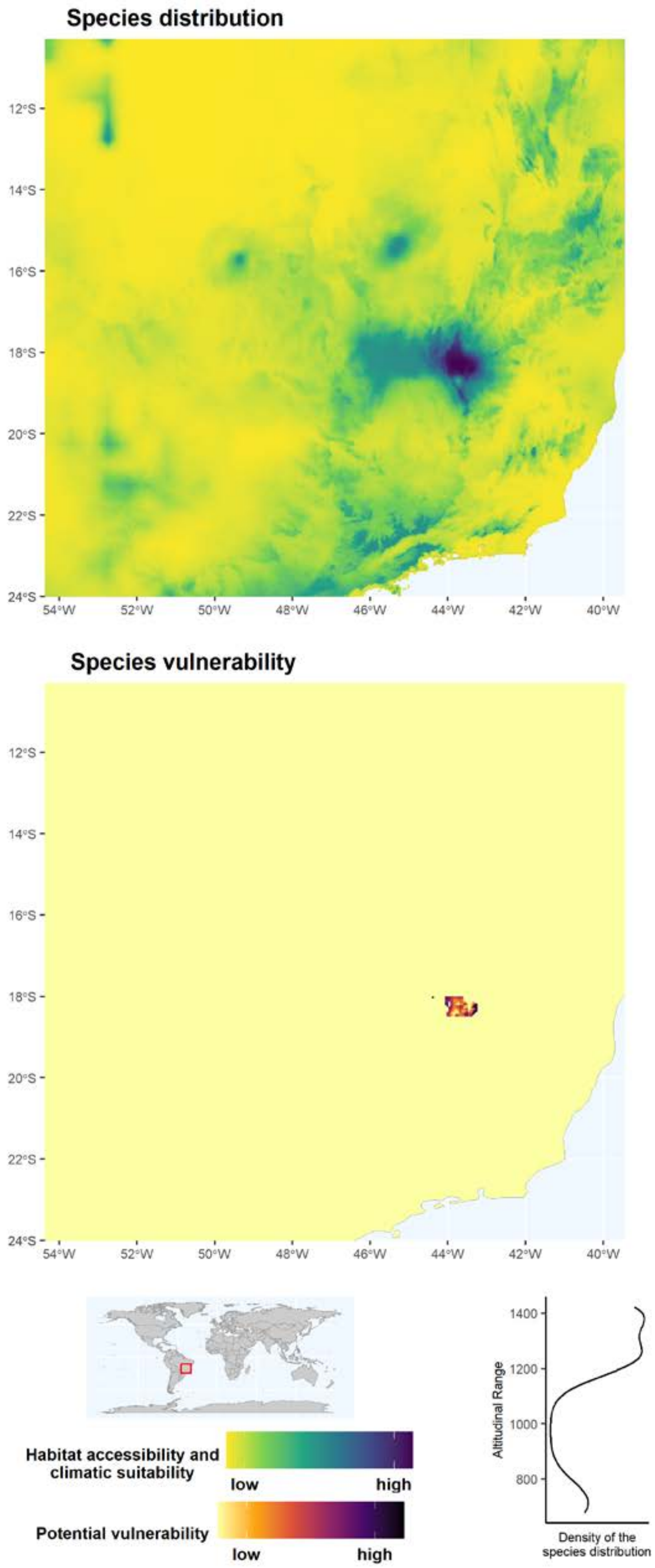
B. graminifolia is a DT plant whose distribution is restricted to Brazil Southeast. *B. graminifolia* individuals can be primarily found in equatorial and warm temperateclimates, ranging from 741 to 1400 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. graminifolia* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

Barbacenia longiflora Mart.



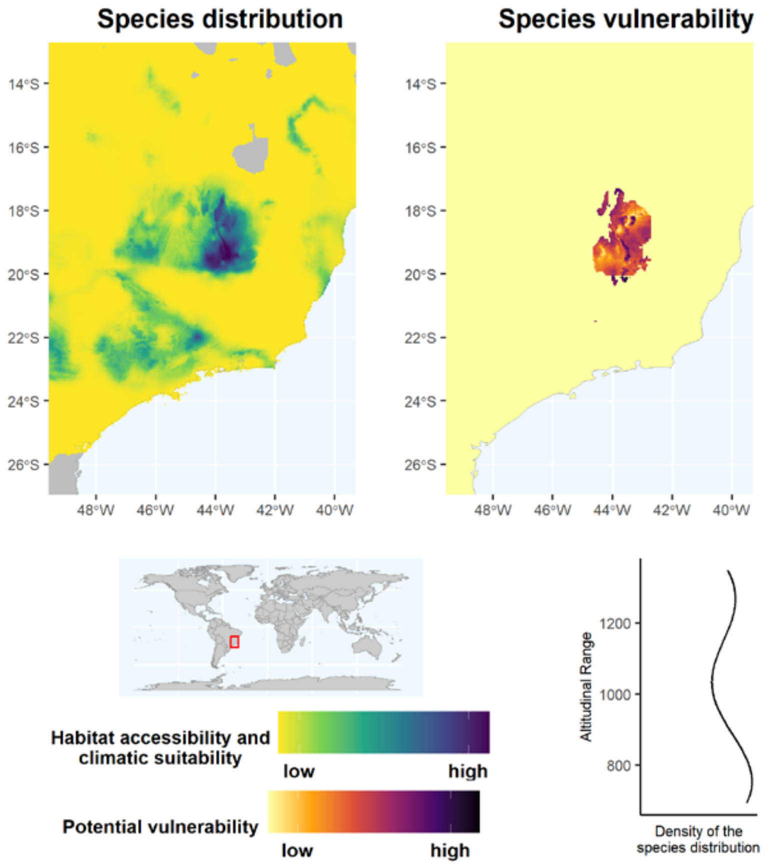
B. longiflora is a DT plant whose distribution is restricted to Brazil Southeast. *B. longiflora* individuals can be primarily found in warm temperate climates, ranging from 1064 to 1646 m.a.s.l. Their occurrence is restricted to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. longiflora* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.

Barbacenia longiscapa Goethart & Henrard



B. longiscapa is a DT plant whose distribution is restricted to Brazil Southeast. *B. longiscapa* individuals can be primarily found in equatorial and warm temperate climates, ranging from 679 to 1423 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *B. longiscapa* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Barbacenia macrantha Lem.

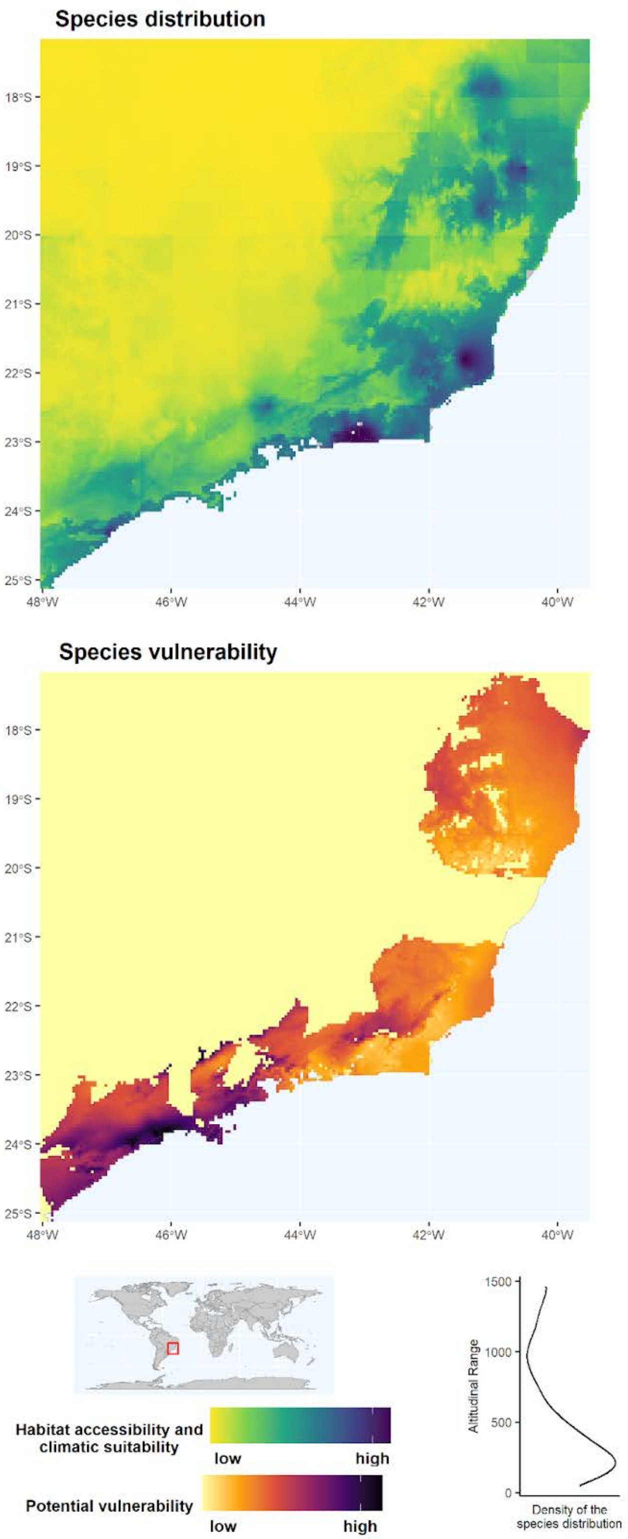


B. macrantha is a DT plant whose distribution is restricted to Brazil Southeast. *B. macrantha* individuals can be primarily found in equatorial and warm temperate climates, ranging from 693 to 1349 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. macrantha* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

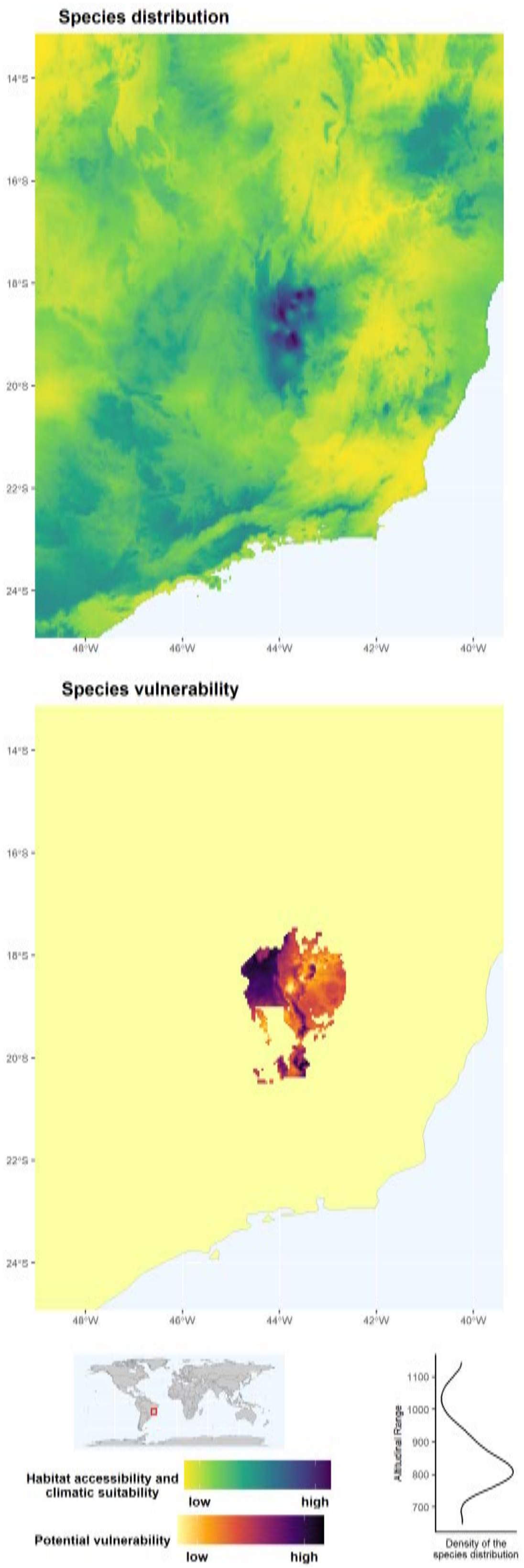
Barbacenia purpurea Hook.

(also cited as *Pleurostima purpurea*)

B. purpurea is a DT plant whose distribution is restricted to Brazil Southeast. *B. purpurea* individuals can be primarily found in equatorial and warm temperate climates, ranging from 49 to 1464 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). *B. purpurea* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.



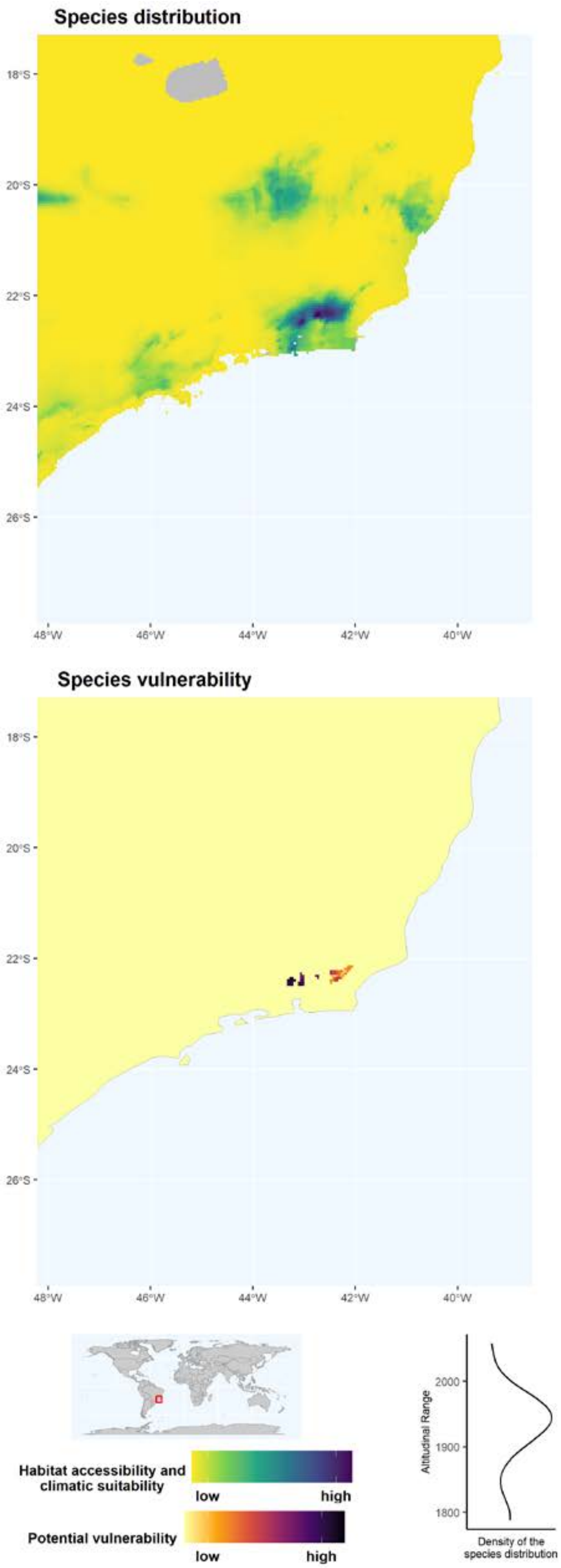
Barbacenia riedeliana Goethart & Henrard



B. riedeliana is a DT plant whose distribution is restricted to Brazil Southeast. *B. riedeliana* individuals can be primarily found in equatorial and warm temperate climates, ranging from 648 to 1145 m.a.s.l. Their occurrence is restricted to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. riedeliana* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

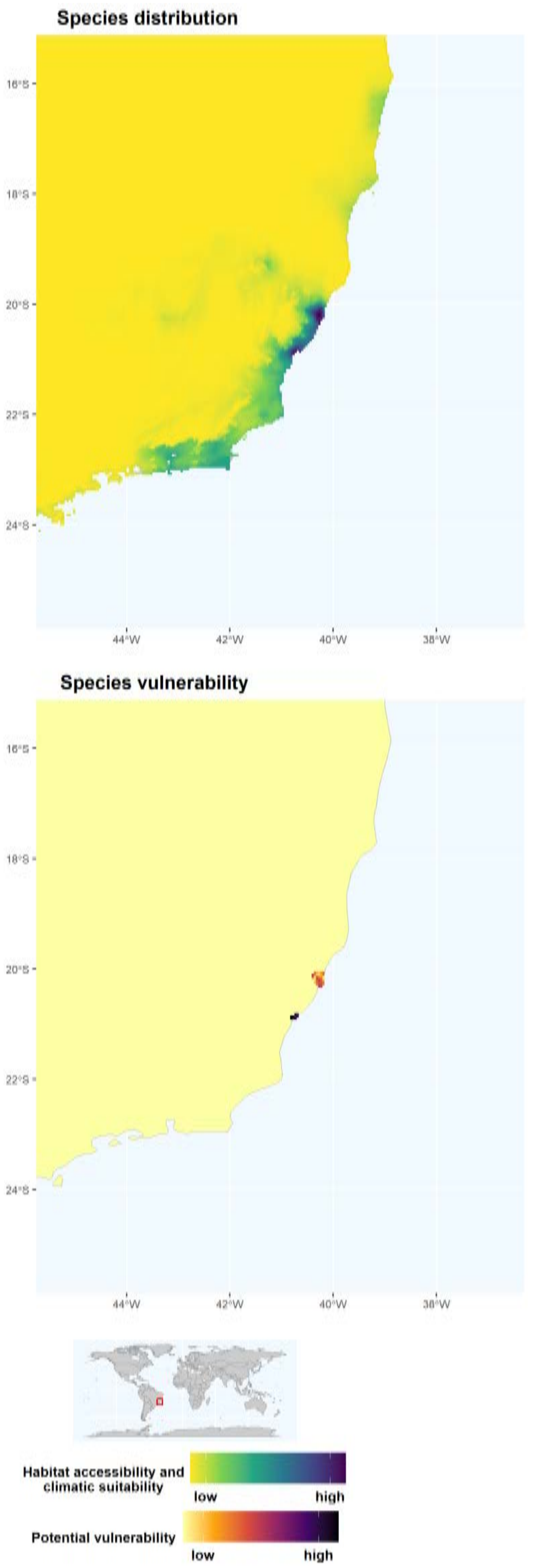
Barbacenia seubertiana Goethart & Henrard
(also cited as *Pleurostima seubertiana*)

B. seubertiana is a DT plant whose distribution is restricted to Brazil Southeast. *B. seubertiana* individuals can be primarily found in warm temperate climates, ranging from 1788 to 2058 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). *B. seubertiana* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and 57% of its distribution range is currently found within protected areas.



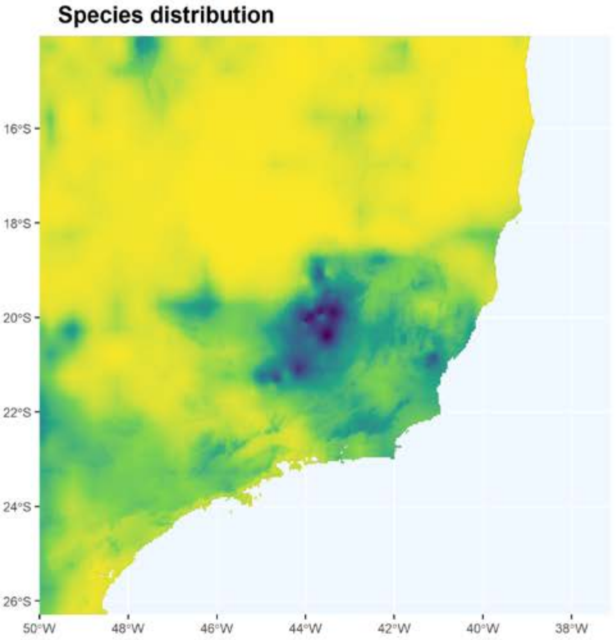
Barbacenia spectabilis L.B. Sm. & Ayensu
(also cited as *Pleurostima spectabilis*)

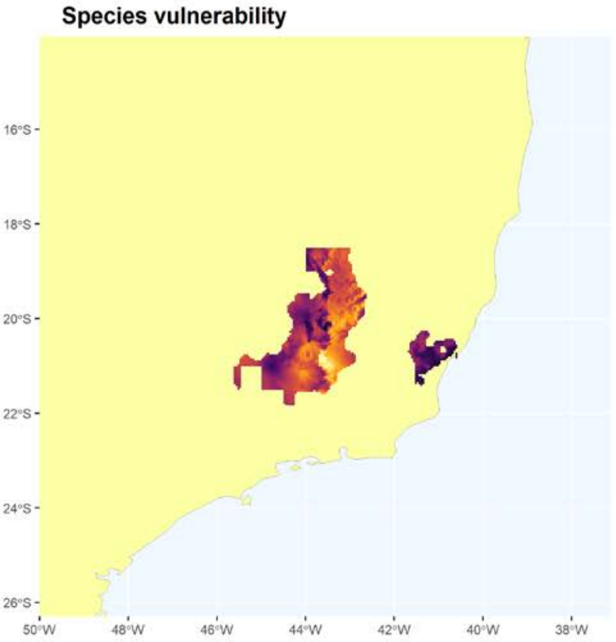
B. spectabilis is a DT plant whose distribution is restricted to Brazil Southeast. *B. spectabilis* individuals can be primarily found in equatorial climates, circa 513 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). *B. spectabilis* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 44% of its distribution range is currently found within protected areas.

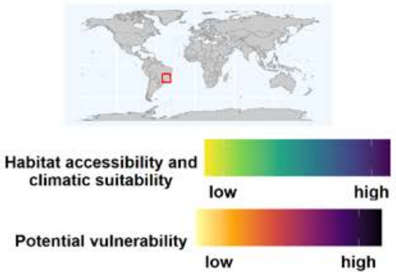


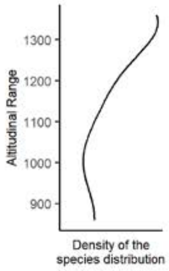
Barbacenia tomentosa Mart.

B. tomentosa is a DT plant whose distribution is restricted to Brazil Southeast. *B. tomentosa* individuals can be primarily found in equatorial and warm temperate climates, ranging from 860 to 1360 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *B. tomentosa* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

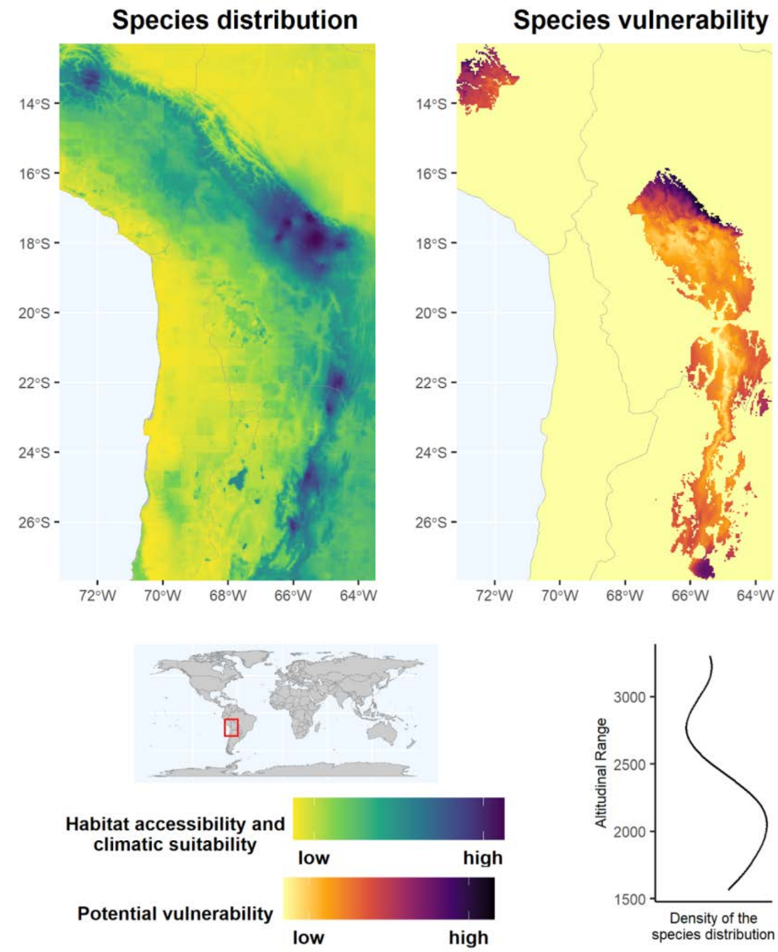






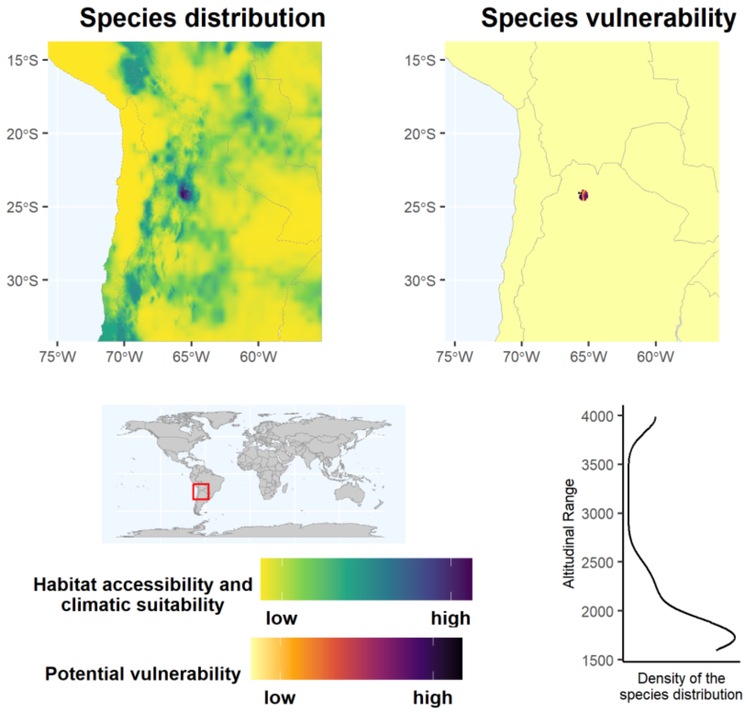


Barbaceniopsis boliviensis (Baker) L.B. Sm.



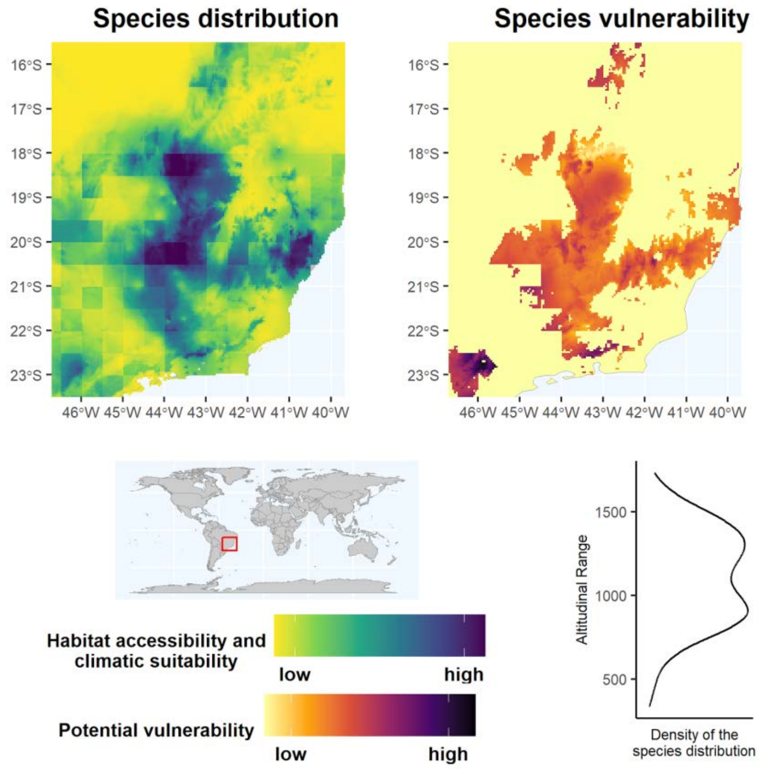
B. boliviensis is a DT plant whose distribution comprises Argentina Northwest, Bolivia. *B. boliviensis* individuals can be primarily found in arid and warm temperate climates, ranging from 1566 to 3305 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *B. boliviensis* populations are expected to be potentially more vulnerable to climate change in parts of Argentina, Bolivia, Peru. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

Barbaceniopsis humahuaquensis Noher



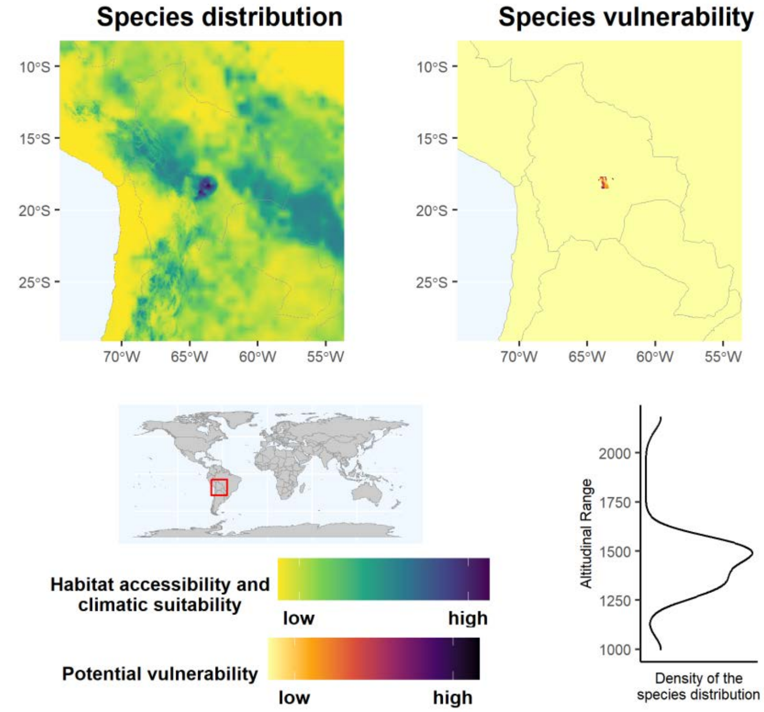
B. humahuaquensis is a DT plant whose distribution is restricted to Argentina Northwest. *B. humahuaquensis* individuals can be primarily found in arid and warm temperate climates, ranging from 1599 to 3987 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the dry season is long) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *B. humahuaquensis* populations are expected to be potentially more vulnerable to climate change in parts of Argentina. This species has not yet been assessed by IUCN, although 41% of its distribution range is currently found within protected areas.

Vellozia albiflora Pohl



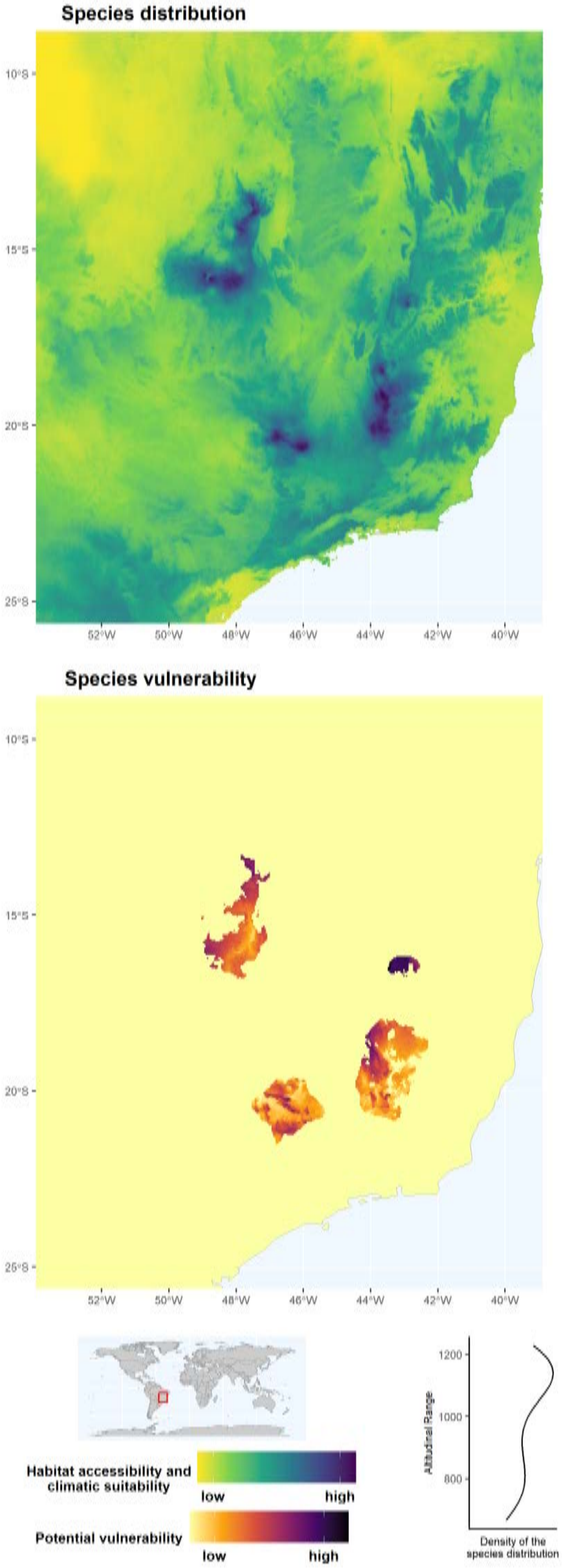
V. albiflora is a DT plant whose distribution is restricted to Brazil Southeast. *V. albiflora* individuals can be primarily found in equatorial and warm temperate climates, ranging from 337 to 1734 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *V. albiflora* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 15% of its distribution range is currently found within protected areas.

Vellozia andina Ibisch, R. Vásquez & Nowicki



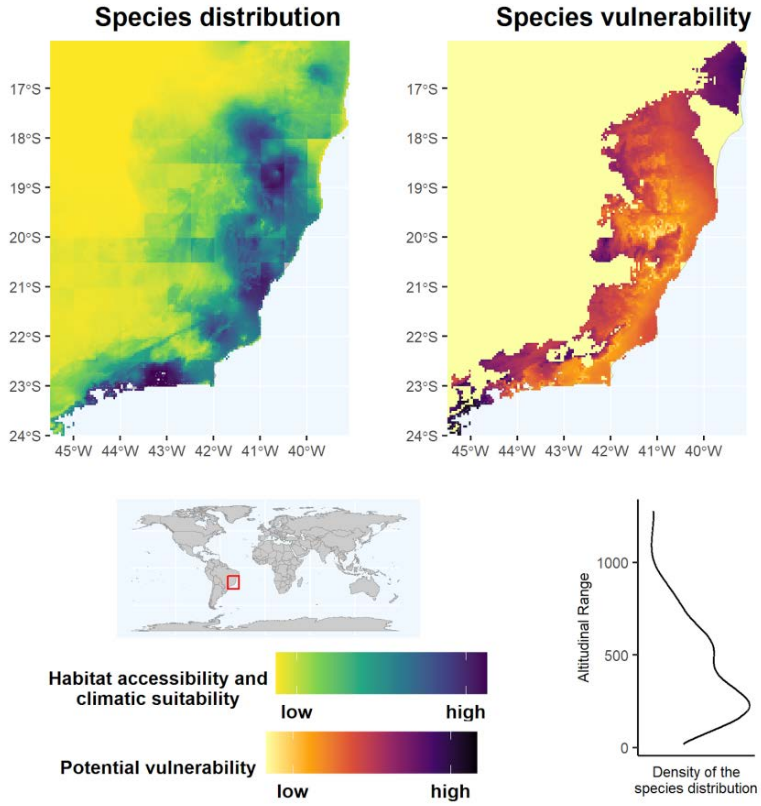
V. andina is a DT plant whose distribution is restricted to Bolivia. *V. andina* individuals can be primarily found in arid and warm temperate climates, ranging from 996 to 2184 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *V. andina* populations are expected to be potentially more vulnerable to climate change in parts of Bolivia. This species has not yet been assessed by IUCN, although 85% of its distribution range is currently found within protected areas.

Vellozia angustifolia Goethart & Henrard



V. angustifolia is a DT plant whose distribution comprises Brazil Southeast, Brazil West-Central. *V. angustifolia* individuals can be primarily found in equatorial and warm temperate climates, ranging from 666 to 1229 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. angustifolia* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

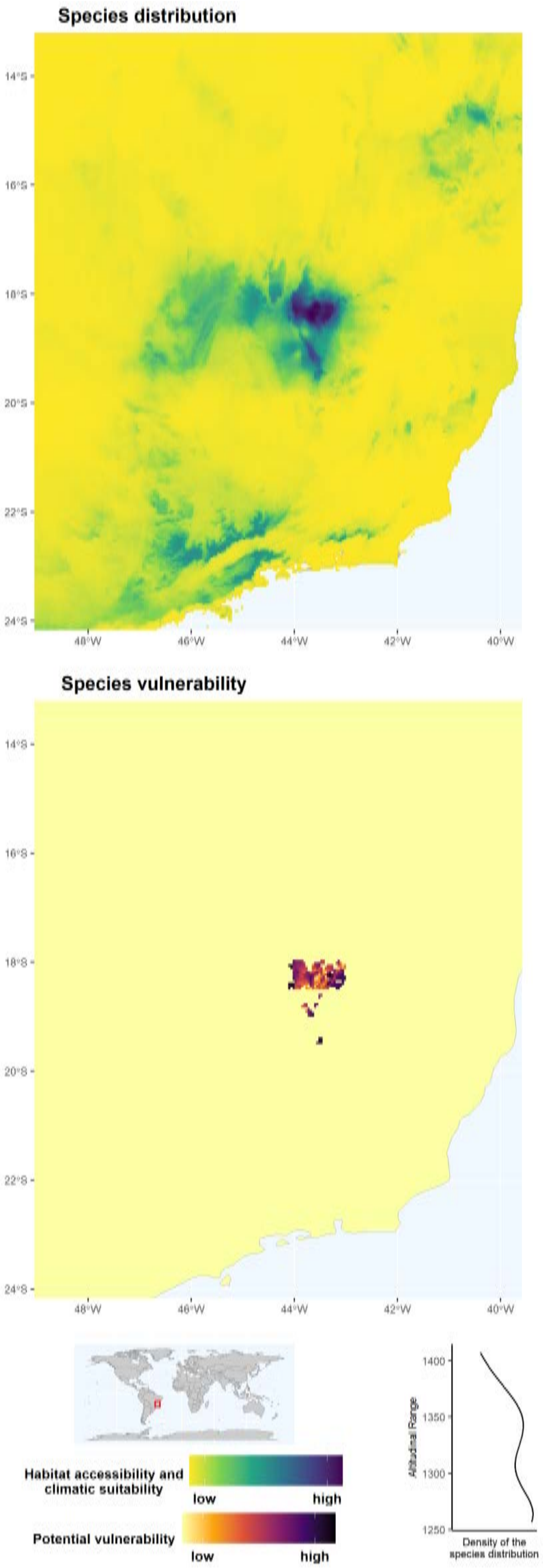
Vellozia candida J.C. Mikan



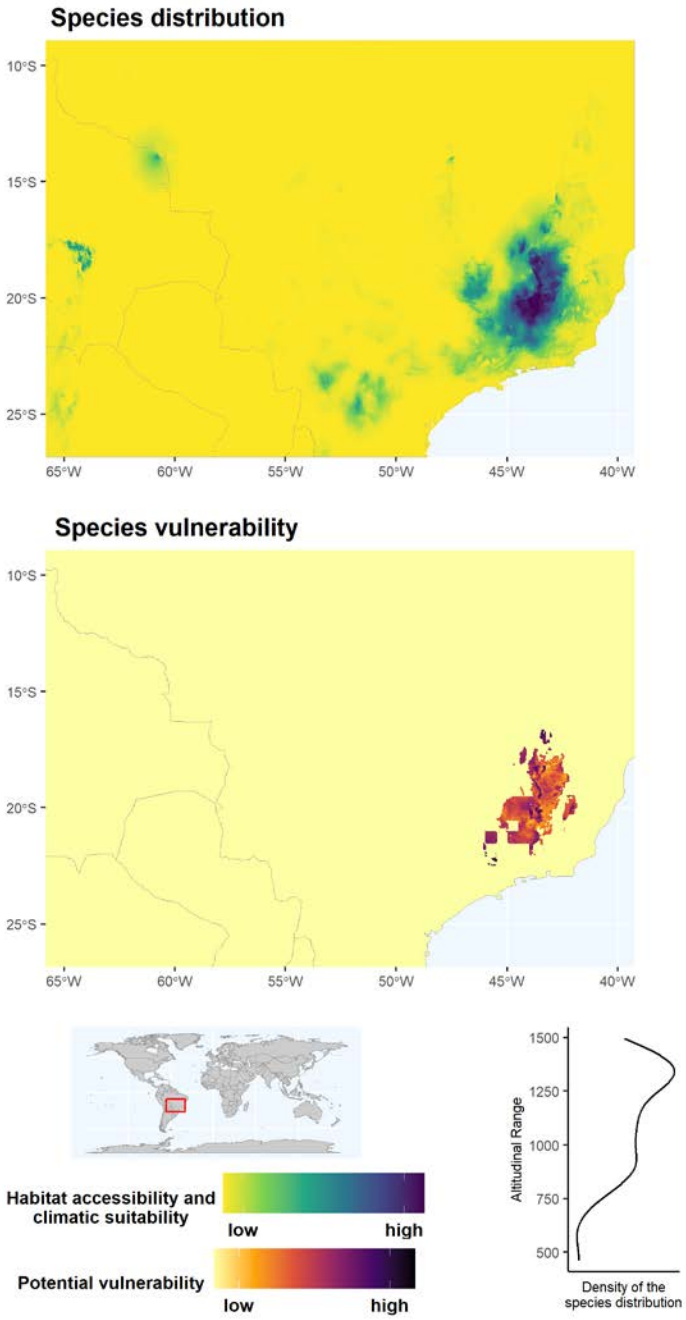
V. candida is a DT plant whose distribution is restricted to Sudeste do Brasil. *V. candida* individuals can be primarily found in equatorial and warm temperate climates, ranging from 20 to 1278 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *V. candida* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

Vellozia caput-ardeae L.B. Sm. & Ayensu

V. caput-ardeae is a DT plant whose distribution is restricted to Brazil Southeast. *V. caput-ardeae* individuals can be primarily found in equatorial and warm temperate climates, ranging from 1257 to 1407 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. caput-ardeae* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 24% of its distribution range is currently found within protected areas.



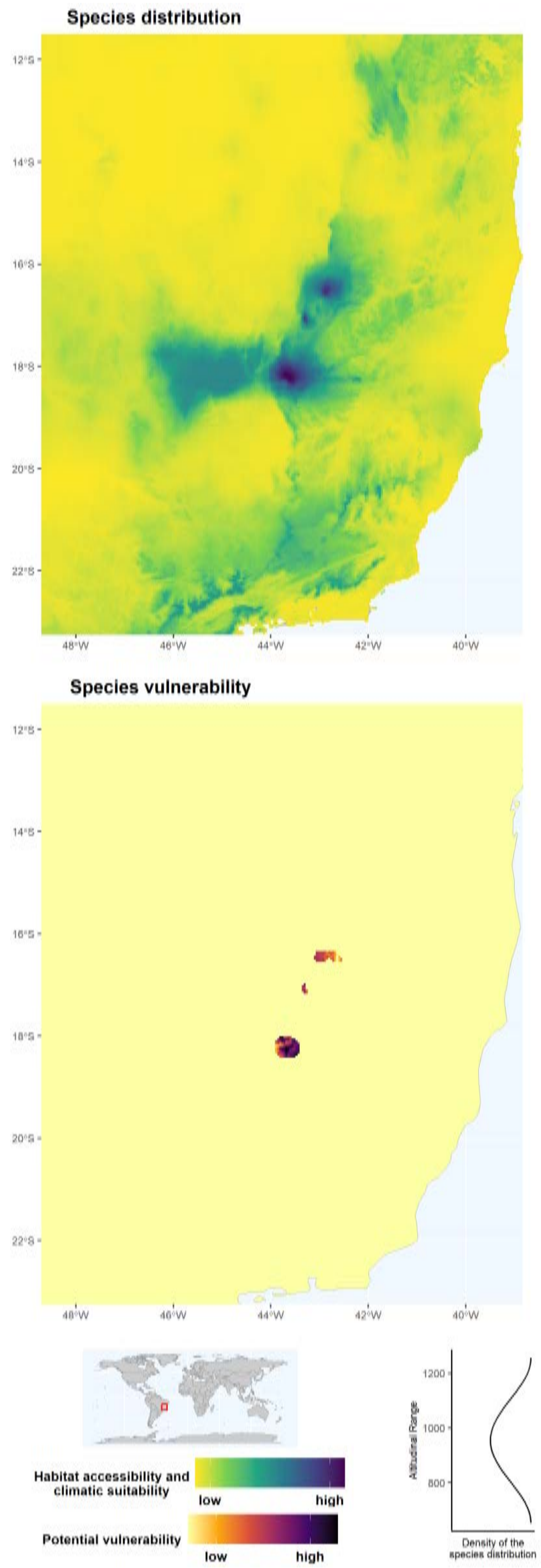
Vellozia caruncularis Mart. ex Seub.



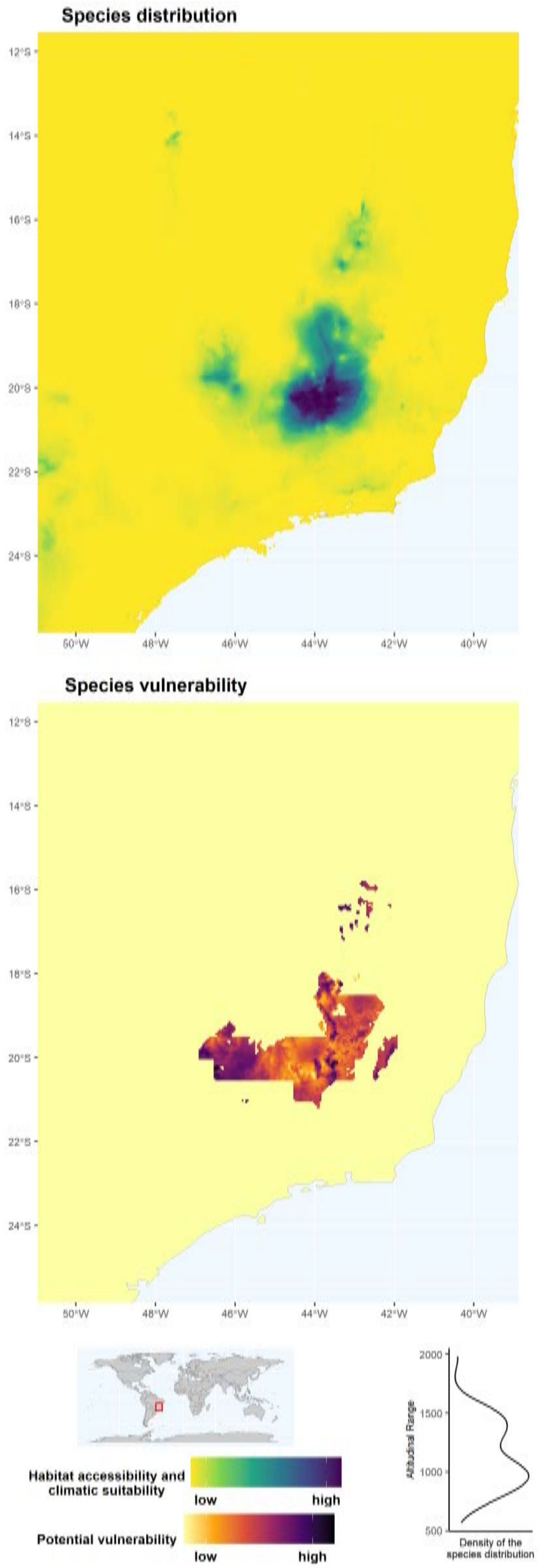
V. caruncularis is a DT plant whose distribution comprises Bolivia, Brazil Southeast. *V. caruncularis* individuals can be primarily found in equatorial and warm temperate climates, ranging from 462 to 1496 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. caruncularis* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

Vellozia ciliata L.B. Sm.

V. ciliata is a DT plant whose distribution is restricted to Brazil Southeast. *V. ciliata* individuals can be primarily found in equatorial and warm temperate climates, ranging from 653 to 1257 m.a.s.l. Their occurrence is restricted to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. ciliata* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 17% of its distribution range is currently found within protected areas.

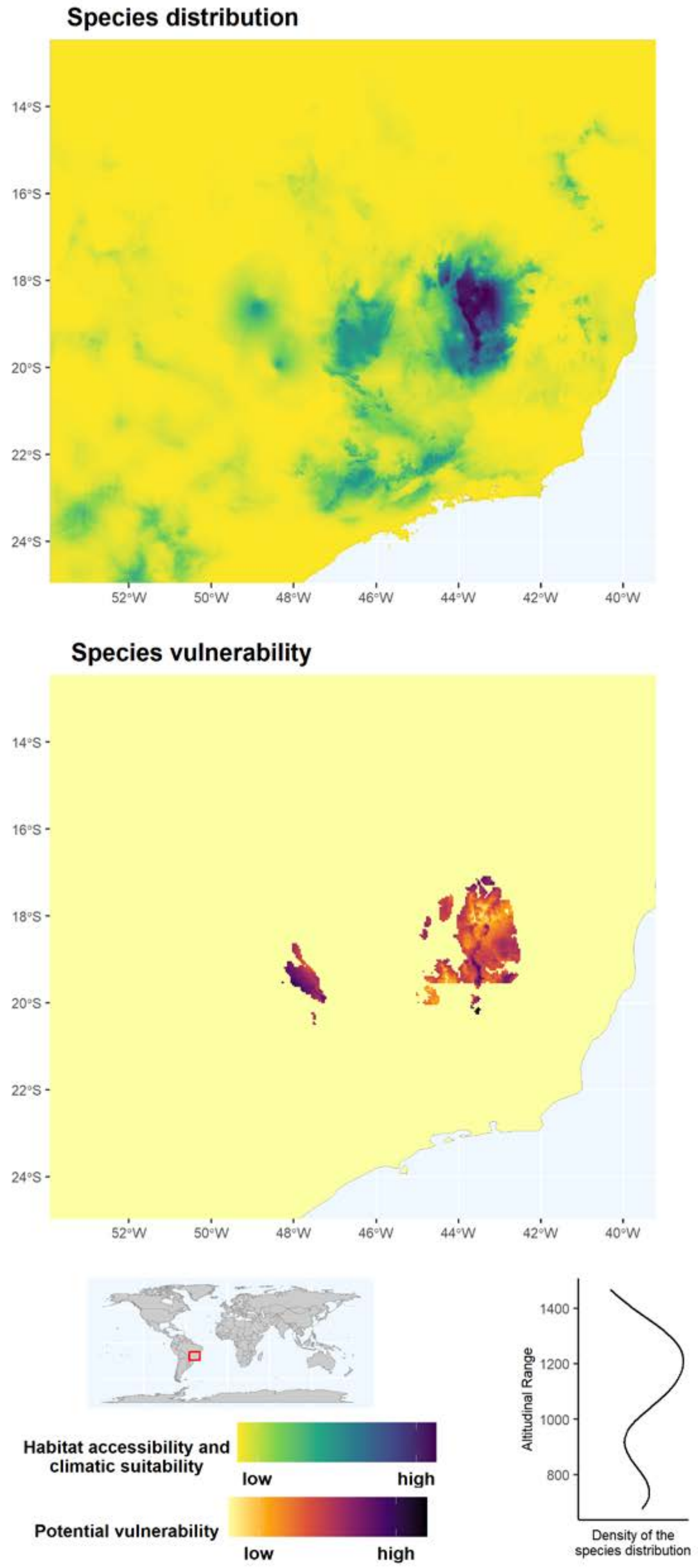


Vellozia compacta Mart. ex Schult. F.



V. compacta is a DT plant whose distribution is restricted to Brazil Southeast. *V. compacta* individuals can be primarily found in equatorial and warm temperate climates, ranging from 569 to 1982 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. compacta* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

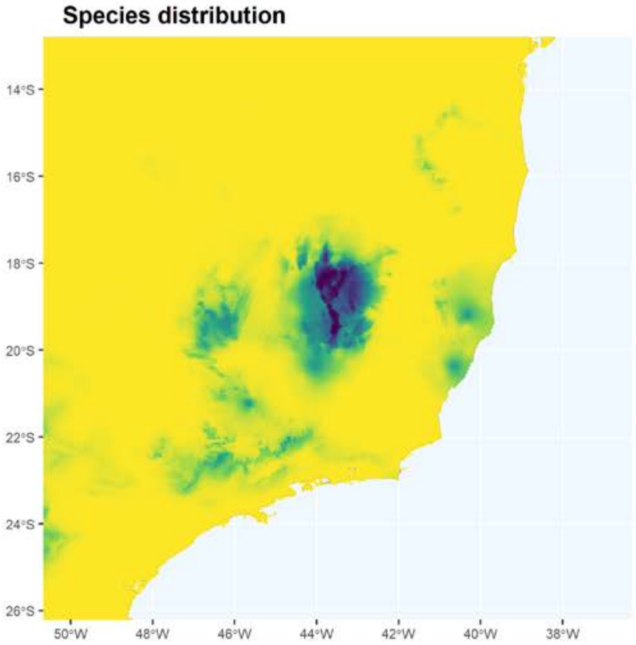
Vellozia declinans Goethart & Henrard

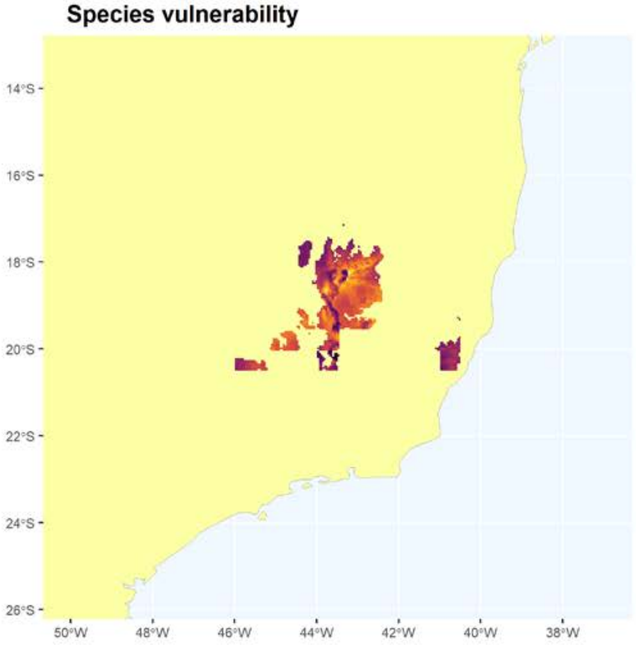


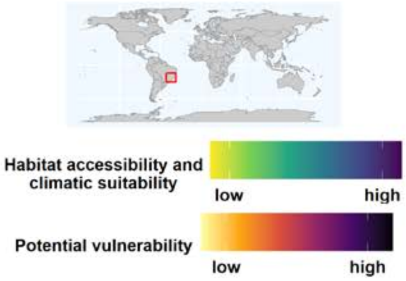
V. declinans is a DT plant whose distribution is restricted to Brazil Southeast. *V. declinans* individuals can be primarily found in equatorial and warm temperate climates, ranging from 677 to 1468 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. declinans* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

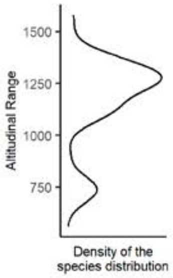
Vellozia epidendroides Mart. ex Schult. F.

V. epidendroides is a DT plant whose distribution is restricted to Brazil Southeast. *V. epidendroides* individuals can be primarily found in equatorial and warm temperate climates, ranging from 563 to 1580 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. epidendroides* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 16% of its distribution range is currently found within protected areas.

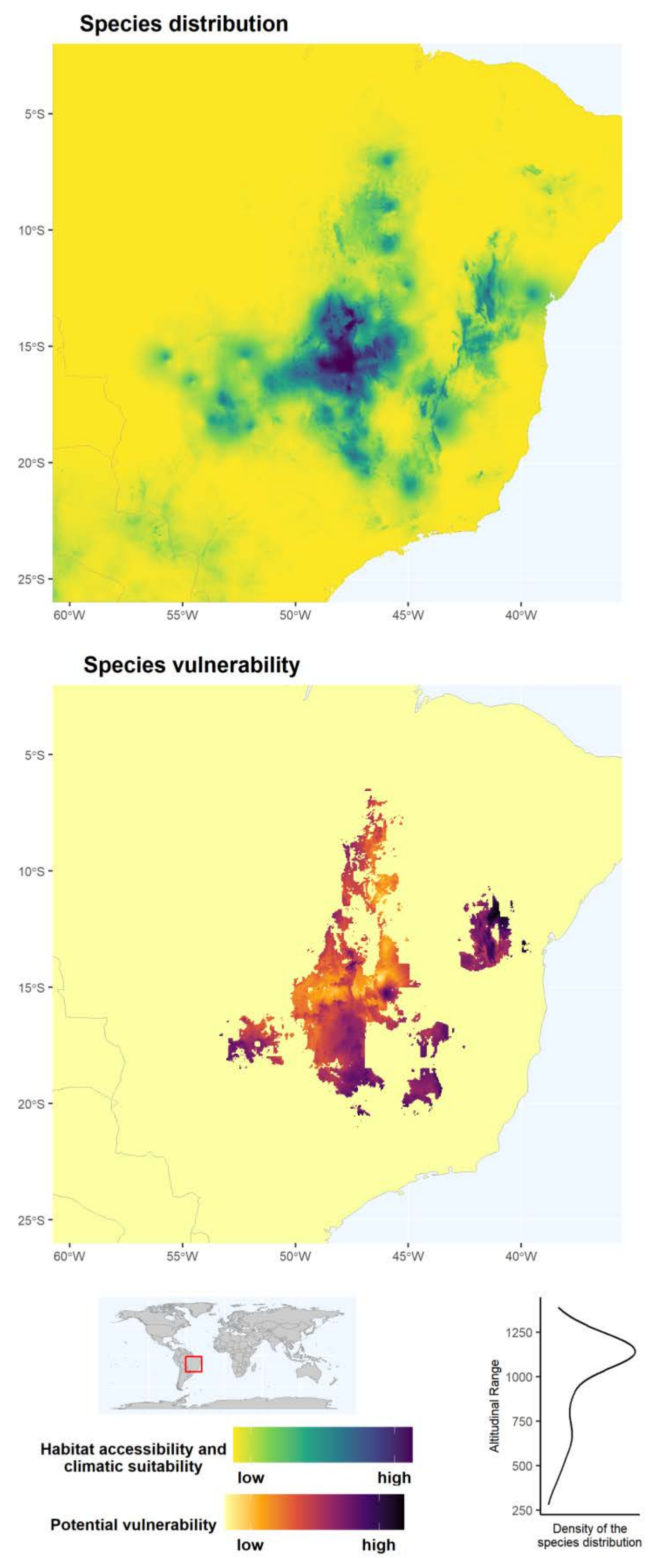






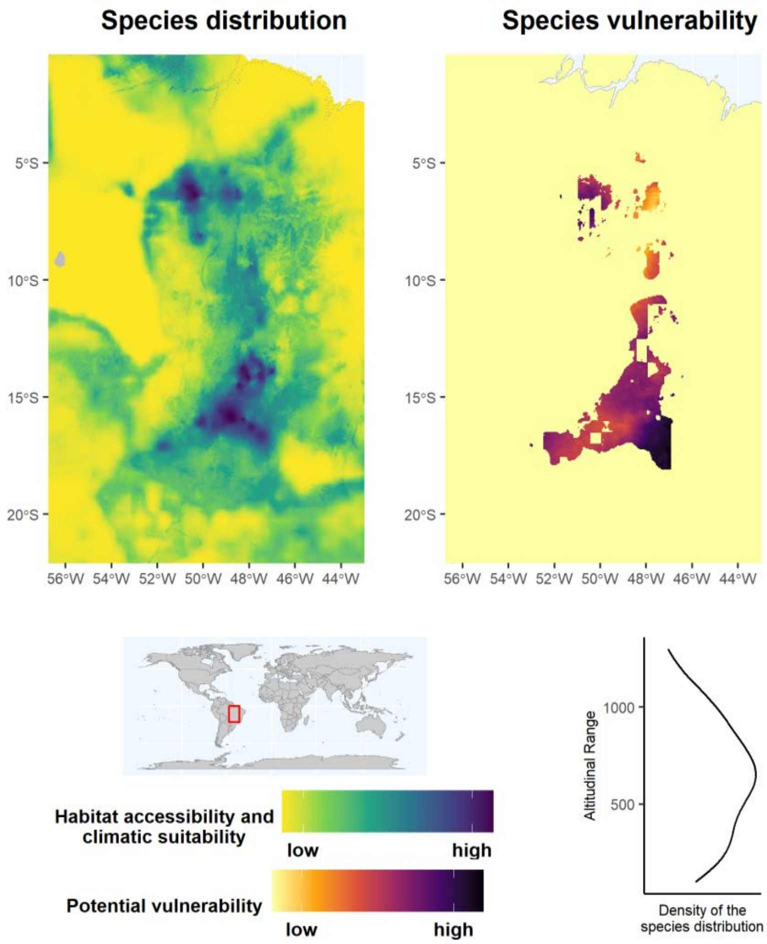


Vellozia flavicans Mart. ex Schult. F. (also cited as *Vellozia squamata*)



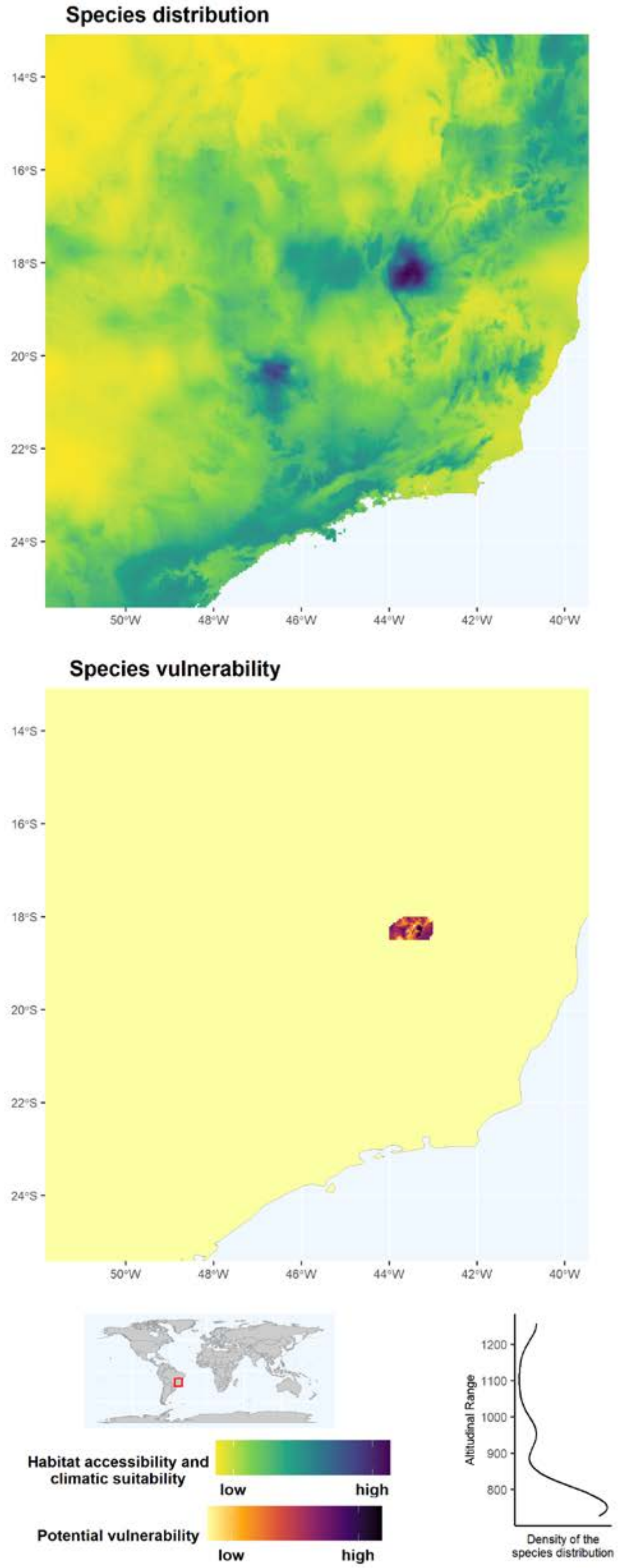
V. flavicans is a DT plant whose distribution comprises Brazil Northeast, Brazil Southeast, Brazil West-Central. *V. flavicans* individuals can be primarily found in equatorial and warm temperate climates, ranging from 280 to 1391 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *V. flavicans* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species is listed as Least concern by IUCN, although only 11% of its distribution range is currently found within protected areas.

Vellozia glochidea Pohl



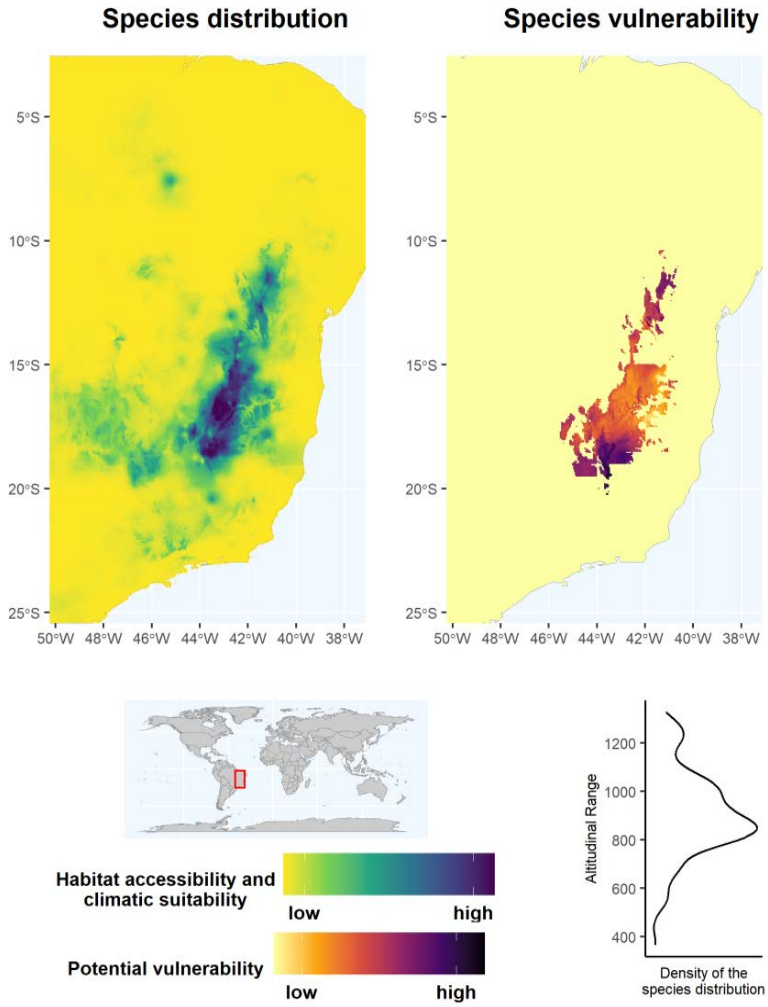
V. glochidea is a DT plant whose distribution comprises Brazil North, Brazil Southeast, Brazil West-Central. *V. glochidea* individuals can be primarily found in equatorial climates, ranging from 99 to 1299 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *V. glochidea* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

Vellozia hatschbachii L.B. Sm. & Ayensu



V. hatschbachii is a DT plant whose distribution is restricted to Brazil Southeast bahia (flora do brasil). *V. hatschbachii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 727 to 1257 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. hatschbachii* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

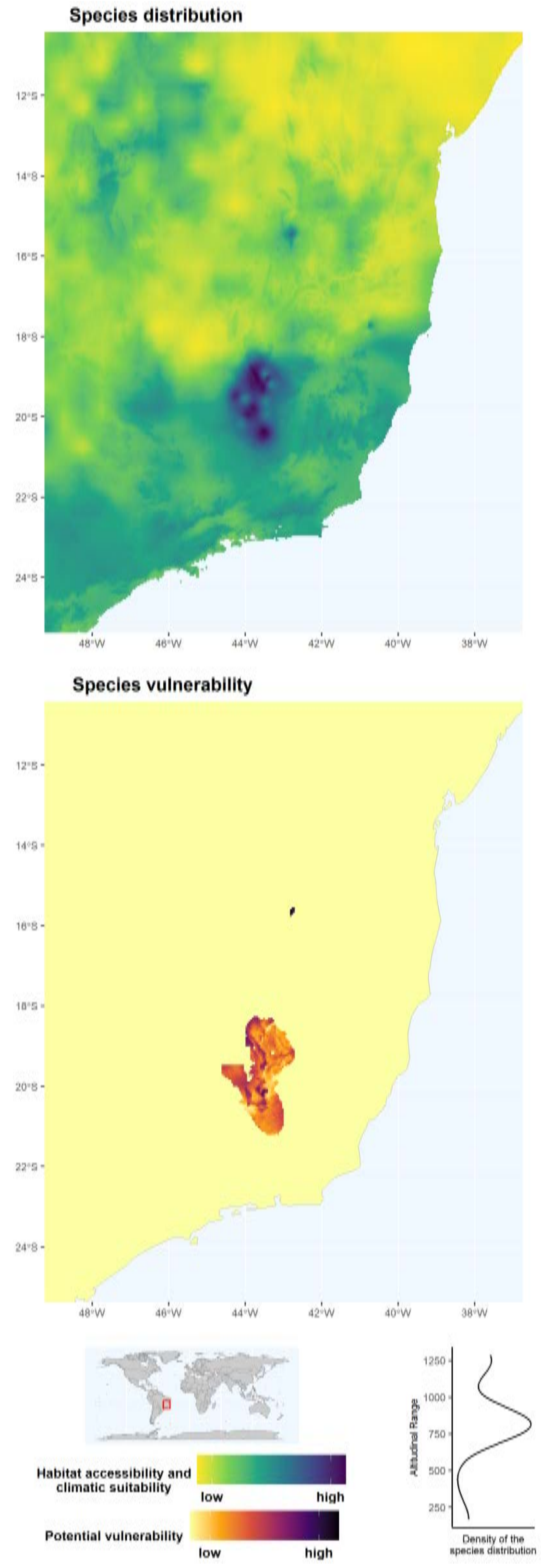
Vellozia hirsuta Goethart & Henrard



V. hirsuta is a DT plant whose distribution comprises Brazil Northeast, Brazil Southeast. *V. hirsuta* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 366 to 1329 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *V. hirsuta* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 9% of its distribution range is currently found within protected areas.

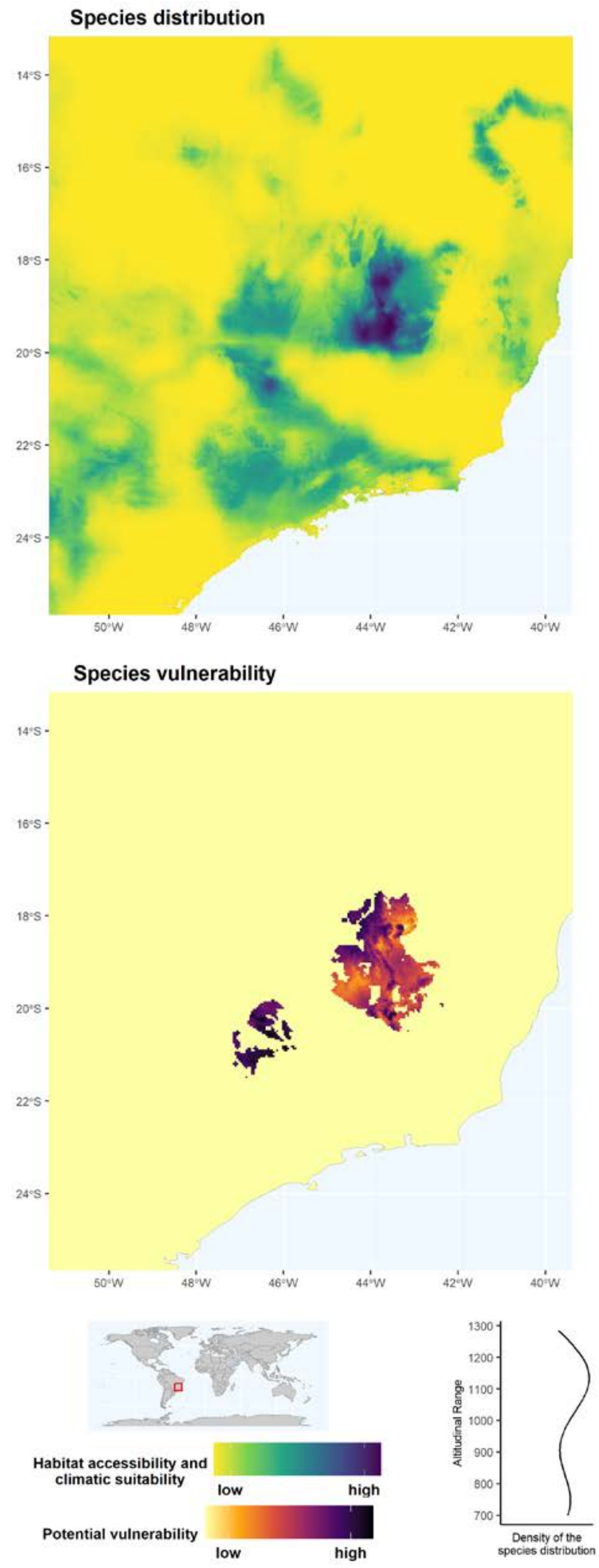
Vellozia nanuzae L.B. Sm. & Ayensu

V. nanuzae is a DT plant whose distribution is restricted to Brazil Southeast. *V. nanuzae* individuals can be primarily found in equatorial and warm temperate climates, ranging from 167 to 1287 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *V. nanuzae* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 23% of its distribution range is currently found within protected areas.

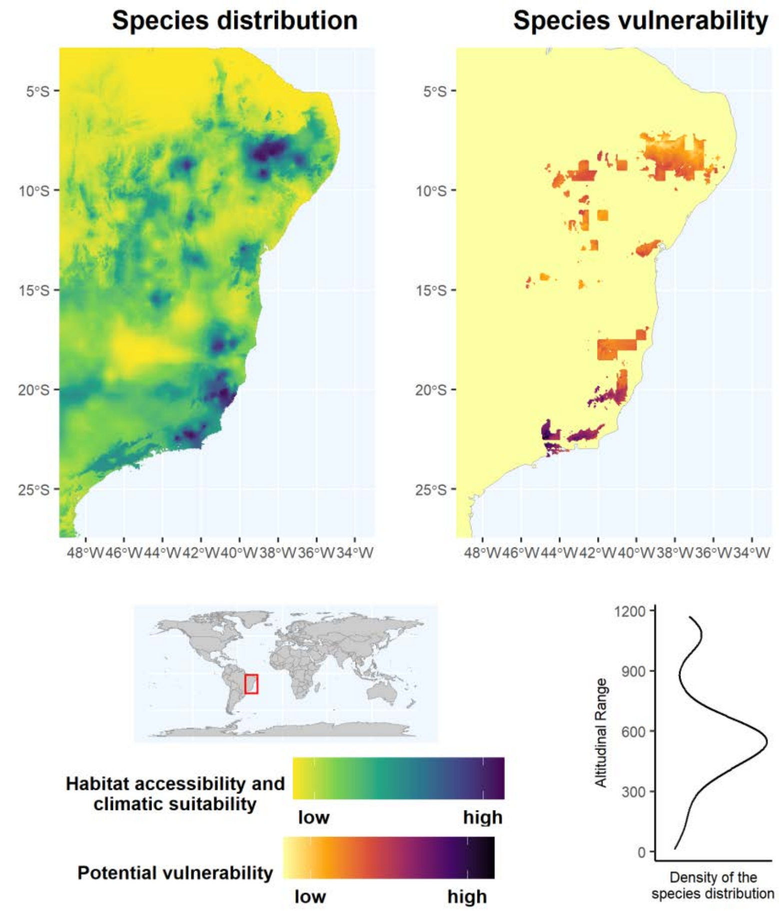


Vellozia nivea L.B. Sm. & Ayensu

V. nivea is a DT plant whose distribution is restricted to Brazil Southeast. V. nivea individuals can be primarily found in equatorial and warm temperate climates, ranging from 700 to 1285 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. V. nivea populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 19% of its distribution range is currently found within protected areas.

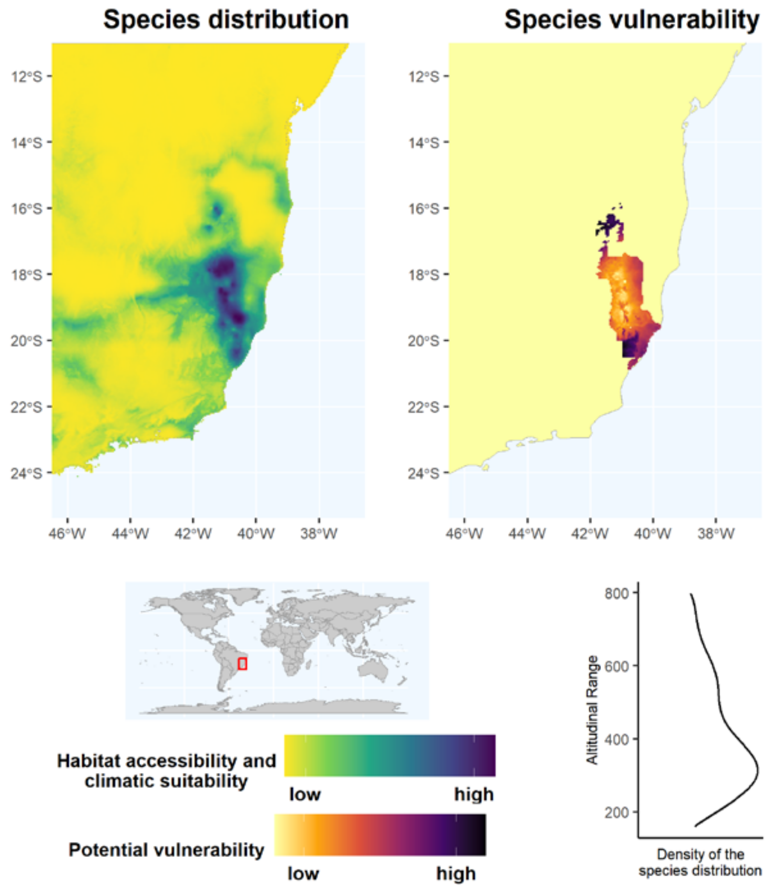


Vellozia plicata Mart.
(also cited as *Nanuza plicata* and *Vellozia triquetra*)



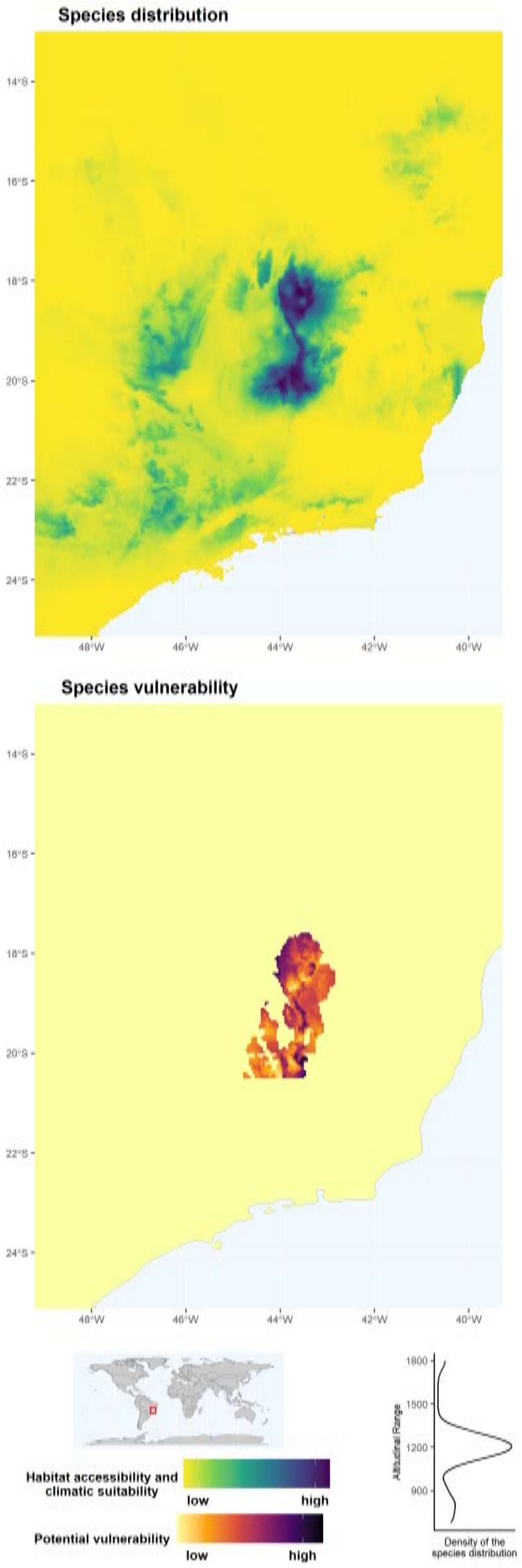
V. plicata is a DT plant whose distribution comprises Brazil Southeast and Brazil Northeast. V. *plicata* individuals can be primarily found in equatorial and warm temperate climates, ranging from 13 to 1172 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which the dry season is long). *N. plicata* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

Vellozia pulchra L.B. Sm.



V. pulchra is a DT plant whose distribution is restricted to Brazil Southeast. *V. pulchra* individuals can be primarily found in equatorial climates, ranging from 161 to 798 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *V. pulchra* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 8% of its distribution range is currently found within protected areas.

Vellozia resinosa Mart. ex Schult. f.

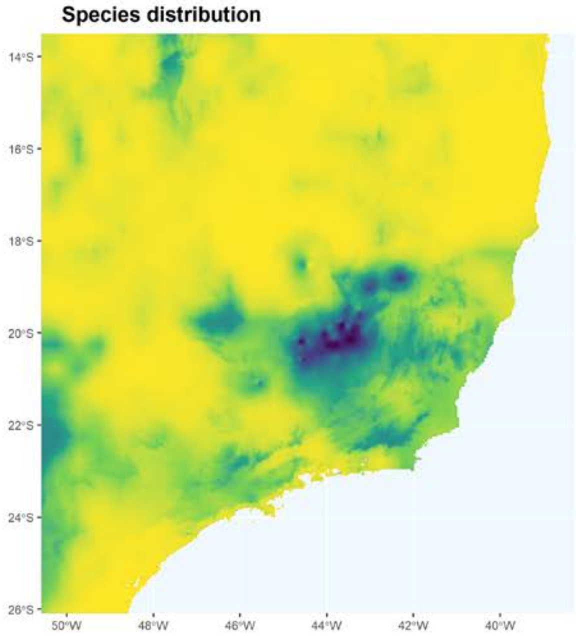


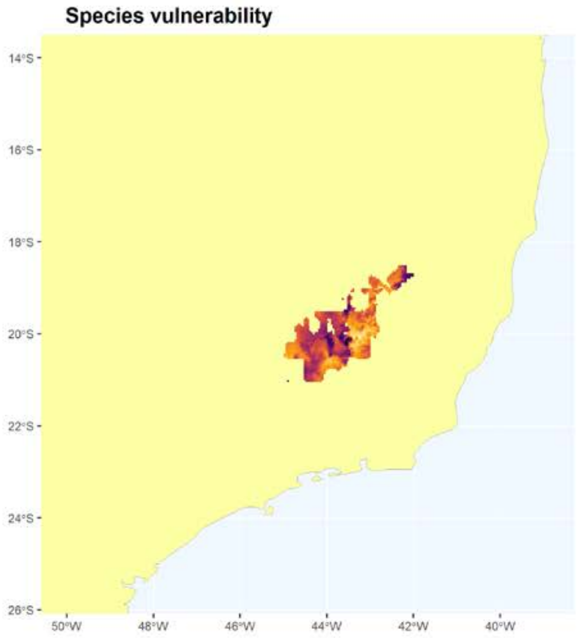
V. resinosa is a DT plant whose distribution is restricted to Brazil Southeast. *V. resinosa* individuals can be primarily found in equatorial and warm temperate climates, ranging from 679 to 1796 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. resinosa* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 25% of its distribution range is currently found within protected areas.

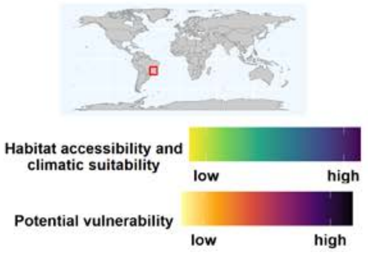
Vellozia sellowii Seub.

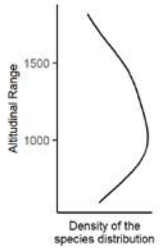
(also cited as *Vellozia virgata*)

V. sellowii is a DT plant whose distribution comprises Bolivia, Brazil Southeast. *V. sellowii* individuals can be primarily found in equatorial and warm temperate climates, ranging from 592 to 1818 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. sellowii* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

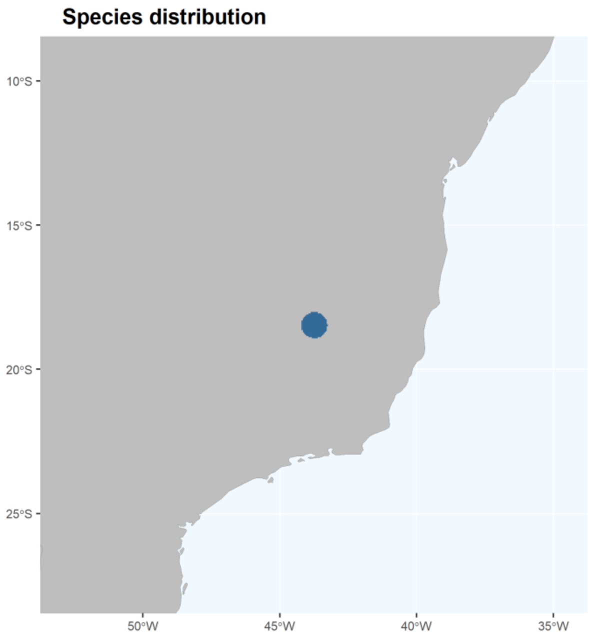


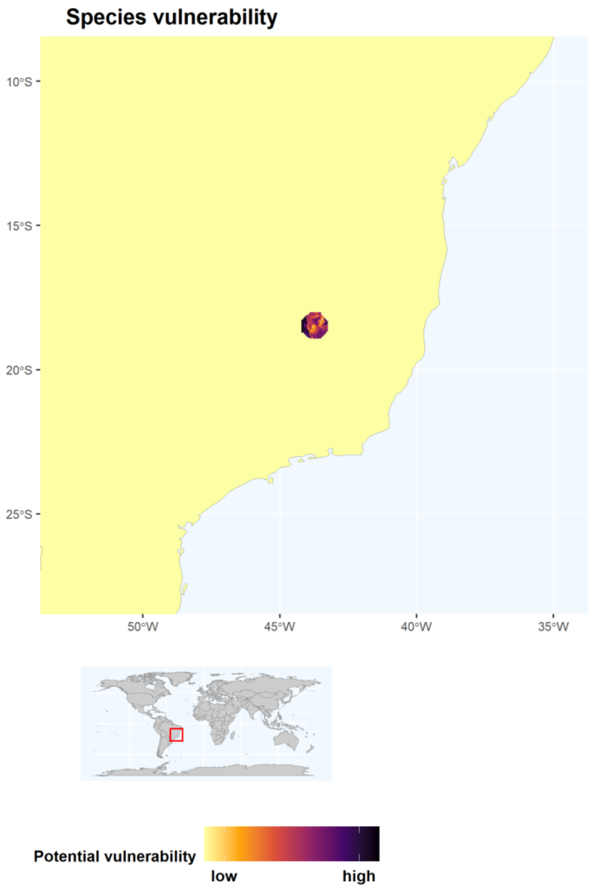






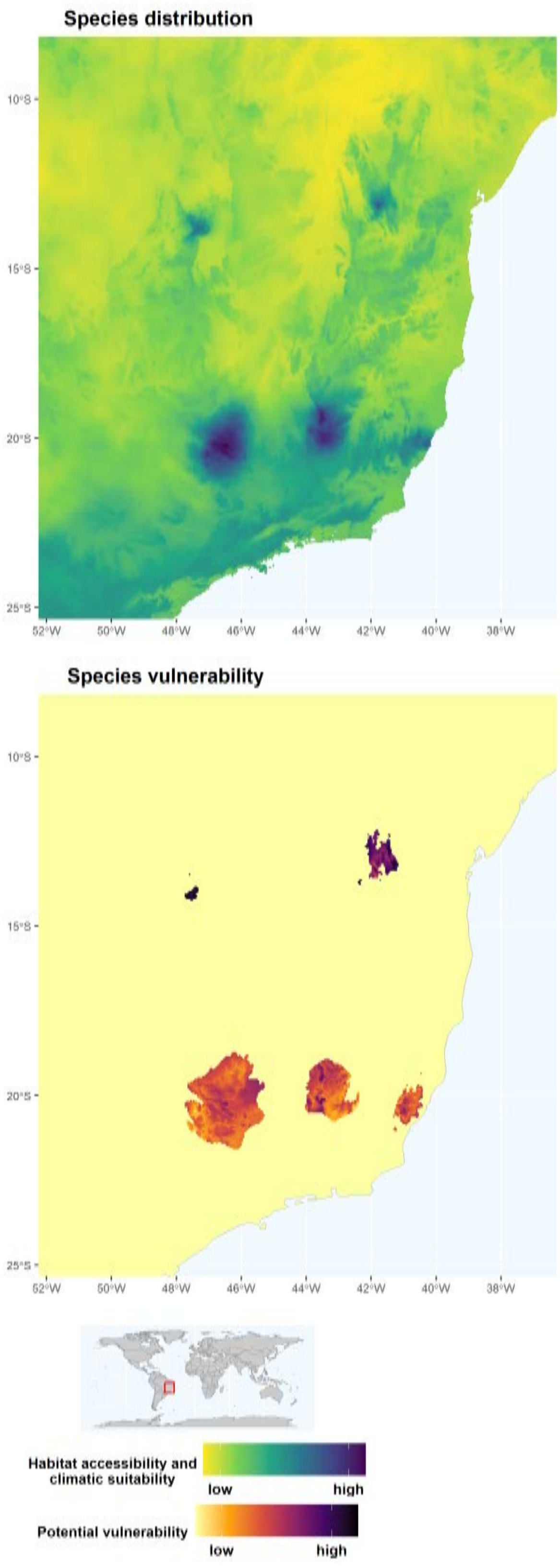
Vellozia semirii Mello-Silva & N.L. Menezes





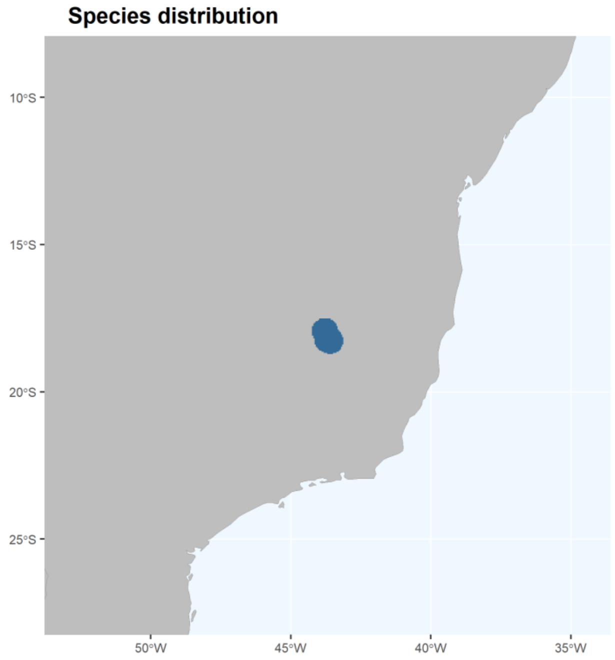
V. semirii is a DT plant whose distribution is restricted to Brazil Southeast. More occurrence points are needed for a consistent evaluation of the ecological aspects and conservation of *V. semirii* populations. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

Vellozia squalida Mart. ex Schult. F.

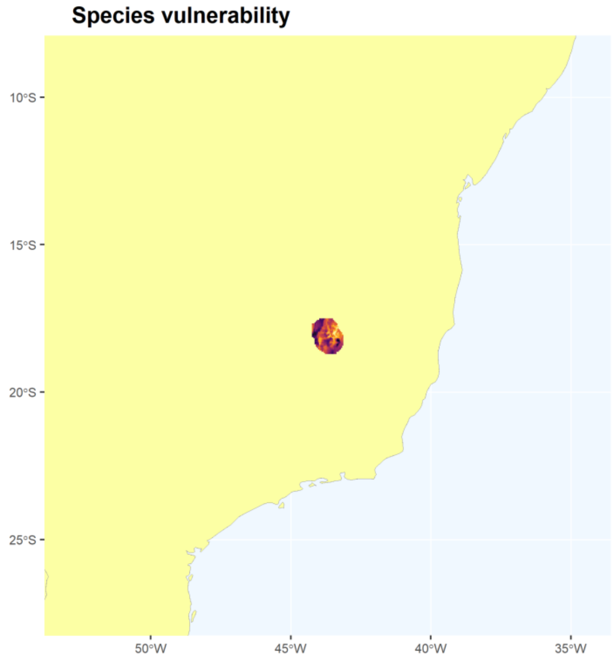


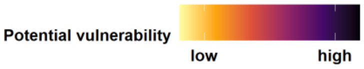
V. squalida is a DT plant whose distribution is restricted to Brazil Southeast. More occurrence points are needed for a consistent evaluation of the ecological aspects of *V. squalida* individuals populations. *V. squalida* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

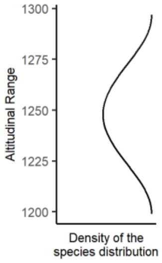
Vellozia streptophylla L.B. Sm.



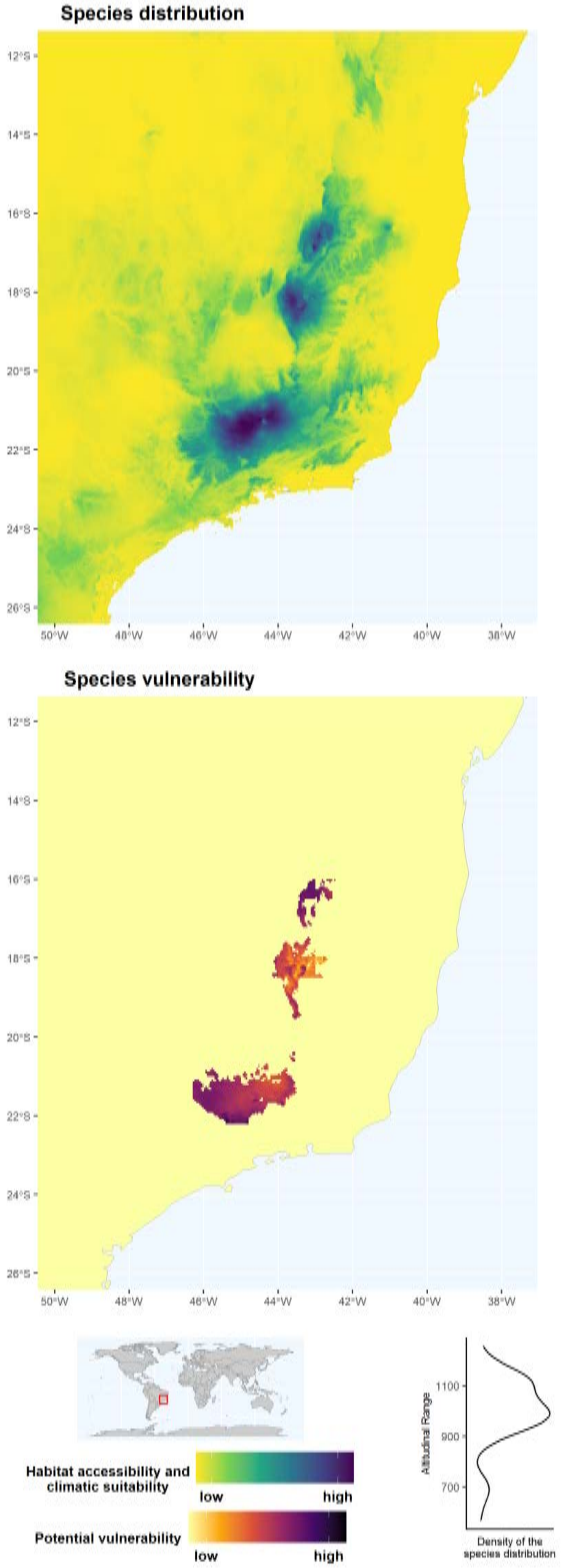
V. streptophylla is a DT plant whose distribution is restricted to Brazil Southeast. *V. streptophylla* individuals can be primarily found in warm temperate climates, ranging from 1199 to 1297 m.a.s.l. Their occurrence is restricted to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. More occurrence points are needed for a consistent evaluation of the conservation of *V. streptophylla* populations. This species has not yet been assessed by IUCN, and only 22% of its distribution range is currently found within protected areas.





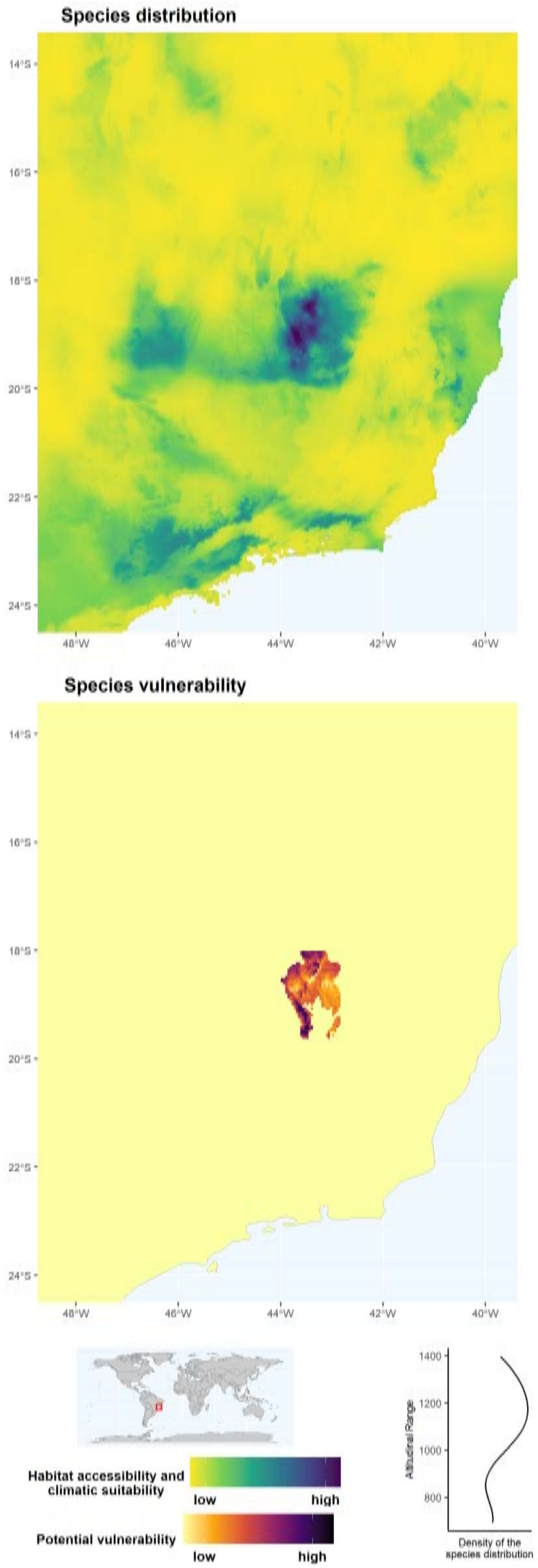


Vellozia subscabra J.C. Mikan



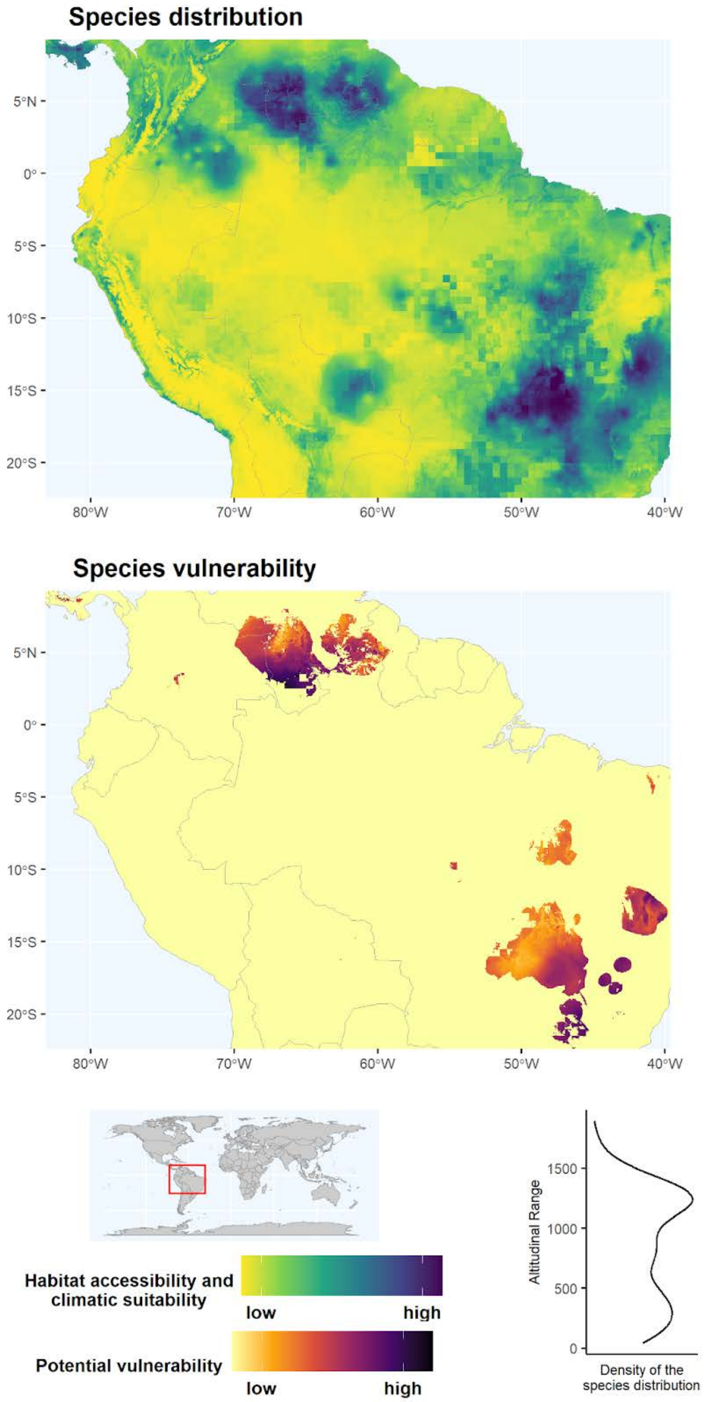
V. subscabra is a DT plant whose distribution is restricted to Brazil Southeast. *V. subscabra* individuals can be primarily found in equatorial and warm temperate climates, ranging from 567 to 1257 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *V. subscabra* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 12% of its distribution range is currently found within protected areas.

Vellozia taxifolia (Mart. ex Schult. f.) Mart. ex Seub.



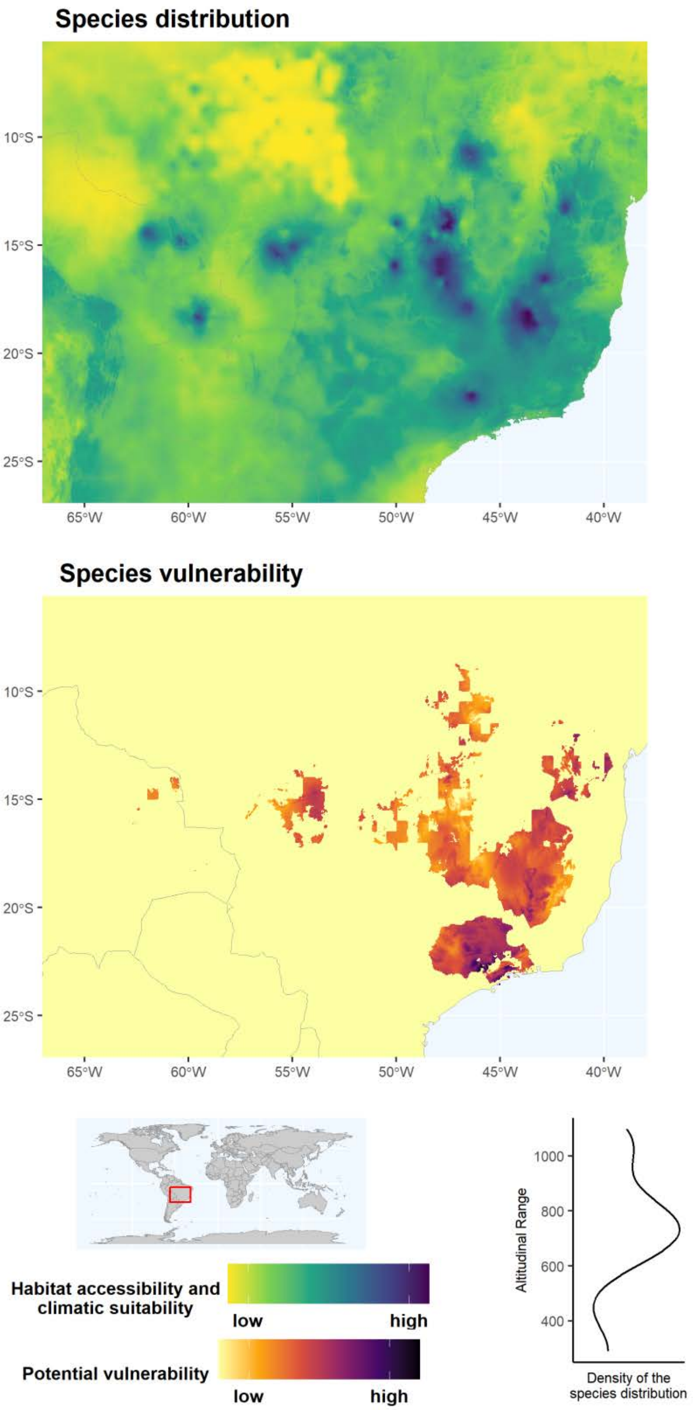
V. taxifolia is a DT plant whose distribution is restricted to Brazil Southeast. *V. taxifolia* individuals can be primarily found in equatorial and warm temperate climates, ranging from 693 to 1397 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *V. taxifolia* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 21% of its distribution range is currently found within protected areas.

Vellozia tubiflora (A. Rich.) Kunth
(also cited as *Vellozia dawsonii*)



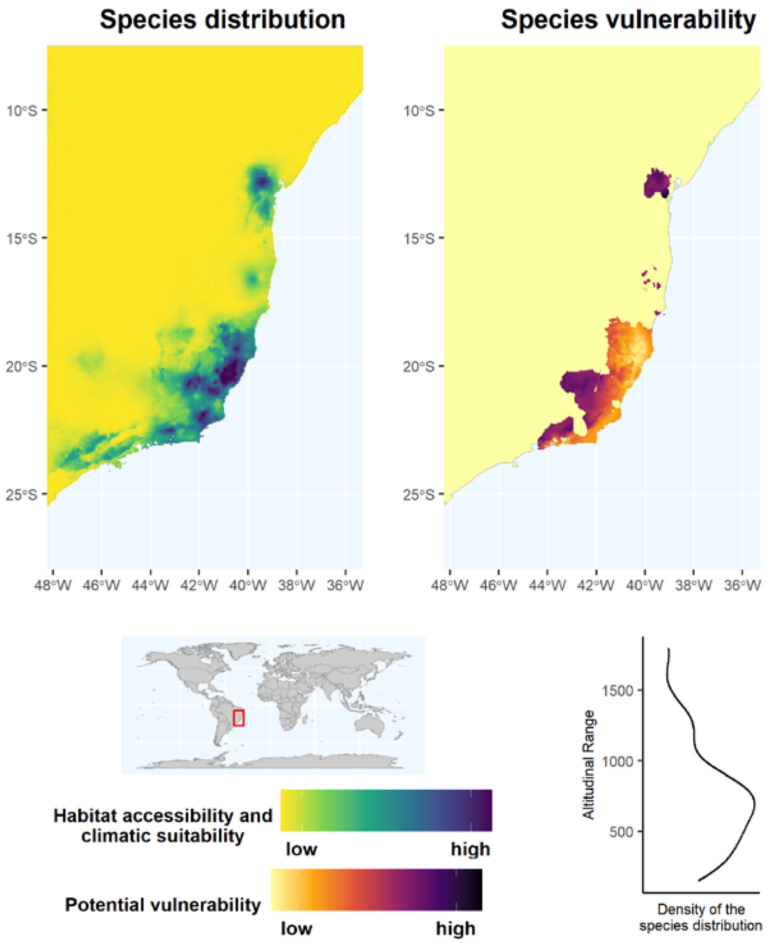
V. tubiflora is a DT plant whose distribution comprises Bolivia, Brazil North, Brazil Northeast, Brazil Southeast, Brazil West-Central, Colombia, Guyana, Panamá, Venezuela. *V. tubiflora* individuals can be primarily found in equatorial and warm temperate climates, ranging from 44 to 1895 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the dry season is long). *V. tubiflora* populations are expected to be potentially more vulnerable to climate change in parts of Brazil, Colombia, Guyana, Panama, Venezuela. This species has not yet been assessed by IUCN, and only 26% of its distribution range is currently found within protected areas.

Vellozia variabilis Mart. ex Schult. F.
(also cited as *Vellozia alutacea*)



V. variabilis is a DT plant whose distribution comprises Bolivia, Brazil Southeast, Brazil West-Central. *V. variabilis* individuals can be primarily found in equatorial and warm temperate climates, ranging from 290 to 1098 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime. *V. variabilis* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 14% of its distribution range is currently found within protected areas.

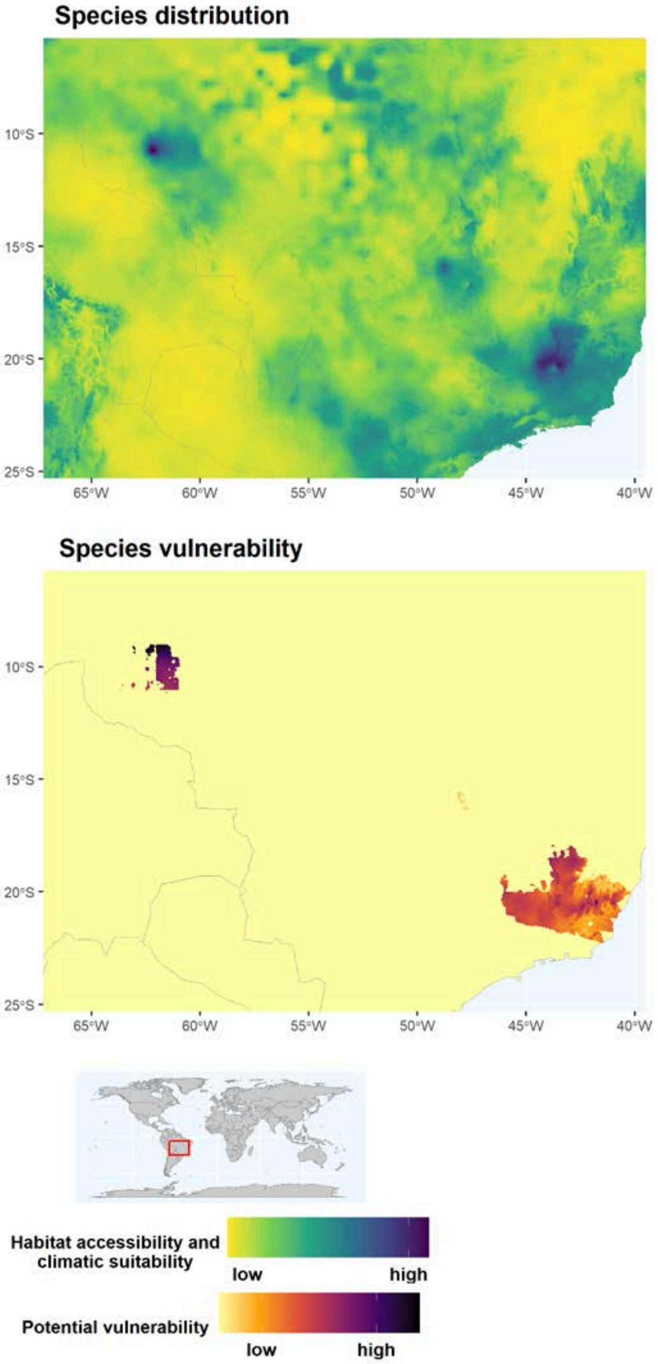
Vellozia variegata Goethart & Henrard



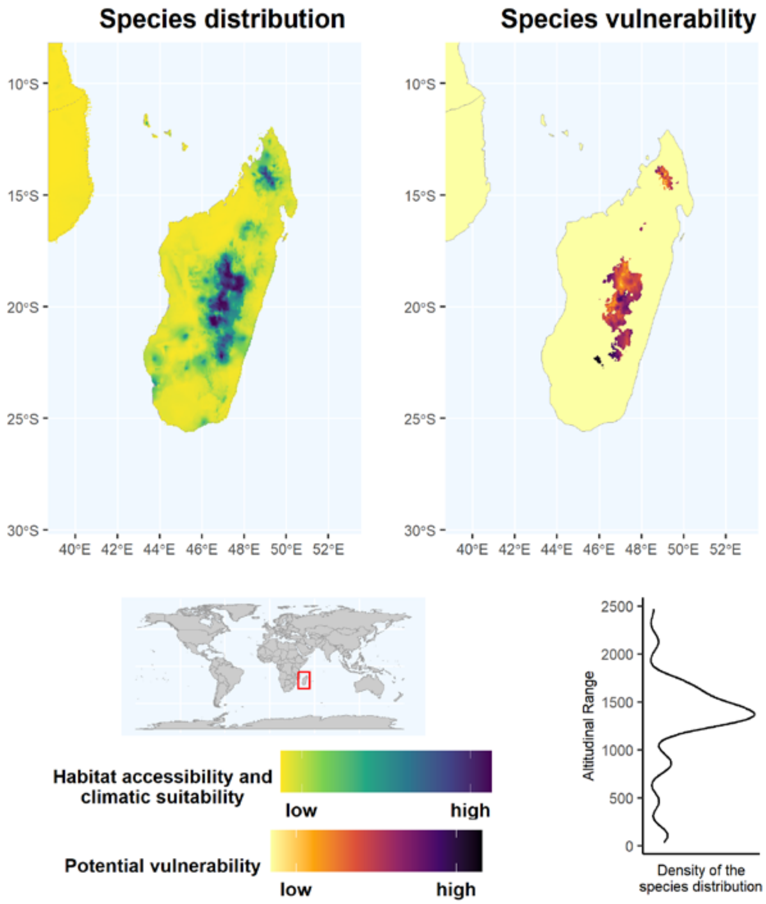
V. variegata is a DT plant whose distribution is restricted to Brazil Southeast. *V. variegata* individuals can be primarily found in equatorial and warm temperate climates, ranging from 149 to 1798 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime. *V. variegata* populations are expected to be potentially more vulnerable to climate change in parts of Brazil. This species has not yet been assessed by IUCN, and only 11% of its distribution range is currently found within protected areas.

Vellozia verruculosa Mart. ex Schult. F.

V. verruculosa is a DT plant whose distribution comprises Brazil West-Central and Brazil Southeast. *V. verruculosa* individuals can be primarily found in Aw climates, circa 1194 m.a.s.l. Their occurrence is restricted to moderate summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. V. verruculosa populations are expected to be potentially more vulnerable to climate change in parts of Brazil West-Central. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

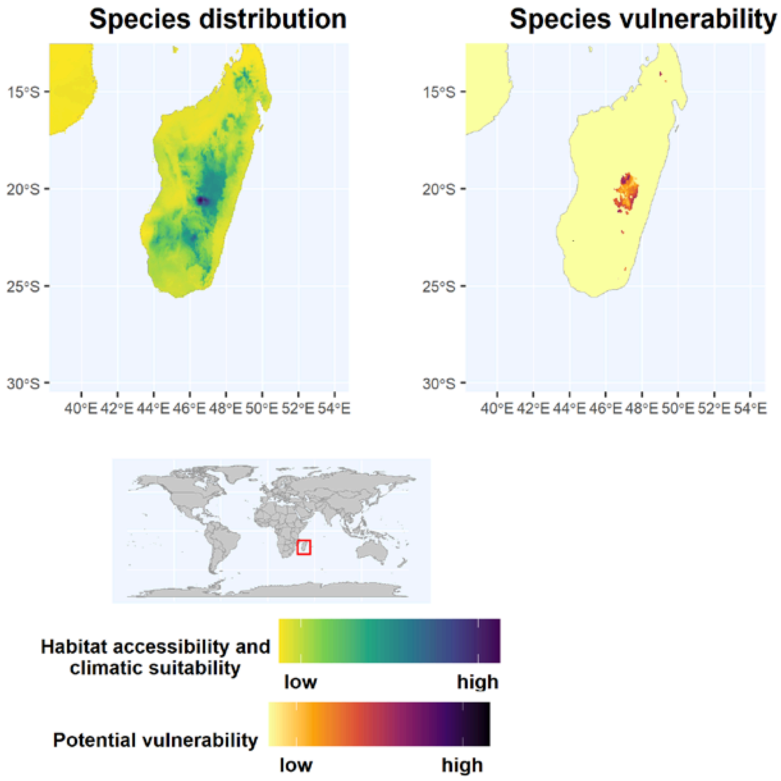


Xerophyta dasylirioides Baker



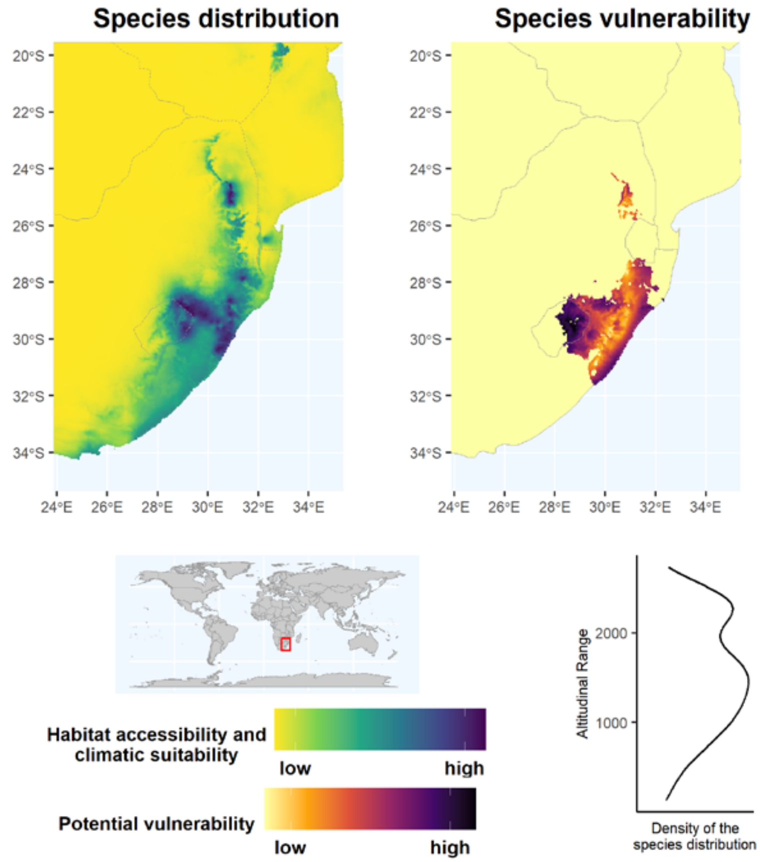
X. dasylirioides is a DT plant whose distribution is restricted to Madagascar. *X. dasylirioides* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 39 to 2468 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *X. dasylirioides* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and 13% of its distribution range is currently found within protected areas.

Xerophyta eglandulosa H. Perrier



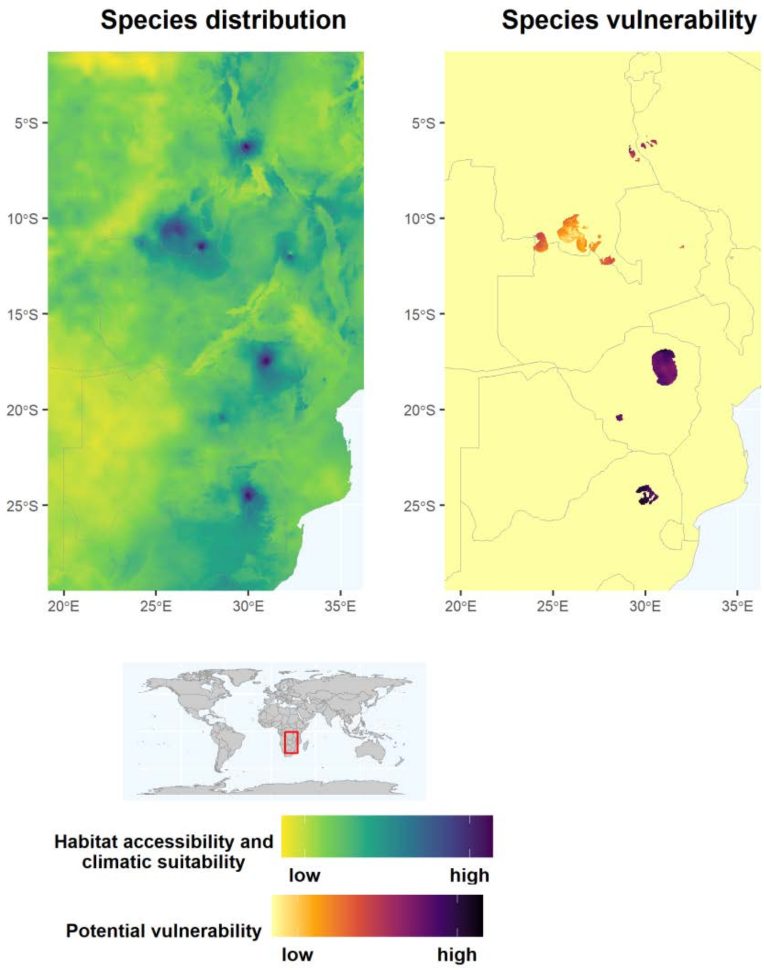
X. eglandulosa is a DT plant whose distribution is restricted to Madagascar. *X. eglandulosa* individuals can be primarily found in warm temperate climates, circa 741 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). More occurrence points are needed for a consistent evaluation of the conservation of *X. eglandulosa* populations. This species has not yet been assessed by IUCN, although 38% of its distribution range is currently found within protected areas.

Xerophyta elegans (Balf.) Baker
(also cited as *Talbotia elegans*)



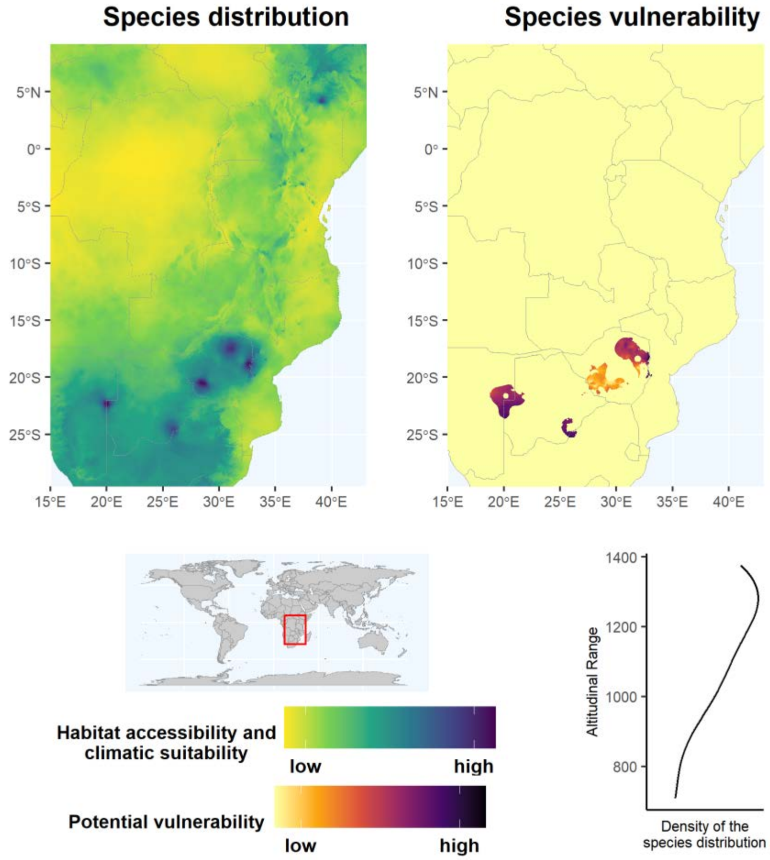
X. elegans is a DT plant whose distribution comprises KwaZulu-Natal, Northern Provinces. *X. elegans* individuals can be primarily found in warm temperate climates, ranging from 132 to 2738 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to moderate summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime. *X. elegans* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho. This species has not yet been assessed by IUCN, and only 20% of its distribution range is currently found within protected areas.

Xerophyta equisetoides Baker



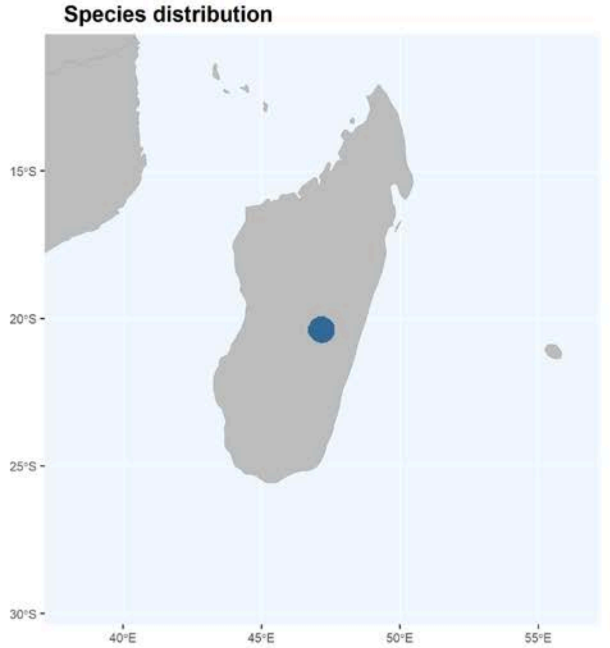
X. equisetoides is a DT plant whose distribution comprises Angola, Mozambique, Namibia, Northern Provinces, Swaziland, Tanzania, Zambia, Zaïre, Zimbabwe. More occurrence points are needed for a consistent evaluation of the ecological aspects of *X. equisetoides*. *X. equisetoides* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Tanzania, Zimbabwe. This species has not yet been assessed by IUCN, and only 9% of its distribution range is currently found within protected areas.

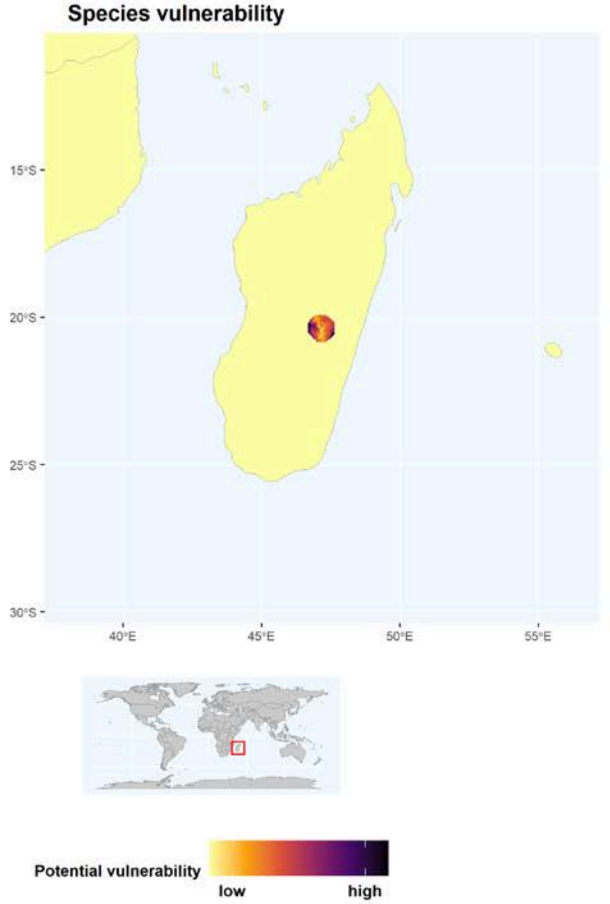
Xerophyta humilis (Baker) T. Durand & Schinz



X. humilis is a DT plant whose distribution comprises Angola, Botswana, Ethiopia, Mozambique, Namibia, Northern Provinces, Sudan, Swaziland, Zambia, Zimbabwe. *X. humilis* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 709 to 1376 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *X. humilis* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, South Africa, Botswana, Namibia, Zimbabwe. This species has not yet been assessed by IUCN, and only 10% of its distribution range is currently found within protected areas.

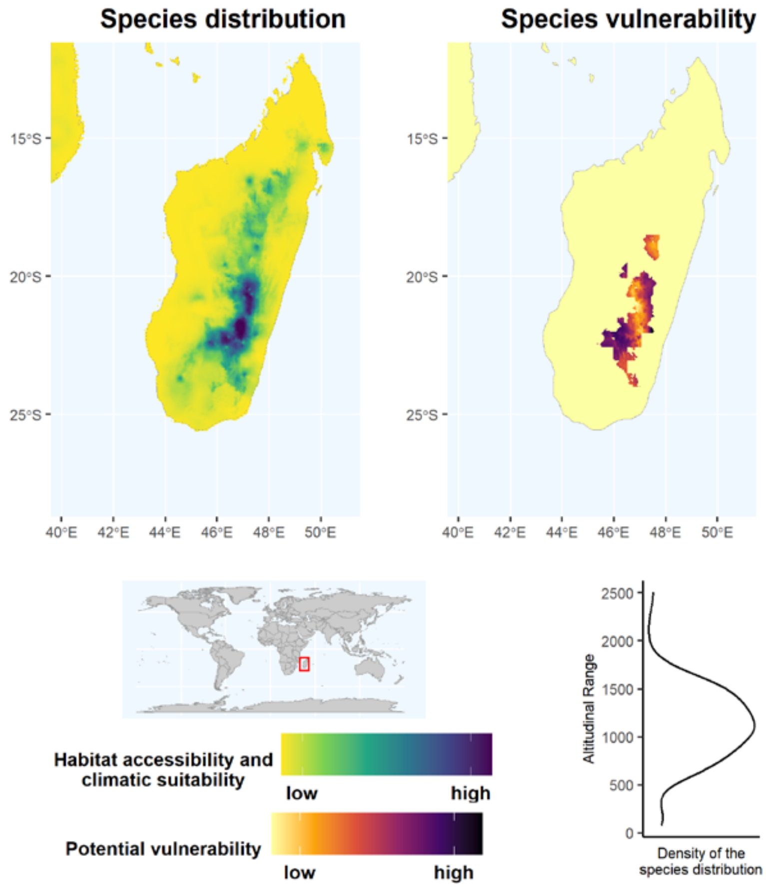
Xerophyta nandrasanae Phillipson & Lowry





X. nandrasanae is a DT plant whose distribution is restricted to Madagascar. *X. nandrasanae* individuals can be primarily found in warm temperate climates, circa 1264 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the dry season is long). More occurrence points are needed for a consistent evaluation of the conservation of *X. nandrasanae* populations. This species has not yet been assessed by IUCN, and only 6% of its distribution range is currently found within protected areas.

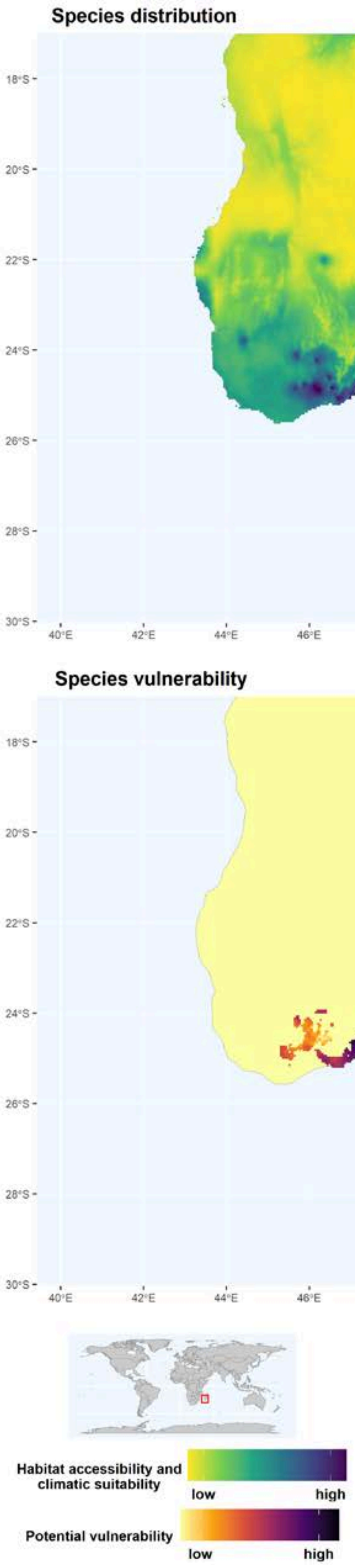
Xerophyta pectinata Baker



X. pectinata is a DT plant whose distribution is restricted to Madagascar. *X. pectinata* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 80 to 2507 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *X. pectinata* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 6% of its distribution range is currently found within protected areas.

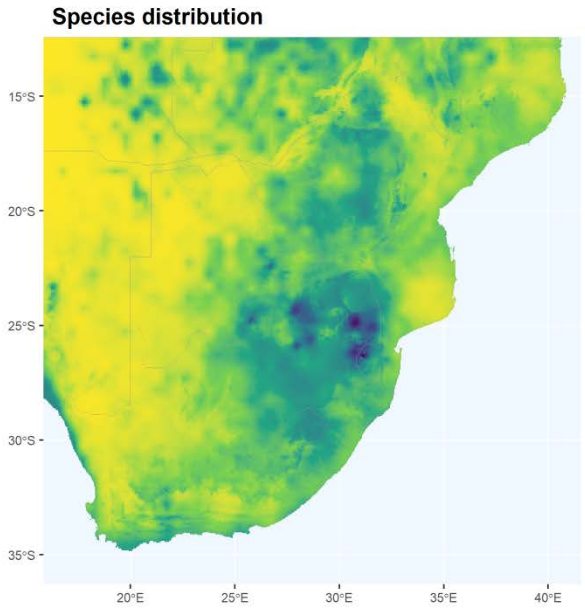
Xerophyta pinifolia Lam.

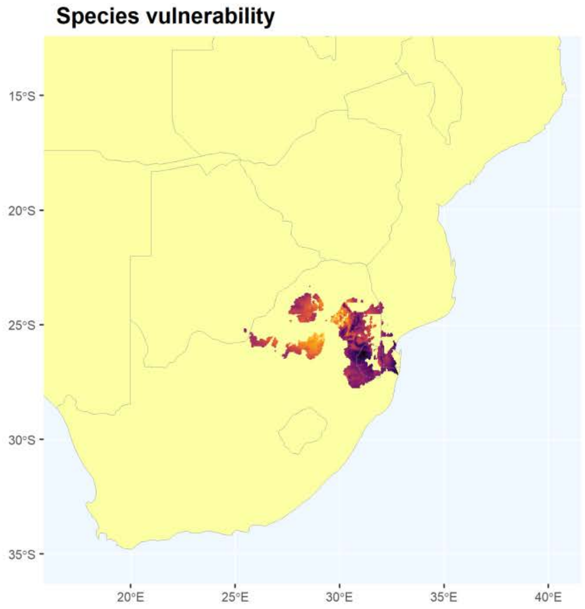
X. pinifolia is a DT plant whose distribution is restricted to Madagascar. *X. pinifolia* individuals can be primarily found in equatorial climates, circa 76 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *X. pinifolia* populations are expected to be potentially more vulnerable to climate change in parts of Madagascar. This species has not yet been assessed by IUCN, and only 13% of its distribution range is currently found within protected areas.

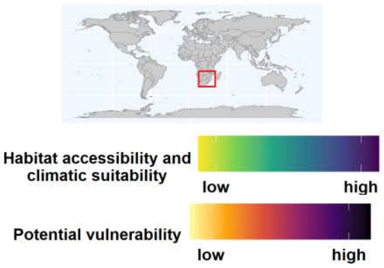


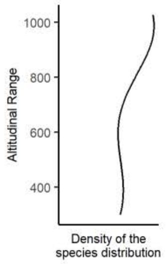
Xerophyta retinervis Baker

X. retinervis is a DT plant whose distribution comprises Botswana, Northern Provinces, Swaziland. *X. retinervis* individuals can be primarily found in arid and warm temperate climates, ranging from 300 to 1027 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and is restricted to areas with seasonal precipitation regime. *X. retinervis* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, South Africa, Swaziland. This species has not yet been assessed by IUCN, and only 32% of its distribution range is currently found within protected areas.

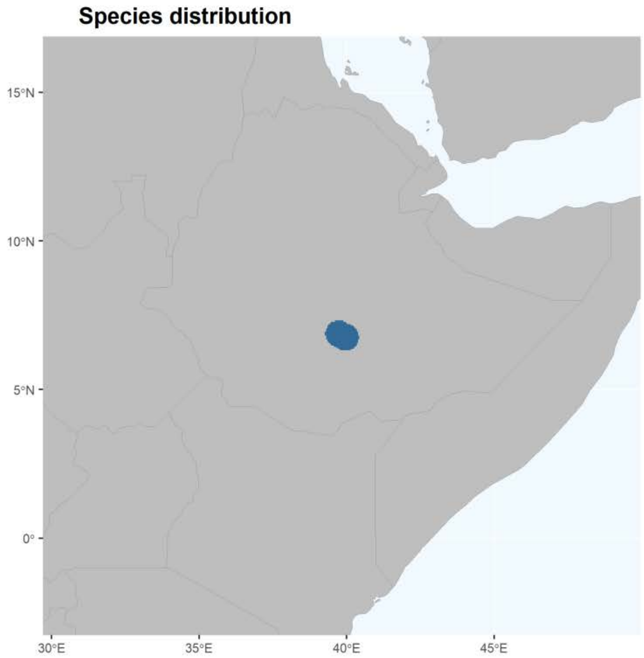


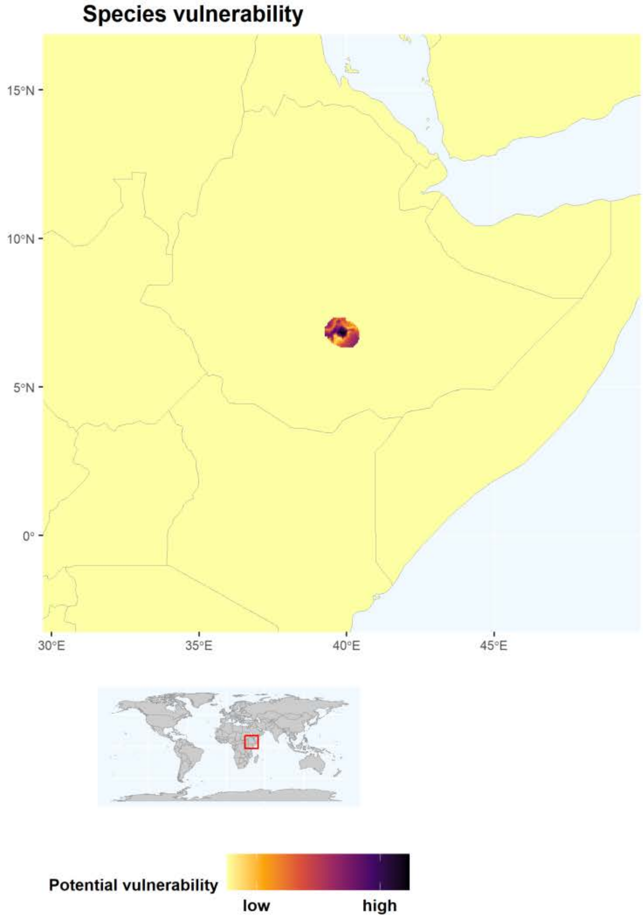






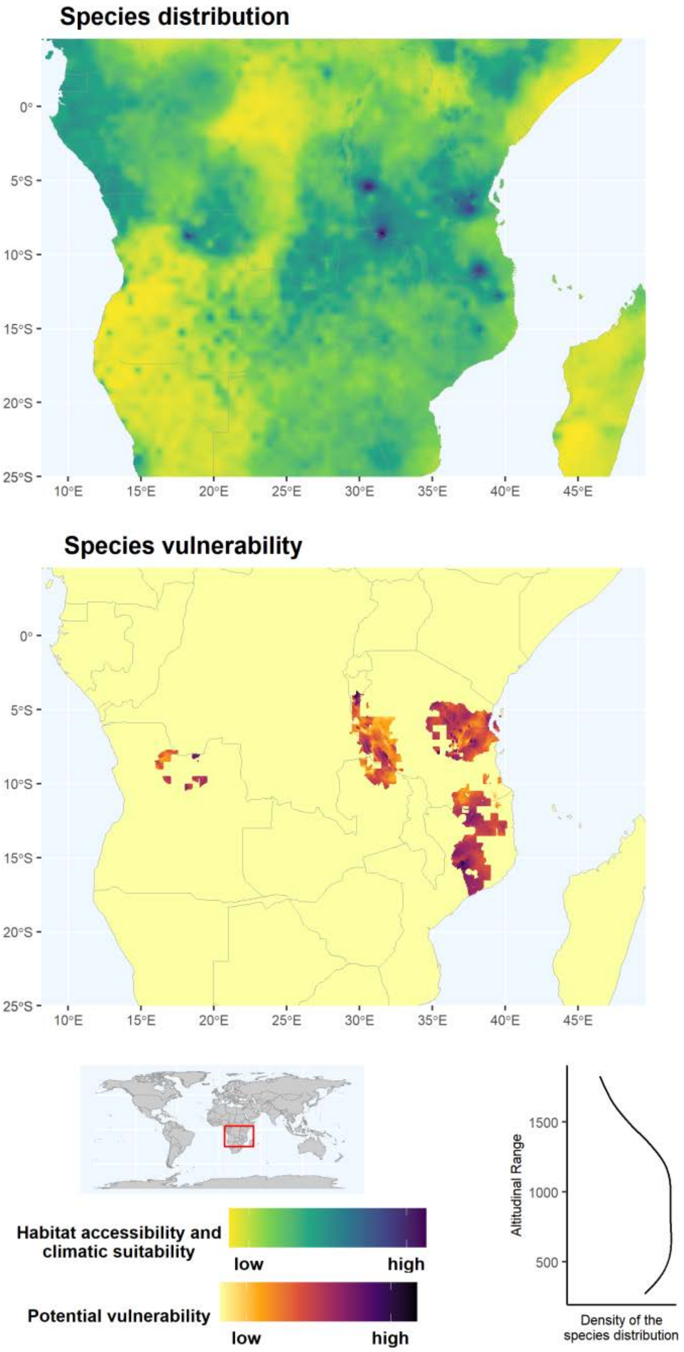
Xerophyta rippsteinii L.B. Sm., J.-P. Lebrun & Stork





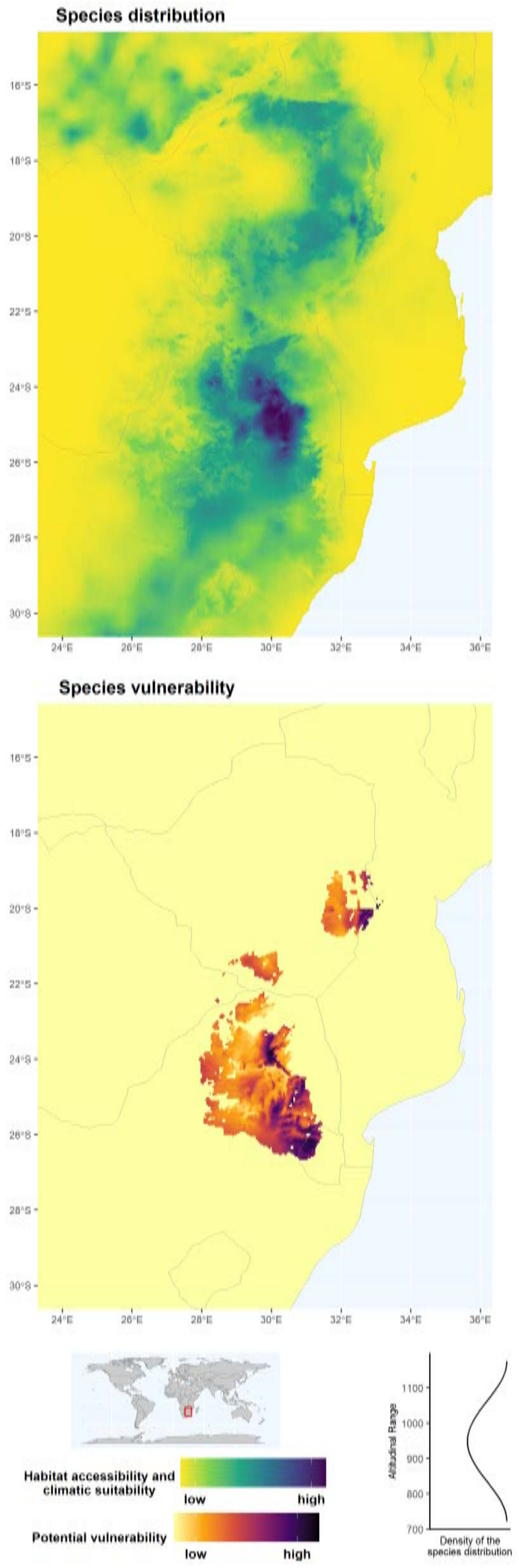
X. rippsteinii is a DT plant whose distribution comprises Ethiopia, Somalia. *X. rippsteinii* individuals can be primarily found in warm temperate climates, circa 3431 m.a.s.l. Their occurrence is restricted to little or no water deficiency, and is restricted to areas with seasonal precipitation regime (in which the drier season is short). More occurrence points are needed for a consistent evaluation of the conservation of X. rippsteinii populations. This species has not yet been assessed by IUCN, and 62% of its distribution range is currently found within protected areas.

Xerophyta scabrida (Pax) T. Durand & Schinz



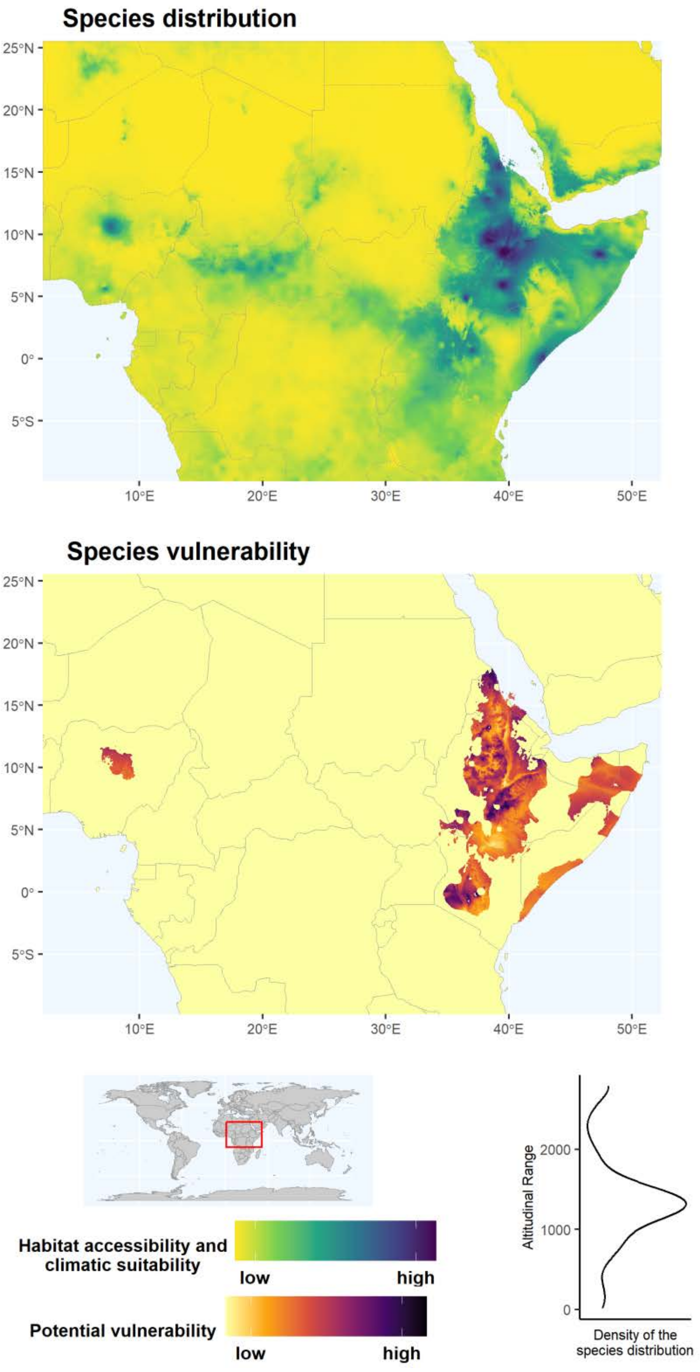
X. scabrida is a DT plant whose distribution comprises Angola, Zaïre. *X. scabrida* individuals can be primarily found in equatorial and warm temperate climates, ranging from 271 to 1829 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *X. scabrida* populations are expected to be potentially more vulnerable to climate change in parts of Angola, Democratic Republic of the Congo, Burundi, Mozambique, Tanzania. This species has not yet been assessed by IUCN, and 31% of its distribution range is currently found within protected areas.

Xerophyta schlechteri (Baker) N.L. Menezes



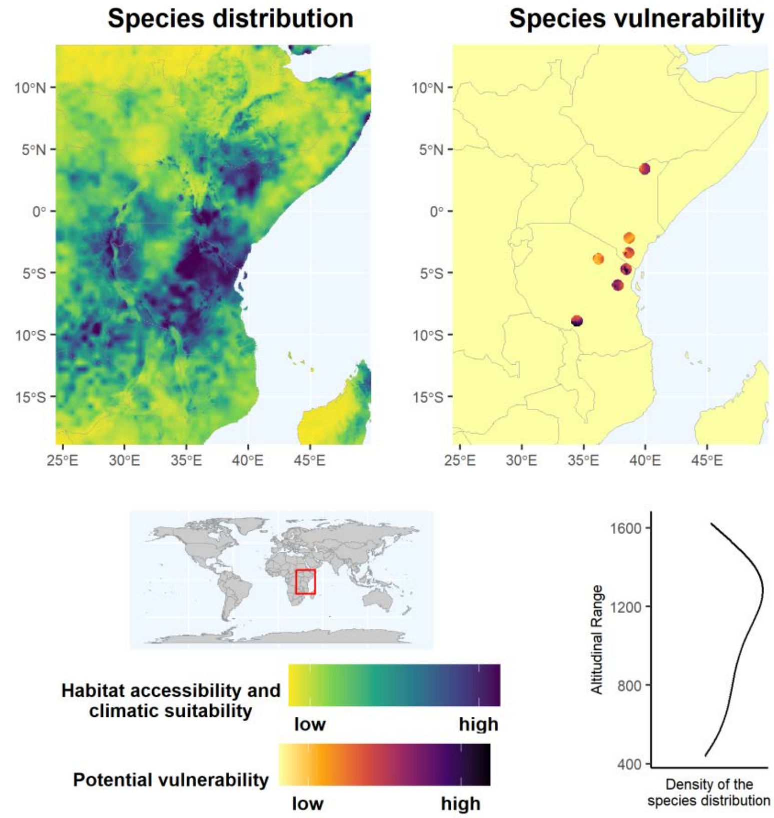
X. schlechteri is a DT plant whose distribution comprises Botswana, Northern Provinces, Zimbabwe. *X. schlechteri* individuals can be primarily found in arid climates, ranging from 722 to 1176 m.a.s.l. Their occurrence is restricted to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *X. schlechteri* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, South Africa, Swaziland, Zimbabwe. This species has not yet been assessed by IUCN, and only 32% of its distribution range is currently found within protected areas.

Xerophyta schnizleinia (L.B. Sm. & Ayensu) Baker



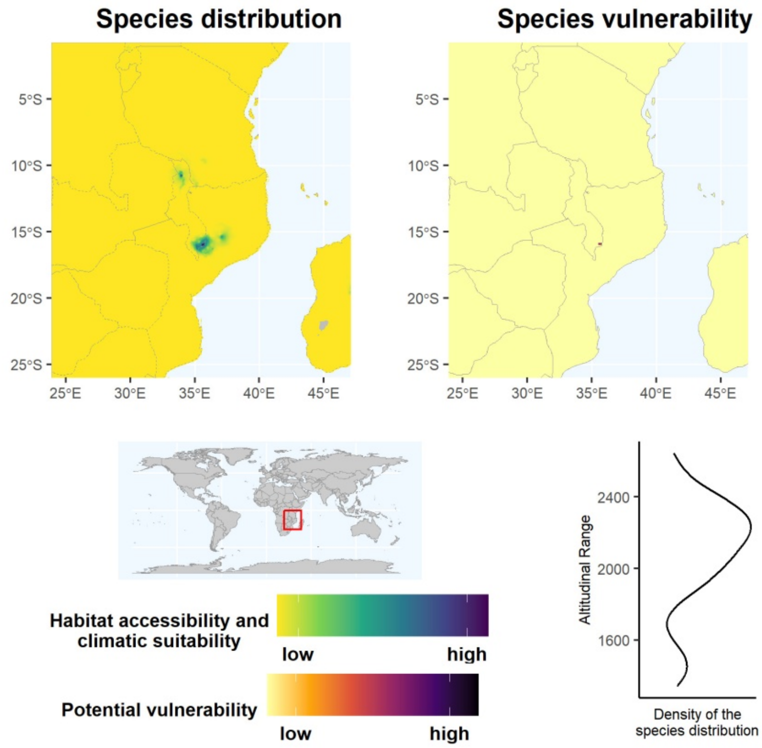
X. schnizleinia is a DT plant whose distribution comprises Equatorial Guinea, Eritrea, Ethiopia, Kenya, Nigeria, Somalia, Uganda. *X. schnizleinia* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 18 to 2788 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *X. schnizleinia* populations are expected to be potentially more vulnerable to climate change in parts of Eritrea, Ethiopia, Kenya, Somalia, Sudan. This species has not yet been assessed by IUCN, and only 18% of its distribution range is currently found within protected areas.

Xerophyta spekei Baker



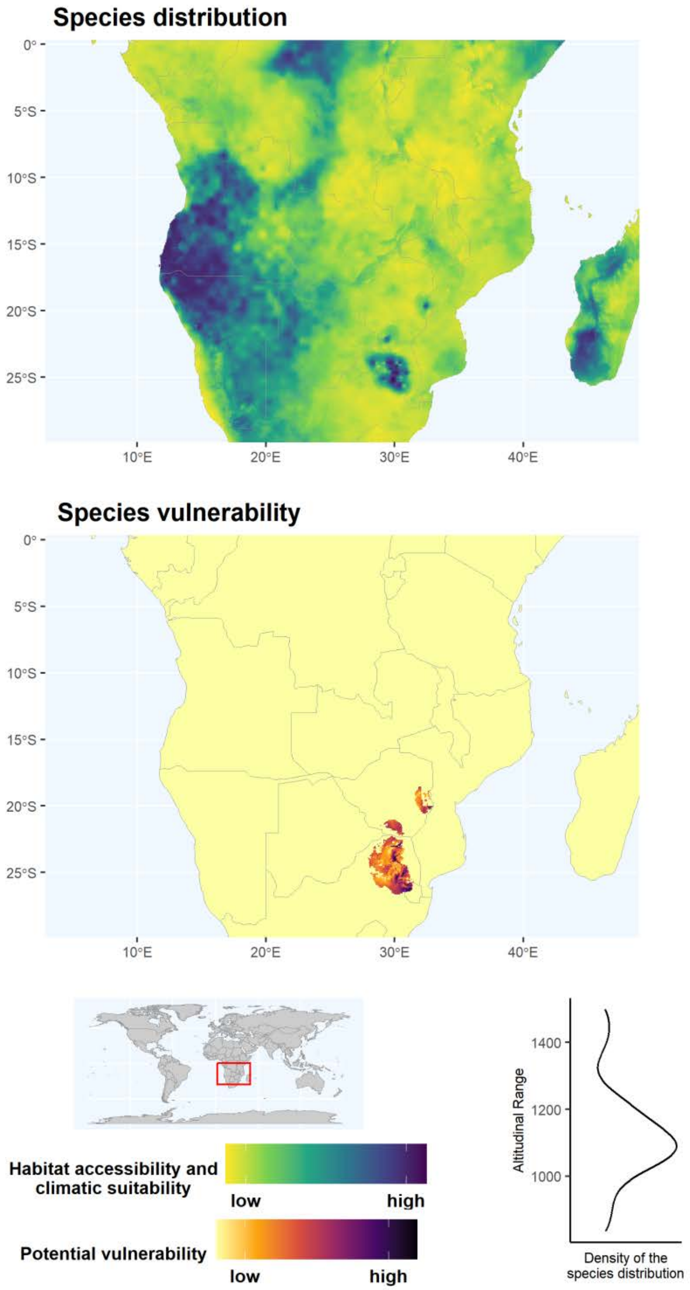
X. spekei is a DT plant whose distribution comprises Ethiopia, Kenya, Tanzania, Zambia, Zaïre. *X. spekei* individuals can be primarily found in equatorial, arid, and warm temperate climates, ranging from 439 to 1625 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which the dry season is long). *X. spekei* populations are expected to be potentially more vulnerable to climate change in parts of Kenya, Tanzania. This species has not yet been assessed by IUCN, and only 39% of its distribution range is currently found within protected areas.

Xerophyta splendens (Rendle) N.L. Menezes



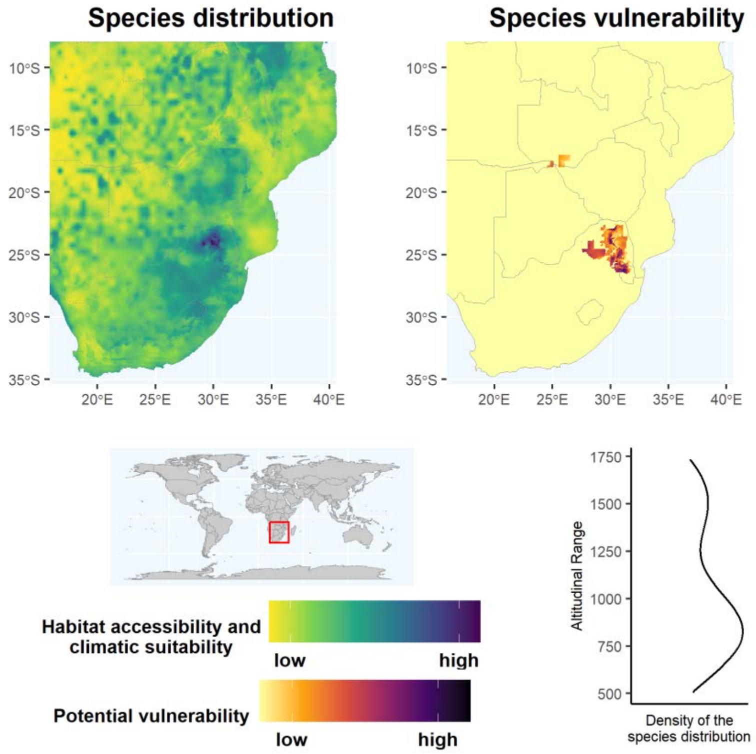
X. splendens is a DT plant whose distribution is restricted to Malawi. *X. splendens* individuals can be primarily found in warm temperate climates, ranging from 1343 to 2644 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *X. splendens* populations are expected to be potentially more vulnerable to climate change in parts of Malawi. This species is listed as Least concern by IUCN, and the totality of its distribution range is currently found within protected areas.

Xerophyta squarrosa Baker



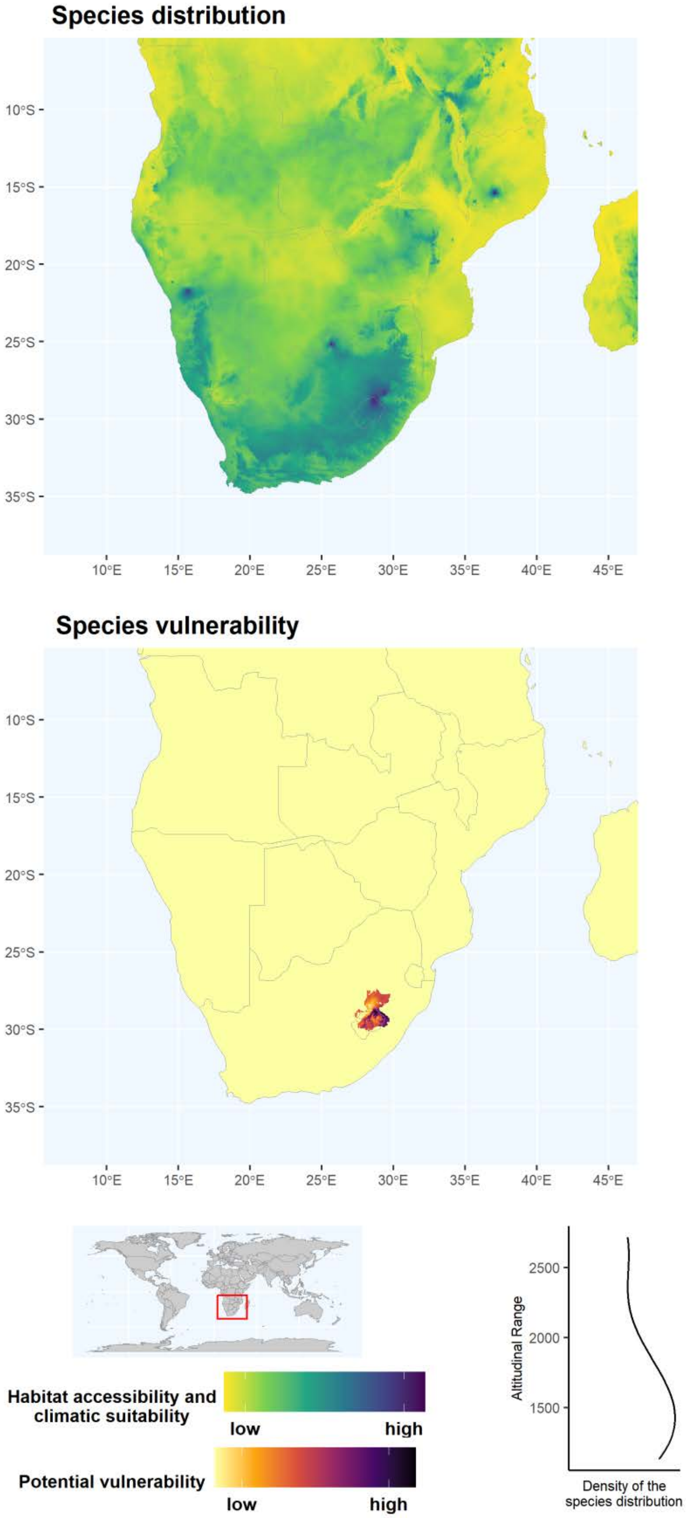
X. squarrosa is a DT plant whose distribution comprises Angola, Namibia. *X. squarrosa* individuals can be primarily found in equatorial and arid climates, ranging from 836 to 1499 m.a.s.l. Their occurrence varies from locations with moderate summer/winter water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which the dry season is long). *X. squarrosa* populations are expected to be potentially more vulnerable to climate change in parts of Mozambique, South Africa, Swaziland, Zimbabwe. This species has not yet been assessed by IUCN, and only 35% of its distribution range is currently found within protected areas.

Xerophyta villosa (Baker) L.B. Sm. & Ayensu



X. villosa is a DT plant whose distribution comprises Northern Provinces, Zambia, Zimbabwe. *X. villosa* individuals can be primarily found in arid and warm temperate climates, ranging from 507 to 1734 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *X. villosa* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Swaziland. This species has not yet been assessed by IUCN, and only 48% of its distribution range is currently found within protected areas.

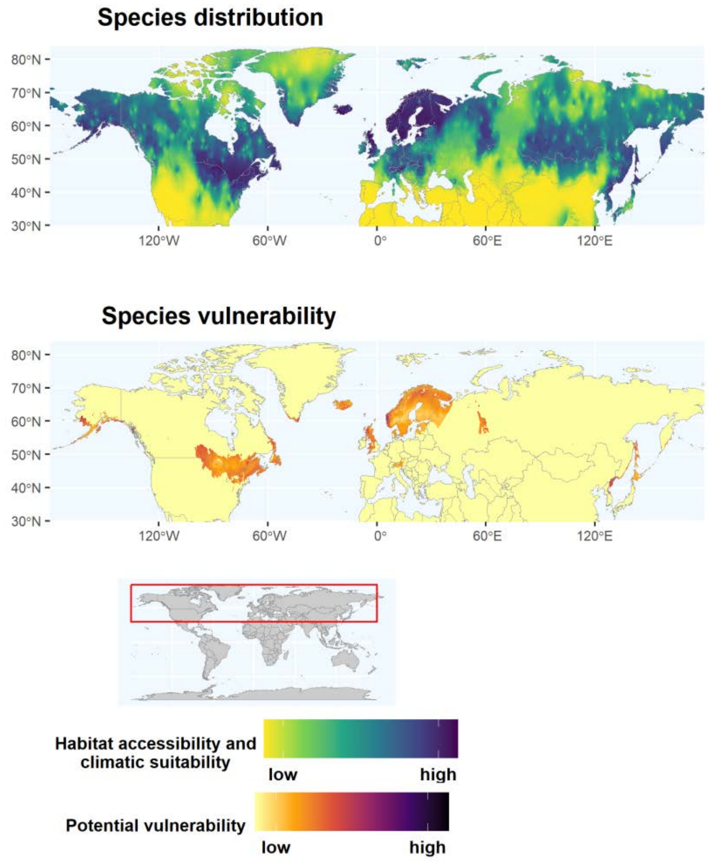
Xerophyta viscosa Baker



X. viscosa is a DT plant whose distribution comprises Cape Provinces, Free State, KwaZulu-Natal, Lesotho, Swaziland. *X. viscosa* individuals can be primarily found in arid and warm temperate climates, ranging from 1131 to 2716 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas with seasonal precipitation regime (in which the drier season is short) to seasonal precipitation regime (in which most precipitation occurs within 3 months in the year). *X. viscosa* populations are expected to be potentially more vulnerable to climate change in parts of South Africa, Lesotho. This species has not yet been assessed by IUCN, and only 28% of its distribution range is currently found within protected areas.

Woodsiaceae

Woodsia ilvensis (L.) R. Br.



W. ilvensis is a homoiochlorophyllous plant whose distribution comprises Alaska, Alberta, Altay, Amur, Austria, Baltic States, Belarus, British Columbia, Buryatiya, Central European Rus, China North-Central, Chita, Connecticut, Czechoslovakia, East European Russia, Finland, France, Germany, Great Britain, Greenland, Hungary, Iceland, Illinois, Inner Mongolia, Iowa, Irkutsk, Italy, Japan, Kamchatka, Kazakhstan, Khabarovsk, Krasnoyarsk, Krym, Labrador, Magadan, Maine, Manchuria, Manitoba, Maryland, Massachusetts, Michigan, Minnesota, Mongolia, New Brunswick, New Hampshire, New Jersey, New York, Newfoundland, North Carolina, North Caucasus, North European Russi, Northwest European R, Northwest Territorie, Norway, Nova Scotia, Nunavut, Ohio, Ontario, Pennsylvania, Poland, Primorye, Québec, Rhode I., Romania, Sakhalin, Saskatchewan, Sweden, Switzerland, Transcaucasus, Tuva, Ukraine, Vermont, Virginia, West Siberia, West Virginia, Wisconsin, Xinjiang, Yakutskiya, Yugoslavia, Yukon. *W. ilvensis* individuals can be primarily found in arid, warm temperate, and snow climates, ranging from 26 to 1577 m.a.s.l. Their occurrence varies from locations with little or no water deficiency to large summer/winter water deficiency, and ranges from areas which precipitation is spread throughout the year (with a definite wetter season) to seasonal precipitation regime (in which the drier season is short). *W. ilvensis* populations are expected to be potentially more vulnerable to climate change in parts of Canada, United States. This species is listed as Least concern by IUCN, although only 22% of its distribution range is currently found within protected areas.

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LUIZ BONDI

Wismarsche Str 43-45, 18057, Rostock, GER
luizbondi@gmail.com
+49 1520 4165531
researchgate.net/profile/Luiz-Bondi

EDUCATION

2019 - Ongoing	**Ph.D candidate in Botany** by University of Rostock, Germany. (Co-advisors: Dr. Stefan Porembski and Dr. Bruno Henrique Pimentel Rosado).
2015 - 2017	**M.Sc. in Biology** by Federal University of the Rio de Janeiro State, Brazil. (Co-advisors: Dr. Laura Jane Moreira Santiago and Dr. Camila Maistro Patreze).
2009 - 2013	**B.Sc. in Biology** by Federal University of the Rio de Janeiro State, Brazil. (Advisor: Dr. Laura Jane Moreira Santiago).

SKILLS

Functional Ecology – Theoretical Ecology – Ecosystem Functioning – Biodiversity Assessment – Conservation Biology – Climate Change - Floristic Studies – Taxonomic Identification – R Programming – Arduino Programming – Statistical Analysis – Modelling – Geographic Information Systems (GIS) – Teaching – Public Outreach – Scientific Communication – Scientific Conferences – Fieldwork – Laboratorial work – Teamwork.

GRANTS

2019 - 2023	Scholarship from DAAD - German Academic Exchange Service.
2015 - 2017	Scholarship from CAPES - Coordination for the Improvement of Higher Education Personnel.
2010 - 2011, 2013 - 2013	Scholarship from CNPq - National Council for Scientific and Technological Development.
2012 - 2012	Scholarship from FAPERJ - Rio de Janeiro's Research Foundation.

PUBLICATIONS

Bondi L, de Paula LFA, Rosado BHP, Porembski S. 2023. Demystifying the convergent ecological specialization of desiccation-tolerant vascular plants for water deficit, Annals of Botany, mcad005.

Porembski S, Rexroth J, Weising K, **Bondi L,** Mello-Silva R, Centeno DC, Datar MN, Watve A, Thiombano A, Tindano E, Rabarimanarivo M, de Paula LFA. 2021. An overview on desiccation-tolerant mat-forming monocotyledons on tropical inselbergs. Flora: Morphology, Distribution, Functional Ecology of Plants, 285(October).

RESEARCH PROJECTS

2022 - Ongoing	Coordinator at the research project DT Plants of the World.
2010 - 2017	Undergraduate research student at the research project Diversity and Conservation of the Rio de Janeiro State Inselbergs; coordinated by Dr. Laura Jane Moreira Santiago.
2010 - 2016	Collaborator at the public outreach project Sugarloaf Mountain-UNIRIO Program: university, society, and environment; coordinated by Dr. Laura Jane Moreira Santiago.
2010 - 2015	Tutor at the teaching project The Diversity of Flowering Plants; coordinated by Dr. Laura Jane Moreira Santiago.

PARTICIPATION IN CONFERENCES

Regular Talk

2022	**Bondi L**, Loiro RP, Patreze CM, Santiago LJM. Approaching inselberg biodiversity conservation through plant growth and dispersal strategies. European Conference of Tropical Ecology. Montpellier, France.
2017	**Bondi L**, Rosado, BHP. Developing low-cost environmental sensors: Yes, biologists can do it. XXIII Biology week of UERJ. Rio de Janeiro, Brazil.

Poster

2016	**Bondi-Macedo LF**, Loiro RP, Patreze CM, Santiago LJM. The influence of plant attributes on the distribution pattern of the Sugarloaf Rocky Complex flora. II Symposium of the post-graduation program in Neotropical Biodiversity, Rio de Janeiro, Brazil.
2015	**Bondi-Macedo LF**, Loiro RP, Santiago LJM. Floristic and environmental relationships of an inselberg complex in the southeast coast of Brazil. 66th Brazilian Congress of Botany, Santos, Brazil.
2015	**Bondi-Macedo LF**, Loiro RP, Santiago LJM. Floristic relationships and abiotic filters on the Sugarloaf Rocky Complex flora. XII Ecology Congress of Brazil, São Lourenço, Brazil.
2014	**Bondi-Macedo LF**, Louro RP, Andrade IF, Santiago LJM. Distribution pattern of Sugar Loaf Natural Monument Flora and its relationship with Brazilian rocky outcrops. 8th Spanish Congress of Biogeography, Sevilla, Spain.
2014	**Bondi-Macedo LF**, Loiro RP, Santiago LJM. Distribution pattern of the flora of the Natural Monument of Sugarloaf and Urca and its relationships with other Brazilian rock outcrops. XI Latin American congress of Botany/ 65th Brazilian Congress of Botany, Salvador, Brazil.
2013	**Bondi-Macedo LF**, Fontes AHB, Loiro RP, Santiago LJM. Floristics and distribution of Natural Monument of Sugarloaf species, Rio de Janeiro, Brazil. 64th National Congress of Botany, Belo Horizonte, Brazil.
2012	**Bondi-Macedo LF**, Fontes, AHB, Fonseca JGA, Louro RP, Santiago LJM. Floristic Inventory of Natural Monument of Sugarloaf, Rio de Janeiro, Brasil. 63rd National Congress of Botany, Joinville, Brazil.

Organization

2014 X Biology Week of UNIRIO, Rio de Janeiro, Brazil.

Attendance

2021 71st National Congress of Botany, virtual meeting.

2021 Virtual Meeting of the Association for Tropical Biology and Conservation.

2021 1st International Meeting of the Latin American and Caribbean Network for Research and Innovation in Mountain Environments, virtual meeting.

2018 II International Conference on Research for Sustainable Development in Mountain Regions, Nova Friburgo, Brazil.

2018 III Workshop on Sustainable Development in Mountain Environments, Nova Friburgo, Brazil.

2016 International Seminary of Statistics with R, Rio de Janeiro, Brazil.

2016 Workshop on Historical Biogeography of Neotropical Myrtaceae, Rio de Janeiro, Brazil.

2013 XIV Brazilian Congress of Plant Physiology, Poços de Caldas, Brazil.

2013 XIV Brazilian Symposium of Paleobotany and Palynology/ 5th Latin American Meeting of Phytoliths, Rio de Janeiro, Brazil.

2012 10th International Congress of Cell Biology, Rio de Janeiro, Brazil.

2011 X Ecology Congress of Brazil/ I Sustainability Symposium, São Lourenço, Brazil.

2011 XXX Fluminense Journey of Botany, Mendes, Brazil.

2010 IX Biology week of UNIRIO, Rio de Janeiro, Brazil.

2009 VII Biology week of UNIRIO, Rio de Janeiro, Brazil.

TEACHING AND TRAINING EXPERIENCE

Mentorship

2017 Danilo Alves de Carvalho. Determinants of the distribution pattern of rupicolous species in Southeast Brazil in the coastal plains. Bachelor thesis, Federal University of the State of Rio de Janeiro, Brazil.

Short-term courses

2021 Lecturer at the course “First steps in R”, hosted by the project Se Liga, Ciência!, virtual course.

2018 Lecturer at the course Demystifying R, hosted by the event XXIII Biology week of UERJ, Rio de Janeiro, Brazil.

Tutorship

2012 - 2012 Tutor at the discipline of "Chordate Zoology" in the Biology course of UNIRIO.

2011 - 2011 Tutor at the discipline of "Fundamentals of Botany" in the Biomedicine course of UNIRIO.

2010 - 2015	Tutor at the discipline of "Phanerogamic plants" in the Biology course of UNIRIO

PUBLIC OUTREACH

2018 - Ongoing	Scientific communicator at the committee for technical communication of the Natural Monument of the Sugarloaf Mountains, SMAC-RJ - Municipal Secretary for the Environment of Rio de Janeiro.
2010 - 2015	Scientific communicator at the project "Seed bank and seedlings of native tropical species"; coordinated by Dr. Laura Jane Moreira Santiago.
2010 - 2015	Scientific communicator at the project "Documentation and diffusion of Sugarloaf Mountain"; coordinated by Dr. Laura Jane Moreira Santiago.
2010 - 2015	Scientific communicator at the project "Herbarium - HUNI"; coordinated by Dr. Laura Jane Moreira Santiago.

COMPLEMENTARY TRAINING

2016	Inselbergs - biodiversity, ecology and conservation in a global context (6h); hosted by IP/JBRJ - Research Institute of the Rio de Janeiro Botanical Garden.
2015	Introduction to biostatistics, multivariate analysis and geostatistics (10h); hosted by SEB - Ecological Society of Brazil.
2015	Basic statistics with the R language for plant ecology analysis (8h); hosted by SBB - Botanical Society of Brazil.
2014	Analysis of functional traits evolution (12h); hosted by SBB - Botanical Society of Brazil.
2014	Systematics, phylogeny, biology and conservation of Cactaceae (12h); hosted by SBB - Botanical Society of Brazil.
2014	Introduction to species distribution modeling (8h); hosted by UNIRIO - Federal University of the State of Rio de Janeiro.
2013	Cryopreservation of plant structures (4h); hosted by SBFV - Brazilian Society of Plant Physiology.
2012	Plant cell biology (3h); hosted by SBBC - Brazilian Society of Cell Biology.
2012	Photosynthesis in algae and plants (16h); hosted by SBB - Botanical Society of Brazil.
2011	Reforestation and soil (8h); hosted by UNIRIO - Federal University of the State of Rio de Janeiro.
2011	Botanical phenology (8h); hosted by UNIRIO - Federal University of the State of Rio de Janeiro.
2011	Quality control of plant drugs (8h); hosted by SBB - Botanical Society of Brazil.
2011	Identification of Brazilian commercial woods (8h); hosted by UNIRIO - Federal University of the State of Rio de Janeiro.

STATEMENT OF INDEPENDENCE

The opportunity for this PhD project was not communicated to me commercially. In particular I have not engaged any organisation that for money seeks supervisors for the drawing up of dissertations or that performs entirely or partially on my behalf the duties incumbent upon me regarding the examinations. I hereby declare under oath that I have completed the work submitted here independently and have composed it without outside assistance. Furthermore, I have not used anything other than the resources and sources stated and where I have taken sections from these works in terms of content or text, I have identified this appropriately.

SELBSTSTÄNDIGKEITSERKLÄRUNG

Die Gelegenheit zum vorliegenden Promotionsvorhaben ist mir nicht kommerziell vermittelt worden. Insbesondere habe ich keine Organisation eingeschaltet, die gegen Entgelt Betreuerinnen/Betreuer für die Anfertigung von Dissertationen sucht oder die mir obliegenden Pflichten hinsichtlich der Prüfungsleistungen für mich ganz oder teilweise erledigt. Ich versichere hiermit an Eides statt, dass ich die vorliegende Arbeit selbstständig angefertigt und ohne fremde Hilfe verfasst habe. Dazu habe ich keine außer den von mir angegebenen Hilfsmitteln und Quellen verwendet und die den benutzten Werken inhaltlich und wörtlich entnommenen Stellen habe ich als solche kenntlich gemacht.

Luiz Fernando Bondi de Macedo

Rostock, 09 February 2023