Technology
Arts Sciences
TH Köln

UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

TH KÖLN - UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

POTENTIAL OF USING MORPHOLOGICAL AND FUNCTIONAL TRAITS OF WOODY SPECIES AS INDICATORS OF DRY CONDITIONS IN THE TRANSITION ZONE OF THE ATLANTIC FOREST (MATA ATLÂNTICA) IN THE RIO DE JANEIRO STATE, BRAZIL

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

AND

MASTER OF SCIENCE

NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT

DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

PRESENTS:

DIEGO ALEXANDER GUARIN CIFUENTES

CO-DIRECTOR OF THESIS PMPCA

DR. JUAN ANTONIO REYES AGUERO

CO-DIRECTOR OF THESIS ITT

DR. CLAUDIA RAEDIG

ASSESSOR:

DR. DIETMAR SATTLER

COLOGNE, GERMANY DATE: August/2018

Technology
Arts Sciences
TH Köln

PROYECTO FINANCIADO POR:

State University of Northern Fluminense

(Universidade Estadual do Norte Fluminense "Darcy Ribeiro", UENF)

PROYECTO REALIZADO EN:

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

COLOGNE UNIVERSITY OF APPLIED SCIENCES

PROGRAMAS MULTIDISCIPLINARIOS EN CIENCIAS AMBIENTALES

UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

CON EL APOYO DE:

CONSEJO NACIONAL DE CIENCIA Y TECNOLOGÍA (CONACYT)

DEUTSCHER AKADEMISCHER AUSTAUSCH DIENST (DAAD)

LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS

(PNPC - CONACYT)

Technology
Arts Sciences
TH Köln

Erklärung / *Declaración*

Name / *Nombre*: Diego Alexander Guarín Cifuentes

Matrikel-Nr. / *N° de matricula*: 111173915 **(TH Köln)**., 0269387 **(UASLP)**

Ich versichere wahrheitsgemäß, dass ich die vorliegende Masterarbeit selbstständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen sind, sind als solche kenntlich gemacht.

Aseguro que yo redacté la presente tesis de maestría independientemente y no use referencias ni medios auxiliares a parte de los indicados. Todas las partes, que están referidas a escritos o a textos publicados o no publicados son reconocidas como tales.

Die Arbeit ist in gleicher oder ähnlicher Form noch nicht als Prüfungsarbeit eingereicht worden.

Hasta la fecha, un trabajo como éste o similar no ha sido entregado como trabajo de tesis.

Köln /San Luis Potosí, den /*el* 21 de Agosto de 2018

Unterschrift / *Firma*:

Ich erkläre mich mit einer späteren Veröffentlichung meiner Masterarbeit sowohl auszugsweise, als auch Gesamtwerk in der Institutsreihe oder zu Darstellungszwecken im Rahmen der Öffentlichkeitsarbeit des Institutes einverstanden.

Estoy de acuerdo con una publicación posterior de mi tesis de maestría en forma completa o parcial por las instituciones con la intención de exponerlos en el contexto del trabajo investigación de las mismas.

Unterschrift / Firma:

ACKNOWLEDGEMENTS

This project would not have been possible without the following people and institutions that supported this work.

Muito Obrigado com Brazil:

Personnel of EMATER RIO São Francisco de Itabapoana: Walmir Macedo, Thiago Manhães Nogueira, and João Pereira for all the logistic help during my staying for the field work. And EMATER RIO in Niterói to Helga Hissia and Marcelo Costa.

Izolmar Soares Filho Secretary of Environnment of São Francisco de Itabapoana for the provided information about the situation of drought in the municipality

CEMADEN-RJ Natural Disasters Early Warnings State Center in Rio de Janeiro State: Lt. Col Rodrigo Werner da Silva, and Eng. Leandro Camargo for their help in SIG topics.

Dr. Rafaela Campostrini Forzza, of the Herbarium of Rio de Janeiro Botanical Garden JABOT, for her support to guide the proposed research.

Dr. Marcelo Trinidade Nascimento, and Ph.D Students Mariana Faitanin and Igor Broggio of the State University of Northern Region Fluminense “Darcy Ribeiro” UENF for their special support and guidance to select the place for this research, the field material and all the provided information

Dr. Fatima Pina de Rodrigues of UFSCAR for her help in the interviews

To the Deutscher Akademiker Austausch Dienst (DAAD)for the Financial aid that allowed me to study this master, and eventually carry out this interesting project.

To the assistance of all the staff at the PMPCA and the ITT specially of Sandra Avendaño and Maricela Rodríguez for their patience and the support during these years

To the thesis comitee. Dr Claudia Raedig, Dr. Juan Antonio Reyes Agüero and Dr Dietmar Sattler for their supervision and corrections to carry out satisfactorialy this project.

To the great ENREM generation 2016-2018 for their spiritual, technical, and all kind of help that I received of each one of you guys when I needed. Thanks to this wonderful group. And to all my friends who supported me to the distance.

Finally, to God, my Parents, my brother, and all my family that always believed in me, for all the blessings and good vibes since the beginning of this adventure.

Definitively thanks so much to all of you.

Table of Content

INDEX OF FIGURES

INDEX OF TABLES

ABSTRACT

Plants have certain characteristics which allow them to respond to various environmental conditions, like changes in climate, water loss in the soil, lack of minerals; among others. In some of these so-called traits, the responses to climatic phenomena such as drought can be evidenced through morphological adaptations (spines, succulent tissues, trichomes, among others) or physiological adaptations (regulation of water potential at the cellular level, the concentration of nutrients, etc.)

In certain areas of Brazil such as the Mata Atlântica biome, drought events are increasingly occurring and affecting human activities and the environment, and it is required to understand if tree species with traits adapted to dry conditions are occurring in drought-prone areas. For this reason, it is intended to find out the potential of using morphological functional traits of woody species as indicators of dry conditions in the transition zone of the Atlantic Forest. RJ Brazil.

Therefore, this work was carried out considering a field phase in a drought prone area known as “Mata de Tabuleiros” or Semideciduous Seasonal Lowland Forest that belongs to the domain of the Mata Atlântica, there were selected morphological traits in order to know which of them can give a hint as drought tolerant traits. On the other side there was searched in the Rio de Janeiro Botanical Garden JABOT database for species with recorded characteristics related to drought adaptations. For the traits in the field, and the selected species from the database was elaborated a Species Distribution Model SDM in order to know how some climatic variables allow the distribution of species and morphological traits.

As main result there was elaborated a set of trait indicators that can be considered for further analysis in the region; and also the results of the SDM obtained at large scale for the Mata Atlântica for the species selected from the database, and the SDM for the traits analyzed in the field in the Mata de Tabuleiros. Besides that, the consultations with experts in the subject were an important input that allowed to carry out this research. The use of morphological and functional traits is important to understand the interactions between organisms and their environment, in this case to cope and tolerate a climate phenomenon like drought.

Keywords: Mata de Tabuleiros, Drought tolerance, Morphological traits, Species Distribution Modeling

RESUMEN

Los organismos como las plantas tienen ciertas características o rasgos por los cuales pueden mostrar algunas respuestas a diversas condiciones ambientales, como cambios en el clima, pérdida de agua en el suelo, falta de minerales; entre otros. En algunos de esos rasgos, las respuestas de resistencia o sensibilidad a fenómenos climáticos como la sequía pueden evidenciarse a través de morfológicas (espinas, tejidos suculentos, tricomas, entre otros) o adaptaciones fisiológicas (regulación del potencial hídrico a nivel celular, la concentración de nutrientes, etc.)

En biomas de Brasil como el Bosque Atlántico “Mata Atlântica”, hay ciertas áreas donde los eventos de sequía son cada vez más recurrentes afectando las actividades humanas y el medio ambiente. se requiere comprender si especies de árboles con características adaptadas a condiciones secas se encuentran en áreas propensas a la sequía. Por esta razón, se pretende conocer el potencial de uso de rasgos morfológicos funcionales de especies leñosas como indicadores de condiciones secas en la zona de transición del Bosque Atlántico. RJ Brasil.

Por lo tanto, este trabajo se llevó a cabo realizando una fase de campo en un área propensa a la sequía conocida como "Mata de Tabuleiros" o Bosque Semideciduo de Tierras Bajas que pertenece al dominio de la Mata Atlántica, se seleccionaron rasgos morfológicos para saber cuáles de ellos pueden indicar tolerancia a la sequía. Por otro lado, se buscó en la base de datos JABOT del Jardín Botánico de Río de Janeiro especies con características registradas relacionadas con adaptaciones ante la sequía. Para los rasgos en el campo, y las especies seleccionadas de la base de datos se elaboró un Modelo de Distribución de Especies SDM para saber cómo algunas variables climáticas permiten la distribución de las especies y rasgos morfologicos.

Como resultado principal, se elaboró un conjunto de rasgos indicadores que pueden considerarse para análisis posteriores en la región; y también los resultados del SDM obtenidos a gran escala para la Mata Atlântica para las especies seleccionadas de la base de datos, y el SDM para los rasgos analizados en campo en la Mata de Tabuleiros. Además de eso, las consultas con expertos en el tema fueron un aporte importante que permitió llevar a cabo esta investigación. El uso de rasgos morfológicos y funcionales es importante para comprender las interacciones entre los organismos y su entorno, en este caso para resistir y tolerar fenómenos climáticos como la sequía.

Palabras clave: Mata de Tabuleiros, Tolerancia a la sequia, Rasgos morfológicos, Modelos de Distribución de Especies

INTRODUCTION

The Atlantic Forest or “Mata Atlântica” is a biome located in Brazil, Paraguay, and Argentina. In Brazil, it is located along the coastal zone of the country in 17 states from Rio Grande do Norte to Rio Grande do Sul corresponding almost 95 percent of the total extension of the biome (Conservation International do Brasil, 2000) reaching inland to the Province of Misiones in northeastern Argentina, and east of Paraguay (Tabarelli et al., 2010), is composed of two major vegetation types: the coastal forest or Atlantic Rain Forest and the tropical seasonal forest or Atlantic Semi-deciduous forest. Is the second largest tropical forest after the Amazon Rain Forest which extends through the Amazon River basin, located in the northern region of Brazil, extending to neighboring countries such as Bolivia, Colombia, Ecuador, Guyana, French Guiana, Peru, Suriname and Venezuela (Santos,2010).

The Atlantic Forest was one of the largest rainforests of the Americas, originally covering around 150 million ha. It is extended into tropical and subtropical regions, between 3° S to 31° S, and from 35° W to 60° W; currently remains from 11.4% to 16.0% of the original vegetation 15.719337 ha (SOSMA & INPE, 2008; and Silva & Casteleti, 2003; in Ribeiro et al., 2009).

The geographical and climatic characteristics of this biome, have favored the high plant diversity and presence of endemisms; more than 8000 of estimated 20000 species of plants (40%) are thought to be endemic (Brooks et al., 2002 ; Mittermeier et al.,2004). During the years 1990-2006 more than 1000 new species of angiosperms were discovered, representing 42% of the total described for Brazil in this period (Sobral & Stehmann, 2009)

All this diversity, is based in the important role that plays this biome by the regulation and maintenance of available water resources in seven of the largest basins in the country, the Amazon basin, the Atlantic or Northeast basin, the Tocantins basin, the São Francisco basin, the Paraguay Basin, the Parana basin, the East Atlantic basin, the South Atlantic basin, and the Uruguay basin; which encompass also 22 microbasins (RBMA Conselho Nacional Reserva da Biosfera da Mata Atlântica, 2004). Being fundamental to the maintenance processes of hydric resources; ensuring the quantity, and quality of drinking water required for more than 120 million Brazilians, which are almost 61 % of the total population of Brazil; distributed in 3400 municipalities along the country; and for the economic sectors of the country, such as agriculture, fishing, industry, tourism, and power generation (Santos, 2010).

But those sectors, and in general the regulation of the hydric cycle is being affected by the increase of drought events in Brazil during the last years, especially in the north part of the country, and along the Mata Atlântica biome; the human activities and the increasing urban sprawl, make this zone more prone to this climate events considering them as a hazard, putting the drought in the agenda of the Brazilian government and its institutions, as an issue that has to be consider urgently to attend through the elaboration and implementation of plans and programs aimed to mitigate the impacts of this climate phenomena.

Besides the affectations to the human activities, the impact in the forest cover is also noticeable; the recurrent events of drought during the last years have led to evidence changes in the vegetation composition, and also in the distribution of some species vulnerable or prone to dry longer conditions.

One of the adaptations that plants have developed to withstand with climate adverse conditions, are some morphological adaptive traits like thorns, rough leaves, succulent structures (stem, roots, leaves, etc.), mechanisms at cellular level; among others, to regulate the water loss, prevent overheating and regulate cooling of the plant. This is evidenced in dry and arid environments, but also in tropical and humid biomes as the Mata Atlântica.

To comprehend better the role of those plant traits to cope with drought, it is necessary to inquire which characteristics could give a hint as drought tolerance traits, in order to look for some particular traits that influence the vegetation performance. This has to be done together with an analysis in the field, and spatial modeling considering environmental parameters of climate information for instance.

For this reason, this study is aimed to find the potential of using functional and morphological traits of woody species as indicators of dry conditions which is made in two scales, at biome level (large scale), and at particular vegetation level (small scale) considering the inquires mentioned above.

At large scale for the Mata Atlântica it will be conduct to find some species recorded in the database of the Botanical Garden of Rio de Janeiro (JABOT) where plant species occurrences are collected together with special characteristics of the species considered, some of those characteristics can be taken into account as drought tolerant.

At small scale it is considered one of the most affected types of vegetation in the northeast part of Rio de Janeiro State, the lowland seasonal forest or “Mata de Tabuleiros”, which is part of the semideciduous seasonal forest in the domain of the Mata Atlântica; the information provided is based in many studies related with physiognomy and ecology of the region (Abreu, 2013, Garay et al., 2003, and Silva & Nascimento, 2001) to mention the most relevants.For this part it is found how some traits are distributed in this type of vegetation in some forest fragments.For both scales are analysed which climatic patterns influence their distribution. Therefore, is generated an input of morphological traits that could be useful to measure in the field; for further studies in order to know how those characteristics can be used to inquire if there are changes in the distribution of some botanical groups in relation to climate changes.

1. THE MATA ATLÂNTICA: ENVIRONMENTAL CONDITIONS

1.1 Vegetation of the Atlantic Forest

The Mata Atlântica has a complex of many vegetation physiognomies along the country; such as dense ombrophilous forests, ombrophilous mixed forests, and seasonal deciduous and semideciduous forests (Joly et al.,2014) the main vegetal formations that compose the big biome of Atlantic Forests, are the following. Figure 1 (RBMA Conselho Nacional Reserva da Biosfera da Mata Atlântica, 2004).

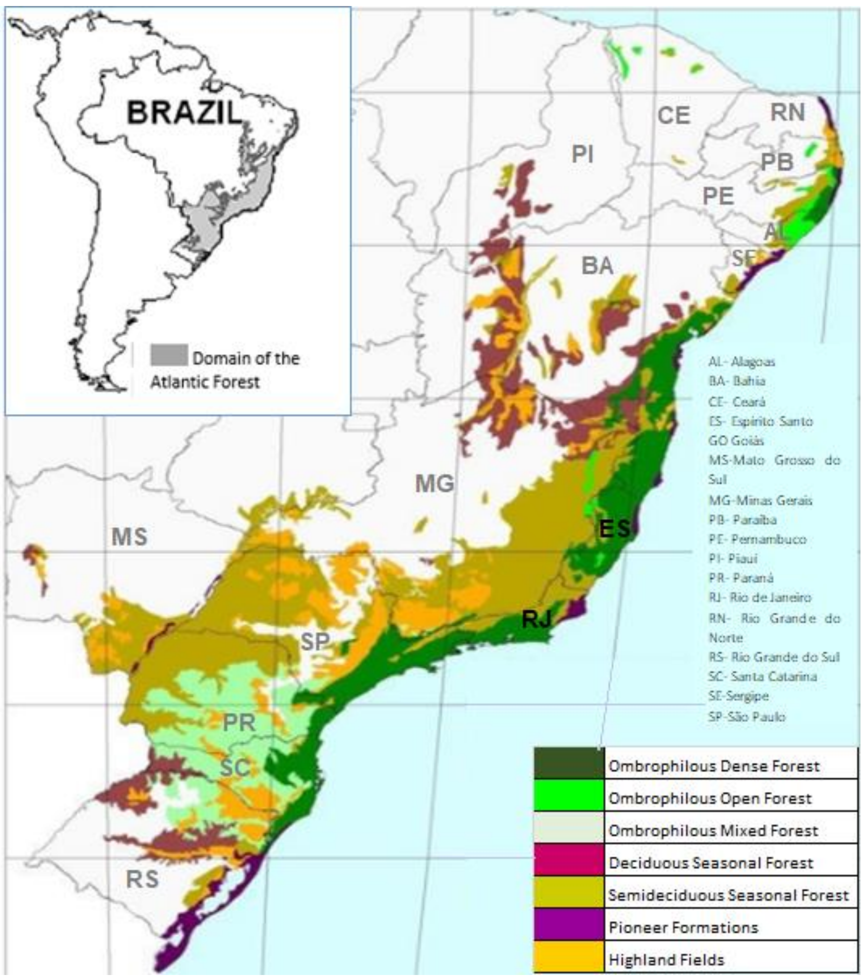


Figure 1 Ecosystems of the Atlantic Forest
Source modified from (Conselho Nacional Reserva da Biosfera da Mata Atlântica, 2004)

The Mata Atlântica belongs to the floristic region of southeastern Brazil (Dense Ombrophilous Forests, Semidecidual Seasonal Forest, Decidual Seasonal Forest, and

Savana) of the Atlantic Shield; where it was sheltered the flora that originated part of the floristic coverage that will cover the plateau during the Triassic-Jurassic period in this region.

During the Pilopleistocene the forest cover along the Atlantic mountainous area was dense ombrophilous (tropical pluvial) type (IBGE, 2012). At present; this forest is restricted to clusters on the slopes facing the sea, in the states of Espírito Santo, Rio de Janeiro, São Paulo, and Santa Catarina. According to the Brazilian Institute of Geography and Statistic IBGE, the main vegetation formations of this biome, are classified as it is shown in Table 1.

Table 1 Types of Vegetation in the Atlantic Forest Source modified from (IBGE, 2012)

Ecosystem	Type of vegetation
Atlantic Dense Ombrophilous Forest or Atlantic Tropical Rainforest (evergreen)	Dense Alluvial -ciliary forest
	Dense Lowlands
	Dense Submountain
	Dense Mountainous
	Dense High Mountainous
Open Ombrophylous Forest.	Open Ombrophylous Alluvial
	Open Ombrophylous Lowlands
	Open Ombrophylous Submountainous
	Open Ombrophylous Mountain
Mixed Ombrophylous Forest.	Mixed Ombrophylous Alluvial
	Mixed Ombrophylous Submountainous
	Mixed Ombrophylous Mountainous
	Mixed High Ombrophylous Mountainous
Deciduous Seasonal Forest	Deciduous Seasonal Alluvial
	Deciduous Seasonal Lowland
	Deciduous Seasonal Submountainous
	Deciduous Seasonal mountainous
Semideciduous Seasonal Forest	Semideciduous Seasonal Alluvial
	Semideciduous Seasonal Lowland
	Semideciduous Seasonal Submountainous
	Semideciduous Seasonal Mountainous
Pioneer Formations	Vegetation with Marine Influence (Restinga)
	Vegetation with fluviomarine influence (Mangroves and Saline fields)
	Vegetation with fluvial influence (Alluvial communities)
High-Altitude Fields	

Next, are described the characteristics of the vegetation in the Semideciduous Seasonal Forest and its formation of Semideciduous Seasonal Lowland Forest; which is the main type of vegetation where this work was carried out.

1.1.1 Semideciduous Seasonal Forest

Also known as “Mata de Interior”, the ecological characteristics that stand out in this type of vegetation are the double climatic seasonality and the so-called physiological dryness. This plant formation occurs along the states of São Paulo, Paraná, Minas Gerais, Rio de Janeiro, Mato Grosso do Sul, Santa Catarina, and Rio Grande do Sul. (Santos,2010). The ecological concept of this formation type is established in function of the occurrence of seasonal climate that determines the semideciduousness of the foliage of the forest cover. In the tropical zone, it is characterized by an accentuated winter drought and intense summer rains; in the subtropical zone, correlates with the climate without dry periods, but with a very cold winter (average monthly temperatures below 15°C), which determines physiological rest and partial falling of the foliage (IBGE, 2012).

The Semideciduous Seasonal Forest shows some variations ranging from the evergreen to deciduous trees, reaching heights between 30-40 m; without forming an uninterrupted superior canopy. This characteristic is a deal for the sunlight to reach the forest ground, this allows the growth of a vigorous lower stratum, there are also shrubs, lianas, and epiphytes, but in lower abundance and richness respect to rainforests (Scheer & Blum 2009). Unlike ombrophilous forests, this type consists of phanerophytes with foliar buds protected from drought by scales, cataphylls or trichomes and whose adult leaves are sclerophyllous or membranaceous. The percentage of deciduous trees in the forest complex, that lose leaves individually, is usually between 20% and 50% (IBGE, 2012). It presents also different vegetation formations as its shown in Figure 2 and Table 2.

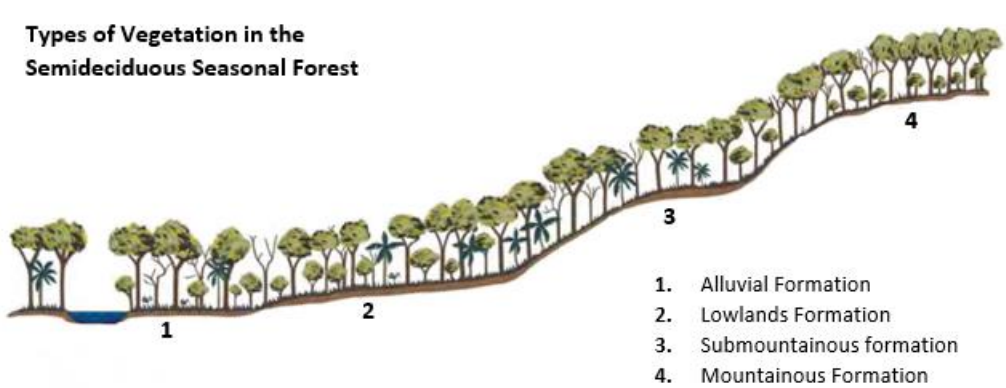


Figure 2 Profile of Vegetation of the Semideciduous Seasonal Forest Source Modified from (Veloso et al.,1991 in (IBGE, 2012)

Table 2 Types of Vegetation in the Semideciduous Seasonal Forest Source. Modified from (Abreu 2013; Afonso 2010; Gonçalves et al. 2006; IBGE 2012; and Meira-Neto & Martins 2002)

1. Semideciduous Seasonal Alluvial Formation / Formação Estacional Semidecidual Aluvial
It is a formation found frequently on the great depression "pantaneira mato-grossense-do-sul", always bordering the rivers of the Paraguay River Basin, this formation has abundant species of the genera *Handroanthus* and *Amburana* which is a genus of economic-logging value, associated with the ecotypes *Calophyllum brasiliense, Tapirira guianensis, Inga sp, Podocarpus sellowii, Cedrela lilloi,* and *Guarea guidonia* among others. The richness of this habitat is also represented by families like Lauraceae, Arecaceae, Euphorbiaceae, Rubiaceae and Moraceae (Gonçalves et al., 2006).
2. Semideciduous Seasonal Lowlands Formation / Formação Estacional Semidecidual das Terras Baixas
This formation is also known as the "Mata de Tabuleiros" is frequently found in plateaus of Pliocene-Pleistocene origin of the Barreiras Group, from the south of Natal to the north of the state of Rio de Janeiro, with discontinuous distribution the eastern coastal border (Abreu, 2013). it is a forest type characterized by the genus *Caesalpinia echinata* Brazil-wood, and other genera as *Lecythis*, which dominates lower rivers valleys, accompanied by other genera like *Cariniana* (jequitibá) and *Eschweilera*. Other important large trees like *Paratecoma peroba* (peroba de campos) of pantropical dispersion, are currently threatened by logging; are found in the States of Espirito Santo, Rio de Janeiro and Minas Gerais (IBGE, 2012). Other families of high representativity are Fabaceae (Leguminosae), Myrtaceae, Sapotaceae and Meliaceae (Abreu, 2013).
3. Semideciduous Seasonal Submountain Formation / Formação Estacional Semidecidual Submontana
This formation in dry soils in the lower parts of frequently occurs on the interior slopes of mountainous relief (Afonso, 2010) like the Serra de Mantiquiera and Serra dos Órgãos, and in the central plateaus of sandstones of the Botucatu, Bauru, and Caiuá geological formations. It is distributed from the State of Espírito Santo and the south of the State of Bahia to the States of Rio de Janeiro, Minas Gerais, São Paulo, north, and southwestern Paraná; entering the south of Goiás through the Paranaíba River, as well as in the states of Mato Grosso and Rondônia. The dominant ecotype *Aspidosperma polyneuron* is mainly distributed in the Paraná Plateau in the west of the State of São Paulo, Some species have deciduous characteristics, like the genera *Hymenaea* (jatobá), *Copaifera* (oil-red), *Peltophorum* (canafistule), *Astronium*, *Handroanthus*, among other species (IBGE, 2012).
4. Semideciduous Seasonal Mountainous Formation / Formação Estacional Semidecidual Montana
There are few areas occupied by this formation located above 500 m of altitude. They are located mainly on the interior part of Serra dos Órgãos, in the State of Rio de Janeiro and in Serra da Mantiqueira, in the states of São Paulo, Rio de Janeiro, and Minas Gerais (Itatiaia) and Espírito Santo (Caparaó). These areas are characterized to have igneous origins noticed by the basaltic sills where vegetation is established. The Mountainous formation is almost always dominated by the genus Anadenanthera with the species Anadenanthera peregrina, and other genera of wide dispersion like *Chamaecrista, Parapiptadenia, Astronium* among others (IBGE, 2012). The diversity of families like Leguminosae, Euphorbiaceae, and Annonaceae is also significant in this region (Meira-Neto & Martins, 2002).

1.1.2 Semideciduous Seasonal Lowland Formation "Mata de Tabuleiros"

This formation has some particular geological and ecological characteristics, its name of "tabuleiros"is given by the fact that the topography is flat in large extensions, not reaching altitudes higher than 200 m (Rizzini et al., 1997 in Broggio et al., 2011 ; Garay et al., 2003) Located in the sparse sediments of Cenozoic Barreiras group origin along the seafront (Silva & Nascimento, 2001), the vegetation is distributed along a climatic gradient from the seashore to inner lands; causing differences among the species occurring in the seashore, respect the ones to the inner lands close to the mountain ranges or "serras".

This gradient make that this type of vegetation shows a floristic composition that has a multiple origin; constituted of the mixture of three phytogeographic elements: the first one is the "Mata de Tabuleiros", the second corresponds to the typical species of the neighboring "Mata Atlântica " that contours the western limit of the "Tabuleiros", and the third element are the species coming from the Amazon Forest; relicts of an ancient distribution over the Barreiras group over to the coast (Rizzini, 2000 in Garay et al., 2003 ; Stehmann et al., 2009). An important characteristic of this vegetation is that many species have sclerophyllous and hard leaves (with thick epidermal walls and cuticle); which is an adaptation to heat seasons or drought (Silva & Nascimento, 2001 ; Díaz et al., 2004).

It has been estimated the specific richness in this type of vegetation; that approaches almost to 400 species per hectare distributed in 30000 individuals, with 1000 to 1600 adult trees, that are part of at least 200 or 250 populations of different species, perhaps more; representing about 40 to 50 botanical families (Jesus & Rolim, 2000; Rizzini, 2000 in Garay et al., 2003). Of the 840 species registered in the Mata Atlântica, 631 (75%) occur in Ombrophilous Forest, and 406 (48%) in Semideciduous Seasonal Forest (Stehmann et al., 2009) this shows a high diversity even more per hectare than the Amazon forest; in spite that is already known is strongly fragmented, or modified by the various forms of anthropic impacts (Garay et al., 2003).

Among the arboreal species that represent the diversity of the "Mata de Tabuleiros" belong in particular, to several families: the pink jequitibá, *Cariniana legalis* (Lecythidaceae); jacaranda caviuna, *Dalbergia nigra*, pau-sangue, *Pterocarpus rohrii*, óleo de copaiba, *Copaifera langsdorffii,* brauna preta, *Melanoxylon brauna*, the different ingás, *Inga sp.,* or the angico rosa, *Pseudopiptadenia contorta* (Leguminosae); the gonçalo alves, *Astronium concinnum* (Anacardiaceae); the peroba bone, *Aspidosperma cylindrocarpon*

(Apocynaceae); the rose cedar, *Cedrela odorata*, the batingas, *Eugenia sp*, and the jabuticabas, *Myrciaria jaboticaba* and *Myrciaria sp* (Meliaceae); among many other families (Garay et al., 2003). Most of this richness can be evidenced in the forest of the north of Espírito Santo State and south of the Bahia State, more than other forests in southeast Brazil (Gonçalves et al.,2016) Figure 3.

On the other side, many studies in this region have led to propose initiatives or guidelines that allow to establish or redefine some areas where important diverse forest remnants can be protected (Dantas, 2005 ; Gonçalves et al., 2006 ; Garay et al., 2003); considering actions that must be taken to manage and conserve these forests, such as establish forest corridors that connect fragments particularly using zoochorous tree species; and use forest enrichment techniques with species that are absent, or present at low density as a result of the suffered intensive exploitation in the past (Abreu et al., 2014).

Figure 3 View of the "Mata de Tabuleiros" in the Sooretama Reserve, Espírito Santo State
Source (Instituto Chico Mendes de Conservação da Biodiversidade ICMBio,2018)

1.2 Description of the Study Area in the "Mata de Tabuleiros"

The environmental characteristics of this diverse biome have made it susceptible to diverse anthropic and natural changes along the time, and one of the regions where these changes are noticed is in the north of Rio de Janeiro (RJ) state, especially in the Northern Fluminense Region that limits with the state of Espírito Santo in the north. There, the study municipality of São Francisco do Itabapoana in RJ has 26.6% of Atlantic Forest of the Northern Fluminense region; which corresponds to 30219 hectares of forest fragments and associated ecosystems, such as mangroves and restinga. The forest fragments of this municipality are classified as Semidecidual Seasonal Forest (SOSMA e INPE, 2011)

This region is characterized to have many fragments spread along the municipality, from the coastline to the inner land; according to the Structural Connectivity Index (ICE) the dimension and quantity of those fragments, makes the region with a potential of medium connectivity, delimiting areas that do not present significant barriers to the movement of the fauna, and the dispersion of the flora. Areas with high connectivity may be of great interest for conservation; while areas with low connectivity that exhibit fragments of interest should be the subject of restoration projects to reestablish connectivity between fragments and favor long-term ecological succession (SEA / INEA, 2011).

The largest forest fragment in this region is the Coal Forest or "Mata de carvão" which belonged to the São Pedro Ranch; is called in that way due to the intensive timber extraction mainly for charcoal, and deforestation for sugarcane cultures and livestock production, during the decades of the 1960s and 1980s. By 1965 had 4500 ha, and currently, that area has been reduced to 1182 ha (Silva & Nascimento, 2001). This forest fragment was recognized in 1992 by the UNESCO like part of the Atlantic Forest Biosphere Reserve, adding it in 2003 to the State Ecological Station (SES) Conservation Unit of Guaxindiba; managed by the State Environmental Institute of Rio de Janeiro (INEA). Nowadays this protected area comprises about of 3000 ha and is located in the micro-basin between the creeks of Floresta and Cobiça, both tributaries of the Guaxindiba river (Abreu, 2013). The main studies carried out in this forest are related to phytosociological studies (Silva & Nascimento, 2001), nutrient cycling (Villela et al.,2006), and ecophysiological adaptations to forest gaps caused by logging (Rabelo et al.,2013); among others.

Besides this fragment, other important forest remnants in this area belong to private lands, ranches or “fazendas”; the Fazenda Santo Antônio, Fazenda Santana, Fazenda Imburi, Fazenda Palmeiras, and Mata do Funil. These are the remnants close to the “Mata do carvão”. One of the studies carried out in this region was the research for Doctorate thesis of Dr. Karla Pedra de Abreu entitled “Structure and Floristic Diversity of Semideciduous Seasonal Forest Fragments in the North of Northeast Fluminense Region”.

In that study there were characterized the richness, diversity, and structure of the woody species of Semideciduous Seasonal Forest (SSF) of the fragments mentioned above, in relation to environmental variables, and the effects of fragmentation through the use of landscape metrics; there were selected in three types of SSF: Submontane Semideciduous Seasonal Forest, Lowland Semideciduous Seasonal Forest, and the “Mata de tabuleiros”

This latter was the type of vegetation chosen as the main reference to develop my work in that area, there were selected three of those remnants; in the “fazendas” Imburi, Santana, and Santo Antônio. Figure 4. For the present study; the characteristics of these fragments are described further on, in the section of Results.

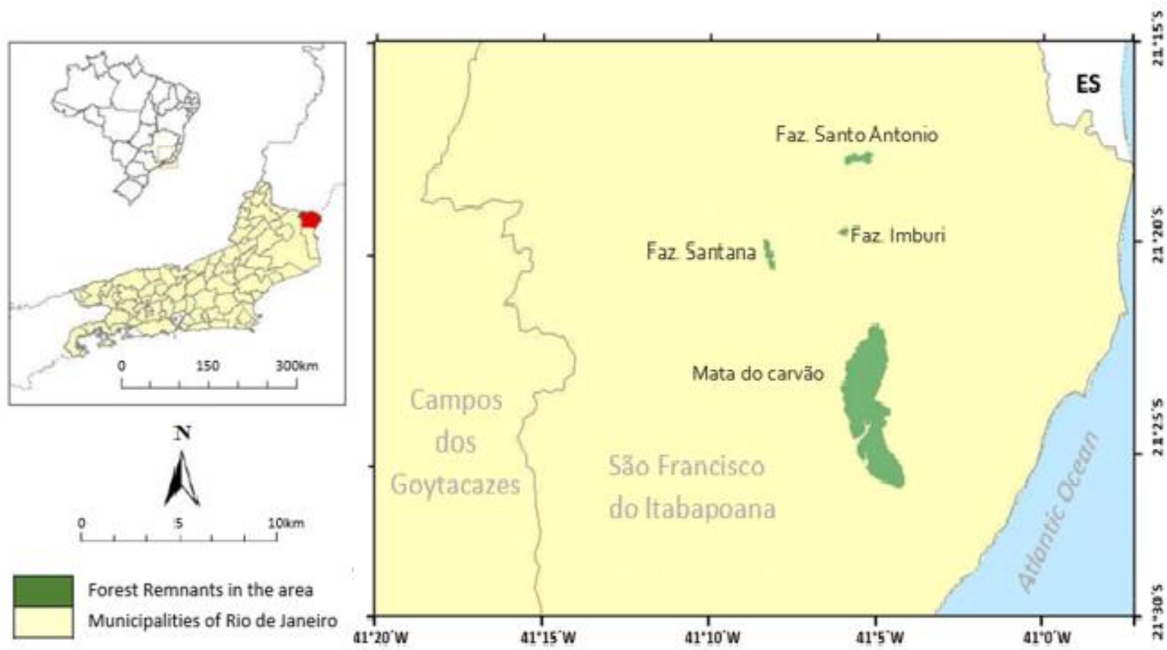


Figure 4 Remnants of Mata de Tabuleiros in the Study Area Source modified from (Abreu, 2013)

2. DROUGHT: EFFECTS ON THE MATA ATLÂNTICA BIOME

2.1 Climate of the Atlantic Forest

The Atlantic Forest experiences two types of climate, one warm and wet without a dry season; and a seasonal climate with a moderately severe dry season (usually from April to September) that predominates over the distribution of the Atlantic Semi-deciduous Forest (Oliveira-Filho & Fontes 2000 in Morellato & Haddad 2000). The mean temperature varies from 14-21 ° C, reaching the maximum of 35ºC, not passing the absolute minimum of 1ºC. Although in the South of the country, the temperature may fall below 0ºC (IZMA, 2009 in Santos, 2010).

The wide latitudinal and longitudinal range is important in producing differences in forest composition, because of the decreased rainfall away from the coasts due to the orography of the region. Coastal areas receive large amounts of rain year-round, reaching more than 4000 mm, while inland forests receive around 1000 mm/year (Câmara & Galindo-Leal 2003) and average rainfall of 1200 mm per year (IZMA 2009 in Santos, 2010). In the north-south direction, the Mata Atlântica presents a sequence of climatic types based on Köppen classification, adapted for Brazil (Bernardes, 1960 in Baptista, 2009) as follows:

- Climate As ' (The tropical climate with autumn-winter rains, its tropicality reverses the rainy season, because in winter the Atlantic polar air mass (Pa), coming from the South Atlantic, near Argentina; penetrates the Oceanic Atlantic route, joining to the trade winds, producing abundant rains. Towards the interior, the rainfall decreases progressively.
- Climate Af (hot and super humid without dry season). Because of its constant rainfall has equatorial characteristics. It extends from the Recôncavo Baiano in the state of Bahía to the extreme north of the Espírito Santo State. In the Southeast, it occurs in the low and medium slopes of the Serra do Mar.
- Climate Am (hot and super humid climate with short dry season). It is also very rainy, and usually substitutes the Af climate to the inner lands, both in the South-Bahia stretch and in the Southeast Region; in most cases, the interiorization of the climate implies a decrease in rainfall.
- Climate Cw (tropical climate of altitude). It is a tropical climate with mesothermic characteristics, as it presents mild and rainy summers and dry and cold winters, with

occasional frost occurring in the most favorable latitudes. This type of climate occurs in the mountainous areas of the Southeast. The enclaves of *Araucaria* forests existing in this region are related to this climate.

- Climates Cfa and Cfb (mesothermic climates with rains regularly distributed over the year). This type of subtropical climate presents low temperatures in the winter, due to the influence of the extratropical latitudes. In the winter period, frosts are frequent with sporadic and localized snowfall.

Next, in Figure 5, it is shown the climate classification adopted by the IBGE based on 3 systems that integrate quantitative methods and atmospheric dynamics. The first one based on dynamic climatology and atmospheric circulation patterns defines the three zonal climates (Equatorial, Tropical, and Temperate) and their regional subunits. The second system delimits the thermal regions (Mesothermic medium, Mild, Semiwarm, and Warm), and is based on the frequency and averages of monthly extreme values. The classification of regions for monthly moisture and dryness patterns (ranging from Superhumid to Semi-Arid) is the result of the third system adopted. Those systems relate the number of dry months with the predominant type of natural vegetation, in order to show the interaction of the climatic regime with biogeography and ecology of the biome.

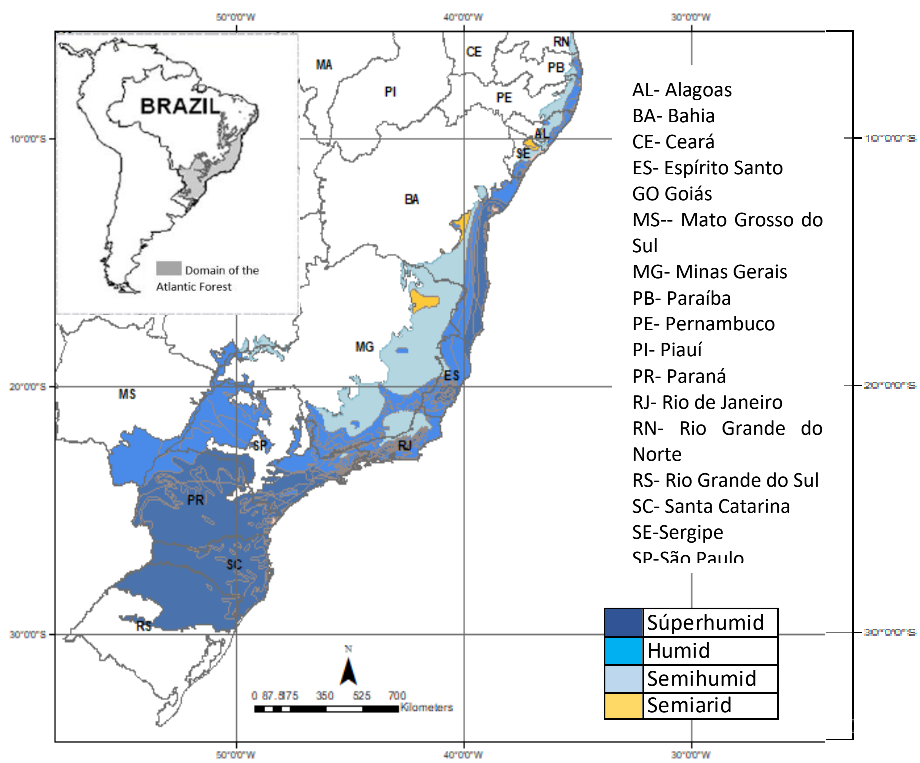


Figure 5 Climate of the Atlantic Forest.
Source elaborated from INDE 2018 in http://www.visualizador.inde.gov.br/

2.1.1 Climate in the Mata de Tabuleiros

Regarding the climate, according to the Köppen classification in the study area is (Aw). Tropical weather with a dry season (three months Jun-Jul-Aug) in winter Figure 6. With an average temperature of 25°C, it can descend to 18°C and has an average pluviosity of 1000 mm.

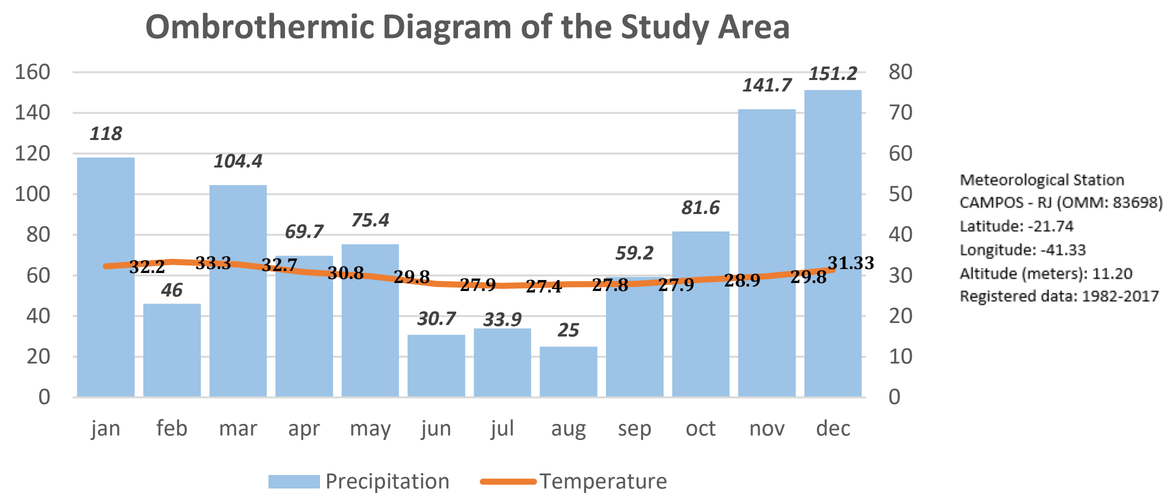


Figure 6 Ombrohermic Diagram of the Study Area Source elaborated from (Instituto Nacional de Meteorologia 2018) in http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep

As was consulted in the municipality during the last years specially in the dry season, it has been registered a deficit in the precipitation respect to the average of 1000 mm, during July-September of 2017, and during the last three years 2014-2017 the precipitation decreased significantly with indexes between 725 and 413 mm; when at least the indexes in the region should be between 1200 and 1500 mm for a good maintenance of the fruit and sugarcane crops[1]. This desence of the precipitation during the dry season is considered as drought.

[1] Information provided by reports of EMATER-RIO São Francisco do Itabapoana. See Annex Section of Interviews

2.1.3 Definition of Drought

The concept of drought has many definitions; one of the most common and taken as reference is the definition of the National Drought Mitigation Center at the University of Nebraska, that describes the drought as: "when the precipitation is lower than the long-term normal for a prolonged period, and to most observers, it seems to start with the delay in the timing (or failure) of the rains" (Wilhite & Glantz, 1985). Another definition is "drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems" (World Meteorological Organization WMO, 1986 in Martínez-Sánchez, n.d.)

Due to its characteristics, the drought is considered as a slow-onset natural hazard that is typically referred as a creeping phenomenon. Because, the effects of this climate event are often slow to occur, lagging precipitation deficits by weeks or even months. Because precipitation deficits generally start to appear as deficits in the soil and water, productive sectors as the agriculture are usually affected in the first place (Sivakumar et al.,2010).

Drought differs from other natural hazards (e.g., floods, tropical cyclones, and earthquakes) in many ways. First, since the effects of drought often cumulative slowly over a considerable period of time and may last for years after the termination of the event; the start, and end of drought is difficult to determine. Second there is still a need to agree a precise and generally accepted definition of drought; sometimes this makes unclear about whether or not a drought exists in some areas, and if it does, its degree of severity; having this in account, the definitions of drought should be focused considering its impacts a regional level (Wilhite, 2000).

For instance, droughts that occur in the North American Great Plains will differ from those that occur in Northeast Brazil, southern Africa, western Europe, or eastern Australia; and naturally the characteristics of this phenomenon vary extensively between each one of these locations. Besides this, drought impacts are nonstructural and spread over a larger geographical area, than damages that result from other natural hazards. The areas affected by severe droughts, change with time (season or year), as well as regions of maximum intensity (i.e., drought epicenter); in larger countries, such as Brazil, China, India, the United States, or Australia, drought would hardly affect the whole country (Sivakumar et al.,2010).

2.1.4 Drought in Brazil and the Atlantic Forest

Brazil as one of the biggest countries in the world has been suffered the impacts of drought especially after the second half of the 20th Century. One of the most impacting drought events in Brazil was recorded in 1975 with a total cost of total losses of US$ 8.1 billion, being one of the most expensive disasters in the history of the country (WMO, 2014) followed by other countries like Venezuela, Peru and Argentina with other type of natural hazards. Figure 7.

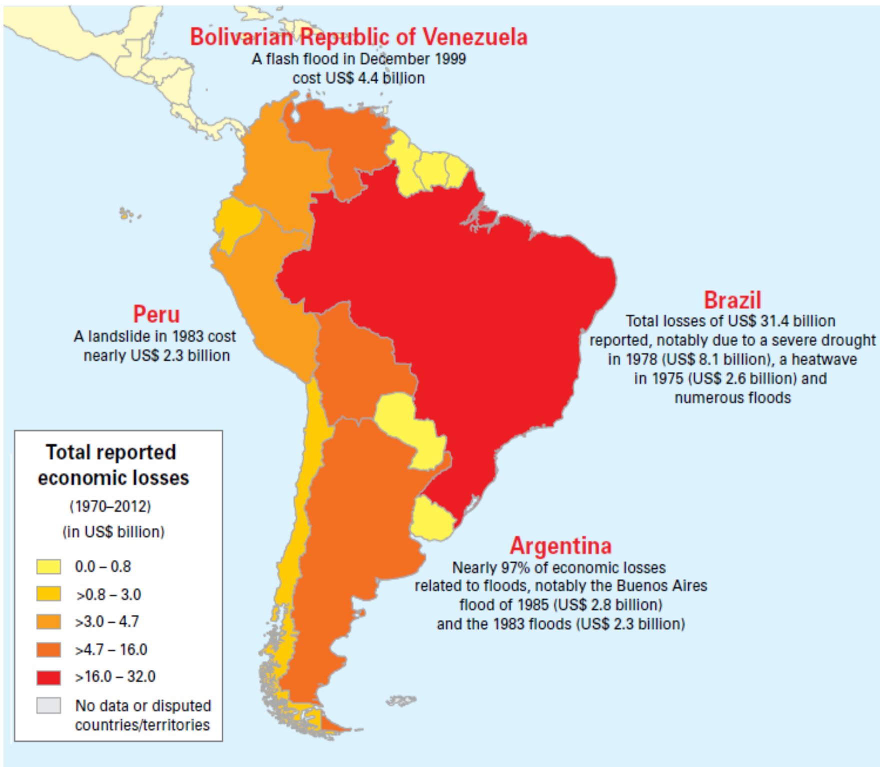


Figure 7 Map of reported disasters and their related economic losses in Southamerica (in US$ billion, 1970–2012) Source. Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes 1970–2012 (WMO, 2014 in CGEE, 2016)

Historically, the most affected region by drought has been the northeast region of Brazil that includes the states of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia, and the northern part of Minas Gerais; these states include mainly the biomes of the Caatinga, the Cerrado and also part of the Mata Atlântica. Drought and water scarcity are contributing also to desertification in this region, but the main reasons are overgrazing, the increased frequency of fires, deforestation, and overexploitation of groundwater reservoirs (CGEE, 2016).

According to the Ministry of Environment (MMA). During the period 2003 to 2015, there were reported the highest drought registers in the country, between 16 and 25 registers by municipality. Figure 8, other important registers of drought were reported in the South of Brazil and the Amazonia during the years 2004, 2005, and 2006 (Marengo, 2007).

Currently, the Brazil Government through its National Action Program to Combat the Effects of Desertification and Mitigation of Drought (PAN-Brazil), is taking measures at environmental, economic, social, and political level; with the aim to reduce the impacts of this phenomenon in order to stick to the sustainable development goals (MMA, 2005).

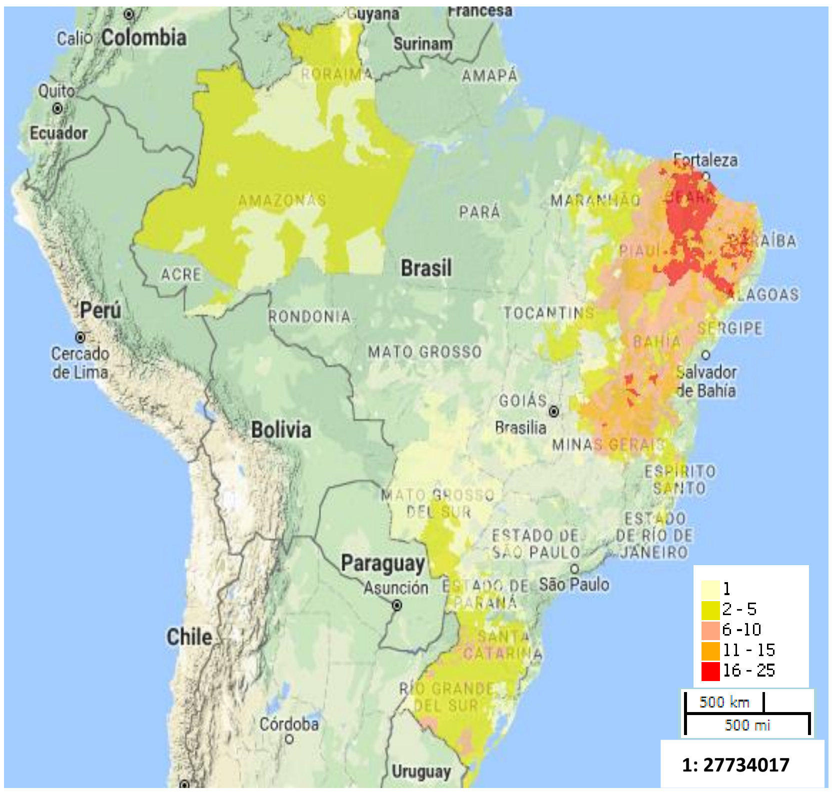


Figure 8 Registers of Drought per Municipality in Brazil (2003-2015)
Source. Extracted from INDE 2018 in http://www.visualizador.inde.gov.br/

The effects of drought and their characteristics are different in each region of Brazil, being the Northeast region the most vulnerable at economic and social level. On the other side with the rapid growth of the population over the past half-century in the Southeast region in states like São Paulo, Rio de Janeiro, and Minas Gerais; droughts have caused significant impacts on the residents and the ecosystems; being the Mata Atlântica one of the most affected along those states, with a tendency to increase in the years to come (Engle et al.,2017).

Currently, in the fragments of “Mata de Tabuleiros” in the north fio Rio de Janeiro state, the drought is considered a natural hazard being evidenced a hydrological drought (water courses interrupted and low level of the flow in water bodies), which have led to declare an emergency situation. Adapting the municipality plan of water reserves that states to make use and extend water reservoirs for agriculture and livestock and others for rainfall water collection, this is stressed out by the Civil Defense Department of the municipality in Decree N°56 Nov 10 -2017 Decree of Identification of Emergency Situation-Hydrological Drought[2].

According to some predictive models it can be estimated an increase of drought due to anomalous precipitation tendencies for the period 2011- 2100, taking as baseline the historical register from 1965 to 2005; considering the dynamic seasonality of the southern hemisphere; the rainfall and temperature values in the humid season (December-January-February) Figure 9, and the dry season (June-July-August) Figure 10, through regional climatic models (Eta-MIROC5), that use the lowest concentration of greenhouse gases or (Representative Concentration Pathway RCP 4.5) to generate these models during these periods (Ministério do Meio Ambiente, 2018).

It can be seen in Figure 9, a negative reduction of precipitation, between (-40 % / -60 % in a small stripe of the Mata Atlântica in the northern part of the country, and in the rest of the biome a reduction between 60% to 20%; and it is predicted that if greenhouse gases reach high levels (RCP 8.5) the precipitation may decrease between (-60 % / -80%) in this area by the year 2100.

In Figure 10, it is estimated also a decrease of precipitation in order to -60% / -40% in most part of the biome in the southern part will decrease from 20% to -20%, and the small stripe in the north seashore will maintain values of 20%; but in the north part of Minas Gerais and south of Bahia is expected a decrease close to -80% to the end of this century also with high levels of greenhouse gases (RCP 8.5).

2 Information provided by reports of EMATER-RIO São Francisco do Itabapoana. See Annex Section of Interviews

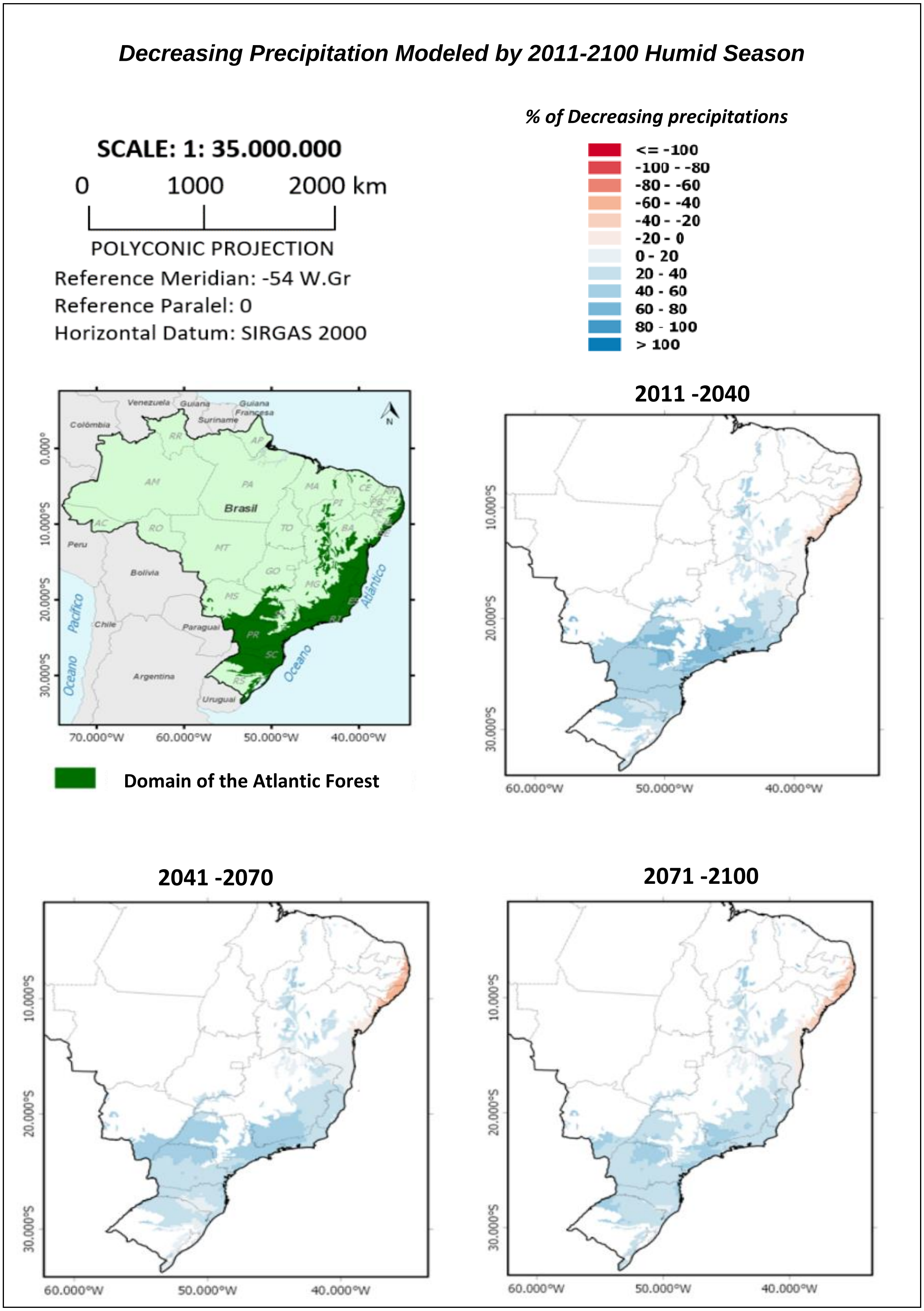


Figure 9 Tendency of Decreasing Precipitation 2011-2100 (DJF) Humid Season
Source Modified from (Ministério do Meio Ambiente, 2018)

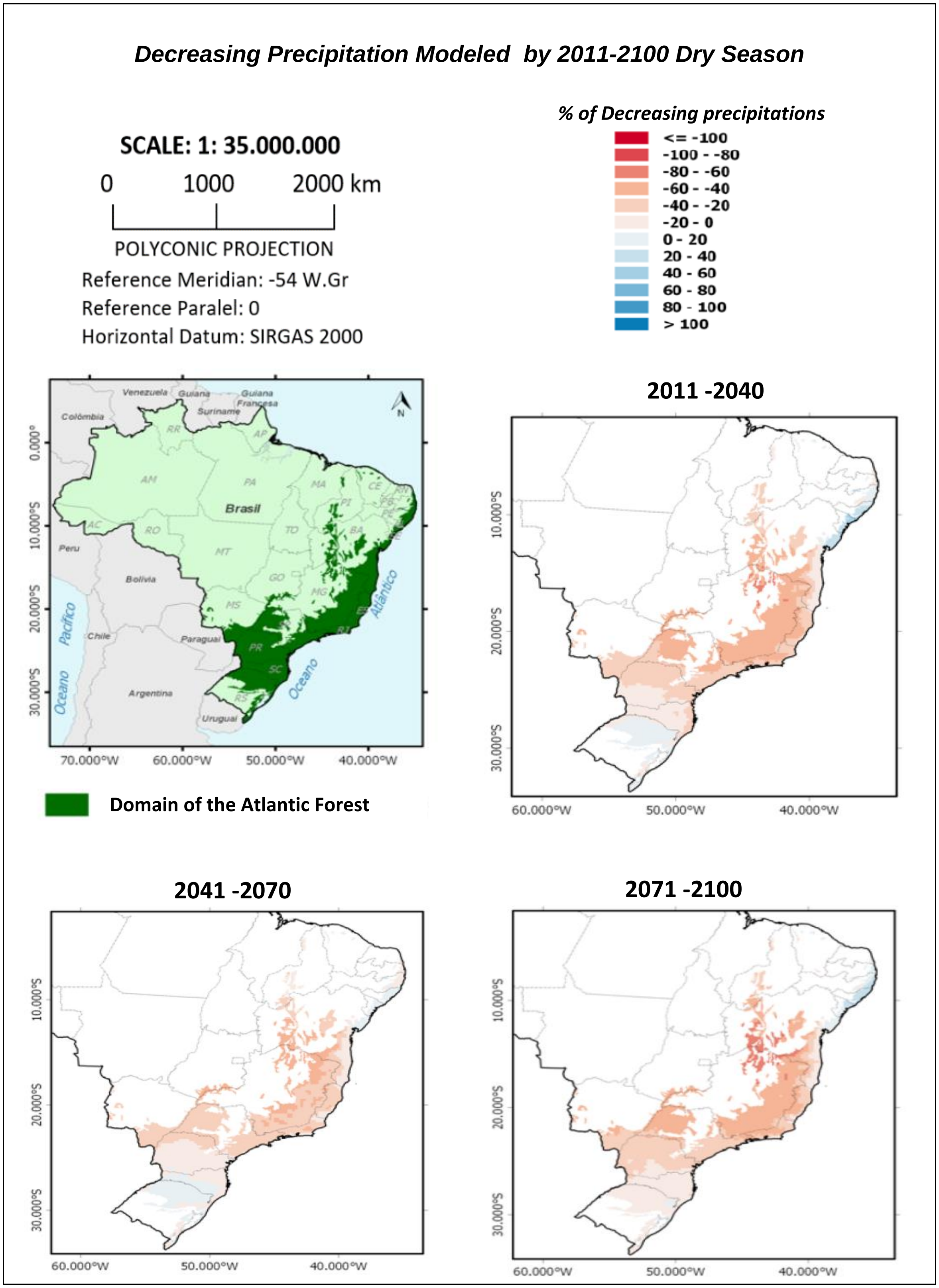


Figure 10 Tendency of Decreasing Precipitation 2011-2100 (JJA) Dry Season
Source Modified from (Ministério do Meio Ambiente, 2018)

In the study area, and in general in the state of Rio de Janeiro; the evidence of drought has been registered during the last 80 years. According to the Global Drought Monitor, the calculation of the Standardized Precipitation and Evaporation Index SPEI (12 months), shows that Rio de Janeiro always has been submitted to drought regimes at least during the last 20 years 1990 -2010, with extended severe events to 2017. Showing the high drought proneness of this area. Figure 11.

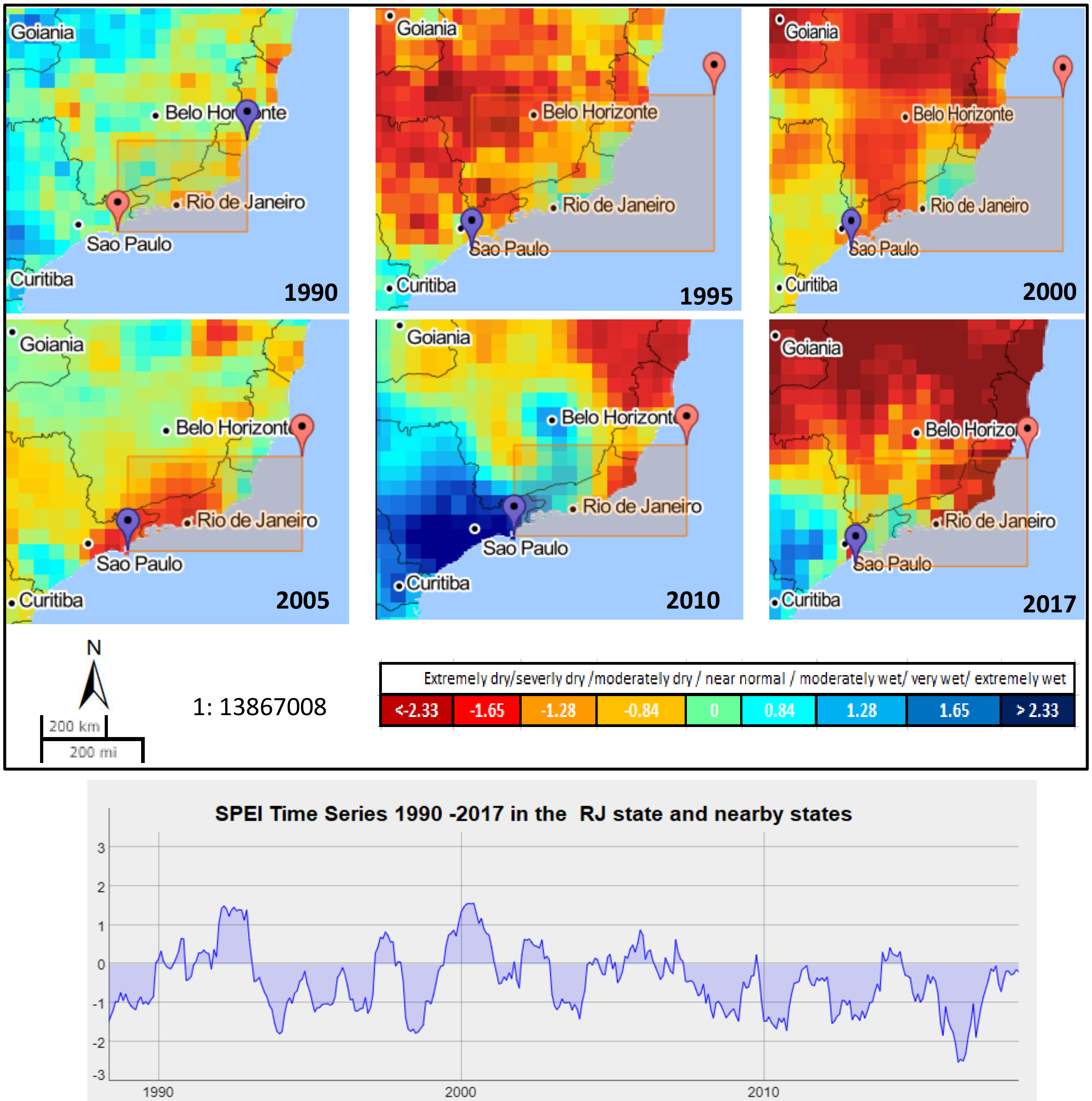


Figure 11 SPEI for Rio de Janeiro State
Source Modified from (Beguería et al., in Global Drought Monitor, 2018) in http://spei.csic.es/map/maps.html#months=1#month=5#year=2018

2.3 Effects of Drought in Plants

The effects of drought in plants range from molecular to morphological levels and are evident at all phenological stages of plant growth at whatever stage the water deficit takes place (Farooq et al.,2009). In nature, plants are exposed to gradually developing water shortage (days-weeks-months) or short-term water deficits (hours-days) Figure 12. In the case of gradually developing water shortage, plants can avoid dehydration by reducing their life cycle or optimizing their obtention of resources at long term through responses like acclimation. In the case of rapid dehydration, plants react by diminishing water loss through mechanisms of metabolic protection against the harmful effects of dehydration (Chaves et al., 2003).

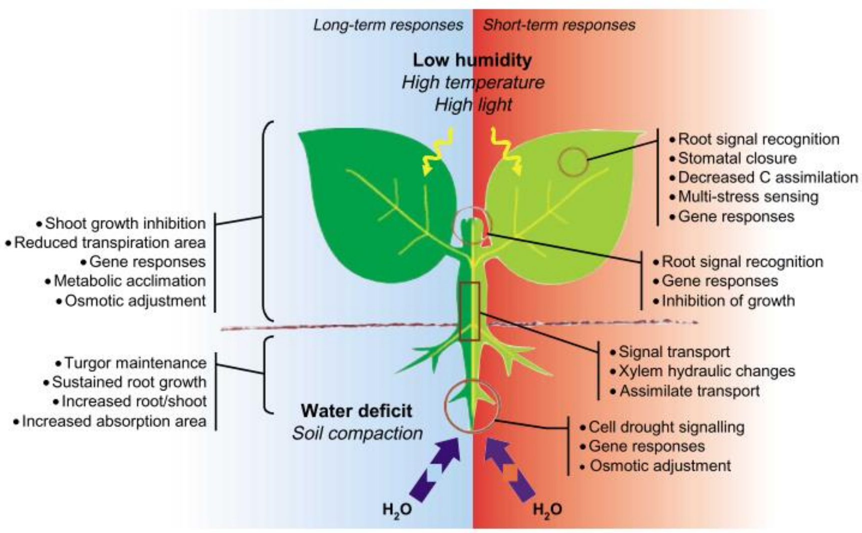


Figure 12 Whole-plant responses to drought stress. Left (blue): long-term or acclimation responses; right (red): short-term responses Source (Chaves et al., 2003)

Those effects produce in the plant usual responses, like resistance to adverse conditions, relying on adaptive strategies based on the timing of phenophases; and on the presence of characteristics associated to the increase of water uptake and storage, like prevent wilting through the mechanical reinforcement of tissues, but that may lead to damages at cellular level (Micco & Aronne, 2012). These mechanisms influence the plant performance to drought, that is the ability of species to survive low water availability in the field (Kursar et al., 2009).

The drought performance has been found to be an important factor of species distribution in relation to the duration of dry season, as species with low drought performance are excluded from drier forests (Engelbrecht et al., 2007).

To understand better the mechanisms that allow the plants to resist drought, these can be explained through escape, avoidance, and tolerance adaptations (Levitt 1972, and Turner 1986 in Diémé, 2016). These strategies are not mutually exclusive that means those adaptations or morpho-functional adaptive traits as can be called, can occur at the same time in the same organism, relating a range of response types; for that, a classification of these traits is not relevant: the same traits can be useful for each of them. Such traits are generally constitutive rather than stress-induced (Ludlow 1989 in Chaves et al., 2003 ; Micco & Aronne, 2012).

2.4 Types of Drought Adaptations in Plants

According to (Markesteijn, 2010) the relations between the drought adaptations can be represented in a scheme that shows them, considering that occur at the same time in an individual as was mentioned above. Figure 13. Species can be located along the axis of their “persistence” (horizontal axis) and “deciduousness” (vertical axis). The persistence axis sorts species along a gradient from dry to moist forests, and the deciduousness axis sorts species from evergreen to deciduous species.

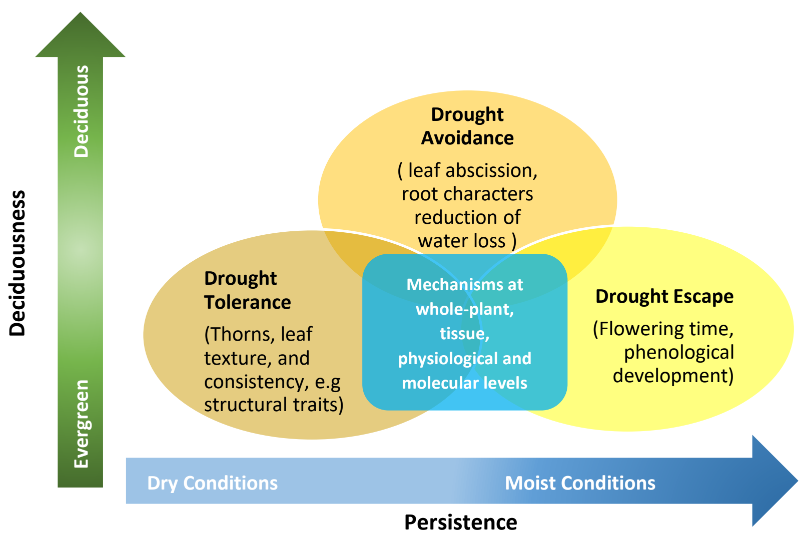


Figure 13 Types of Drought Adaptations present among dry and moist forest tree species
Source Modified from (Markesteijn, 2000)

It can be observed that the persistence is more associated to drought tolerance conditions than the moist ones; as the evergreen characters which pass to be a tolerance adaptation to an avoidance adaptation with the deciduous character of the species; and the escape adaptations are regulated mainly by the moist conditions in order to modulate their growth cycles. The definitions of each type of drought adaptations are explained as follows.

2.4.1 Drought Escape Adaptations

Escape is a strategy based on the ability to complete the life cycle before the period of water shortage. In this case, plants do not experience water deficit because they are able to modulate their vegetative and reproductive phenology according to the most favorable seasons (Aronne and Wilcock 1997 in Micco & Aronne, 2012). Drought escape occurs when phenological development matches with periods of soil moisture availability, where the growing season is shorter and terminal drought stress predominates (Araus, 2002). Among the characteristics related to drought escape, flowering time demonstrated that evolves rapidly (i.e. in a few generations) before the onset of severe hydric stress (Chaves et al., 2003); this is evidenced in plants like desert ephemerals *Arabidopsis thaliana* or spring ephemerals like *Claytonia virginica* that a have rapid phenological development, completing their life cycle during a period of adequate moisture and forming dormant seeds before the onset of dry seasons (Ahmad & Mohd, 2014).

Besides escape strategies, which consist mainly on successful reproduction before the start of severe water deficits; for instance, plants adapted to arid and semi-arid conditions invest energy for water conservation and photoprotection instead carbon gain, which is noticed at structural and physiological level (Chaves et al., 2003).

2.4.2 Drought Avoidance Adaptations

Drought avoidance consists of mechanisms that reduce water loss from plants, one of them is the stomatal control of transpiration, and maintain water uptake through an extensive and abundant root system (Turner et al., 2001 in Farooq et al., 2009). The root characteristics such as biomass, length, density, and depth; are the main drought avoidance traits that contribute to avoid water losses under drought conditions (Subbarao et al., 1995).

Additionally to these characters, another drought avoidance trait is the leaf shedding or deciduousness this adaptation allows the plant to withstand dryness through leaf abscission, is the best strategy to survive to drought, besides a thickened taproot is important as well (Markesteijn, 2010). In semiarid environments like the Sahelian savannah is a common adaptative strategy (Diémé, 2016); but also along gradients with more precipitation in the tropics, like tropical dry forests, savanna and caatinga vegetation. During annual seasonal drought, the deciduousness may also be an advantage during these event by providing an ability to maintain latency while reducing resources expenditure (Goldstein et al., 2016).

Deciduousness it has been also more regularly found in the adult stage than in the seedling stage, perhaps seedlings do not have sufficient carbohydrate reserves to replace every year a whole set of leaves (Markesteijn, 2010). The cost of this potential drought survival trait would be suspended carbon income, which could make deciduous species vulnerable to mortality by carbon shortage during dry seasons (Goldstein et al., 2016).

Another adaptation for drought avoiding species apparently is the ability to survive drought without having a high cavitation resistance, therefore they do not suffer the adverse consequences of this type of resistance, as the reduction of hydraulic efficiency and growth. Consequently, drought-avoiding species may have relatively high growth rates, which allows them to be comparatively good competitors for light as well. This is why deciduous species are relatively more abundant in dry and moist forests. Nevertheless, a negative effect of a drought-avoiding strategy is possibly that at some point the leafless, dormant period will limit competitiveness for resources with other species (Markesteijn, 2010).

Another mechanism that can be associated to drought avoidance is the ability of some species to avoid desiccation by folding leaflets; compound leaves are able to drop individual leaflets instead the whole leaf, thus fine-tuning leaf area under drought stress conditions (Poorter & Markestejin 2008 in Lohbeck et al., 2013).

2.4.3 Drought Tolerance Adaptations

Drought tolerance can be described as the ability to grow, flower and display economic yield under water shortage. Drought stress affects at cellular, tissue and organ levels the water relations of plants, causing damage and adaptation reactions as a response (Beck et al., 2007 in Farooq et al., 2009). To withstand the drought, plants have developed mechanisms of tolerance against water deficit (Chaves & Oliveira, 2004).

Some drought tolerance adaptations that can be found at a physiological level; like the metabolic pathways for the production of osmolytes such as mannitol, fructans, trehalose, among others, might increase resistance to drought. The process by which these metabolites provide protection is still under study (Valliyodan & Nguyen, 2006). Also, the leaf water potential at wilting or turgor loss point underlies drought tolerance and species distributions, in relation to water supply along the biomes (Maréchaux et al., 2015).

Another important adaptation is the conservative attribute of evergreen species in contrast to deciduous species to maintain constant conductivity during wet and dry seasons (Sobrado, 1997); it has been evidenced that the values or measurements of some characteristics like leaf dimensions and photosynthetic rates in broad-leaved evergreen trees are lower than broad-leaved deciduous trees in tropical regions; but the mean values of leaf span in months (mo), for species in the desert (14 mo), tropical evergreen forests (20 mo), temperate evergreen forests (44 mo), temperate deciduous forests (13 mo), and tundra (7 mo); are greater than the average value (6 mo) for deciduous species in Australia (Chaturvedi et al.,2011).

Other related characteristics with drought tolerance are structural traits, like leaf mass per area (LMA), leaf thickness, spines, leaf toughness and wood density (Maréchaux et al., 2015), root architecture (Lasley, 2013 ; Berger et al.,2010). Of those, leaf toughness is associated with sclerophylly, which reduces the leaf shrinkage and dehydration under drought (Scoffoni et al., 2014). Leaf trichomes production increases tolerance to drought in some ephemeral species like *Arabidopsis lyrata* (Huttunen et al., 2010); and glaucousness or waxy bloom on leaves helps with maintenance of high tissue water potential, for drought tolerance (Farooq et al., 2009).

On the other hand, it has to be taken in account that most of those traits are considered as “proxies” since there are no characteristics that confer a whole drought tolerance (Passioura, 1996); that means within a given community, for instance, drought-sensitive species may present many variations in the leaves characteristics, like size (high or low dimensions) or thickness (tough or thick leaves); possibly in response to other environmental drivers, such as shade and light, nutrients and water availability, type of soil, herbivory; among others. Besides this, it has to be considered the successional stage of the individual, and even the type of presented drought in the area (Maréchaux et al., 2015).

3. MORPHOLOGICAL AND FUNCTIONAL TRAITS: PERFORMANCE OF THE PLANTS

3.1 Definition of Traits

Accordiing to (Nock et al., 2016) "Functional traits are morphological, biochemical, physiological, structural, phenological or behavioural characteristics of organisms that influence performance or fitness" which can be measurable at the individual level, from the cell to the whole-organism level (Violle et al., 2007). are generally measured at the individual level in order to analyze the influence, and the performance of the species or the effect of the organism within the ecosystem; and therefore, allow understanding and explaining the interactions of the organisms with their environment (Díaz & Cabido, 2001).

The study of functional traits is a field of study by disciplines like the functional ecology, which focuses on the unique roles, or functions that each species, population, or community performs in its home ecosystem. In other words, this field is interested in identifying what process, activity, or role each species provides, and how these individual contributions help to the ecosystem function as a whole (Haak, 2003). This has led to the functional ecology to connect the response of the species to environmental variations and their impact on ecosystem processes (Kattge et al., 2011).

Those traits can be qualitative or quantitative, the qualitative or categorical data are associated with multi-state variables, for example the pollinating agent (birds, insects, bats, or wind) or the type of feeding in birds: frugivore, granivore, insectivore, etc; but quantitative or numerical data can be obtained from counting or measurements that are expressed in continuous units, for example the dimensions and measures of an individual as weight, length, width, and height; among others (Salgado Negret, 2015).

3.2 Functional traits in Plants

The use of characteristics to explain the performance, distribution or even the behavior of the species studies is not new, starting since the classification of plants species with Theophrastus (ca. 300 B.C.) which recorded in the Enquiry into Plants “Historia Plantarum” classifying plants into trees, shrubs, and herbs considering morphological aspects as the woodiness and height of the stems of certain plants (Weiher et al., 1999). With the time Raunkiaer in 1934 began with the classifications of the species according to their morphological or physiological characteristics, proposing a system of classification of life forms based on the position and degree of protection of the buds. Later Grime in 1977 suggested a classification of plant adaptations according to the environmental conditions related to stress and disturbances; to see how competitive or tolerant the plants could be (Salgado Negret, 2015).

In 1941 Jenny H. in the book “Factors of soil formation” explained how the species response to the environment independent of its phenology (Suding & Goldstein 2008); later in 2000, it was proposed that the species composition may change due to environmental factors, reflected in changes in the ecosystemic processes, through changes in functional traits in the species (Chapin et al., 1998).

Other studies have been conducted to research the relations of the plant economy production of leaves, stems, roots and their environment (Reich et al., 1999; Wright et al., 2004; Chave et al., 2009; Baraloto et al., 2010, in Salgado Negret, 2015), or for example understanding how changes in biodiversity can have significant impacts on ecosystem and landscape processes through the study of some specific traits (Chapin et al., 1998). Those studies have shown that some plant traits can indicate a response to the environment and their influence on the ecosystems, according to the type of traits.

In plants, these functional traits are some key traits which have been found due to their importance for the performance of the plants, because they are related to ecological adaptations. Figure 14 (Westoby, et al., 2002), among those traits, are:

- Traits of the leaves such as the specific leaf area -SLA- and foliar longevity -FL-, which informs about the rates of profit and growth of the individual.

- Characteristics of wood, important for its relationship with water and nutrient transport and support of individuals, their resistance to drought and damage by natural enemies.
- Root traits, related to the transport and storage of substances and the mechanical support of individuals.
- Regenerative traits, which can be vegetative like cloning, and reproductive traits sexual-like mass and seed production.
- Other morphological traits of the plants as a form of growth and maximum height that determines the position of individuals in the vertical stratum in its community and therefore, their access to light and its potential growth rate.

Those traits can be classified or categorized through different methodologies that may be adapted depending on the type of plants; for example, it is different to measure traits in herbaceous species than woody, and in some groups as ferns and palms there is no a general consensus to analyze some traits of them (Missouri Botanical Garden et al., 2012). Other elements like the conservation status of the place or habitat where the vegetation is located, the temperature, the time of the year; among other environmental variables, can be considered in order to measure the respective traits to complement and support studies on vegetation responses and vegetation effects on environmental changes; e.g. changes in climate, atmospheric chemistry, land use or other disturbances (Cornelissen et al., 2003).

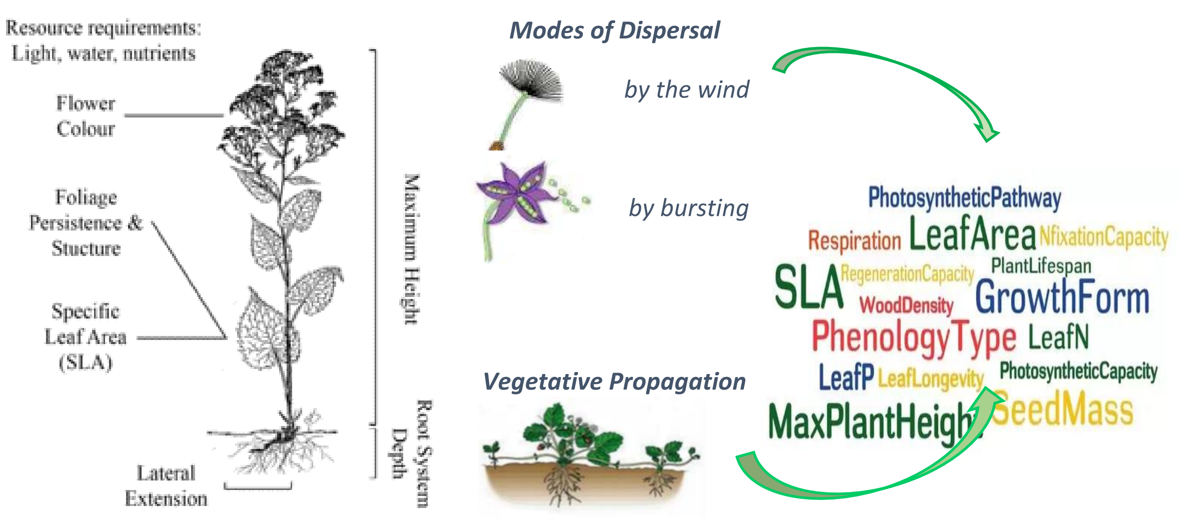


Figure 14 Examples of functional Traits in Plants Source modified from (Kohtari Shan, 2015) in https://www.quora.com/What-are-functional-trait-based-approaches-to-plant-ecology-and-why-are-they-important

3.3 Types of Plant Functional Traits

The functional traits can be classified or organized considering the enhancement of studies on plant functional types and traits, adopting an approach towards a better explanation of how and which plant traits are appropriate to understand processes; like the responses and effects of vegetation at various scales; from ecosystems to landscapes, to biomes and continents; helping to answer questions of ecological theory and ecosystem dynamics relating environmental factors including global changes (Cornelissen et al., 2003 ; Pérez-Harguindeguy et al., 2013).

Considering the aim of the research, the plant life history and their morphological, physiological and biochemical traits, the functional traits can be classified considering their "ease" (soft traits) or "hard" (hard traits) to be measured or analyzed (Cornelissen et al., 2003 in Castellanos-Castro & Newton, 2015); also can be classified through some ecological interactions like (dispersal, competitive abilities, response to disturbance, among others) which guide how and what type of traits can be considered to assess these interactions (Noble & Slatyer 1980 in Weiher et al., 1999).

The relation between ease traits and hard traits allows to study the ecosystem functioning processes and the effects or responses to environmental changes (Lavorel & Garnier, 2002 ; Gross 2007 in Chelli, 2013). Correlations between structural and ecophysiological traits, ecosystem functioning (including primary productivity), decomposition and nutrient cycling, and water availability; can make possible to predict changes in ecosystem services from changes in their functional composition (Chaturvedi, 2010).

For that the soft and hard traits are compiled according to their importance to study the environmental challenges regarding climate response, responses to CO_2, soil resources, disturbances, competitive strength, plant defense/protection, effects on biogeochemical cycles, and effects on disturbance regime. Due to the relation between them, e.g, the effects on disturbance regime may result in effects on climate or CO_2 concentration; for instance, fire promotion traits may be linked with large-scale fire regimes, which in turn may affect regional climates (Cornelissen et al., 2003).

The number of functional traits can be wide, considering the aiming of the research; since 2007 a global initiative lead by vegetation scientists as Jens Kattge, Sandra Diaz, Sandra Lavorel, and Gerhard Boenisch, has allowed gathering many traits in a worldwide database in the "The TRY Plant Trait Database" available in https://www.try-db.org/TryWeb/Home.php, there are 7 million trait records for 1,800 traits of 2.6 million individual plants, representing 140,000 plant taxa (mostly species). Their main objectives are to provide a comprehensive web-archive of the functional biodiversity of plants at the global scale aiming at understanding the emergence of plant biodiversity and its consequences for ecosystem function; and analyze the dynamics and predicting the fate of global ecosystems in the face of global change and biodiversity loss with the application of dynamic global ecosystemic models. So these traits join those already raised in protocols such as Cornelissen 2003 and Pérez- Hargindeguy 2013, which provides a range of traits to analyze.

3.3.1 Soft traits

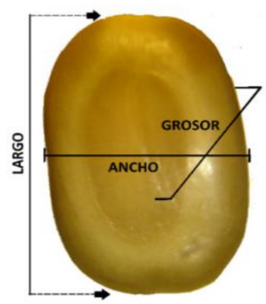
Soft traits are morphological characteristics that are easy and quick to quantify (Weiher et al., 1999) and their measurement is less labor intensive (Nock et al., 2016); through some soft traits it can be studied the plant local persistence on community structure, and response to environmental changes; for example the study of leaf dry matter content and lateral spread can predict response to land use changes (Gross et al., 2007 in Chelli, 2013). Usually the measure of soft traits is expressed in units like (m, m^3, mm, mm^2, cm, cm^2, g, g/cm^3, mg/g, etc.); as was mentioned above the classification of these traits was elaborated considering certain parameters and characteristics, established in the "handbooks for standardized measurement of plant functional traits worldwide" which are currently the guide protocols to assess and measure these traits.

Here are presented the most common measured soft traits based on this handbook, including others from other studies. Table 3- Figure 15; this indicates that several characteristics have been annexed since not all can be measured. However, it is generally recommended to follow the recommendations of the protocol in the handbook, to measure the most representative traits considering the addresed research.

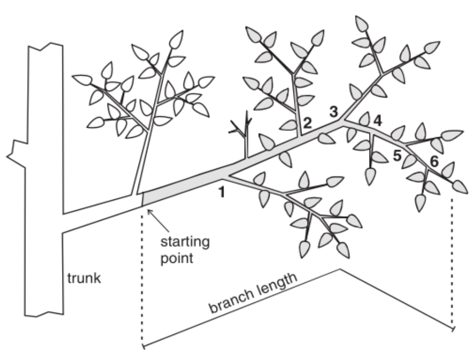
Table 3 Soft Plant Traits Source compiled from: (Cornelissen et al., 2003 ; Ruíz Molina, 2015 ; Pérez-Harguindeguy et al., 2013 ; Danielsen & White, 2003 ; Lavorel & Garnier, 2002 ; JBRJ, 2017 ; Markesteijn, 2010)

Soft Traits	
• Bark thickness	• Physical strength of leaves
• Branching architecture	• Plant height
• Clonality	• Presence and type of lenticels
• Dew Retention angle	• Seed mass
• Diameter of fine root	• Seedling morphology
• Dispersule shape and size	• Specific leaf area
• Distribution of rooting depth	• Specific root length
• Flammability	• Spinescence
• Leaf Area	• Stem density
• Leaf consistency	• Stem specific density
• Leaf dry matter content	• Trichomes
• Leaf Slenderness	• Twig dry matter content
• Leaf thickness	• Twig drying time
• Leaf Water content LWC	• Wood density

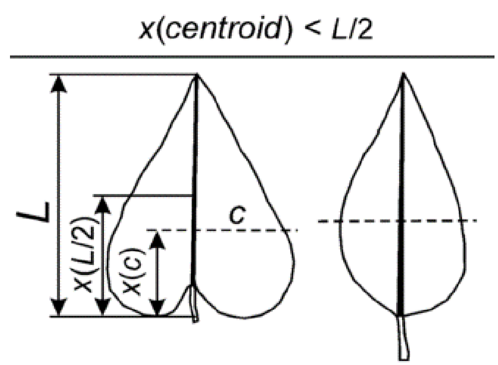
Trichomes



Seed Mass



Branch Architecture



Measurement of patterns (Leaf Area)

Figure 15 Examples of Soft Functional Traits
Source. (Cornelissen et al., 2003; Ruíz Molina, 2015 ; Romero & Pérez, 2016 ; Niinemets et al., 2007)

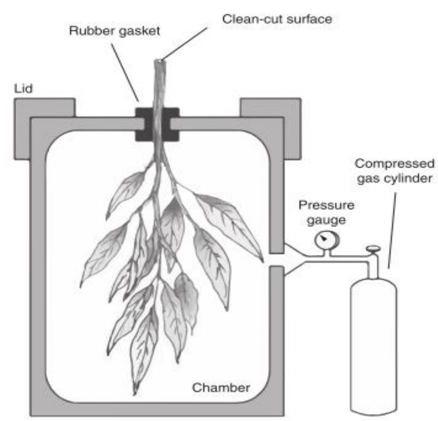
3.3.2 Hard traits

Hard traits or "physiological and demographic traits" are more time-intensive to measure and consequently difficult to quantify for large numbers of species in many regions of the world (Lavorel & Garnier, 2002; Weiher et al., 1999). Many of these require procedures that are too laborious for large-scale screening purposes. Table 4- Figure 16; nevertheless at the same time are more accurate indicators of plant and species functions responsible for community responses or ecosystem effects (Cornelissen et al., 2003 ; Nock et al., 2016).

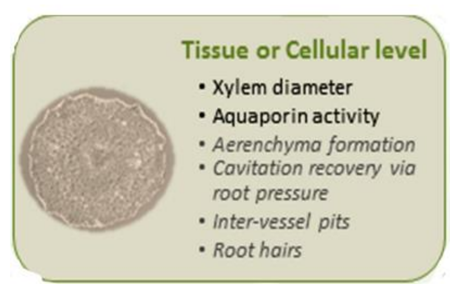
It is recognized that it is extremely unlikely measure hard traits for an entire regional flora; therefore, it is more feasible to use soft traits that are easy and quick to quantify (Weiher et al., 1999).

Table 4 Hard Plant Traits Source compiled from (Cornelissen et al., 2003; Pérez-Harguindeguy et al., 2013; Herz et al., 2017; Lavorel & Garnier, 2002; JBRJ, 2017 ; Markesteijn, 2010; Chaturvedi, 2010; Lopez-iglesias et al.,2014; Apgaua et al., 2015)

Hard Traits
• Concentration of nutrients (C, N, Mg, P, K) in the plant: Root, Stem, Leaves µmol/g, %, mg/g, g/g
• Leaf area per unit total dry mass (cm^2/g)
• Leaf dry mass per leaf fresh mass (mg/g)
• Root dry mass per root fresh mass (mg/g)
• Root mass per unit root volume (g/cm^3)
• Dry mass of roots per unit dry mass of above-ground organ (g/g)
• Leaf Life Span (weeks-months)
• Leaf phenology (weeks-months)
• Photosynthetic pathways
• Chlorophyll concentration($mg\ g^{-1}$)
• Leaf stomatal conductance($mmol\ m^{-2}\ s^{-1}$)
• Leaf Transpiration rate, ($mmol\ m^{-2}\ s^{-1}$)
• Leaf construction cost, LCH ($g\ glu.g^{-1}$)
• Bark Carbon mass (%)
• Xylem conductivity ($k\ gm^{-1}\ s^{-1}\ MPa^{-1}$)
• Min Leaf water potential (MPa)
• Max Leaf water potential (MPa)
• Salt tolerance



Measure of Water potential



Water difussion through the root

Figure 16 Examples of Hard Plant Traits Source (Comas et al., 2013 ; Cornelissen et al., 2003)

3.4 Study of Functional Traits in the Mata Atlântica

The study of functional traits in the Mata Atlântica currently takes place around environmental factors is being considered currently, mainly through actions of mitigation and adaptation to climate change. Next are described the main studies carried out in this biome.

Example of that is the study of functional traits focused on suggesting species that can be used in ecological restoration; such as tree plantations and agroforestry systems. These study considered attributes like the potential for biological fixation of atmospheric nitrogen, the attractiveness of wildlife, and supply of timber and non-timber forest products; of native species of the families, Anacardiaceae, Leguminosae (Fabaceae), Euphorbiaceae, and Salicaceae, etc (Canosa & Moraes, 2016). Other attributes that have been considered in processes of ecological restoration are the size of the seed, shade tolerance, lifespan, wood traits; among others, besides the diversity of species as ecological criteria (Preiskorn & Couto, 2009).

Other traits like (stem density, nitrogen fixation capacity, vegetative phenology, leaf compoundness, seed mass, specific leaf area, and leaf nitrogen / phosphorus concentration); have been used to predict the survival of promising trees species for the restoration and production, in seasonal tropical forests in Southern Brazil (Dias & Siddique, 2014)

Likewise, in some regions like the reserve of Poço das Antas in Rio de Janeiro State, were measured the differences in structure and composition of functional groups, through the study of functional traits related to leaves, wood, bark, fruits, and seeds; among areas with distinct fire frequency and land use history; showing that plant communities in the Brazilian Atlantic Forest subjected to fire are undergoing a ”savannization” process (Sansevero, 2013). In areas of the Cerrado and Seasonal Semideciduous Forest in southeastern Brazil, it has been also studied the influence of environmental factors and functional attributes on the occurrence of species, comparing the size of leaves and leaf nutrients concentration (Gorne, 2010).

In other biomes like the Mixed Ombrophilous Forest, in the State of Santa Catarina in Southern Brazil; currently is being studied which functional traits represent competitive advantages or disadvantages facing different climate change scenarios; and it has been found that found that species like *Vernonanthura discolor, Araucaria angustifolia*, and

Sapium glandulosum have reduced their area of potential occurrence in 58% on average; showing their high sensitivity to climate changes (Machado et al.,2016 ; Duarte et al., 2017).

In hábitats like the Restinga of the Jurubatiba National Park in Rio de Janeiro State, the variation of morphological leaf traits in ten species showed a trend towards higher leaf-trait values in dry months during three years suggesting that plant responses to temporal heterogeneity in water availability, independent of leaf phenological patterns and phylogeny, considering the water availability as a limiting factor for the success of sandy-coastal-plain occupation for the plants (Rosado & Mattos, 2007).

For Cloud Forest, was shown, that places with higher fertility soils favored species with acquisitive strategies (i.e lower wood density and greater leaf area), and had a higher functional diversity; lower fertility soils sites favored conservative strategies (i.e higher wood density and smaller leaf area). The representative species of this biome; *Myrceugenia oxysepala, Ilex paraguariensis,* and *Ilex microdonta,* present different ecological adaptations in function of edaphic variations (Soboleski et al., 2017).

On the other hand, in the “Mata de Tabuleiros” forests; the main studies are correlated to aspects of phytosociology, functional diversity, floristic composition, and ecological restoration; which includes functional traits like arboreal biomass with the aim to predict potential impacts of climate changes on carbon storage; and others that relate the sclerophylly and deciduousness respect to the Nitrogen content in leaf biomass (Silva & Nascimento, 2001; Garay et al., 2003).

Recently, the main studies in the Mata de Tabuleiros and other type of vegetation, that considered into their criteria some functional traits to be carried out, were: The temporal variation of Atlantic forest arboreal biomass at Biological Reserve União: Effect of Fragmentation Climate in 2017 with the aim to predict potential impacts of climate changes on carbon storage in this area; the impact of anthropic action on establishment of seedlings of 20 native tree species in riparian forest areas of water reservoir of Salminho, and the recovery of degraded areas of riparian forest in the same area, during the years 2000 and 2012.

Nevertheless, in relation to climate conditions, there is still missing information of how morphological-functional soft traits, considered as drought-tolerance traits of species adapted to dry conditions, sometimes not usually taking in count for these studies; can be used to analyse species distribution at large scale in the Mata Atlântica biome, and at small scale in the Mata de Tabuleiros.

It is recognized that is extremely unlikely measure hard traits for an entire regional flora; therefore, it is more feasible to use soft and morphological traits that are easy and quick to quantify (Weiher et al., 1999). Therefore, it is interesting to find out which soft traits, can give a hint of drought tolerant adaptations in those scales, at large scale, this can be explored with the JABOT database, and at a small scale this can be tested in the field in fragments of Mata de Tabuleiros, because the gathered information is expected to be an input to consider for future studies with the aim to compare different types of traits not only in this biome, but others as well to understand better how climate conditions can influence the performance of the species through the analysis of plant traits.

4. GENERAL OBJECTIVE

General Objective

- To find out the potential of using morphological functional traits of woody species as indicators of dry conditions in the transition zone of the Atlantic Forest. RJ Brazil.

5. RESEARCH QUESTIONS

1. Which functional traits of woody species can be used as indicators for drought-tolerance?
2. Are there species (or taxa) which exhibit several traits for drought adaptations, which can be used as indicator species for drier conditions?
3. Are there indicators which can be applied without considering taxonomic classification in the field?
4. Is there a trend
    - in the distribution modeling of best equipped indicator species occurrences in the Mata do Tabuleiros?
    - in species distribution modeling of best equipped indicator species, in the Mata Atlântica?
5. How is being impacted the vegetation of the Mata Atlântica due to drought conditions?

6. METHODS AND PROCEDURES

In order to develop a structured line to answer the research questions, next are described the performed methods considering their numerical order, intended to solve each one of them.

6.1 Method N°1. General definition of traits used in analysis

6.1.1 Collection of studies which have worked on soft traits in response to dry climate conditions

To develop this method, In first place there was searched in protocols for plant field traits like the "New Handbook for standardized measurement of plant functional traits worldwide", in their editions of 2003 (Cornelissen et al., 2003), and 2013 (Pérez-Hargindeguy et al., 2013) respectively; which compiles an international methodological protocol scoped to explain for instance, how those traits can be assessed, how can be measured, and how many traits can be analyzed considering the aim of the study, in the **¡Error! No se encuentra el origen de la referencia.** are highlighted some general traits related to climate responses that can be considered as drought indicator traits.

	Climate response	CO_2 response	Response to soil resources	Response to disturbance	Competitive strength	Plant defence/ protection	Effects on biogeochemical cycles	Effects on disturbance regime
Whole-plant traits								
Growth form	*	*	*	*	*	*	*	*
Life form	*	*	*	*	*		*	*
Plant height	*	*	*	*	*	*	*	*
Clonality	*	?	*	*	*			?
Spinescence	*	?			*	*		?
Flammability		?			*	?	*	*
Leaf traits								
Specific leaf area	*	*	*		*	*	*	
Leaf size	*	?	*		*	*	*	
Leaf dry matter content	*	?	*			*	*	*
Leaf N and P concentration	*	*	*	*	*	*	*	
Physical strength of leaves	*	?	*	*		*	*	
Leaf lifespan	*	*	*	*	*	*	*	*
Leaf phenology	*		*		*		*	*
Photosynthetic pathway	*	*			*			
Leaf frost resistance	*				*	*		
Stem and belowground traits								
Stem specific density	*	?	?	*		*	*	*
Twig dry matter content	*	?	?	?		*	*	*
Twig drying time	*	?	?				?	*
Bark thickness			*	*		*		?
Specific root length	*	?	*		*	*		?
Diameter of fine root	*	?	*					
Distribution of rooting depth	*	*	*	*	*		*	*
95% rooting depth	*	?	*		*			*
Nutrient uptake strategy	*	*	*	*	*		*	

Figure 17 Plant Functional Traits Associated with Responses to Environmental Changes
Source "New Handbook for standardized measurement of plant functional traits worldwide" (Cornelissen et al., 2003)

Beside this there were also search in researches which have studied soft traits in response to dry climate conditions, those were the studies of (Herz et al., 2017; Cornelissen et al., 2003; Díaz et al., 2004; Lavorel & Garnier, 2002; Lebrija-Trejos et al., 2010; Wagner et al., 2014; Castellanos-castro & Newton, 2015). as a result, there were compiled the traits related to drought and dry conditions.

6.2 Method 2. Search for botanical groups as indicators of dry conditions that exhibit traits for drought adaptations

6.2.1 Search in the Rio de Janeiro Botanical Garden- JABOT database

In order to look for the traits that may give a hint as drought tolerance indicators, there was reviewed the Rio de Janeiro Botanical Garden- JABOT database, that counts with records of 138 families, 600 genera, and 2130 species, with 5961 recorded exsiccates The described entries in the database have information related to the collection site or biome, in this case the Mata Atlântica, year, habitat description, taxonomic information, and morphological characteristics; among other parameters. Next in Figure 18, it is shown an example of the database with some criteria as coordinates biome, taxa, etc.

genero		cidade	longitude	coletor	bioma_ibge
CLUSIACEAE	Tovomitopsis paniculata (Spreng.) Plan	Rio de Janeiro	-22.5000000	-42.250000	Sub-arbusto com 2 m de altura. Folhas concolores. Frutos imaturos de cor verde, deiscen
CLUSIACEAE	Tovomitopsis paniculata (Spreng.) Plan	Rio de Janeiro	-22.5000000	-42.250000	Arbusto,ca. 2m de altura; folhas discolores com nervura prim ria alvacenta; frutos imatur
CLUSIACEAE	Tovomitopsis paniculata (Spreng.) Plan	Rio de Janeiro	-22.5000000	-42.250000	Sub-arbusto com 2 m de altura. Frutos com epicarpo verde, endocarpo vermelho, sement
CLUSIACEAE	Tovomitopsis paniculata (Spreng.) Plan	Rio de Janeiro	-22.4333333	-42.833333	Arbusto, folhas discolor, ramos e pedunculos verdes, botoes verdes, flores verde-amarel
CLUSIACEAE	CLUSIACEAE	Espírito Santo	-21.2344444	-40.963056	lâmina cartácea esverdeada.
CLUSIACEAE	CLUSIACEAE	Rio de Janeiro	-22.5000000	-42.250000	Arbusto com cerca de 2m de altura, com folhas membranaceas e discolores. Latex transp
COMBRETACEAE	Combretum laxum Jacq.	Minas Gerais	-19.2744445	-43.745000	Arbusto escandente, heliofilo ca. 4m alt. ramos da base estriada. Inflorescência amarel
COMBRETACEAE	Combretum laxum Jacq.	Minas Gerais	-19.2744445	-43.644444	Arbusto escanente sob arvoreta de ca. De4 m de alt. Heliófilo. Ramo da base estriada; f
COMBRETACEAE	Conocarpus erectus L.	Rio de Janeiro	-22.9263889	-42.349444	Arbusto de 1,80m. de altura; heliófilo; folhas cartáceas discolores, flores esverdeadas e
COMBRETACEAE	Conocarpus erectus L.	Rio de Janeiro	-22.9263889	-42.349444	Arbusto com cerca de 2,5m de altura, heliófilo, folhas cartáceas discolores verdes, inflor
COMBRETACEAE	Laguncularia racemosa (L.) C.F.Gaertn.	Rio de Janeiro	-22.9263889	-42.349444	Arbusto de 1,70m. de altura; heliófilo; pneumatóforo, folhas cartáceas discolores verdes
COMBRETACEAE	Terminalia glabrescens Mart.	Rio de Janeiro	-22.6058333	-42.017500	Arbusto de 3,5 m e DAP 2,5 cm.
COMBRETACEAE	COMBRETACEAE	Rio de Janeiro	-21.4091667	-41.675833	lâmina papirácea esverdeada.
COMMELINACEAE	Dichorisandra hexandra (Aubl.) C.B.Clar	Minas Gerais	-20.1391666	-44.236944	Arbusto com flores arroxeadas
COMMELINACEAE	Dichorisandra pubescens Mart. ex Schu	Rio de Janeiro	-22.4333333	-42.833333	Sub-arbusto, ciófila; folhas discolores; caule na base vinoso; inflorescência verde com fl
CONNARACEAE	Connarus nodosus Baker	Rio de Janeiro	-22.2925000	-41.711667	Área antropisada. Arbustos, heliófilo, rfamificado, ca.2 m alt; repleto de frutos, de verde

Figure 18 Example of the JABOT database Source Modified from JABOT-Botanical Garden of Rio de Janeiro 2017.

There was searched for the species that presented more than two or three characteristics that can be considered as drought tolerance traits; as rigid and cartaceous leaves, spinescence, succulence, trichomes; among others.

6.2.2 Search for botanical groups and traits indicators in the field

Regarding the protocol of (Cornelissen et al., 2003) and the JABOT database, was elaborated a preselection of traits in order to know which of them could indicate adaptations to drought conditions, Table 5; with the purpose to be consulted with experts on the subject, in this case, the researchers, Prof. Dr. Marcelo Nascimento from the State University of Northern Region Fluminense "Darcy Ribeiro" UENF, Dr. Rafaela Campostrini from Herbarium of Rio de Janeiro Botanical Garden JABOT, Prof. Dr. Fatima Pina Rodrigues Federal University of São Carlos UFSCAR-Campus Sorocaba, and Prof. Dr. Dietmar Sattler from University of Leipzig; which have carried out many studies related to taxonomy, diversity, and ecology in the Cerrado and Mata Atlântica biomes. The experts were interviewed to know which of those traits could be analyzed in the field, and also to know also the current state of the studies of functional traits in those biomes (see part of interviews in the Annex Section).

Table 5 Preselected Traits to Assess in the Field.. Source compiled from (Cornelissen et al., 2003) and JABOT Database 2017.

LEAF TRAITS RELEVANT FOR DROUGHT ADAPTATION									
Thickness (mm)	No changes (average-normal measure) (**0**) value in _____mm	Decrease (**1**) value in______mm	Increase (**2**) value in_____mm						
Physical strength of leaves	No changes (average-normal resistance) (**0**)	Weakening yes (**Y**) no (**N**)							
Leaf Area LA (cm^2)	No changes (average-normal measure) (**0**) value in ____ cm^2	Decrease (**1**) value in ____ cm^2	Increase (**2**) value in ____ cm^2						
Specific Leaf Area SLA (cm^2/g)	No changes (average-normal measure)____ cm^2/g	Decrease (**1**) value in ___ cm^2/g	Increase (**2**) value in ___ cm^2/g						
Petiole lenght (mm)	No changes (average-normal measure) (**0**) value in ____ mm	Decrease (**1**) value in ___ mm Increase (**2**) value in ___mm							
Leaf form	**Simple**						**Composed**		
	Oblong: **Obl**	Acicular **Ac**	Elliptic **El**	Rhomboid **Ro**	Linear **Li**	Another form:	Imparipinnate **Ip**	Paripinnate **pp**	Bipinnate **Bp**
	Ovate: **Ov**	Obovate **Ob**	Cordate **Co**	Elongate **El**	Spear **Sp**		Bifoliate **Bf**	Trifoliate **Tf**	Polyfoliate **Pf**
	Lobed: **Lo**	Falcate **Fa**	Lanceolate **La**	Acuminate **Ac**	Subulate **Su**		Digitate **Dg**		Palmate **Pm**
Reduced leaves	No evidence of leaf reduction: **0** Reduced or no leaves **1**	Thorniness: no thorns: **0**; thorny **1**	**Leaf phenology type** Deciduousness: **D**	Evergreen: **E**					
Leaf surface	Trichomes: Yes (**Y**) no (**N**) N° of trichomes per cm^2 _____	Rough: Yes(**Y**) no (**N**)	Glabrous: Yes(**Y**) no (**N**)	Wax coating: Yes(**Y**) no (**N**)					
Leaf consistency	succulence: Yes(**Y**) no (**N**)	Coriaceous: Yes(**Y**) no (**N**)	Rigid: Yes(**Y**) no (**N**)	Membranaceous: Yes(**Y**) no (**N**)					

STEM TRAITS RELEVANT FOR DROUGHT ADAPTATION	
Bark thickness (mm)	Smooth: **1** Fibrous: **2** Corky: **3**
Spinescence	(**1**) No spines
	(**2**) Low or very local density of soft spines <5mm long; plant may sting or prickle when hit carelessly, but not impart strong pain.
	(**3**) High density of soft spines, intermediate density of spines of intermediate hardness, or low density of hard, sharp spines >5mm long; plant causes actual pain when hit carelessly.
	(**4**) Intermediate or high density of hard, sharp spines >5mm long; plant causes strong pain when hit carelessly.
	(**5**) Intermediate or high density of hard, sharp spines >20mm long; plant may cause significant wounds when hit carelessly
	(**6**) Intermediate or high density of hard, sharp spines >100mm long; plant is dangerous to careless large mammals, including humans.

After the expert's review, there was elaborated a second table but this time suggesting soft drought tolerance traits at general level that could be analyzed in the field, Figure 19; following the comments of the experts and the protocols already mentioned, besides adding another traits from authors like (Apgaua et al., 2015; Danielsen & White 2003). Nevertheless, the experts suggested to include other traits that can be measured in the field; but those traits require another equipment and more time to assess them, which would be useful for more exhaustive researches. As an example, it is shown also in Figure 19, the comments made by Dr. Rodrigues about other traits that could be included for further studies.

Place:			Total Height:	Date: DD MM YY	Coordinates: Lat:	Elevation (M.A.S.L)									
Species:	Ind N°:	DBH(cm):		Hour of the day:	Long:										
Leaf dimensions exposed leaves to sunlight	Height where exposed leaves to sunlight are collected: 7 m														
	Leaf 1	Leaf 2	Leaf 3	Leaf 4	Leaf 5	Leaf 6	Leaf 7	Leaf 8	Leaf 9	Leaf 10	Leaf 11	Leaf 12	Leaf 13	Leaf 14	Leaf 15
Leaf Área (mm)															
Leaf blade length (mm)															
Leaf width (mm)															
Thickness (mm)															
Leaf Surface	Rough: Yes __ no __	Glabrous: Yes __ No__	Wax coating: Yes__ no __	Spines Yes _ no__											
	Natural occurrence of trichomes: Yes _ no __	If yes: Presence of trichomes: Beam __back__ both __none__ *none refers to loss or undeveloped trichomes due to conditions like (disease ,age, adverse climate conditions, others)													
	Presence of glands: Yes___ No __														
Leaf consistency	Coriaceous: __ Rigid: ___ Membranaceous: _ Succulence: ___ Other ____________														
Exudation	Latex ___resins___ oily substances__ none__ organ of exudation: leaf __ Stem__ other__														
Bark/Branch stem surface	Lenticels: Fine ___ coarse __ Evidenced in: Bark__ Branch stem __	Trichomes: Evidenced in: Bark__ Branch stem ___ none__													
	(1) No thorns, spines or prickles __														
	(2) Low or very local density of soft thorns, spines or prickles <5mm long; ___														
	(3) High density of soft thorns, spines or prickles, intermediate density of spines of intermediate hardness, or low density of hard, sharp spines >5mm long ___														
	(4) Intermediate or high density of hard, sharp thorns, spines or prickles >5mm long ___														
	(5) Intermediate or high density of hard, sharp thorns, spines or prickles >20mm long ___														
	(6) Intermediate or high density of hard, sharp thorns, spines or prickles >100mm long ___														
	Rind aspect: Smooth: ___ Fibrous: __ Corky: ___ other_________														
	Exudation: Latex ___resins___ oily substances__ none ___ organ of exudation: leaf __ Stem__ other__														
Observations of the sampled individual:															
Evidence of recent rains Yes __ No_ Describe:															
Evidence of fires Yes__ No __ Describe:															
Evidence of grazing Yes__ No __ Describe:															
Evidence of logging Yes__No __ Describe:															
Other observations:															

Editor_FPR
You can put also height of the tree crown, and shape and diameter of the tree crown

Editor_FPR
Is recommended hydric potential because reflects the stomatal conductancy that can be controlled in dry environments, there are field equipments easy to use to measure this trait

Editor_FPR
Information about bifurcation is missing. the number and height of bifurcations respect to the soil, gives information respect to drought.

Editor_FPR
Amount of leaf litter under the canopy in relation to the area outside the canopy (average of the parcels). Indicating grade of deciduousness (consider the time of the year)

Figure 19 Proposed Soft Traits to Analyze in the Field Source compiled from (Cornelissen et al., 2003 ; JABOT Database; Apgaua et al., 2015; Danielsen & White) and comments of the consulted experts.

After the preselection of this set of proposed traits, there was located a place along a gradient in the Mata Atlântica, in order to test the indicator set.(see section 7.4.2 Findings for botanical groups and traits indicators in the field (Indicators set)) Eventually was found an area of forest fragments in Semideciduous Seasonal Lowland Forest “Mata de Tabuleiros” in the municipality of São Francisco de Itabapoana in the north of Rio the Janeiro State, where there were found three remnants (see section 1.3 Description of the Study Area in the “Mata de Tabuleiros”), considering the study of (Abreu, 2013).

6.2.3 Elaboration of the table for the selected set of traits in the field

Therefore, relying on the study of (Abreu, 2013); in those fragments, there were selected the species and the traits, to analyze them, and considering their morphological and functional traits It was elaborated the table selecting the soft traits that can be related with drought-tolerance adaptations. In the chapter of results are presented the tables with the compiled information for each species. Next are presented the selected species for the study area.

Selection of species in the Mata de Tabuleiros

The selected species were considered regarding the work of (Abreu, 2013). In this work, 194 woody species, are reported for the forest fragments. For my work, I selected the species with higher number of occurences corresponding to 12 species with an n>_40 individuals Table 6.

Species	Family	Common name	Number of individuals per species n>_40	Successional category
Schott. *Astronium concinnum*	Anacardiaceae	Gurubu / Guaribu-rajado	51	Initial secondary
(Vell.) Croizat. *Senefeldera verticillata*	Euphorbiaceae	guarapoca	86	Late secondary
(Klotzsch) Baill. *Actinostemon verticillatus*	Euphorbiaceae	cheiro de vômito	52	Late secondary
(DC.) G.P. Lewis & M.P. Lima *Pseudopiptadenia contorta*	Leguminoseae	monjolo-sabão	109	Initial secondary
Dwyer. *Copaifera lucens*	Leguminoseae	copaíba	49	Late secondary
Mart. *Trichilia lepidota*	Meliaceae	óleo-de-marceneiro	44	Late secondary
Pilg. & Schmale. *Alseis pickelii*	Rubiaceae	Pau-candeia, goiabeira	44	Late secondary
A. St.-Hil.*Metrodorea nigra*	Rutaceae	goroeitá	539	Late secondary
(Radlk.) Acev. -Rodr. *Melicoccus oliviformis subsp. intermedius*	Sapindaceae	pitomba	56	Late secondary
Cronquist. *Chrysophyllum lucentifolium*	Sapotaceae	jacoá	45	Late secondary
Mik. *Metternichia princeps*	Solanaceae	Cafezinho	52	Initial secondary
E.F. Guim. & Miguel. *Trigoniodendron spiritusanctense*	Trigoniaceae	milho-cozido	44	Late secondary

Table 6 Selected Species in the Study Area. Source Modified from (Abreu,2013)

In each forest fragments, 4 parcels of 20 x 20 m (400m^2) were established in previous studies. per species (60 in total) 5 individuals were selected, considering criteria like the diameter at breast Height (DBH) between 5-10 cm and heights between 6 and 12 meters, that had a plate or mark for their identification in the field from previous researches; once in field, they had to be located again and GPS referenced.

6.3 Method N°3. Selection of traits regardless taxonomic information

6.3.1 Collection and Analysis of Traits

Following the field protocol of (Cornelissen et al., 2003 in Pérez-Harguindeguy et al., 2013), there were collected branches of 30 cm long exposed to the sunlight, from 5 individuals per species (12), sampling in total 60 individuals, per each individual were collected 15 leaves (900 leaves in total); preferably without damages caused by herbivory, affected by diseases, or presenting a different aspect respect to the normal, including the branch stem. The height of the collected branches was between 5 and 10 meters, depending on the ease to collect. Figure 20.

Access to the area of study

Selection of individuals to collect the branches

Collecting the branches for sampling

Selecting the branches to collect the leaves

Collecting the leaves to analyze the traits

Figure 20 Collection of samples in the field. Source (Guarín Diego, 2018)

There were recorded the following morphological-functional traits present in the leaves, bark, and stem of the branches: Leaf Area (LA), Leaf Thickness (LT), Leaf Slenderness (LS), Sclerophylly, Trichomes, Spinescence, and Bark-Rind texture. Next are described the methods to measure or analyze the traits, and their definitions, following the protocols and manuals of (Corneliessen et al., 2003; Lebrija-trejos et al., 2010; Martins da Silva et al., 2014). The measured traits are recorded in the elaborated table for the selected field traits (see indicators set), The samples were collected between the 5th and 14th of May of the current year, between the 9:00 – 16:00 hrs. There was registered an average temperature of 28°C with occasional rains during those days.

6.3.2 Analysis of the Studied Traits

Leaf Area LA

The leaf size or leaf area (LA), is the one-sided projected surface area of a single or an average leaf per unit of ground surface area (Frazer et al.,1997) measured in mm^2 or cm^2. Leaf size is a trait that influx physiological processes related to leaf energy and water balance. The leaf size varies sometimes interspecifically, that has to be with climatic variation, geology, altitude or latitude; where stress caused by temperature (heat/cold), drought, and high radiation tend to select for comparatively small leaves (Cornelissen et al., 2003; Pérez-Harguindeguy et al., 2013 ; Gorne, 2010 ; Chapin et al., 2002). To measure the leaf area, the collected leaves are extended under a transparent cover to be photographed and analyzed using the software Image- J to obtain the measure in mm^2 or cm^2 to categorize them according to their size considering the classification made by Raunkiaer in 1934 which have the following updated categories. Table 7.

Table 7 Classification of the leaves size. Modified from Raunkiaer 1934 Source (Department of Agronomy, Iowa State University 2018)

Size Class	Leaf area in cm^2	Dimension Class
Leptophylls	**Small:** 0-0.056	*Le-S*
	Medium: 0.056-0.12	*Le-M*
	Big: 0.12-0.25	*Le-B*
Nanophylls	**Small:** 0.25-0.52	*N-S*
	Medium: 0.52-1.08	*N-M*
	Big: 1.08-2.25	*N-B*
Microphylls	**Small:** 2.25-4.68	*Mi-S*
	Medium: 4.68-9.74	*Mi-M*
	Big: 9.74-20.25	*Mi-B*
Mesophylls	**Small:** 20.25-42.09	*Me-S*
	Medium: 42.09-87.68	*Me-M*
	Big: 87.68-182.25	*Me-B*
Macrophylls	**Small:** 182.25-378.82	*Ma-S*
	Medium: 378.82-789.13	*Ma-M*
	Big: 789.13-1640.25	*Ma-B*
Megaphylls	**Small:** 1640.25-3409.31	*Mg-S*
	Medium: 3409.31-7102.11	*Mg-M*
	Big: 7102.11-*x*	*Mg-B*

Leaf Slenderness (LS)

This trait is the ratio between the leaf lamina length and leaf lamina width, as an index of leaf shape (Lebrija-trejos et al., 2010 ; Yamazaki & Ohsaki, 2006), it determines the available area for transpiration and control of water status (Vertessy 1995 in Apgaua et al., 2015). For this measure, it has to be considered if the leaves are simple, composed or doubly composed. Figure 21. To obtain this trait is calculated the length and width of the leaf blade, also with the software Image-J. According to Dr. Jorge Meave[3] this trait has no exact measure, the result is a numerical index that takes much larger values in those species that tend to have long and narrow leaves, compared to those species with rather "roundy" leaves; in theory, slenderer leaves are associated with less self-shading within the plant's crown, regardless of leaf area, the index values are not correlated with the latter.

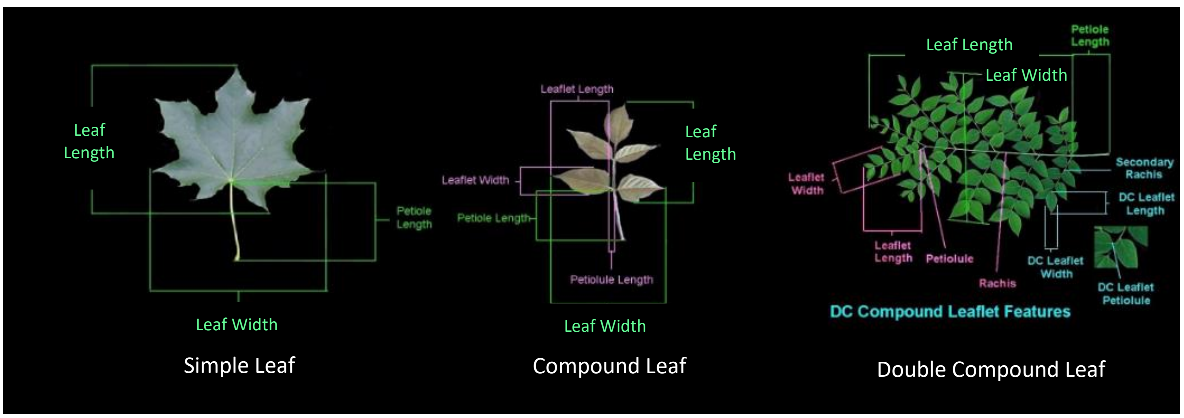


Figure 21 Dimensions of leaves to measure the slenderness index Source (College of Arts and Sciences Miami University, 2009)

Leaf Thickness (LT)

This trait is associated with many physical and physiological characteristics like strength of leaves (Pérez-Harguindeguy et al., 2013), and resistance to leaf drying due to the thickness of the mesophyll (Apgaua, 2015); To measure this trait was used a digital caliper Starrett ® model 727-2001.Figure 22. Avoiding to press the main nerves of the leaf. The obtained measure is in mm or a tenth of a millimeter, there were measured at least the 30% of leaves per species to obtain an average measure of the thickness.

[3] Comments made by Dr. Jorge Meave (National Autonomous University of Mexico) as an answer to the question of calculation of the leaf slenderness as an adaptation to drought. In https://www.researchgate.net/publication/43147003_Functional_traits_and_environmental_filtering_drive_community_assembly_in_a_species-rich_tropical_system/comments?focusedCommentId=5afdcd8f4cde260d15df5187&sldffc=0

This trait can be grouped in categories or classes according to the thickness of the leaves in mm. Table 8 (Tafur 1989 in Rangel & Velásquez, 1997).

Figure 22 Measure of thickness in leaves of Metrodorea
Source (Guarín Diego, 2018)

Table 8 Categories of leaf thickness
(Tafur 1989 in Rangel & Velásquez, 1997)

Category	Thickness of the Leaf Lamina in mm
A	0.005-0.15
B	0.16-0.35
C	0.36-0.45
D	0.46-0.55
E	0.56-0.65
F	> 0.66

Sclerophylly

The term “sclerophyllous” means hard-leaved and is associated with a rough, rigid and leathery aspect of some leaves (Edwards, 2000) this characteristic makes the leaves less susceptible to mechanical damages and herbivory (Gorne, 2010). The thick epidermal walls and cuticle confers the sclerophyllous leaves to resist desiccation, maintaining the thermal stability (Sobrado & Medina, 1980), which is an adaptation to heat seasons or drought in regions like semiarid Mediterranean biomes (Lopez-Iglesias et al., 2014; Micco & Aronne 2012); as well as other environments like the Atlantic Forest (Silva & Nascimento, 2001 ; Díaz et al., 2004)

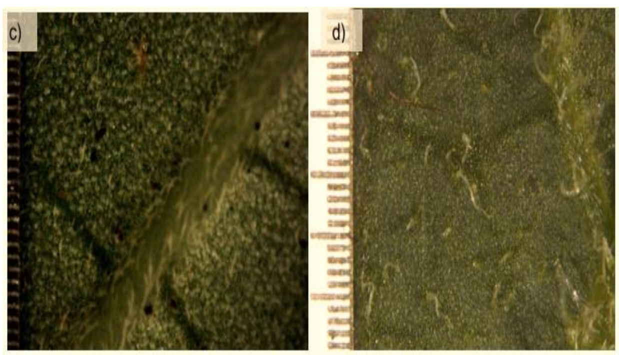
This trait is related to the leaf thickness and can be classified considering a range from the to “hard to soft” in this case rigid to membranaceous. Table 9 (Tafur 1989 in Rangel & Velásquez, 1997; Ramirez, 2004). This classification was used to group the leaves of the selected species considering the literature findings per each one of them.

Table 9 Types of leaves texture. Source compiled from (Rangel & Velásquez, 1997; Ramirez 2004)

Types of leave textures
Rigid leaves: Thicker, opaque, and barely flexible (brittleness)
Cartaceous leaves: Also thick and opaque but less flexible, like a cardboard
Coriaceous leaves: Flexible, and opaque, thick like leather
Papyraceous leaves Semitranslucid to opaque, but thin
Membranaceous leaves: Thinner than the others, sometimes translucid and fragile to touch

Trichomes

The trichomes can be defined as an unicellular or pluricellular outgrowth of the epidermis of plant tissues in a varied way that protrudes from the surface of the organs and includes papillae, hairs and scales (Cabrera & Tillett, 2016; Xiao, Mao, & Lin, 2016) **¡Error! No se encuentra el origen de la referencia.**. Their main function is probably to absorb water and nutrients, but they may also prevent overheating by reflecting sunlight in exposed habitats, deter invertebrate herbivores, and/or promote gas exchange (Pérez-Harguindeguy et al., 2013).



Presence of trichomes in the back of the leaf of the species c) *Piper crassinervium*, d) *Cleome anomala,* the density and the type of trichomes may have some variations even interspecifically due to factors, like the age of the individual, the exposition to sun radiation, presence of herbivores; among others.

Figure 23 Density of trichomes per cm² in different plant species. Source (Ruíz Molina, 2015)

For this work, this trait was observed in the field in order to look, only if was absent or present in the leaves, or stem of the branches of each species.

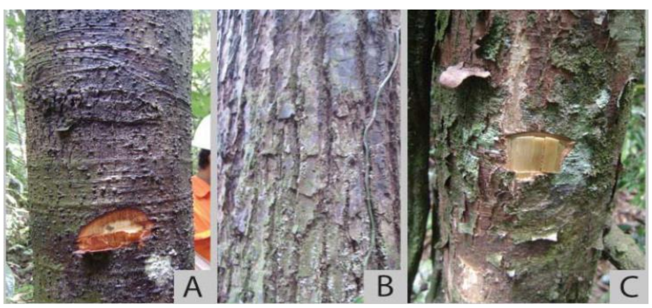
Bark-Rind Texture

It is the part of the stem that is external to the wood or xylem, it includes the vascular cambium, secondary phloem, phelloderm or secondary cortex, cork (Pérez-Harguindeguy et al., 2013 ; Evert & Eichhorn 2006 in Salgado Negret, 2015). Bark texture may determine the capture and/or storage of water (hydric regulation), nutrients and organic matter, also the bark thickness has a role in heat insulation protecting the plant against wildfires and subsequently determine the fire sensitivity of ecosystems (Corneliessen et al.,2003).

Additionally, may provide protection of vital tissues against attack by pathogens, herbivores, frost or drought (Pellegrini, Franco, & Hoffmann, 2016; Speck & Burgert, 2011 ; Casanoves, Pla, & Di Rienzo, 2011 ; Pérez-Harguindeguy et al., 2013).

Bark texture includes ranges from smooth, fibrous to rough. Roughness is caused by various bark characteristics including lenticels, branch scars, and wounds; the lichens and moss are not considered as part of bark texture (Danielsen & White, 2003); but this range from smooth to rough can include another type of textures, like deep fissures, stretch marks, with lenticels, scales or papyraceous, among others; regarding the habitat of the species, (Martins-da-Silva et al., 2014).Figure 24.

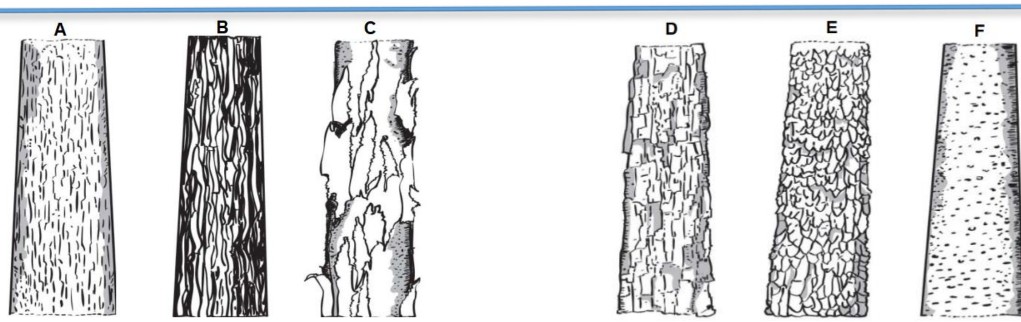
Therefore, the scale of (Martins-da-Silva et al., 2014) that consider tropical tree species is proposed. Figure 25, adapted to the scales of (Corneliessen et al.,2003), being (1) smooth (2) very slight texture [amplitudes of microrelief within 0.5 mm] (3) intermediate texture [amplitudes 0.5–2 mm] (4) strong texture [amplitudes 2–5 mm], and (5) very coarse texture [amplitudes >0.5 mm]. In order to find out which texture could be related with more water retention as an adaptation to drought conditions.



Types of bark:

(A) Rough (Lauraceae);
(B) Fissured (Lecythidaceae)
(C) Irregular plates (Sapindaceae)

Figure 24 Types of bark of tropical tress Source. Arquivo do projeto Dendrogene EMBRAPA/DFID in (Martins-da-Silva et al., 2014)



A. Striated-with small furrows, such as scratches
B. Fissured - with deep grooves
C. Papyraceous-dropping into thin pieces like pieces of paper.

D. with plaques-thick coriaceous plates
E. with scales-embedded like fish scales
F. smooth or with small protuberances

Textures adapted to Cornelissen scales:

- smooth **F**
- very slight texture (amplitudes of microrelief within 0.5 mm) **A, F**
- intermediate texture (amplitudes 0.5–2 mm) **A, C, D**
- strong texture (amplitudes 2–5 mm) **A, B, D, E**
- very coarse texture (amplitudes >0.5 mm) **B, C, E**

Figure 25 Types of bark texture of some tropical trees. Source Modified from (Martins-da-Silva et al., 2014) and (Corneliessen et al.,2003).

Spinescence

This adaptation refers to the degree to which a plant is protected by spines, thorns and/or prickles. Spines are sharp, modified leaves, leaf parts or stipules; they also occur sometimes on fruits; Thorns are sharp, modified twigs or branches, and prickles are modified epidermis or cork like the rose-stem prickles. Figure 26. Spinescence can be an induced response to herbivory but can play additional roles in reducing heat or drought stress. This trait can change according to the age or part of the plant (Cornelissen et al., 2003 ; Pérez-Harguindeguy et al., 2013)

.

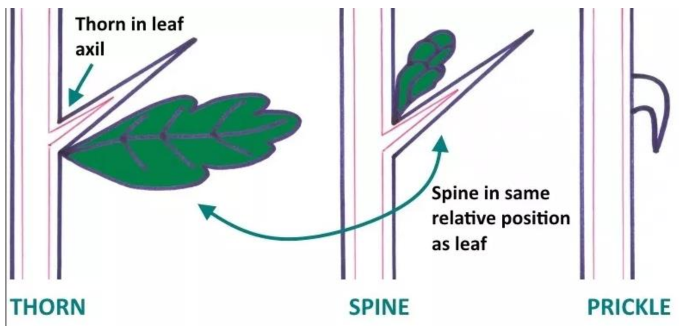


*Figure 26 Types of Spinescence in Plants*Source (Williamson Graham, 2015) in https://www.breamishvalley.com/dog-rose/

This trait was observed for the selected species in the tree trunk, leaves, and branches stem, in order to detect the absence or presence of this characteristic, considering the classification of (Pérez-Harguindeguy et al., 2013). As follows:

Categorical Estimates of Spinescence:

(1) No spines.
(2) Low or very local density of soft spines <5mm long; plant may sting or prickle when hit carelessly, but not impart strong pain.
(3) High density of soft spines, intermediate density of spines of intermediate hardness, or low density of hard, sharp spines >5mmlong; plant causes actual pain when hit carelessly.
(4) Intermediate or high density of hard, sharp spines >5mm long; plant causes strong pain when hit carelessly.
(5) Intermediate or high density of hard, sharp spines >20mm long; plant may cause significant wounds when hit carelessly.
(6) Intermediate or high density of hard, sharp spines >100mm long; plant is dangerous to careless large mammals, including humans.

6.3.3 Assessment of the Selected Traits

This part, was carried out, considering the obtained values in recorded in the indicator set which were compiled, taking in account the ranges and categories stated per selected traits. Table 10, as was described in the Method N°2. Analysis of the Studied Traits.

Table 10 Ranges per selected traits. Source (Guarín, Diego 2018) compiled from (Raunkaier 1934. Department of Agronomy, Iowa State University 2018; Tafur 1989 in Rangel & Velásquez; 1997 Rangel & Velásquez, 1997; Ramirez 2004; Martins da Silva, 2014)

LEAF AREA	LEAF THICKNESS	SCLEROPHYLLY
Classification of leaves size	**Thickness in mm**	**Leaf aspect**
4. (Me-B) Big Mesophyll: 87.68-182.25 cm^2	**4.** > 0.20 mm	**4.** Cartaceous
3. (Ma-S) Small Macrophyll: 182.25- 378.82 cm^2	**3.** Between 0.15-0.19 mm	**3.** Coriaceous
2. (Ma-M) Medium Macrophyll: 378.82-789.13 cm^2	**2.** Between 0.06-0.14 mm	**2.** Papiraceous⁺ (This aspect was not evidenced)
1. (Ma-B) Big Macrophyll: 789.13-1640.25 cm^2	**1.** < 0.05 mm	**1.** Membranaceous
BARK RIND ASPECT	**LEAF SLENDERNESS**	**TRICHOMES**
Types of bark	**Units of slenderness**	There were just evidenced the presence or absence of this trait giving the value of 4 to presence (high tolerance) and 0 to absent (no valuation)
4. Fissured	**4.** > 200 units	
3. Plaques	**3.** Between 150-200 units	
2. Striated	**2.** Between 100-150 units	
1. Smooth or papyraceous (Texture not evidenced in the field)	**1.** < 100 units	

Based on this classification there was developed a scale of valuation, in order to know which of those traits could give a hint as drought tolerance traits, considering the ranges and categories stated per selected trait as was described in the table above.

This valuation gives an estimative weight, since not all the traits have defined measures or units, and some are subjective to qualify or classify them (e.g slenderness index or type of bark). For that, it is proposed an estimative weight expressed in percentage, that allows comparing which soft traits could confer more tolerance to drier conditions.

- Characteristics of the traits that could confer little drought tolerance value of **(1)**
- Characteristics of the traits that could confer little-medium drought tolerance value of **(2)**
- Characteristics of the traits that could confer medium drought tolerance value of **(3)**
- Characteristics of the traits that could confer high drought tolerance value of **(4)**

The estimated weight was elaborated taking in account the measures, mm or cm or other units of classification previously established by the findings in the literature review. It has to be clarified the fact that those traits could show low values in the species, this doesn't mean they are not well adapted, because there are other soft or hard traits that can compensate or balance water loss through other adaptations related to tolerance, avoiding or escape, in the section of results are presented the estimated values per assessed trait.

6.4 Method N°4 Species Distribution Modeling

In this part, the aim is to provide an outlook, an approach for the use of Species Distribution Modeling (SDM) as a tool for species distribution regarding climatic conditions where drought can be included. To see if there is a pattern or a trend in the distribution of the species and traits in the study area.

For the SDM, it is used a software for species distribution modeling MAXENT based on the principle of (Maximum Enthropy Modeling) which explains the estimated distribution of the species regarding the distribution known or inferred from the environmental conditions where it has been recorded. This is conditioned by the imposed restrictions with respect to the available information on the observed distribution of the species and the environmental conditions of the study area. (Phillips et al., 2006) the software is for free use, it can be downloaded from this website: https://biodiversityinformatics.amnh.org/open_source/maxent/ To explain this method is taking as an example one species randomly selected, and recorded in the JABOT database. A. St.-Hil *Guatteria australis.*

This model works with the following type of information.

1. <u>Information of the recorded species:</u> Name of the species and coordinates (Long X, Lat Y). This information has to be saved in a file type (CSV delimited by commas). Next it is shown an example for the species. *Guatteria australis*. Figure 21.

The estimated weight was elaborated taking in count the measures, mm or cm or other units of classification previously established by the findings in the literature review, that can be adapted to the following criteria of valuation.

```
species,X,Y
Guatteria_australis,-42.5247,-22.4361
Guatteria_australis,-42.7228,-22.3439
Guatteria_australis,-41.8356,-20.4103
Guatteria_australis,-43.5586,-19.2633
Guatteria_australis,-43.5189,-19.2472
Guatteria_australis,-43.7511,-18.9475
Guatteria_australis,-41.9111,-21.8997
Guatteria_australis,-41.9908,-21.9436
Guatteria_australis,-43.7942,-19.0486
Guatteria_australis,-43.7667,-19.0058
Guatteria_australis,-42.7606,-22.3542
Guatteria_australis,-43.5533,-19.2906
```

Figure 27 Example of species for Maxent model. Source extracted from JABOT database 2017

It is recommended to use as minimum between 10 and 200 entries per species, less than this may cause a mismatch of the information, or an erroneous predicted distribution of the species (Bravo, 2013). In this case were used 12 entries for *Guatteria australis*.

2. Information of environmental variables: Climate, type of vegetation, altitude; among others, which are the ones that will conditionate the predicted distribution in the area, for the species. For this work, the variables were downloaded from this website http://www.dpi.inpe.br/Ambdata/download.php#var_ind "Environmental Variables for Species Modeling" (DPI-INPE,2018) the registered date of the variables is from 1950 to 2000. The selected variables were the following. Table 11.

Table 11 Variables for Species Distribution modeling. Source (DPI-INPE,2018)

Variables for species distribution Modeling
BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (* 100)
BIO4 = Temperature Seasonality (standard deviation *100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter
Alt= Altitude
Veg= Vegetation types (IBGE 1992)

These variables must to be saved as an ASCII file to include them in the model. The variables (BIO1, BIO2...BIO19, and altitude), are classified as continuous; and variables as the vegetation types are categorical type. Including all these predictor variables may cause an overfitting of the model. For that, it has to be selected the most correlated among them; regarding a Spearman rank correlation matrix, that presented a correlation ($r \geq 0.6$) according to (Raedig et al, 2010). It has to be mentioned that the information of the species and the environmental variables must have the same system of geographic referenciation, in this case is WGS84. The predictor variables that showed the highest correlation were **Alt**-altitude, **BIO5**- Max Temperature of Warmest Month, **BIO15**-Precipitation Seasonality

"Coefficient of Variation", and **BIO18**-Precipitation of Warmest Quarter, and **Veg**-Vegetation types IBGE 1992. Next it is shown an example of the the inserted data to run the model highlighting part of the used information. Figure 28.

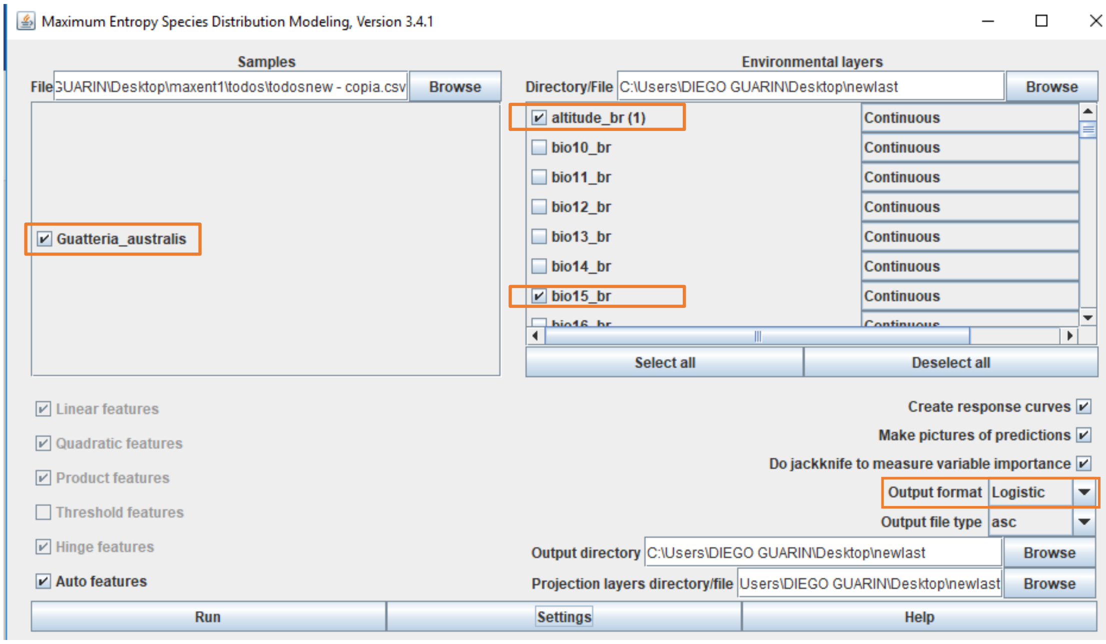
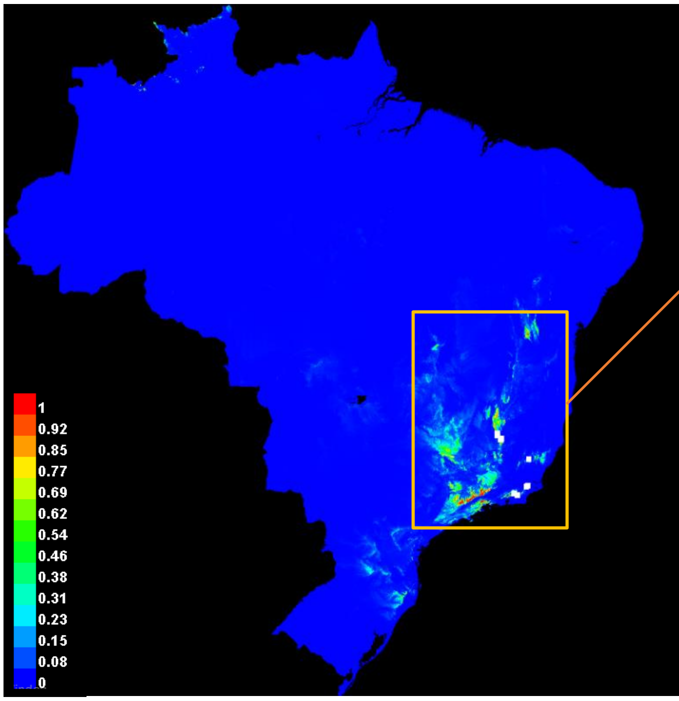
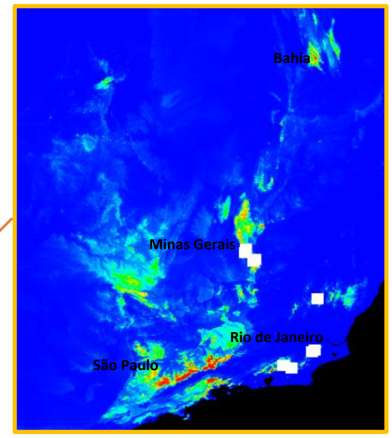


Figure 28 Example of insert data for Maxent modeling . Source (Maxent software for modeling species niches and distributions, 2018) in https://biodiversityinformatics.amnh.org/open_source/maxent/

The output format is type "Logistic" which indicates the predicted probability of appropriate conditions represented with a range of colors; in red (1) indicating high probability of suitable conditions for the species, green indicating conditions typical of those where the species is found, and lighter shades of blue indicating low predicted probability (0) of suitable conditions (Phillips, 2008) the white dots show the presence locations used for the model. As can be seen in Figure

In figure 29 can be observed that the most suitable conditions or the distribution of this species are presented in southeast region of Brazil, it can be appreciated some red shades in the States of São Paulo and the State of Minas Gerais; and a small shade in the south part of the state of Bahía; in general it can be observed that *Guatteria australis* can be found usually in the southeast region of Brazil (green shades). In the same figure 29, it can be observed a table that shows the estimates of relative contributions of the environmental variables to the Maxent model. The variable that most influenced the distribution of this species is the temperature of the warmest months **BIO5** from 1950 to 2000 followed by far by the precipitation of the warmest quarter **BIO18**. This mean that **BIO5** influence whether species distributions are affected by warm temperature anomalies throughout the year.

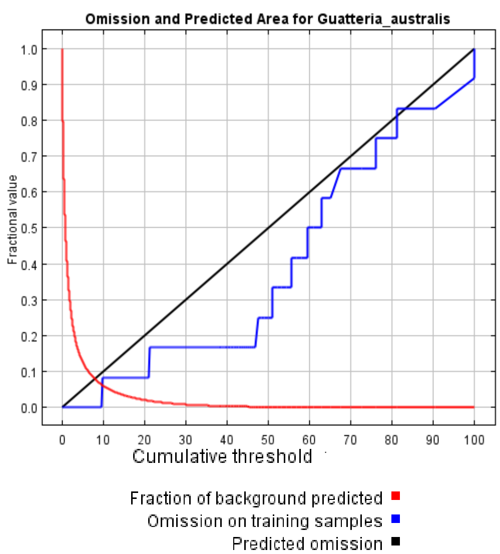




Variable	Percent contribution
bio5_br	50.3
bio18_br	17.3
vegetacao_ibge1992_br	16.7
bio15_br	15.6
altitude_br (1)	0

Figure 29 Example of SDM for Guatteria australis. Source elaborated from (Maxent software for modeling species niches and distributions, 2018)

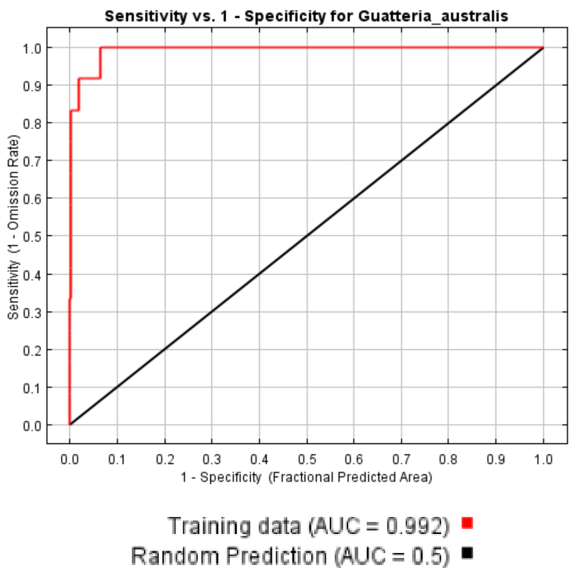
To assess and validate the model two graphs are generated as well: Figure 30.



This graph shows the analysis of error of omission, that means the non-prediction of potential places of presence of the species that could be important for the community.

The omission rate (blue line) represents the 12 entries of the species “training samples” The black line is the predicted omission generated by default to adjust the model. The red line represents the threshold where the species are distributed.

The omission rate should be close to the predicted omission to minimize the error. As was aforementioned the number of entries to insert is also important in this case to reduce the error of omission. And also has to be considered the location of the individuals, too many entries in the same location can influence in the error of omission.



This graph shows the AUC "Area Under the receiver operating Curve" it is a measure of quality of the model, if the obtained value is close to 1 implies very good performances and reliabilities of the model.

The further towards the top left of the graph that the red line is, the better the model is at predicting the presences contained in the test sample of the data

Figure 30. Graphs for validation of Maxent models Source elaborated from (Maxent software for modeling species niches and distributions, 2018)

After the SDM is generated by MAXENT, then is visualized through ARCGIS 10.1 for its respective interpretation and analysis. For this work there were elaborated two SDM, one for the possible drought indicator species regarding their traits recorded in the JABOT database based on the area of in the Mata Atlântica biome (large scale); and other for the assessed traits of the analyzed species in the field based on the study area of the Mata de Tabuleiros to the north of Rio de Janeiro State (small scale), which are shown in the results section.

6.5 Effects of Drought in the Vegetation of the Mata Atlântica

This information was obtained from the consultations and interviews made to ten people of technical personnel of EMATER- (Empresa de Assistência Técnica e Extensão Rural) in São Francisco de Itabapoana, and the researchers Dr. Fátima Pina Rodrigues, Dr. Marcelo Trinidade Nascimento, and Dr. Dietmar Sattler. There were addressed semi-structured interviews which consist in open questions in this case aimed to the subject of study, where the interviewed can express their opinion in order to complement the answer in a natural and flexible form. (Fernández Carballo, 1998; López-Roldán & Fachelli, 2015), the questions were aimed to know the current state of drought-prone areas in the Mata Atlântica in relation to the plant adaptive traits of the species in this biome. There were elaborated three types of interviews (See Annex section: Interviews).

7. RESULTS

7.1 General Description of the Fragments

The fragments are secondary forests located in private properties; presenting different events of anthropic disturbances, such as logging, poaching, and suppression of the original forest cover for agricultural and livestock activities; among others, including motocross and BMX tracks. Figure 31; the fragments have been suffering selective cutting for several decades.

In this way, the noble woods were removed and sold to the sawmill, and the common woods were used for firewood in a flour factory in the region or turned into charcoal. Because of this, is noticed the scarcity of species like braúna *Melanoxylon brauna*, roxinho *Peltogyne discolor*, óleo vermelho *Myrocarpus frondosus*, peroba-rosa *Aspidosperma sp*, peroba amarela *Paratecoma peroba*, ipê *Handroanthus sp*, and jequitibá-rosa *Cariniana legalis* (Abreu, 2013).

Noble wood *Paratecoma peroba*

Housing of local Inhabitants

Pineapple crops

Excavations made by poachers to capture armadillos

BMX tracks inside Fazenda Palmeiras close to other fragments

Harvesting of some crops outside the fragments

Figure 31 General Aspect in the Area of the Fragments. Source (Guarín Diego, 2018)

Around the fragments there were noticed some creeks, but the main water sources are springs located along the place, the water is used to feed the livestock and sometimes for irrigation of crops; just a few farmers count with some water irrigation systems for the main crops, like sugarcane, cassava, pineapple; and in lesser proportion maracuja and guava. The water is extracted from those springs around the area, but for bigger extensions, the crops only depend on the rainfalls; some water springs are currently protected. Also, some Eucalyptus trees are located in small land extensions, not as a plantation just in some areas with few individuals for forestry exploitation at local level. Figure 32.

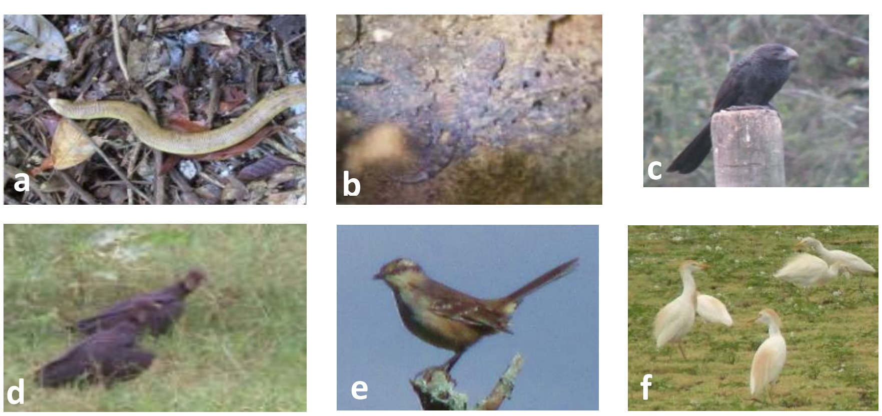

Small plantations of Eucalyptus


water springs used as a trough for livestock


*Protected water springs in the region of Salminho 10 km away from the fragments

Figure 32 Forestry Plantations and Water Springs in the Area
. Source (Guarín Diego, 2018) and * EMATER-São Francisco de Itabapoana

Regarding the fauna, these fragments are also the habitat of some characteristic species of this region that were noticed or reported in the field. Species of mammals like the opossum or "gambá" *Didelphis albiventris*, armadillo *Dasypus novemcinctus;* birds like the seriama *Cariama cristata*, the Smooth-billed ani *Crotophaga ani*, the cattle egret *Bubulcus ibis*; reptiles like Fam. Gekkonidae and some snakes Fam. Viperidae *Bothrops sp* and Fam. Amphisbaenidae *Amphisbaena sp;* among other species. Figure 33, as well as many groups of invertebrates.



a) *Amphisbaena sp* Fam. Amphisbaenidae

b) Gecko Fam. Gekkonidae

c) Smooth-billed Ani *Crotophaga ani*

d) Black Vulture *Cathartes aura*

e) Sabiá-laranjeira *Turdus rufiventris*

f) Cattle Egret *Bubulcus ibis*

Figure 33 Registered fauna in the study area Source (Guarín Diego, 2018)

7.2 Description of the Forest Fragments in the Study Area

7.2.1 Fragment of Fazenda Imburi

Is a fragment of 17 Ha of extension, located in 21°19'31,7"S 41º06'00,0"W It presents a discontinuous and closed canopy with trees average 12-15 m height (Abreu, 2013), most of the vegetation is covered by lianas and bamboos especially on the edge of the fragment. It is noticed the presence of a few clearings that allow the light entrance for the regeneration of new plant individuals; the presence of epiphytes of Araceae, Bromeliaceae, and Orchidaceae families can be also noticed. The access to the fragment is easy by rural roads, presents some fences outside and inside the area, where it can be observed old traces of tree exploitation. The fragment it is surrounded mainly by crops of sugarcane, cassava, pineapple and grassland for livestock. Figure 34.

*****Forest fragment in Fazenda Imburi


Edge of the fragment with grass for grazing


Clearings inside the fragment


Access to the fragment by road


Bromeliads and plantlets in the understory


Cassava crops

Figure 34 Fragment of the Fazenda Imburi. Source (Guarín Diego, 2018; *****Google Earth Pro, 2018 in INDE 2018 in http://www.visualizador.inde.gov.br/)

7.2.2 Fragment of Fazenda Santana

This fragment has an extension of 36 Ha, located in 21º20'08,7" S 41º08'18,3" W, it presents some clearings open by fallen trees; it also presents a discontinuous canopy, with average 12-15m height, a little closed with understorey species. This fragment is cut by a rural road (Abreu, 2013); from the edge to the inner of the fragment along the road is used as a garbage disposal. It is surrounded also by a matrix of plantations of pineapple and sugar cane. Figure 35.

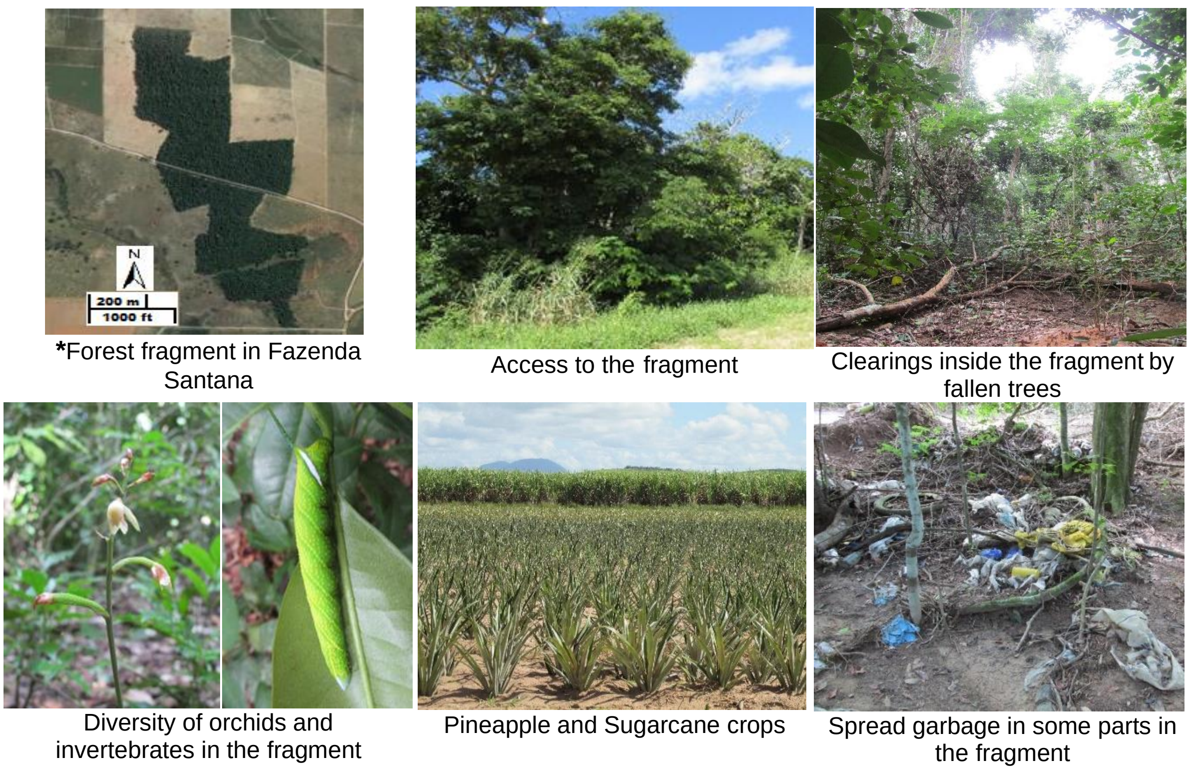


Figure 35 Fragment of the Fazenda Santana Source (Guarín Diego, 2018; ***** Google Earth Pro, 2018 in INDE 2018 in http://www.visualizador.inde.gov.br/)

7.2.3 Fragment of Fazenda Santo Antônio

This fragment has 58 Ha of extension, located in 21º17'48,7” S 41º05'25,2” W, it presents a canopy with a height between 15-20 m, few clearings, many tangles of lianas, and some fallen trees. The presence of epiphytes like bromeliads it is noticed; like the other fragments, it is surrounded by plantations of maracuja and cassava, lands for livestock with a fence circling the fragment, and a footpath for cattle passage. It is located in a steep hillside area, with soft and sparse relief elevations, its access is more restricted and a little further away from main roads. Figure 36.

*Forest fragment in Fazenda Santo Antônio

Access to the fragment

View inside the fragment

Soft relief elevations in the fragment

Land for livestock around the fragment

Individuals of Fam.Bromeliaceae inside the fragment

Figure 36 Fragment of the Fazenda Santo Antônio. Source (Guarín Diego, 2018; * Google Earth Pro, 2018 in INDE 2018 in http://www.visualizador.inde.gov.br/))

7.2.4 Location of the Species in the Area of Study

The selected species were located along the fragments Figure 37, sometimes in the same fragment area or distributed among them, as was previously mentioned; but not all the individuals were located inside the parcels because some of them did not have the established dimensions or were not found in those parcels; for that, had to be located out of them and tagged in the tables as (No Parcel, NP), but in the fragment. The parcels were numbered from previous studies. For the parcels in the fragment of Fazenda Imburi are the parcels (P45, P46, P48, and P49), in the Fazenda Santo Antônio the parcels (P60, P61, P63, and P64); and for the Fazenda Santana the parcels (P51, P52, P53, and P54)

The individuals that did not have a mark for identification, were tagged in the tables with an abbreviation according to the species; for instance: *Alseis pickelli* - Alpi, *Astronium concinnum*- Ascon, *Metrodorea nigra*- Metn, and *Metternichia princeps* - Mprin.

Next it is shown the location of the individuals into the parcels of the fragments. Figures.38, 39 and 40; and it is shown in Tables 12, 13 and 14; the number of individuals located per fragment, in the Fazenda Imburi: 39 individuals, in Fazenda Santo Antônio 9 individuals, and in Fazenda Santana 12 individuals; being a total of 60.

Figure 37 General view of the location of the fragments in the study area. Source Elaborated from (Google Earth Pro 2018 & INDE 2018 in http://www.visualizador.inde.gov.br/)

Table 12 Species Located in the Fragments of Fazenda Imburi Source Modified from (Abreu,2013)

Fragment in Fazenda Imburi	Total of sampled individuals n= 39										
Species	Number of Sampled individuals	Parcel	Plate Number	Parcel	Plate Number	Parcel	Plate Number	Parcel	Plate Number	Parcel	Plate Number
Actinostemon verticillatus	5	45	4839	46	1137	46	1142	46	1162	46	1184
Alseis pickelli	5	46	1182	NP	Alpi2	NP	Alpi3	NP	Alpi4	NP	Alpi5
Astronium concinnum	5	46	1151	NP	Ascon2	NP	Ascon3	NP	Ascon4	NP	Ascon5
Chrysophyllum lucentifolium	3	45	1062	45	1091	45	1164				
Copaifera lucens	2	49	1881	46	1126						
Melicoccus oliviformis subsp. Intermedius	3	48	1293	49	1825	49	1829				
Metrodorea nigra	5	45	1077	45	1085	45	1095	45	Metn4	45	1105
Metternichia prínceps	2	45	4830	46	4838						
Pseudopiptadenia contorta	1	49	1882								
Senefeldera verticillata	5	45	1119	45	1116	45	1118	45	1102	45	1084
Trichilia lepidota	1	48	1296								
Trigoniodendron spiritusanctense	2	45	1094	49	1848						

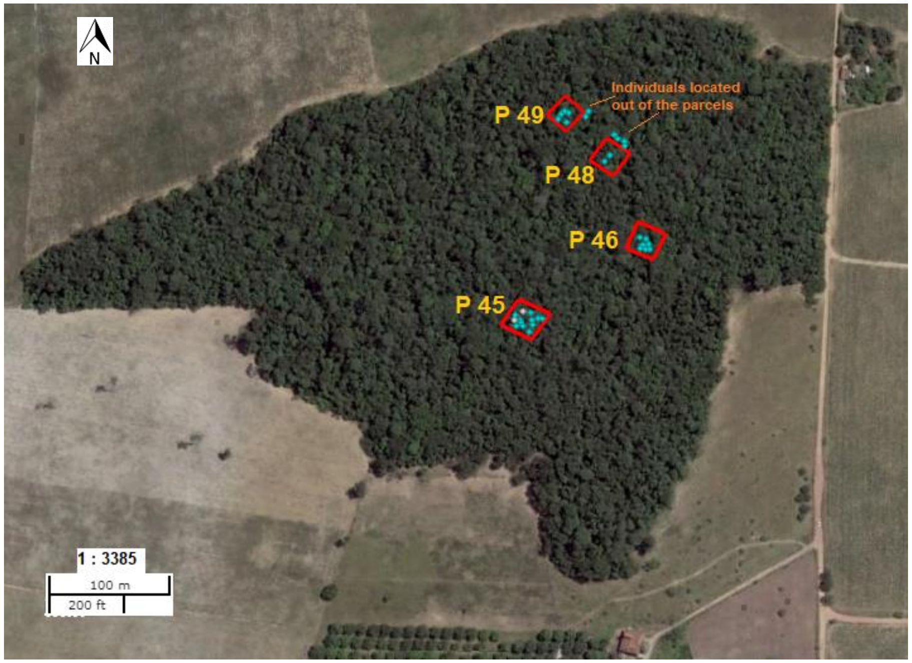


Figure 38 Parcels with the individuals in the fragment of Fazenda Imburi Source Elaborated from (Google Earth Pro 2018 & INDE 2018 in http://www.visualizador.inde.gov.br/)

Table 13 Species Located in the Fragments of Fazenda Santo Antônio Source Modified from (Abreu,2013)

Fragment in Fazenda Santo Antônio	Total of sampled individuals n= 9								
Species	Number of Sampled individuals	Parcel	Plate Number	Parcel	Plate Number	Parcel	Plate Number	Parcel	Plate Number
Chrysophyllum lucentifolium	1	61	309						
Copaifera lucens	3	63	474	60	244	60	276		
Pseudopiptadenia contorta	4	61	4849	64	486	64	526	61	333
Trigoniodendron spiritusanctense	1	61	312						

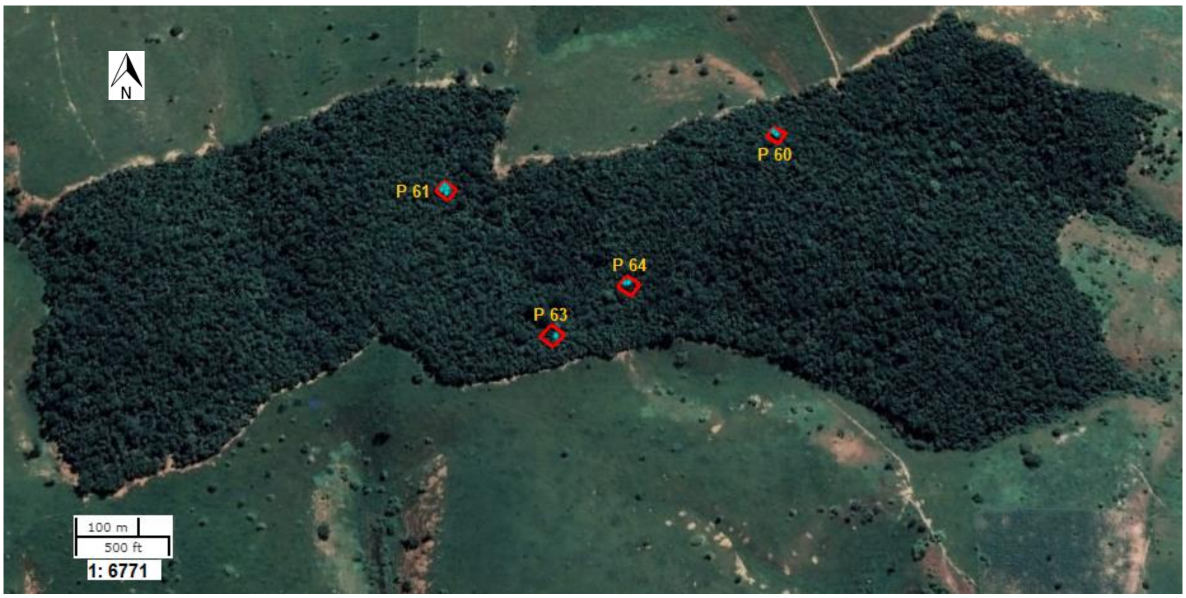


Figure 39 Parcels with the individuals in the fragment of Fazenda Santo Antônio
. Source Elaborated from (Google Earth Pro 2018 & INDE 2018 in http://www.visualizador.inde.gov.br/)

Table 14 Species Located in the Fragments of Fazenda Santana Source Modified from (Abreu,2013)

Fragment in Fazenda Santana	Total of sampled individuals n= 12								
Species	**Number of Sampled individuals**	**Parcel**	**Plate Number**	**Parcel**	**Plate Number**	**Parcel**	**Plate Number**	**Parcel**	**Plate Number**
Chrysophyllum lucentifolium	1	51	2616						
Melicoccus oliviformis subsp. Intermedius	2	52	2676	52	2640				
Metternichia princeps	3	NP	Mprin3	NP	Mprin4	NP	Mprin5		
Trichilia lepidota	4	54	2777	54	2754	NP	Tl4	NP	Tl5
Trigoniodendron spiritusanctense	2	52	2639	53	2719				

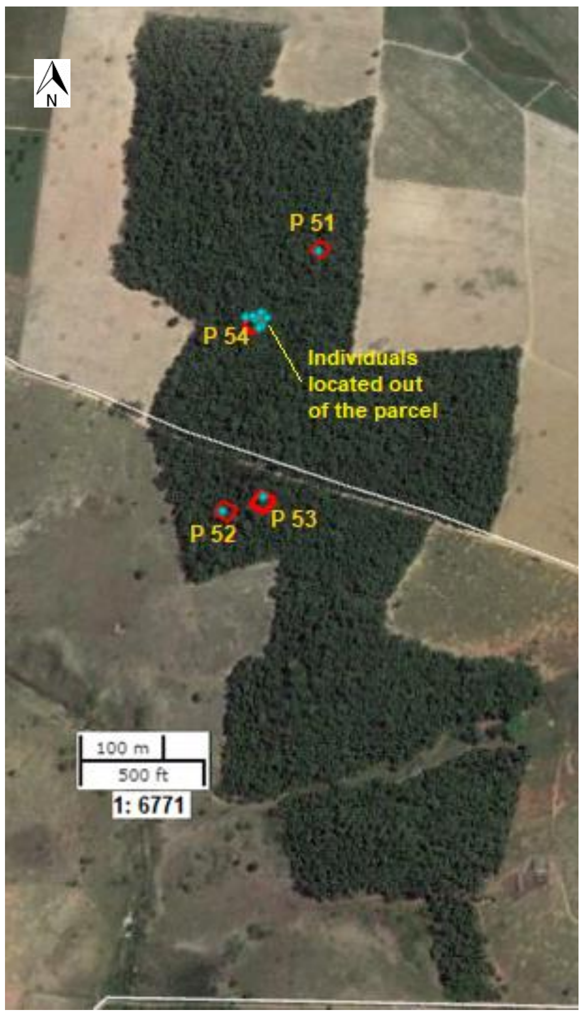


Figure 40 Parcels with the individuals in the fragment of Fazenda Santana.
Source Elaborated from (Google Earth Pro 2018 & INDE 2018 in http://www.visualizador.inde.gov.br/)

7.3 General definition of traits used in analysis

7.3.1 Collection of studies which have worked on soft traits in response to dry climate conditions

As it can be observed, through different types of traits soft and hard, it can be analyzed the responses of the plant to the environment; making an approach selecting the accurate traits to analyze the performance of the individual. In the same way, other traits can indicate how plants are adapted to climate conditions, next in **¡Error! No se encuentra el origen de la referencia.**, are compiled the most common soft and hard traits used to study the response to drought.

Table 15 Functional Traits Related to Drought or Dry Conditions Source compiled from (Herz et al., 2017; Cornelissen et al., 2003; Díaz et al., 2004; Lavorel & Garnier, 2002; Lebrija-Trejos et al., 2010; Wagner et al., 2014; Castellanos-castro & Newton, 2015)

Most Functional Traits Studied as Adaptations to Drought Conditions			
Growth form	Physical strength of leaves	Distribution of rooting depth	Bark Thickness
Life form	Leaf lifespan	rooting depth	Adult plant height (m)
Plant height	Leaf phenology Deciduousness	Nutrient uptake strategy	Stem specific density (mg mm^{-3}) Leaf area (mm^2)
Clonality	Photosynthetic pathway	Resprouting capacity	Leaf mass per area (g m^{-2})
Spinescence	Wood rings	Stomatal Index	Diaspore mass (mg)
Flammability	Stem specific density	Stomatal Density	Diaspore mass (mg) excluding pteridophytes
Specific leaf area	Twig dry matter content	Stomatal Area Fraction	Specific leaf area (SLA)
Leaf size	Twig drying time	Epidermal Cell Area	Dry matter content
Leaf dry matter content	Specific root length	Xylem diameter	Leaf slenderness
N content per unit leaf mass (mg/g^{-1})	sapwood-specific hydraulic conductivity	Axial Root elongation rate	Aquaporin activity

7.4 Search for botanical groups as indicators of dry conditions that exhibit traits for drought adaptations

7.4.1 Search in the Rio de Janeiro Botanical Garden- JABOT database

Based on the JABOT database information it was searched for the species that presented more than two or three characteristics that can be considered as drought tolerance traits, as rigid and cartaceous leaves, spinescence, succulence, trichomes; among others.

After a detailed review, of the JABOT database it was found that not all the botanical families have enough information like a "group or pool of traits" to consider; as an example, it is shown highlighted in yellow the botanical groups with insufficient information to be taken in account, and in green the families with a possible amount of characteristics to look as possible traits related to drought adaptation. Figure 41.

genero	sp	autorsp	cidade	longitude	coletor	bioma_ibge	codtes
CHRYSOBALANACEAE	Hirtella	gracilipes	Minas Gerais	-18.9777778	-43.776389	Arbusto, ca. 2 m de altura; pétalas roxas com base alva; frutos negros. No leito do rio.	
CHRYSOBALANACEAE	Hirtella	gracilipes	Minas Gerais	-18.9744445	-43.772778	Arbusto 2,5 m alt., cálice vináceo, pétalas alvas.	
CHRYSOBALANACEAE	Hirtella		Rio de Janeiro	-21.7138889	-41.263889	Arbusto, ca. 3 m de altura, semi-ciófila. Folhas membranáceas. Flores alvacentas com	
CHRYSOBALANACEAE	Licania	riedelii	Rio de Janeiro	-22.9166667	-42.233333	Fruto imaturo.	
CHRYSOBALANACEAE			Minas Gerais	-20.2075000	-42.532778	Arbusto, 4m de altura, 11 cm de DAP, folha verde discolor, comum no local.	
CHRYSOBALANACEAE			Rio de Janeiro	-22.9105556	-42.035000	Heliófila; caule decumbente; folhas verdes discolores; flores com cálice verde e corola	
CLEOMACEAE	Dactylaena	microphylla	Minas Gerais	-19.0050000	-43.776111	Subarbusto 40 cm alt., flores rosa-forte com centro amarelo, frutos verdes.	
CLETHRACEAE	Clethra	scabra	Rio de Janeiro	-22.4363889	-42.505000	Terrícola, heliófila, folhas dicolores, verdes na face adaxial e albacentas na face abaxi	
CLETHRACEAE	Clethra		Minas Gerais	-20.2102778	-43.839722	Arbusto, 2-2,5m; botões brancos	
CLUSIACEAE	Clusia	arrudea	Minas Gerais	-20.0891666	-43.472778	Arbusto de 1,5 m. alt.; Flore brancas com cheiro adocicado, latecente; Látex branco.	
CLUSIACEAE	Clusia	criuva	Minas Gerais	-19.2902777	-43.567222	Arbusto, ca. 3m alt., latescente; frutos imaturos verdes	
CLUSIACEAE	Clusia	criuva	Rio de Janeiro	-21.8633333	-41.906667	Terrícola, heliófila. Folhas marcadamente discolores, glabras. Pedicelo verde/vináceo.	
CLUSIACEAE	Clusia	criuva	Rio de Janeiro	-21.9433333	-41.988611	Terrícola e saxícola, heliófila. Caule castanho cinéreo, folhas discolores verdes, nervu	
CLUSIACEAE	Clusia	fluminensis	Rio de Janeiro	-22.9491666	-42.071945	Arbusto, heliófilo. Folhas sub coriáceas. Comum na área. Frutos ainda jovens, verdes. I	
CLUSIACEAE	Clusia	fragrans	Rio de Janeiro	-21.8669445	-41.913333	Terrícola, heliófila. Folhas glabras, marcadamente discolores. Pedicelo verde claro, cá	
CLUSIACEAE	Clusia	hilariana	Rio de Janeiro	-22.2166667	-41.584444	Arbusto com cerca de 3,50 m de altura, heliófila, caule e folhas com resina aromática, f	
CLUSIACEAE	Clusia	hilariana	Rio de Janeiro	-22.2175000	-41.586111	Arbusto com cerca de 4,0 cm de altura, heliófila, caule com resina aromática, folhas cr	

Figure 41 Search for traits in the JABOT database. Source (extracted rom JABOT database, 2018)

There was found that 239 species have in their recorded characteristics, traits as spines, cartaceous leaves, trichomes and succulence, but all of them have just one or two of them (e.g. *Gaultheria eriophylla* presents cartaceous leaves and stem with trichomes), this information is the input for the Species Distribution Modelling for the Mata Atlântica. From all those species registered in the JABOT database there were found that six species that presented between 10 and 30 entries which have in their description traits like cartaceous leaves and trichomes. Other potential species and traits (e.g Fam. Cactaceae species like *Brasiliopuntia brasiliensis, Pereskia aculeata* and *Pilosocereus arrabidae*) that present spines and succulent stem; just had one record per species which is not sufficient to make a model with them.

The six species selected to elaborate the SDM were: DC. *Clidemia biserrata* (28 entries, presented trichomes); DC. Cogn. *Leandra reversa* (22 entries- presented trichomes), Cogn. *Leandra nianga* (11 entries presented trichomes); D. Don Cogn. *Tibouchina heteromalla* (16 entries presented trichomes); Lem. *Vanhouttea* calcarata (14 entries presented cartaceous leaves and trichomes); and A.St.-Hil. *Erythroxylum citrifolium* (11 entries presented cartaceous leaves).

7.4.2 Search for botanical groups and traits indicators in the field

Next are shown the tables of traits per species, in order to summarize the obtained data, it is presented an example of one table per individual and its species with the measured traits; since the only characteristics that showed variation were Leaf Area-LA, Leaf Slenderness -LS, and Leaf Thickness-LT. In the other traits like sclerophylly and bark aspect were not evidenced interspecific variations.

As example it is shown a table with the species *Actinostemon verticillatus* Table 16; the obtained data (highlighted in light blue and bold type letter); indicate as an example the results of LA, LS, and LT for that individual (e.g Ind N°: 4839); which are compiled in a small table below the other; with the LA, LS, and LT data obtained from the other individuals of the same species. Table 16.

The compiled tables of the other species are shown as well, Table 17 and the tables per species are presented in the Annex Section.

Table 16 Traits collected for the species Actinostemon verticillatus Source (Guarín Diego, 2018)

Place: Fazenda Imburi	**Parcel N° 45**	**DBH(cm):** 8.5	**Height of the Tree:** 9 m	**Date:** DD 07 MM 05 YY 2018 **Hour of the day:** 10:30	**Coordinates:** **Lat: 21°19'40.29"S** **Long: 41° 6'4.73"W**	**Elevation (M.A.S.L) 53 m**
Species: *Actinostemon Verticillatus*	**Ind N°: 4839**					

Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **7 m**															
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	14.20	35.12	11.46	18.03	13.38	15.36	34.91	44.52	13.21	20.93	8.10	11.53	38.81	42.55	25.75	**347.86**
Leaf Slenderness Index (Ratio Leaf Length/Leaf width)	2.64	2.63	2.81	2.23	2.06	3.07	2.60	2.74	2.41	2.26	1.80	2.29	2.34	4.20	3.99	**40.10**
Thickness (mm)	0.19	0.22	0.18	0.21	0.17	0.2	0.23	0.18	0.2	0.2	0.18	0.17	0.19	0.19	0.18	**2.89**
Leaf surface	Type of leaf: Simple (**x**) Composed ( )															
	Natural occurrence of trichomes: Yes ( ) No (**x**) If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undeveloped trichomes due to conditions like (disease, adverse climate conditions, etc.)															
leaf consistency	Sclerophyllous: Rigid___ Cartaceous ___ Coriaceous_**x**__ papiraceous__ Membranaceous___															
Bark-Rind aspect	Striated_**x**__ Fissured__ Papiraceous ___ Plaques___Scales__ smooth___															
Trunk or Branch Stem surface	Trichomes: Yes __ No_**x**_															
	Absence of thorns, spines or prickles __**x**__															
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __															

Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
4839	**347.86**	**40.10**	**2.89**
1137	370.38	56.25	2.83
1142	563.03	36.29	2.86
1162	269.11	56.49	2.73
1184	278.95	58.89	2.78
TOTAL	**1829.33**	**248.01**	**14.09**

Table 17 Compiled tables of the measures of the analyzed species, Source (Guarín Diego, 2018)

Measured traits for *Alseis pickelii*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1182	728.92	45.15	1.73
Ap2	619.221	44.23	1.87
Ap3	397.322	48.90	1.88
Ap4	731.92	44.02	1.87
Ap5	616.11	42.49	1.88
TOTAL	**3093.493**	**224.79**	**9.23**

Measured traits for *Astronium concinnum*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1151	1159.798	18.95	2.09
Ac2	1352.509	20.98	1.95
Ac3	1162.798	18.84	1.78
Ac4	1159.498	18.91	2.11
Ac5	1162.50	18.83	2.12
TOTAL	**5997.101**	**96.51**	**10.05**

Measured traits for *Chrysophyllum lucentifolium*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1062	174.061	38.67	2.49
1091	183.008	37.11	2.64
1164	177.061	35.47	2.79
2616	240.263	34.67	2.93
309	250.022	34.36	3
TOTAL	**1024.415**	**180.30**	**13.85**

Measured traits for *Copaifera lucens*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1881	1500.672	27.63	1.87
1126	1597.124	27.35	2.02
244	1554.62	18.55	2.04
276	1433.104	22.05	2.04
474	1375.632	22.75	1.88
TOTAL	**7461.152**	**118.35**	**9.85**

Measured traits for *Melicoccus oliviformis subsp. Intermedius*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1293	675.91	35.45	2.97
1825	678.91	34.62	2.82
1829	476.556	30.80	2.47
2676	173.079	28.02	2.61
2640	176.079	27.10	2.58
TOTAL	**2180.534**	**156.01**	**13.45**

Measured traits for *Metrodorea nigra*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1085	309.88	40.22	3.4
1077	475.97	34.63	3.35
1095	380.07	38.29	3.59
Metn	706.48	43.19	3.48
1105	331.17	27.03	3.46
TOTAL	**2203.57**	**183.35**	**17.28**

Measured traits for *Metternichia princeps*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
4830	262.43	39.74	2.27
4838	309.84	45.69	2.20
Mp3	454.63	41.68	2.07
Mp4	441.75	44.14	2.19
Mp5	382.13	39.56	2.25
TOTAL	**1850.77**	**210.81**	**10.98**

Measured traits for *Pseudopiptadenia contorta*			
Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1882	787.68	25.41	0.57
526	786.18	25.49	0.59
4849	789.18	25.30	0.61
486	786.33	25.48	0.61
333	789.93	25.25	0.56
TOTAL	**3939.31**	**126.93**	**2.94**

Measured traits for *Senefeldera verticillata*			
Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1119	604.58	38.54	3.22
1116	468.38	38.43	2.97
1118	370.03	40.38	3.03
1102	655.08	33.85	2.97
1084	589.58	46.96	2.71
TOTAL	**2687.64**	**198.16**	**14.9**

Measured traits for *Trichilia lepidota*			
Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1296	2130.39	19.95	1.56
2777	2131.89	19.92	1.71
2754	2135.64	19.51	1.71
Tl4	2132.64	20.27	1.64
Tl5	2160.39	20.26	1.66
TOTAL	**10690.93**	**99.91**	**8.28**

Measured traits for *Trigoniodendron spiritosanctense*			
Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1094	125.19	36.10	1.60
1848	128.19	34.27	1.76
2639	280.10	36.53	1.78
2719	283.40	35.16	1.75
312	139.07	43.72	1.77
TOTAL	**955.96**	**185.79**	**8.66**

7.4.3 Measures per Selected Trait

Leaf area (LA)

Regarding adverse climate events like drought, for instance, along a timescale, the LA can show responses to drought considering the development of the leaf. In a slowly intensifying drought, plants modulate their leaf areas and thereby adjust the loss of water from the canopy to the size of the supply in the soil; and a greater leaf area index will ensure that water that would otherwise be evaporated directly from the wet soil surface is being used by the plant (Passioura, 1996).

In general leaf traits determine water losses, and are therefore closely related to drought tolerance (Tardieu 2005 in Lopez-Iglesias et al., 2014), and it has been widely studied that a high LA and SLA[4] in woody species implies a greater surface-volume ratio and, consequently, makes them prone to greater water losses. This has been evidenced in accentuated dry conditions, and drought stress in regions along the world; like the Mediterranean region of Spain and Jordan (Lopez-Iglesias et al., 2014 ; Al-tawaha et al., 2017) the tropical forest of Ghana (Amissah, 2014), the dry forests in Bolivia and Venezuela

[4] Specific Leaf Area (SLA) is the one-sided area of a fresh leaf, divided by its oven-dry mass, is used in growth analysis because it is often positively related to potential Relative Growth Rate (RGR), and with mass-based light-saturated photosynthetic rate, and negatively with leaf longevity, and to carbon investment in metabolism of important compounds such as tannins or lignin (Pérez-Harguindeguy et al., 2013).

(Poorter & Markesteijn, 2007 ; Sobrado, 1997), and in dry deciduous and wet evergreen forests of Mexico (Lohbeck et al.,2015).. As was mentioned the leaves were measured using the software Image- J to obtain the measure in mm^2 or cm^2. Figure 43.

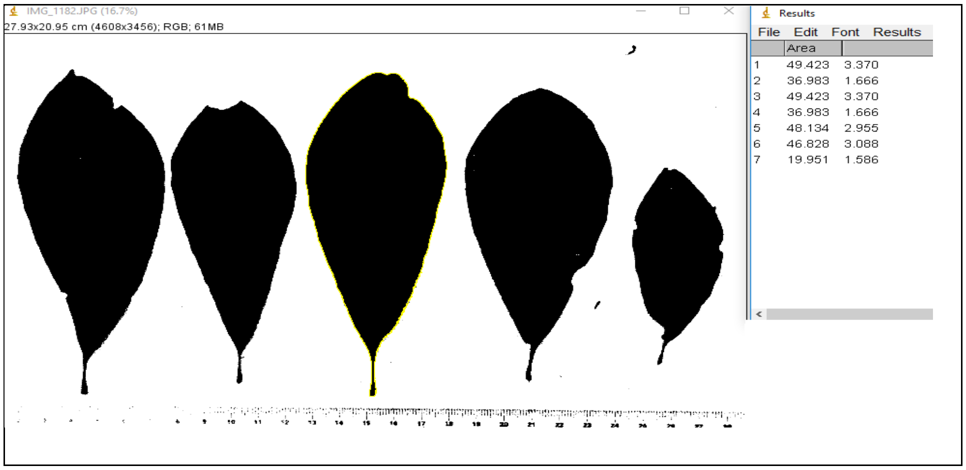


Figure 42 Leaf area measure using Image J. From *A pickelli.* Source (Guarín Diego, 2018)

There was noticed that the species with less LA according to the classification of Raunkiaer are the (Big Mesophylls Me-B 87.68-182.25 cm^2) *T spiritosanctense,* and *C lucentifolium;* followed by the (Small Macrophylls Ma-S 182.25-378.82 cm^2) *A verticillatus, M princeps, M oliviformis, M nigra, S verticillata,* and *A pickelii.* The (Medium Macrophylls-Ma-M 378.82-789.13 cm^2*)* *P contorta, A concinnum,* and *C lucens*, are also in small proportion, with *T lepidota* (Big Macrophyll Ma-B 789.13-1640.25 cm^2) Table 18.

Table 18 Leaf area in mm^2 of the selected species. Source (Guarín Diego, 2018)

Species	Total LA per species in cm^2	Dimension class
T spiritosanctense	95.96	Me-B
C lucentifolium	102.41	Me-B
A verticillatus	182.93	Ma-S
M princeps	185.07	Ma-S
M oliviformis	218.05	Ma-S
M nigra	220.35	Ma-S
S verticillata	268.76	Ma-S
A pickelii	309.34	Ma-S
P contorta	393.93	Ma-M
A concinnum	599.71	Ma-M
C lucens	746.11	Ma-M
T lepidota	1069.09	Ma-B

Leaf Slenderness (LS)

According to Dr. Apgaua[5] it is proposed that the hypothesized functional relevance of this trait, is that a “narrower” or slenderer leaf is, that can be an adaptative strategy to a better avoiding of heat or sun during dry seasons (thermal diffusion perhaps) and water saving; but maybe this is slight within a single ecosystem, and more pronounced across ecosystems. Thus many savanna or heath species may have narrower leaves, compared to forest species.

It has been found that compoundness of leaves also increases leaf cooling and control of water loss (Lohbeck et al., 2015 ; Sanaphre-Villanueva et al., 2016) which allows for a better convective cooling of the leaves (Poorter & Markesteijn, 2007). It can be observed that the leaves with a “narrower” aspect have an index up to “200 units” *M princeps, A pickelii*, and *A verticillatus;* followed by species with an index between “200 and 100 units” as *C lucens, P contorta, M oliviformis, C lucentifolium, M nigra, T spiritosanctense,* and *S verticillata.* The species *T lepidota,* and *A concinnum* present the lowest values of this index below “100 units”. Tabla 19.

Table 19 Slenderness Index of the selected species. Source (Guarín Diego, 2018)

Species	“Units” of Slenderness index
A verticillatus	248.01
A pickelii	224.79
M princeps	210.81
S verticillata	198.16
T spiritosanctense	185.79
M nigra	183.35
C lucentifolium	180.31
M oliviformis	156.01
P contorta	126.93
C lucens	118.35
T lepidota	99.91
A concinnum	96.51

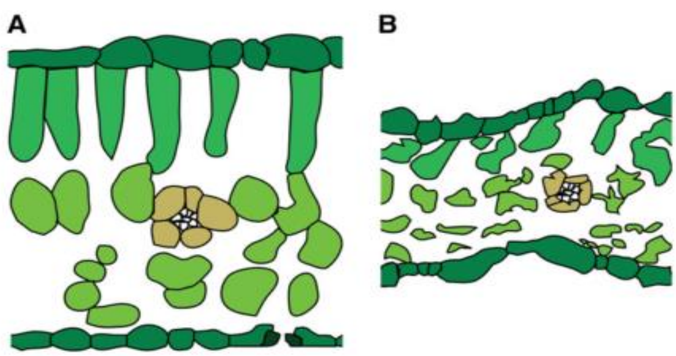
[5] Comments made by Dr. Deborah Apgaua (James Cook University) as an answer to the question of calculation of the leaf slenderness as an adaptation to drought. In https://www.researchgate.net/publication/43147003_Functional_traits_and_environmental_filtering_drive_community_assembly_in_a_species-rich_tropical_system/comments?focusedCommentId=5afdcd8f4cde260d15df5187&sldffc=0

Leaf Thickness

It is reported that the increase of mesophyll thickness enhances the photosynthetic capacity per unit leaf area due to the increment of chloroplasts in the tissues (Oguchi et al., 2005 in Micco & Aronne, 2012 ; Niinemets, 2001). Thick leaves require more energetic consumption to be constructed, and generally, are associated with a longer leaf lifespan (Reich et al., 1991; in Lohbeck et al., 2015).

The leaf thickness determines its consistency, giving the leaves thicker-fleshy aspects as succulence which allows storing high content of water, conferring resistance to drought and/or salinity; other types of resistant drought consistency are present in the sclerophyllous, cartaceous and coriaceous leaves (Díaz et al., 1998; U de La Plata, 2004; Ramírez, 2016)

The reduction of thickness by mild dehydration is a response to drought conditions, some studies under controlled conditions at physiological level have shown that the leaf shrinkage due to dehydration by drought in species of Mediterranean climate, could possibly influence the plant distributions in the ecosystems of this region (Scoffoni et al.,2014). **¡Error! No se e ncuentra el origen de la referencia.**44.



Sketches of a leaf of sunflower, fully turgid (A) versus a dehydrated leaf (B) the reduction in leaf thickness, cell thickness, and intercellular airspaces can be noticed in the dehydrated leaf.

Figure 43 Reduced Leaf Thickness due to Dehydration Source (Fellows and Boyer, 1978 in Scoffoni et al.,2014)

It is shown the average the thickness of the leaves in millimeters of each species, obtained from the total of each one; to categorize them according to (Rangel & Velásquez, 1997), The species with category A (0.005-0.15 mm) are *P contorta, T lepidota, T spiritosanctense, A pickelii, C lucens, A concinnum,* and *M princeps.* The species of category B (0.16-0.35 mm) are *C lucentifolium, A verticillatus, S verticillata, and M nigra.* Table 20.

Table 20 Thickness of the selected species. Source (Guarín Diego, 2018)

Species	Average Leaf Thickness in mm	Summation of Total Thickness in mm	Category
P contorta	2.94	0.04	A
T lepidota	8.28	0.11	A
T spiritosanctense	8.66	0.12	A
A pickelii	9.23	0.12	A
C lucens	9.85	0.13	A
A concinnum	10.05	0.14	A
M princeps	10.98	0.15	A
M oliviformis	13.45	0.18	B
C lucentifolium	13.85	0.18	B
A verticillatus	14.09	0.19	B
S verticillata	14.9	0.20	B
M nigra	17.28	0.23	B

Sclerophylly

In regions like the Atlantic Forest the sclerophyllous property of leaves results from the morphological and physiological characteristics of the species: evergreen tree leaves are harder, heavier and thicker, whereas adult leaves of deciduous trees have opposite characteristics (Garay et al., 2003) and in the Mata de Tabuleiros is common to find many species with both of these traits (Silva & Nascimento, 2001).

In the Mata de Tabuleiros are present populations of evergreen (sclerophyllous-hard leaves), semi-deciduous (intermediate sclerophyllous leaves), and deciduous (membranaceous leaves) species. When this vegetation establishes around a watercourse, it is accentuated the sclerophyllous character of the uniform arboreal cover; for instance, in the ciliary forest, the vegetation has less content of nitrogen but is more lignified than the vegetation in high altitudes. It has been found that an increase of the sclerophyllous character in some species is associated with less productivity caused to a less velocity of decomposition of organic matter (Garay et al., 2003).

Regarding the literature of the species, and corroborated on the field; this trait can be categorized being the most sclerophyllous or cartaceous: *T lepidota, A pickelii, S verticillata* respect to the other species that goes from coriaceous, *M oliviformis subsp. Intermedius,* and *A verticillatus*; to membranaceous, *P contorta, M princeps,* and *T spiritosanctense.*

Including species that may present more than one aspect, or intermedious, like *C lucentifolium, M nigra, C lucens,* and *A concinnum.*

Nevertheless, for the species with leaves that range various aspects (e.g from membranaceous to coriaceous) and others; there was recorded the most representative aspect for each species evidenced in the field. Table 21.

Table 21 Leaf aspect of the selected species Source (Guarín Diego, 2018) compiled from literature review

Species	Aspect of Sclerophylly	Aspect observed in the field
T lepidota	Cartaceous (Cervi, 2005)	cartaceous
A pickelii	Cartaceous (Tulli et al., 2013)	cartaceous
S verticillata	Cartaceous (Cordeiro et al., in Flora do Brasil 2020)	cartaceous
C lucentifolium	Cartaceous to subcoriaceous (Sossai & Alves-Araújo, 2017)	coriaceous
M nigra	Cartaceous to subcoriaceous (Pirani et al., 2002)	coriaceous
M oliviformis subsp. Intermedius.	Coriaceous (Fern K & Fern A in Tropical Plants Database, 2014)	coriaceous
A verticillatus	Coriaceous (Pscheidt & Cordeiro, 2012)	coriaceous
C lucens	Papiraceous to coriaceous (Costa, 2007)	coriaceous
A concinnum	Membranaceous to cartaceous (Luz, C.L.S et al., in Flora do Brasil 2020)	coriaceous
P contorta	Membranaceous (Morim, M.P in Flora do Brasil 2020)	membranaceous
M princeps	Membranaceous (Barbará & Avila Freire de Carvalho, 1996)	membranaceous
T spiritusanctense	Membranaceous (Lleras, E. 2015 in Flora do Brasil 2020)	membranaceous

It has to be considered that this classification is subjective, and to determine the grade of sclerophylly of the leaves is recommended to calculate the sclerophylly percentage through other parameters like Specific Leaf Weight -SLW (g / dm) (Veneklaas, 1985), and Succulence SUC = Water weight / foliar area unit according to the formula (SLW + SUC) x 100% (Rangel &Velásquez, 1997). Next, are shown the type of leaves per species. Figure 44.

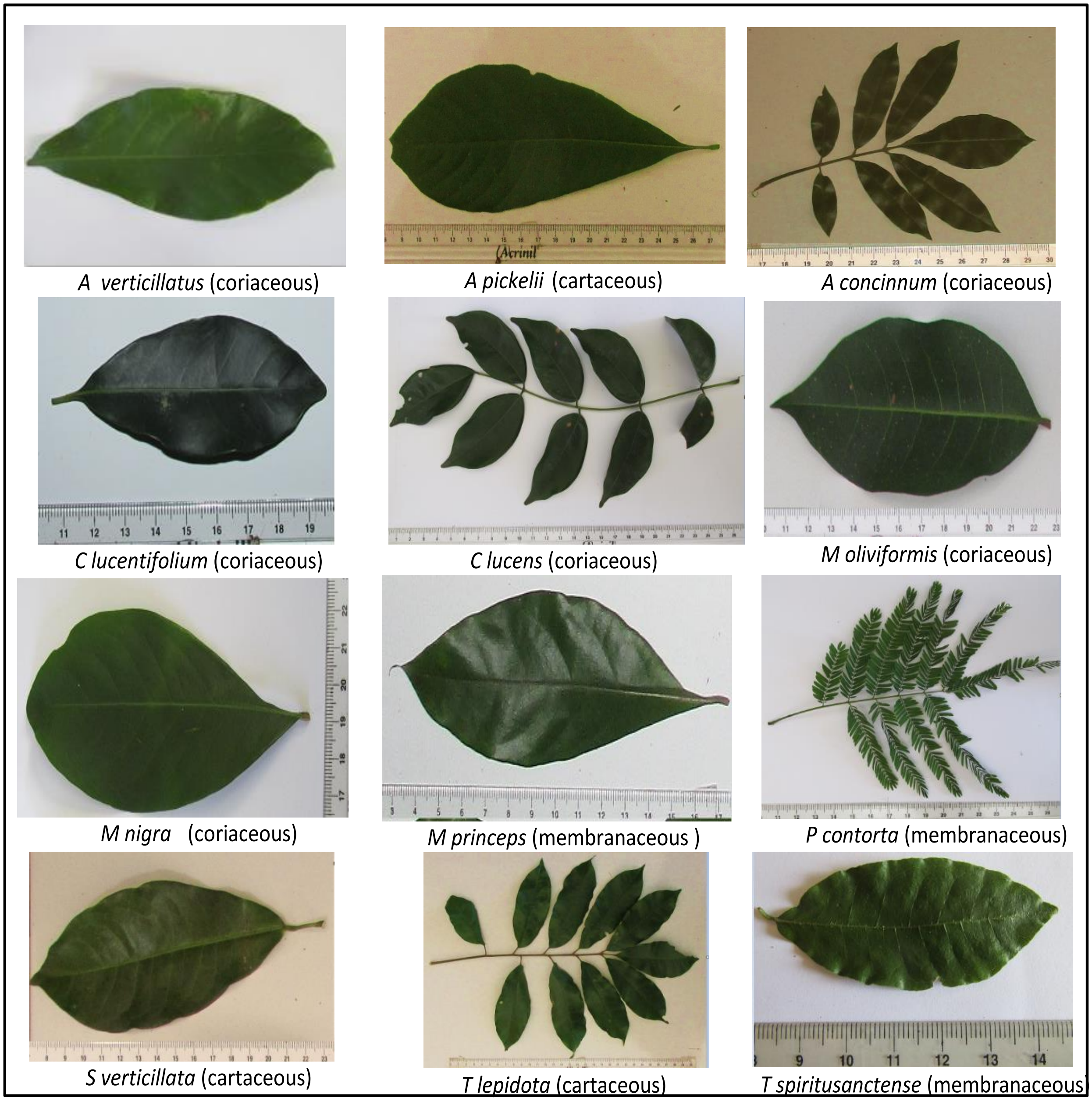


Figure 44 Types of leaves per sampled species Source (Guarín Diego, 2018)

Trichomes

In the leaf surface the absence of trichomes is defined as glabrousness, and the presence of some scales, glands or protuberances make it rough to the touch (Cabrera & Tillett, 2016); but also some leaves have an epidermic cover (cuticles-waxy coat) that can store water only slowly through this cover, this may avoid the physiological desiccation and water loss through evaporation (Pérez-Harguindeguy et al., 2013 ; Xu et al., 2009 , Markesteijn, 2010).

In relation to drought, it has been found that trichomes can protect plants by reducing absorption of solar radiation, which in turn reduces the heat load minimizing the need for transpirational cooling (Espigares & Peco 1995 in Huttunen et al., 2010). This trait was found in the following species and structures Figure 45:

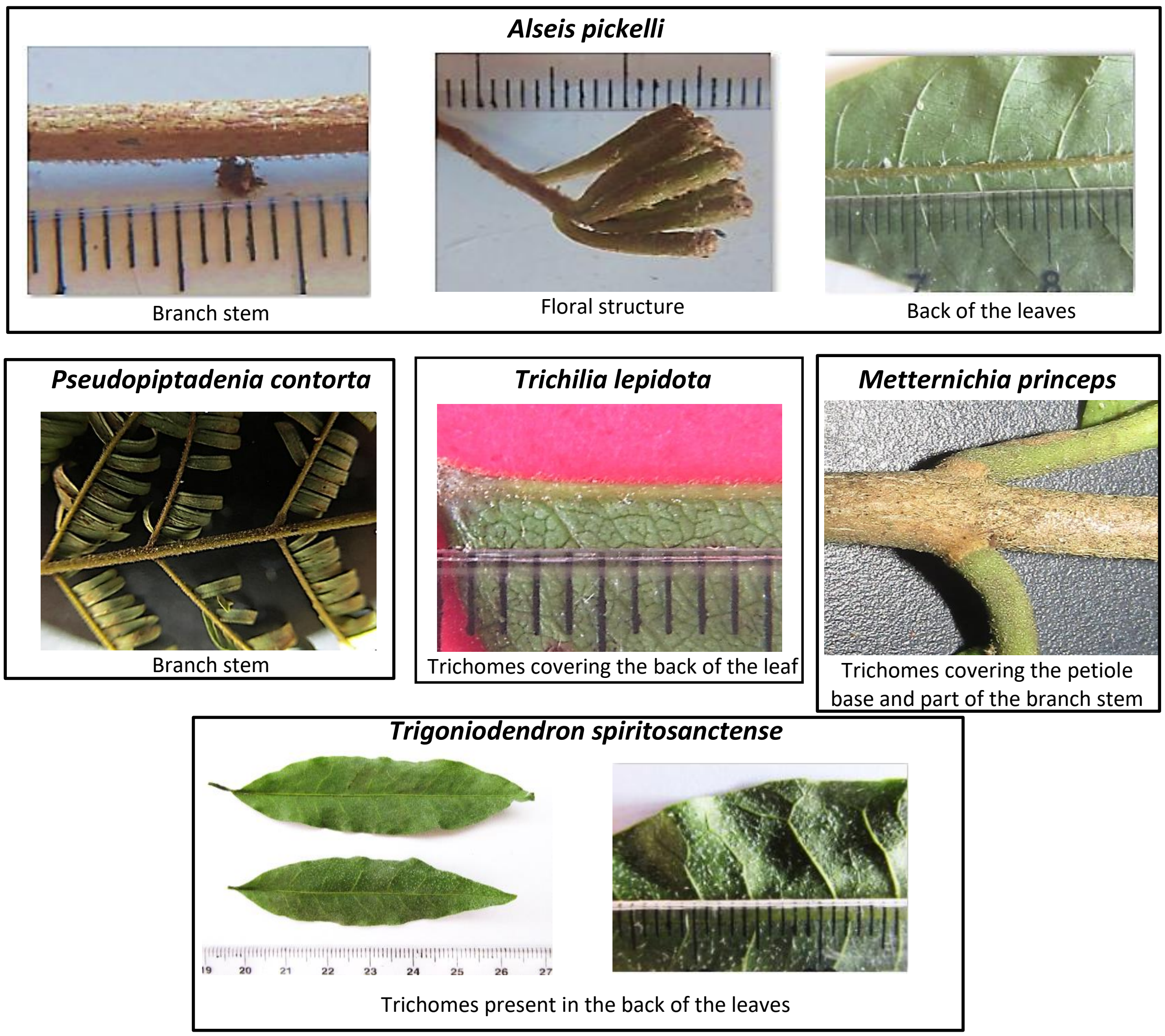


Figure 45 Trichomes present in some selected species Source (Guarín Diego, 2018)

In *A pickelli* this trait was evidenced in more structures than the species *P contorta*, *T spiritosanctense,* and *T lepidota*. The rest of the species did not present trichomes in the observed structures or another part of the plant.

Bark rind texture

It has been found that in Mediterranean climate drought, some large shrubs of Ericaceae which have fibrous bark, are more sensitive than ones with corky bark like the Fagaceae family (Barradas & Novo, 1999); and in tropical areas of Central America some tree genus like *Coccoloba sp* with a less smooth rind or bark and smaller leaves have low capacity of water retention due to the microrelief contrary to a rough and irregular surface that allows retaining more water (Gómez et al., 2012)

Taking in count the type of texture, this trait was observed in the selected species in order to see the type of bark; since as was mentioned above in some species a thin, and smooth bark or less rough bark can be considered as less tolerant to drought; instead a rough or thicker bark. The aspect of the bark rind texture was classified considering the manual of Morphological Notions for Botanical Identification (Martins da Silva et al., 2014) as follows. Figure 46:

**Astronium concinnum* (striated)

Actinostemon verticillatus (striated)

Alseis pickelii (plaques)

Copaifera lucens
striated (horizontal)

Chrysophyllum lucentifolium
(fissured)

Melicoccus oliviformis subsp. Intermedius (plaques)

*Metternichia princeps (*fissured with corky aspect)

Metrodorea nigra (striated)

Pseudopiptadenia contorta (striated soft aspect)

Senefeldera verticillata (fissured) not deep fissures

Trichilia lepidota (striated)

Trigoniodendron spiritusanctense (striated)

Figure 46 Types of bark species Source (Guarín Diego, 2018 and EMATER-RIO*)

Here can be observed that the species with fissured aspect, are *C lucentifolium*, *M princeps*, and *S verticillata;* the species with striated aspect which are the majority are *A concinnum, A verticillatus, C lucens, M nigra, P contorta, T lepidota,* and *T spiritosanctense*. 2 species *A pickelii* and *M oliviformis* present texture with plaques texture.

Spinescence

In places where plants have to withstand severe periods of drought, dry seasons, or arid environments these morpho-anatomical traits can be noticed due to the extreme reduction of leaves into thorns to dissipate heat and reducing water loss. This trait is associated also with reduced or succulent leaves or stems (Micco & Aronne, 2012), or stems covered by wax in sand dune ecosystems (Mahdavi & Bergmeier, 2016). This trait was not found in the selected species, but in some individuals of *T spiritosanctense* was evidenced the presence of small prickles, of < 5 mm long that according to (Pérez-Harguindeguy et al.,2013) are present in low density and does not impart strong pain. Nevertheless, due to the absence of this trait in the rest of the species is not considered for analysis; but it can be suggested that in this species this trait could be probably more a defense than a drought adaptation. Figure 47.

Figure 47 Evidence of spinescence in T spiritosanctense Source (Guarín Diego, 2018)

7.6 Selection of traits regardless taxonomic information

7.6.1 Assessment of the Selected Traits

Considering the proposed scale for the assessed traits Next, are shown the values given to each trait per species from the high drought tolerance to the little drought tolerance level in the following tables 22a, 22b, 22c, 22d, 22e, and 22f.

1	Characteristics of the traits that could confer little tolerance to drought
2	Characteristics of the traits that could confer little-medium tolerance to drought
3	Characteristics of the traits that could confer medium tolerance to drought
4	Characteristics of the traits that could confer high tolerance to drought

Table 22 Estimated Values per Analyzed Trait Source (Guarín Diego 2018)

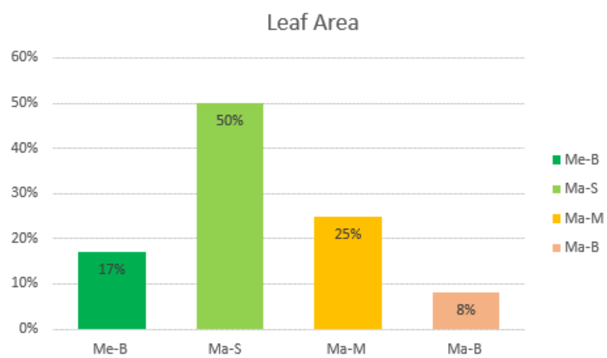
22a

LEAF AREA

Classification of leaves size *

4. (Me-B) Big Mesophyll: 87.68-182.25 cm^2
3. (Ma-S) Small Macrophyll: 182.25- 378.82 cm^2
2. (Ma-M) Medium Macrophyll: 378.82-789.13 cm^2
1. (Ma-B) Big Macrophyll: 789.13-1640.25 cm^2

*Source Modified from Raunkaier 1934.
(Department of Agronomy, Iowa State University 2018)



Species	Total LA per species in cm^2	Dimension class cm^2	Value
T spiritosanctense	95.96	Me-B	4
C lucentifolium	102.41	Me-B	4
A verticillatus	182.93	Ma-S	3
M princeps	185.07	Ma-S	3
M oliviformis	218.05	Ma-S	3
M nigra	220.35	Ma-S	3
S verticillata	268.76	Ma-S	3
A pickelii	309.34	Ma-S	3
P contorta	393.93	Ma-M	2
A concinnum	599.71	Ma-M	2
C lucens	746.11	Ma-M	2
T lepidota	1069.09	Ma-B	1

Here can be noticed that Ma-S leaves (3) are in more proportion 50% respect the others, followed by far of Ma-M (2) and Me-B leaves 25%, and Me-B 17% that offer a better tolerance; and one Ma-B with 8%. Which is observed in the distribution graph. Evidencing that apparently most of these species have developed leaves able to cope with dry seasons with a relative small leaf area, preventing water loss.

22b

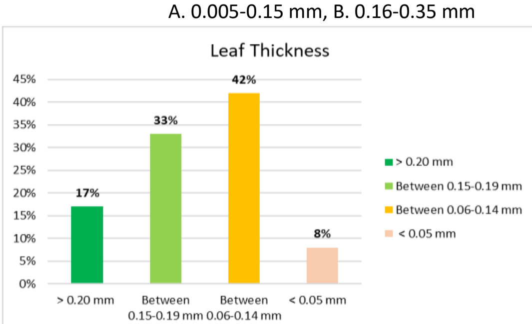
LEAF THICKNESS

Thickness in mm*

4. > 0.20 mm
3. Between 0.15-0.19 mm
2. Between 0.06-0.14 mm
1. < 0.05 mm

Category according to the thickness of the leaf lamina in mm (Tafur 1989 in Rangel & Velásquez, 1997):*

A. 0.005-0.15 mm, B. 0.16-0.35 mm



Leaf Thickness			
Species	Average Leaf Thickness in mm	Cathegory	value
M nigra	0.23	B	4
S verticillata	0.2	B	4
A verticillatus	0.19	B	3
M oliviformis	0.18	B	3
C lucentifolium	0.18	B	3
M princeps	0.15	A	3
A concinnum	0.14	A	2
C lucens	0.13	A	2
T spiritosanctense	0.12	A	2
A pickelii	0.12	A	2
T lepidota	0.11	A	2
P contorta	0.04	A	1

The leaf thickness show percentage of 42% for the value of (2) followed by values of (3) with 33%, being those two the main ones, this means that most of the leaves have not a gross mesophyll tissue; thicker leaves with values of (4) 17% with two species are in less proportion, as well as thin leaves with values of (1) 8% with one species *P contorta*

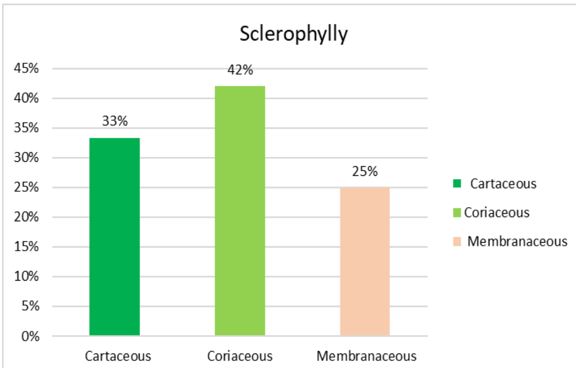
22c

SCLEROPHYLLY

Leaf aspect *

4. Cartaceous
3. Coriaceous
2. Papiraceous+ (This aspect was not evidenced)
1. Membranaceous

*Source (Rangel & Velásquez, 1997; Ramirez 2004)



Sclerophyllous character		
Species	Leaf texture	value
T lepidota	cartaceous	4
A pickelii:	cartaceous	4
S verticillata	cartaceous	4
M nigra	coriaceous	3
A verticillatus	coriaceous	3
M oliviformis	coriaceous	3
C lucentifolium	coriaceous	3
C lucens	coriaceous	3
A concinnum	coriaceous	3
P contorta	membranaceous	1
M princeps	membranaceous	1
T spiritusanctense	membranaceous	1

It can be noticed that the coriaceous leaves aspect was the most evidenced in the field 42% followed by the cartaceous 33%. It has to be reminded that some species present many aspects that may vary along the seasons, for that this is not a static character or parameter. The membranaceous leaves with 25% were evidenced in less percentage.

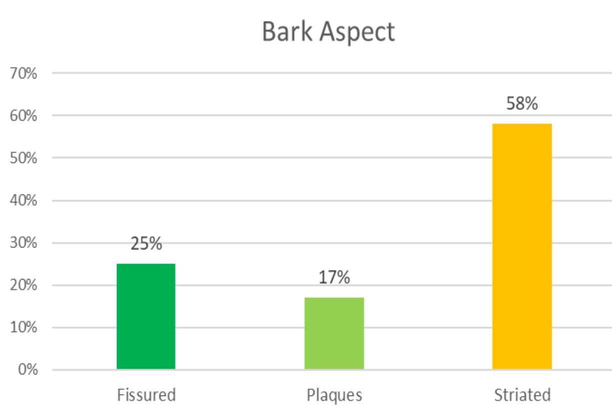
22d

BARK RIND ASPECT

Types of bark *

4. Fissured
3. Plaques
2. Striated
1. Smooth or papyraceous+ (Textures not evidenced in the field)

*Source (Martins da Silva, 2014)



Types of Bark-Rind		
Species	Bark Rind Aspect	value
M princeps	fissured	4
C lucentifolium	fissured	4
S verticillata	fissured	4
A pickelii	plaques	3
M oliviformis	plaques	3
M nigra	striated	2
A verticillatus	striated	2
C lucens	striated	2
A concinnum	striated	2
P contorta	striated	2
T spiritusanctense	striated	2
T lepidota	striated	2

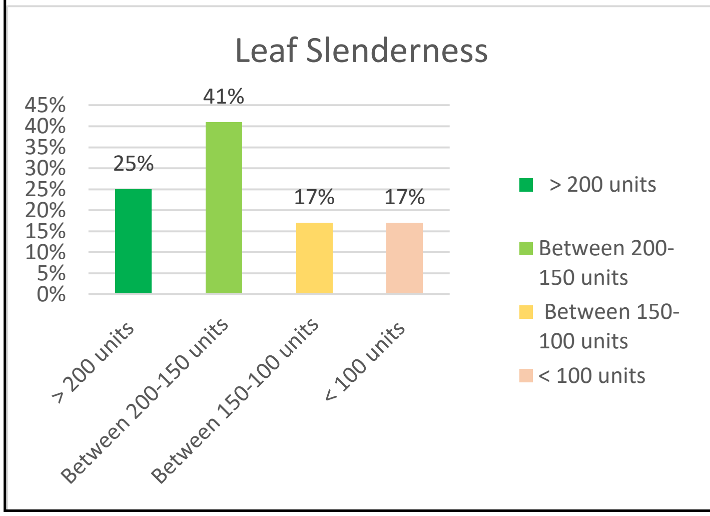
It can be noticed that 58% of the values corresponds to the striated aspect, followed by the fissured 25%. Nevertheless, the striated aspect has many variations from a “soft striated” to a “rough striated” whereby its water retention capacity varies also. And in less proportion is plaques with 17% that regarding their characteristics retain more water than other textures

22e

LEAF SLENDERNESS

"units of slenderness"

> 200 units
Between 200-150 units
Between 150-100 units
< 100 units



Leaf Slenderness Index		
Species	**"Units" of Slenderness index**	**Values**
A verticillatus	248.01	**4**
A pickelii	224.79	**4**
M princeps	210.81	**4**
S verticillata	198.16	**3**
T spiritosanctense	185.79	**3**
M nigra	183.35	**3**
C lucentifolium	180.31	**3**
M oliviformis	156.01	**3**
P contorta	126.93	**2**
C lucens	118.35	**2**
T lepidota	99.91	**1**
A concinnum	96.51	**1**

Here can be evidenced that a 41% could confer medium tolerance, followed by 25% high tolerance "narrower leaves" , and in less proportion 17% for values that confer low medium and low tolerance

22f

TRICHOMES

As was mentioned, there were just evidenced the presence or absence of this trait giving the value of 4 to presence (high tolerance) and 0 to absent (no valuation); showing that 5 species presented this trait in leaves and stem of branches. Aspects like density or length of the trichomes were not considered in this study.

Trichomes	
Species	**Presence/absence**
A pickelii	4
M princeps	4
P contorta	4
T lepidota	4
T spiritosanctense	4
A concinnum	0
A verticillatus	0
C lucens	0
C lucentifolium	0
M nigra	0
M oliviformis	0
S verticillata	0

After the valuation, the estimated weighting is compiled in a matrix in order to see the proportion of the traits that could confer more drought tolerance without regarding the species. Table 23 and Figure 48.

Table 23 Estimated Compiled Values per Trait Source (Guarín Diego 2018)

Estimated Compiled values per Trait						
Species	**Leaf Area**	**Leaf Slenderness**	**Leaf thickness**	**Sclerophylly**	**bark rind aspect**	**Trichomes**
1	4	4	4	4	4	4
2	4	4	4	4	4	4
3	3	4	3	4	4	4
4	3	3	3	4	3	4
5	3	3	3	3	3	4
6	3	3	3	3	2	0
7	3	3	2	3	2	0
8	3	3	2	3	2	0
9	2	2	2	3	2	0
10	2	2	2	1	2	0
11	2	1	2	1	2	0
12	1	1	1	1	2	0

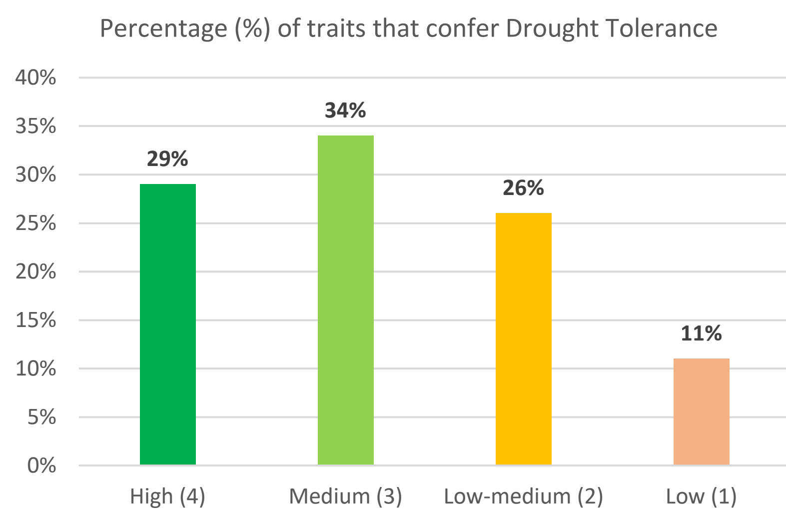


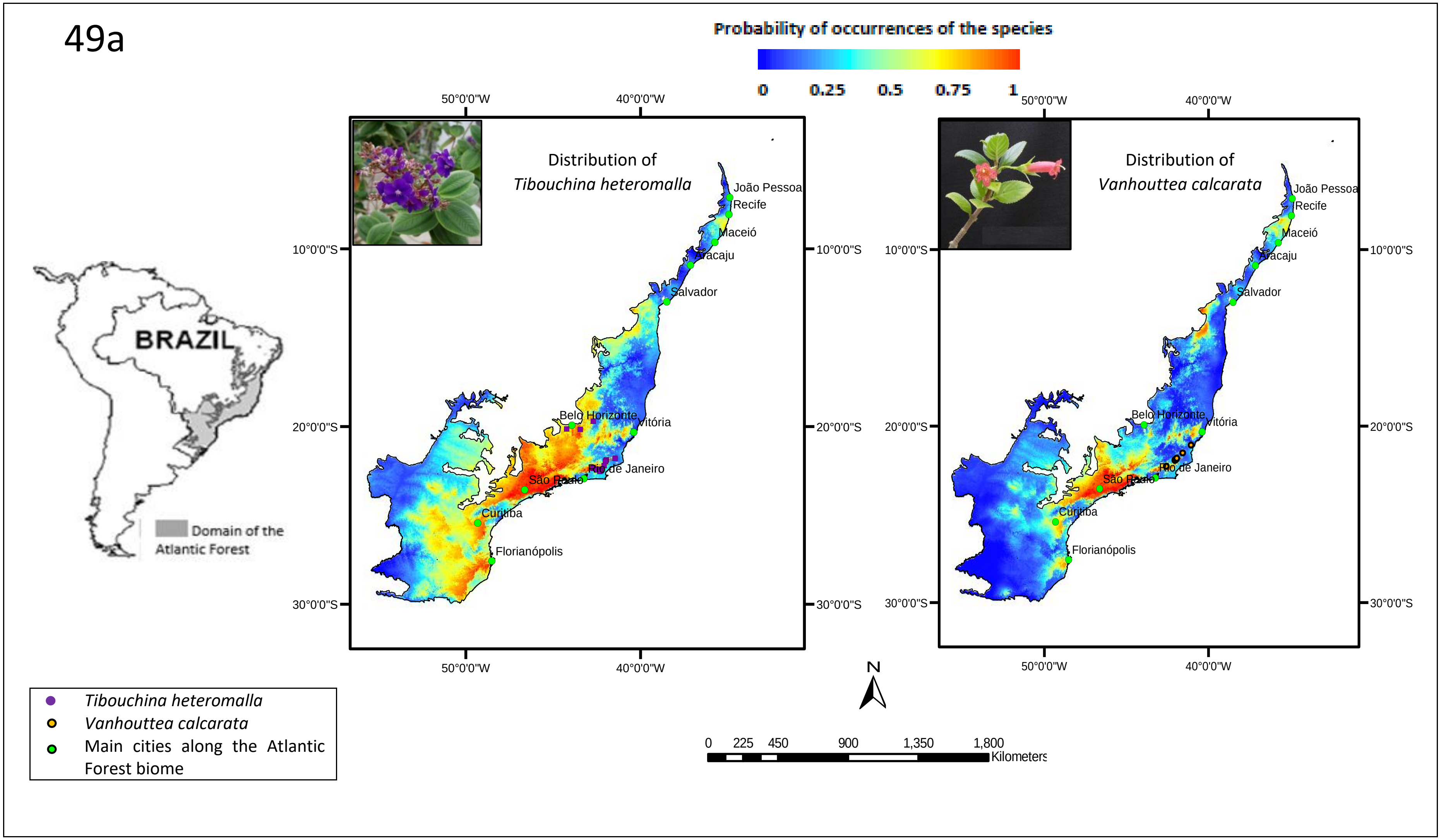
Figure 48 Percentage of Traits that Confer Drought Tolerance Source (Guarín Diego 2018)

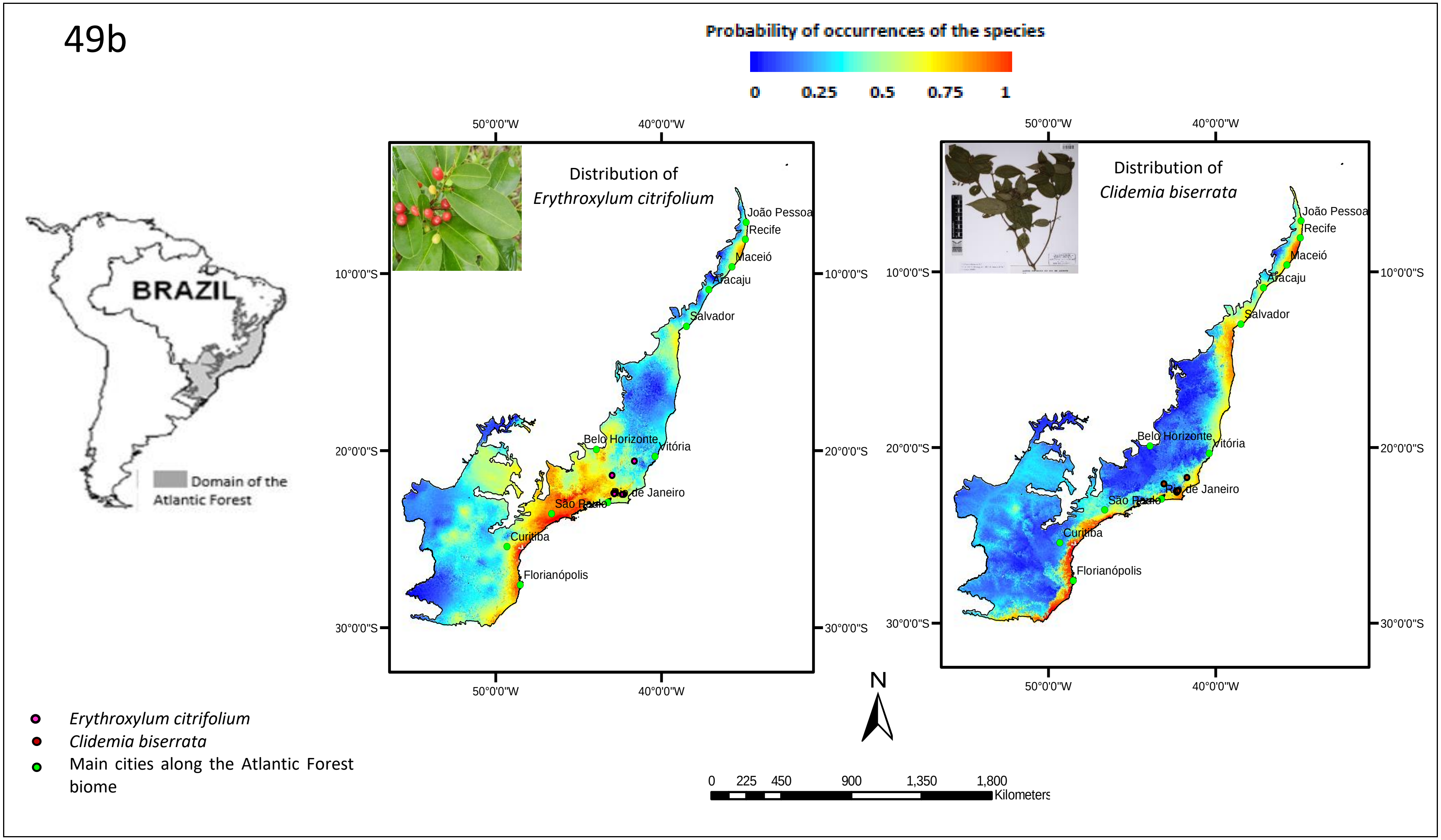
It can be observed that 34% of the traits could confer a medium tolerance to drought, followed by the traits that confer a high tolerance 29%, therefore at least 63% of recorded traits can be attributed a role in drought tolerance, giving a hint that the plants could be well adapted to cope with this phenomenon. Close to the medium values were the traits with low medium values of 26%, and low values 11 % correspondingly. Respect to the traits that showed a trend to high drought tolerance, considering their values, were the trichomes, sclerophylly, followed by the leaf slenderness, bark aspect, leaf area, and leaf thickness respectively. Those traits were present from 2 to 5 species; the traits that presented the medium tolerance values were the same that high values, except for the absence of trichomes. Those were present from 2 to 6 species. The traits with low medium values were the leaf area, leaf slenderness, leaf thickness, and bark aspect present from 2 to 7 species; and the traits with low values were present from 1 to 3 species.

7.7 Species distribution Modeling

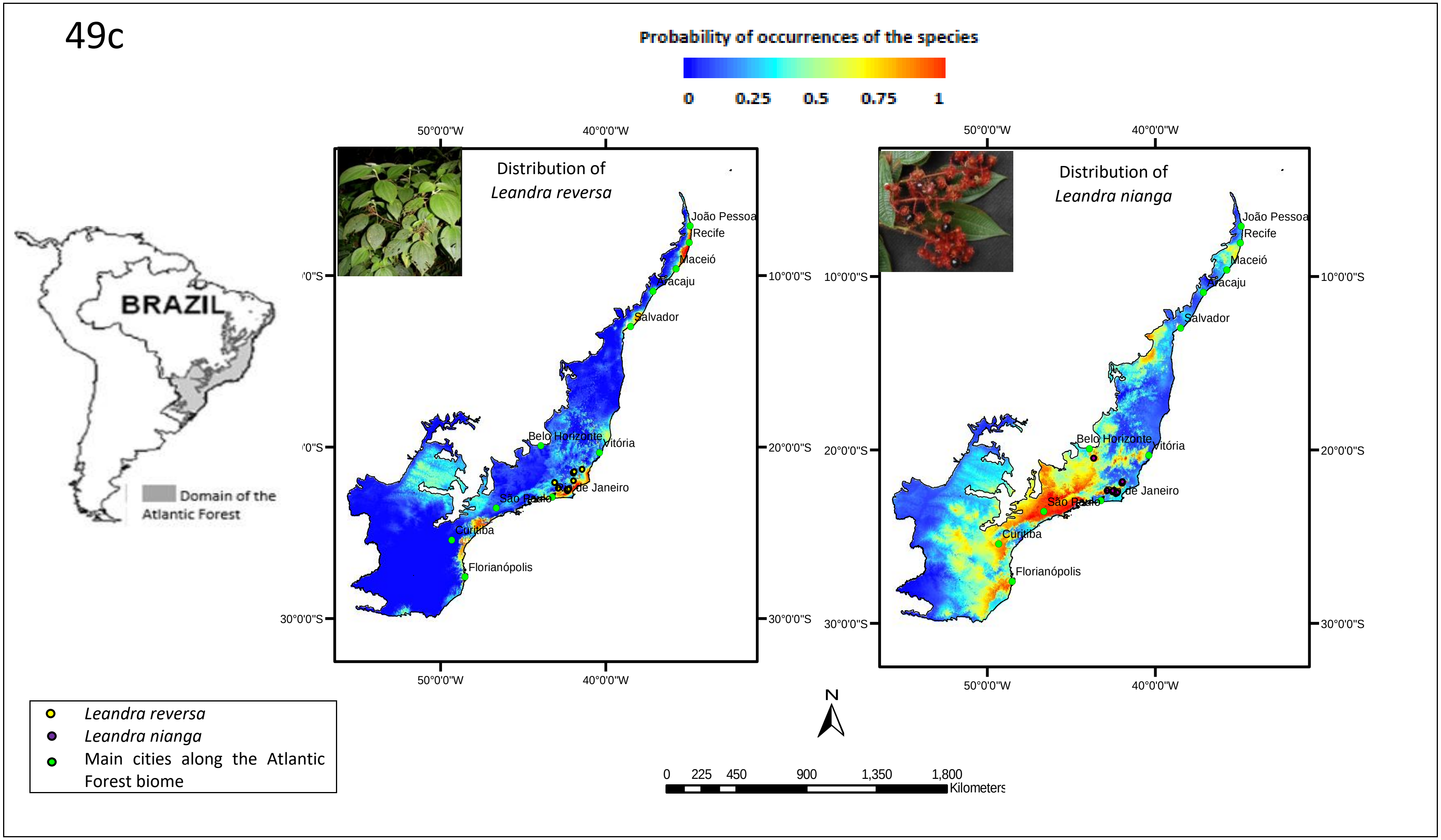
7.7.1 Species Distribution Modeling for Database Species

Based on the number of entries, the six species selected to run the model were: DC. *Clidemia biserrata Leandra reversa Leandra nianga Tibouchina heteromalla Vanhouttea calcarata Erythroxylum citrifolium* to run the models were used the variables regarding the work of (Raedig et al., 2010). Alt-altitude, BIO5- Max Temperature of Warmest Month, BIO15-Precipitation Seasonality "Coefficient of Variation", and BIO18-Precipitation of Warmest Quarter. Next it is shown the SDM per each species along the domain of the Mata Atlântica biome, and the SDM of all the sum of the species to observe the whole distribution of the selected species. Figures 49a *Tibouchina heteromalla* and *Vanhouttea calcarata*; 49b, *Erythroxylum citrifolium* and *Clidemia biserrata*; 49c, *Leandra reversa* and *Leandra nianga,* and 49d. Sum of all the species selected.


49a
Probability of occurrences of the species
0
0.25
0.5
0.75
1
BRAZIL
Domain of the Atlantic Forest
Distribution of
Tibouchina heteromalla
Distribution of
Vanhouttea calcarata
João Pessoa
Recife
Maceió
Aracaju
Salvador
Belo Horizonte
Vitória
Rio de Janeiro
São Paulo
Curitiba
Florianópolis
50°0'0"W
40°0'0"W
10°0'0"S
20°0'0"S
30°0'0"S
N
0 225 450 900 1,350 1,800
Kilometers
Tibouchina heteromalla
Vanhouttea calcarata
Main cities along the Atlantic Forest biome



49b
Probability of occurrences of the species
0 0.25 0.5 0.75 1
BRAZIL
Domain of the Atlantic Forest
Distribution of *Erythroxylum citrifolium*
Distribution of *Clidemia biserrata*
50°0'0"W
40°0'0"W
10°0'0"S
20°0'0"S
30°0'0"S
João Pessoa
Recife
Maceió
Aracaju
Salvador
Belo Horizonte
Vitória
Rio de Janeiro
São Paulo
Curitiba
Florianópolis
N
0 225 450 900 1,350 1,800
Kilometers
Erythroxylum citrifolium
Clidemia biserrata
Main cities along the Atlantic Forest biome


49c
Probability of occurrences of the species
0
0.25
0.5
0.75
1
BRAZIL
Domain of the Atlantic Forest
Distribution of Leandra reversa
Distribution of Leandra nianga
50°0'0"W
40°0'0"W
10°0'0"S
20°0'0"S
30°0'0"S
João Pessoa
Recife
Maceió
Aracaju
Salvador
Belo Horizonte
Vitória
Rio de Janeiro
São Paulo
Curitiba
Florianópolis
Leandra reversa
Leandra nianga
Main cities along the Atlantic Forest biome
N
0
225
450
900
1,350
1,800
Kilometers

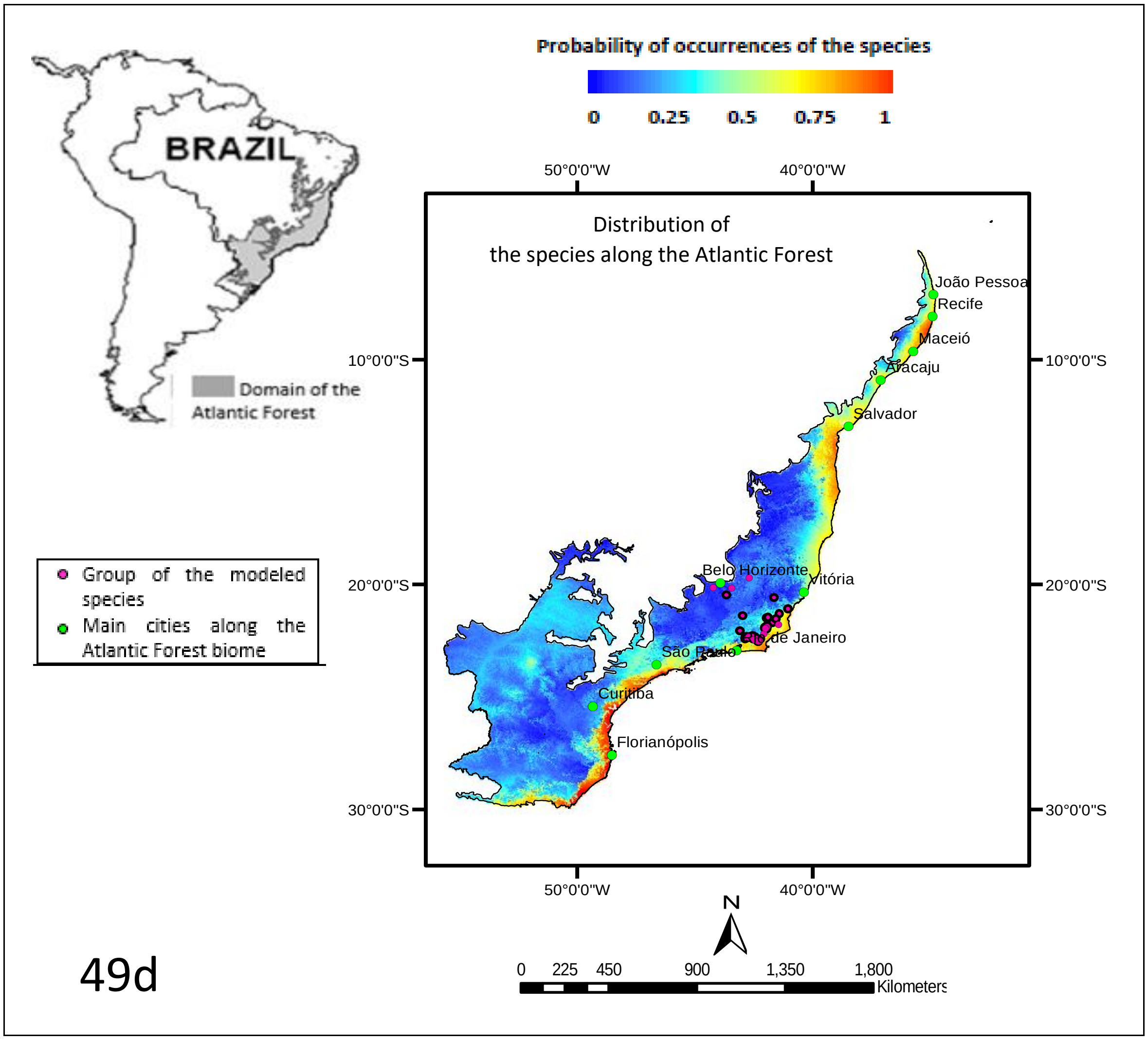


Figure 49 Species Distribution Modeling for the selected species. Source (Guarín Diego, 2018)

From the figures above the variable that most influenced in the distribution of the species was (**BIO5** -Max Temperature of Warmest Month) for the species *Leandra nianga, Vanhouttea calcarata, Tibouchina heteromalla, Leandra reversa,* and *Clidemia biserrata*; on the other side the variable (**BIO 18** -Precipitation of Warmest Quarter) influenced the distribution of *Erythroxylum citrifolium*. (See Maxent models per species in Annex Section). It can be observed that the suitable conditions of distribution for those species are mainly located to Rio de Janeiro, São Paulo, and Belo Horizonte and in stripes to the south to the cities of Curitiba and Florianópolis; to the north of the biome it can be observed also some spots in part of Salvador to João Pessoa at the northeast.

7.7.2 Species Distribution Modeling for trait species analyzed in the field

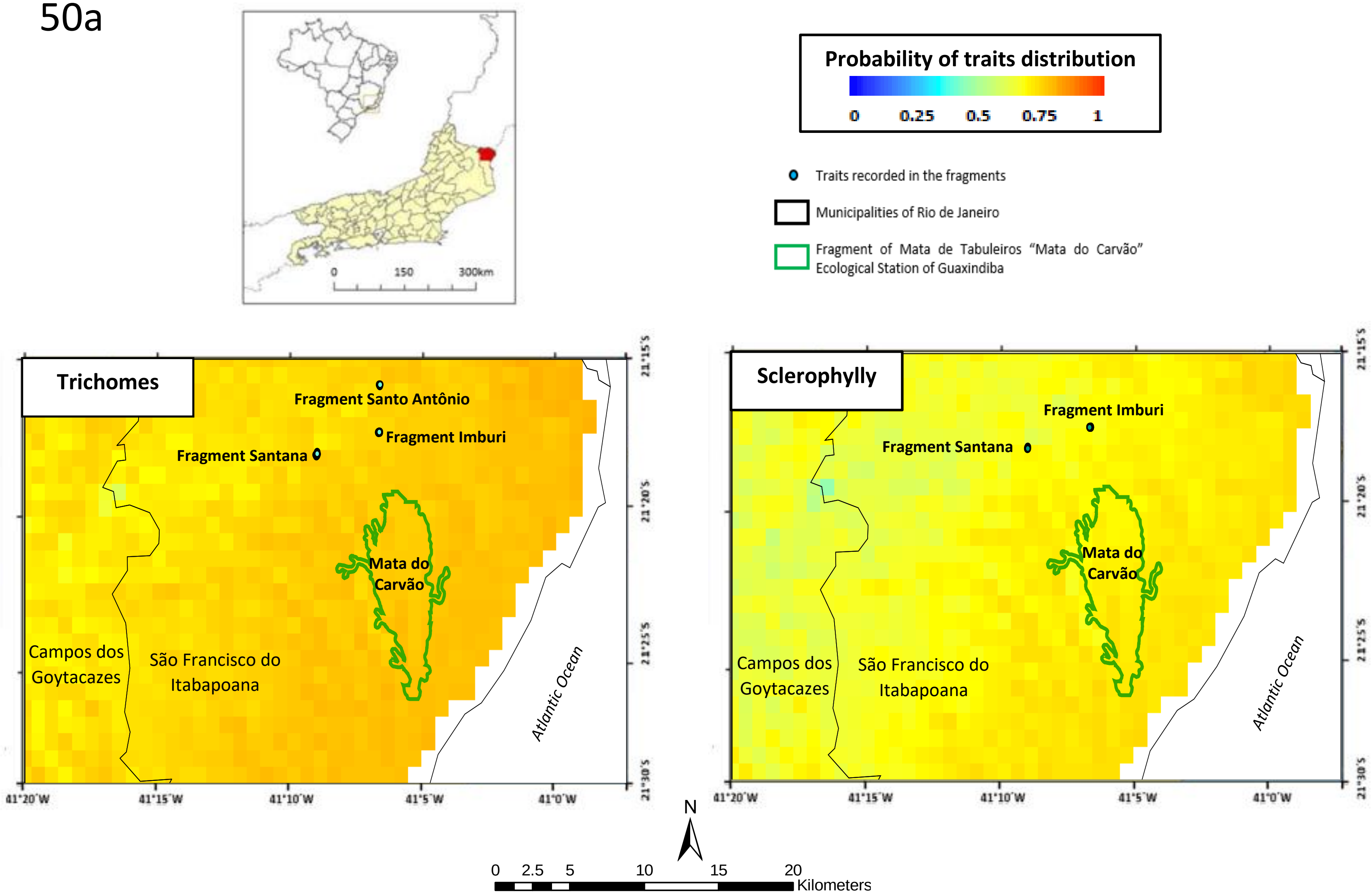
The traits modelled were those that were assessed and obtained values of (4 -high drought tolerance) those were: Presence of trichomes, fissured bark, cartaceous leaves, leaf thickness > 0.20 mm, a slenderness index > 200 units "narrower leaves", and leaf area between 87.68-182.25 cm^2 [Me-B-Big Mesophyll] "smaller leaves". There were used between 10 and 25 entries per modeled trait. Each (✓) represents 5 entries, those were present in the following species. Table 24.

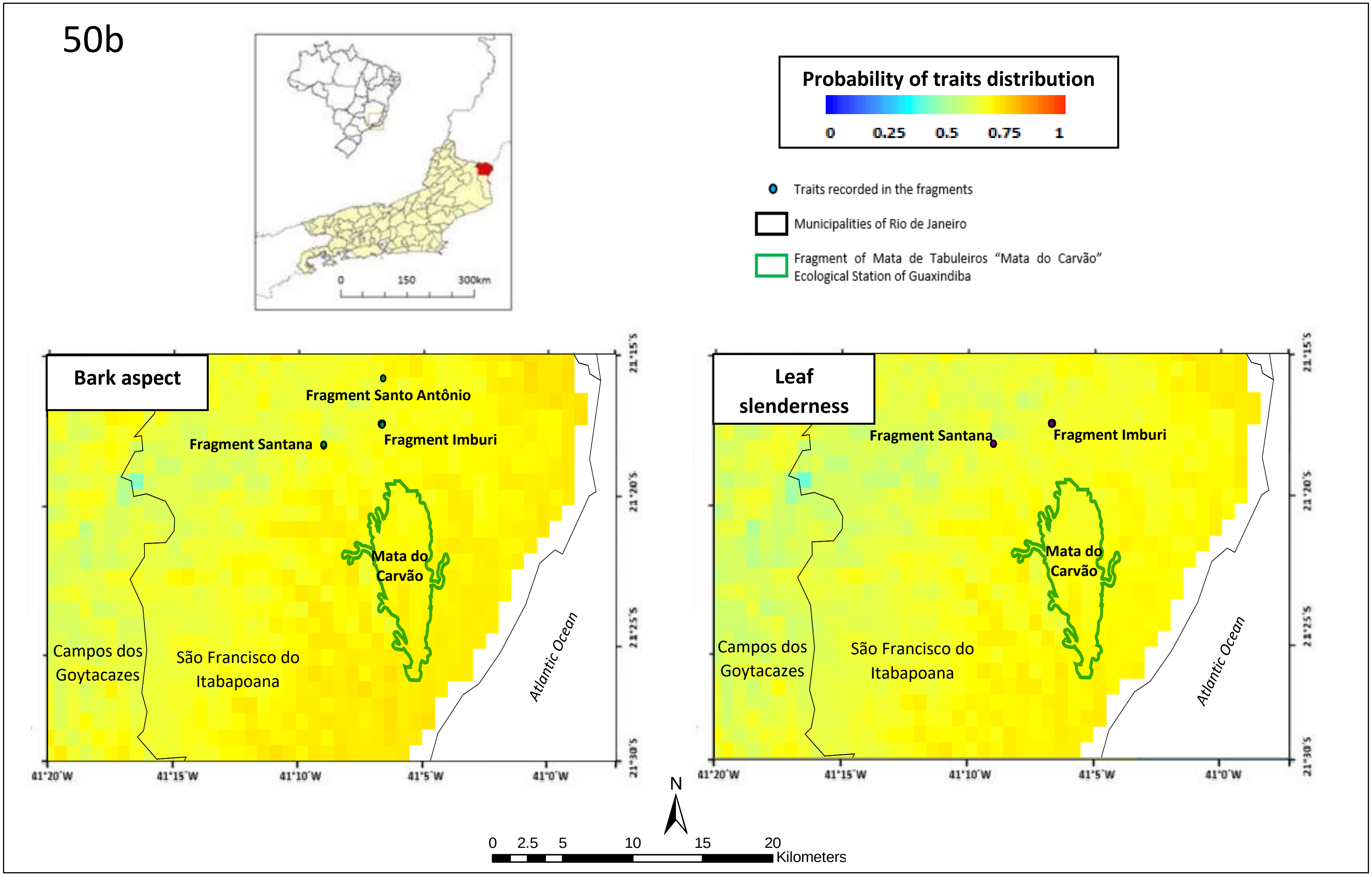
Table 24 Selected traits to elaborate the SDM for Mata de Tabuleiros. Source (Guarin Diego, 2018)

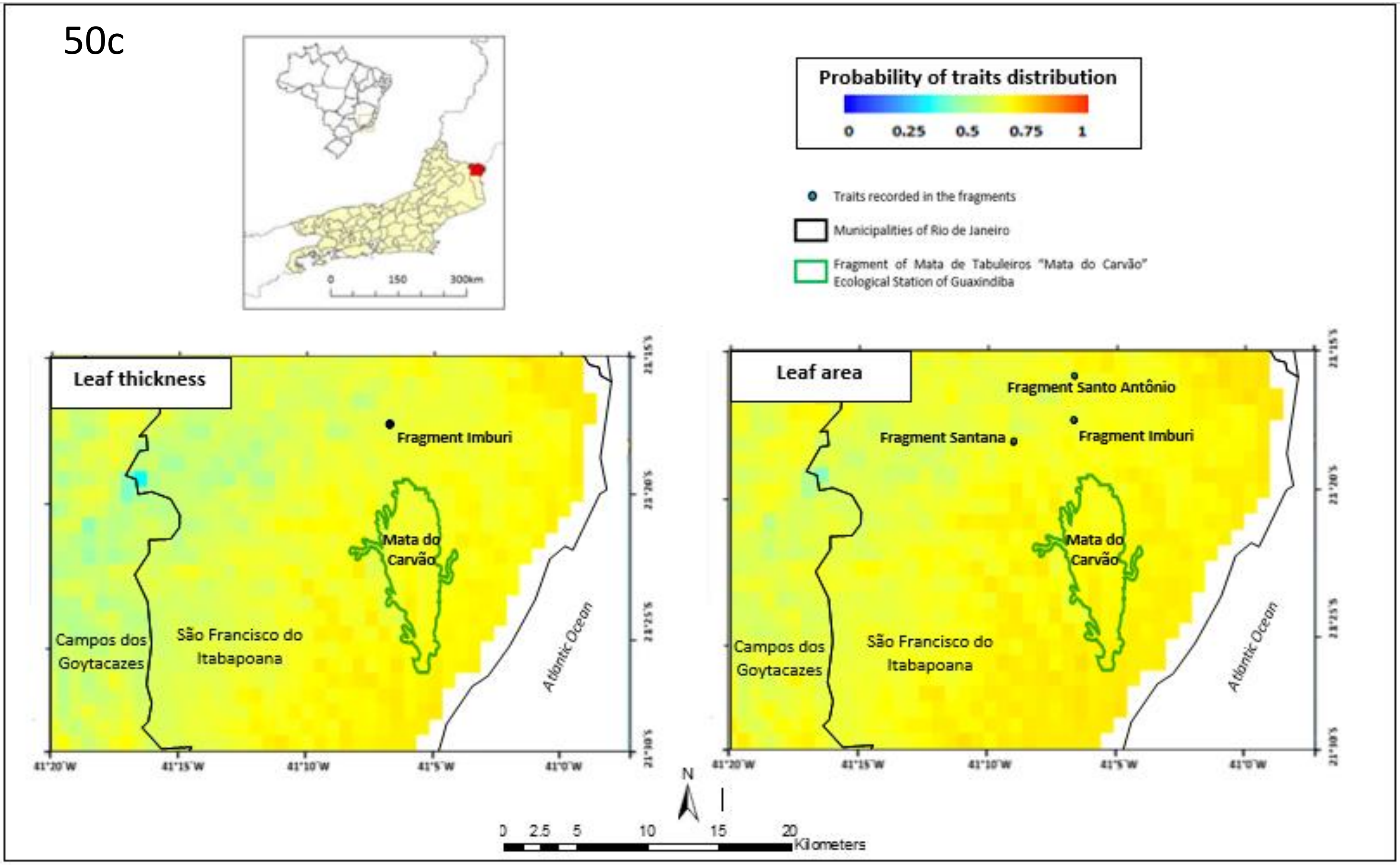
Species \ Traits	Leaf Area	Leaf Slenderness	Leaf thickness	Sclerophylly (cartaceous leaves)	Bark aspect (Fissured bark)	Trichomes
A concinnum				✓		
A pickelii		✓		✓		✓
A verticillatus		✓				
C lucentifolium	✓				✓	
M nigra			✓			
M princeps		✓			✓	✓
P contorta						✓
S verticillata			✓	✓	✓	
T lepidota				✓		✓
T spiritosanctense	✓					✓

For this SDM were used the variables Alt-altitude, BIO5- Max Temperature of Warmest Month, BIO15-Precipitation Seasonality "Coefficient of Variation", BIO18-Precipitation of Warmest Quarter. Next it is shown the SDM per trait in the fragments of the Mata de Tabuleiros taking as reference the "Mata do Carvão" as the bigger fragment in the area; the SDM for the whole sum of recorded traits in the study area. Figures 50a (trichomes and sclerophylly); 50b (bark aspect and leaf slenderness); 50c (leaf thickness and leaf area); and 50d (the sum of all the distribution of traits in the study area).

50a


Probability of traits distribution
0
0.25
0.5
0.75
1
Traits recorded in the fragments
Municipalities of Rio de Janeiro
Fragment of Mata de Tabuleiros "Mata do Carvão" Ecological Station of Guaxindiba
0
150
300km
Trichomes
Fragment Santo Antônio
Fragment Imburi
Fragment Santana
Mata do Carvão
Campos dos Goytacazes
São Francisco do Itabapoana
Atlantic Ocean
Sclerophylly
Fragment Imburi
Fragment Santana
Mata do Carvão
Campos dos Goytacazes
São Francisco do Itabapoana
Atlantic Ocean
N
0 2.5 5 10 15 20
Kilometers


50b
Probability of traits distribution
0 0.25 0.5 0.75 1
Traits recorded in the fragments
Municipalities of Rio de Janeiro
Fragment of Mata de Tabuleiros "Mata do Carvão" Ecological Station of Guaxindiba
0 150 300km
Bark aspect
Fragment Santo Antônio
Fragment Santana
Fragment Imburi
Mata do Carvão
Campos dos Goytacazes
São Francisco do Itabapoana
Atlantic Ocean
Leaf slenderness
Fragment Santana
Fragment Imburi
Mata do Carvão
Campos dos Goytacazes
São Francisco do Itabapoana
Atlantic Ocean
41°20´W 41°15´W 41°10´W 41°5´W 41°0´W
21°15´S 21°20´S 21°25´S 21°30´S
N
0 2.5 5 10 15 20
Kilometers



50c
0
150
300km
Probability of traits distribution
0
0.25
0.5
0.75
1
Traits recorded in the fragments
Municipalities of Rio de Janeiro
Fragment of Mata de Tabuleiros "Mata do Carvão" Ecological Station of Guaxindiba
Leaf thickness
Fragment Imburi
Mata do Carvão
Campos dos Goytacazes
São Francisco do Itabapoana
Atlantic Ocean
Leaf area
Fragment Santo Antônio
Fragment Santana
Fragment Imburi
Mata do Carvão
Campos dos Goytacazes
São Francisco do Itabapoana
Atlantic Ocean
N
0 2.5 5 10 15 20
Kilometers

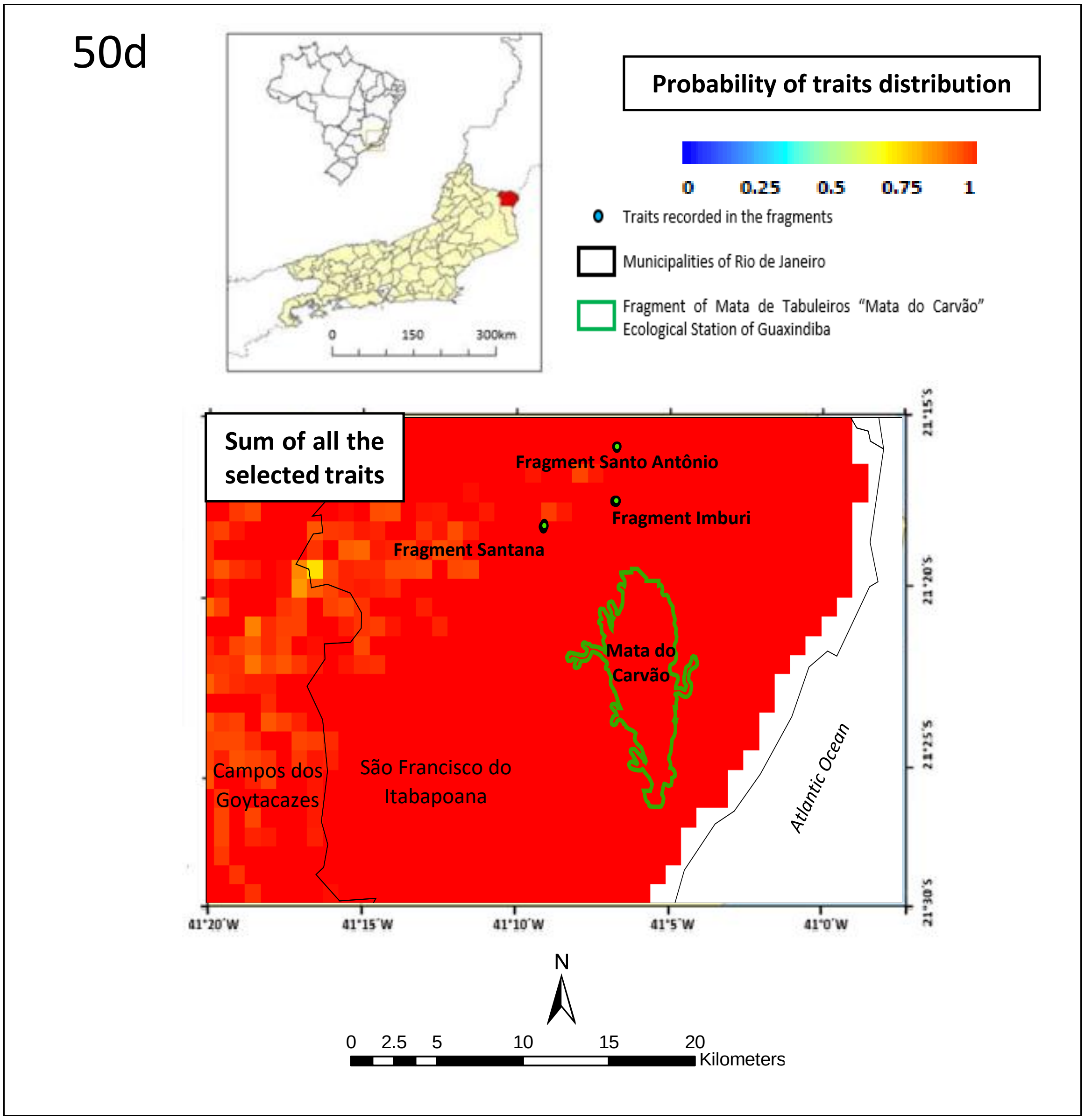


Figure 50 Species Distribution Modeling for the selected traits (Source Guarin Diego, 2018)

In all the analyzed traits, the variable that most influenced the distribution of the traits were (**BIO15-**Precipitation Seasonality) followed by (**BIO18-**Precipitation of Warmest Quarter) (See Maxent models per traits in Annex Section) not all the traits were located in the remnants as can be observed, also the occurrences of the traits apparently show a better distribution form the inner part of the area to the coast, the traits that show a better are more distributed in the area are the trichomes and sclerophylly; followed by the bark texture, leaf area, leaf slenderness, and leaf thickness; nevertheless the differences between these latter four are not easy to detail.

7.8 Effects of Drought in the Vegetation of the Mata Atlântica

Regarding the consultations with local inhabitants and the experts, this is the compiled information about the impacts of drought in the Mata Atlântica biome. Considering the effects of drought in the vegetation, in the region of the Cerrado and the Mata Atlântica it has been detected, the effects in organs like leaf, roots, and stem especially in sensitive species like *Cecropia sp* (Imbauba), *Calophyllum brasiliense* (Guanandi), Mimosa *bimucronata* (Maricá); and also in resistant species to climate conditions, as *Paullinia cupana* (Peroba), *Senefeldera verticillata* (Guarapoca), *Goniohachis marginata* (Itapecuru), *Metrodorea nigra* (Guarataia); among others.

Additionally, it has been detected changes in the vegetation composition, being noticed a decrease of some representative pioneer and secondary species like *Aspidosperma polyneuron* (Peroba rosa), *Handroanthus albus* (Ipê amarelo), *Handroanthus impetiginosus* (Ipê Roxo), *Cariniana legalis* (Jequitibá Rosa), Lafoensia *glyptocarpa* (Mirindiba rosa); and others like *Goniohachis marginata* (Itapicuru), and sapucaia *Lecythis sp*. But also an increasing of Fabaceae species, also species we call "opportunists" some Euphorbiaceae like *Croton*. In areas of seasonal forest, near to beach regions is increased the presence of many Cactaceae species**.**

Other species foreign and natives, with invasive characteristics, have increased their presence in this biomes like Rabo de macaco *Hildewintera colademononis* (Cactaceae), *Dodonaea* (Sapindaceae), vassorinhas *Scoparia dulcis* (Asteraceae), Baleeiras *Cordia verbenacea* (Boraginaceae), and the presence of bamboos (Poaceae). Nevertheless, the origin of the species cannot be considered as a key factor that influences morphological adaptions to drought. However, an aspect to consider could be the change in the occurrence and degree of naturalization of exotic, drought-adapted plants (e.g. *Sansevieria trifascicata*, and some *Cereus* species) in Atlantic Forest (fragments) indicating more favorable (dryer) environmental conditions for competing out the native understorey flora.

All these characteristics have to be taken in count for further researches, considering the habitat of occurrence and distribution of the species and their adaptations; for instance there are many Asteraceae and Fabaceae species from the Atlantic forest biome, restricted to moist ombrophilous (mountain) forest (e.g. *Piptocarpha*), but others are indeed adapted to drought, like *Hymenaea courbaril* (as this species is semideciduous) but it is still occurring both in the Cerrado and Mata Atlântica biome. On the other hand, some species of

Fabaceae show drought and fire adaptions like deciduousness and suberose bark and are restricted to the Cerrado. Even the Cactaceae family, known for being drought adapted, comprises Atlantic forest species (e.g. *Pereskia aculeata, Rhipsalis spp.*) as well as Cerrado species (e.g. *Melocactus spp*.).

8.DISCUSSION

Regarding the available information in field protocols and consulted studies it can be confirmed that the amount of morphological functional traits that can be taken in account as potential drought indicators is considerable, and the group of traits to select, can be modified considering the scale of the study, also the species and the biome. Nevertheless, the use of morphological traits as drought indicators still considers usual trait as spines, thorns, sclerophylly, succulence; among others, for that including various types of traits can complement and enhance the researches aimed to understand better the relation of plant responses and climate events.

The available information as the JABOT database is an important source of information that compiles many records with characteristics along the Mata Atlântica biome that can can be considered as indicators for drought conditions, Nevertheless, was evidenced that some records do not have sufficient information that allows to characterized them, but its information gives a hint to look for more records and include them, this amount of information could address to investigate for other morphological indicators, which could be good biometric attributes to consider as well.

On the other side in the field this method is interesting because can be constituted at small scales in places of collect and monitoing that can be compared not also in the same type of vegetation, but others as well, for instance along an altitudinal gradient, also considering traits easy to assess and others that have not been studied in detail, like leaf slenderness or bark texture for this work; the expertise of the consulted researchers is also an important input that provides a guideline to carry out these studies.

The collect of traits following the field protocols allowed to organize the compiled information considering also the quantitative or qualitative categories for traits classification in order to assess them looking for the potential to use them as drought adaptative traits.

Regarding to the assessed traits, starting with the leaf area (LA), it is known that the leaf area is a characteristic that determines photosynthetic activity, but as was mentioned a bigger leaf area is related also with more surface prone to water loss as have been reported in many regions of Spain and Jordan (Lopez-Iglesias et al., 2014 ; Al-tawaha et al., 2017) the tropical forest of Ghana (Amissah, 2014), the dry forests in Bolivia and Venezuela (Poorter & Markesteijn, 2007 ; Sobrado, 1997) in dry and wet broad leaf tropical forests (Lohbeck et al.,2015). This was especially noticed in species with composed leaves *P contorta, A concinnum, C lucens*, and *T lepidota* all of them with medium and big macrophyll types. Nevertheless, the rest of the species are small macrophylls, except for *C lucentifolium,* and *T spiritosanctense* (Big mesophylls) with a small leaf area, which can be an adaptation to avoid water loss, considering that these species are semideciduous, these species do not invest much energy in leaf size due to the seasonal leaf shedding that are submitted specially during dry seasons.

Leaf area is a trait that can be also analyzed using remote sensors for studies at large scale; approaches of this type are very useful since simplification is required for example in the case of global vegetation models. However, several other aspects of plant behavior and interspecifically variations of LA due to other factors require finer scale enquiries (Box 1996 in Cabido & Díaz,1997) like the one was made, to see which species could be more prone than others to water loss; considering other leaf traits soft or hard like Specific Leaf Area-SLA, physical strength of the leaves, hydric potential; among others.

Other leaf traits like the Leaf Slenderness (LS) that determines the “narrower” aspect of the leaves, was evidenced in the species *A verticillatus, A pickelli,* and *M princeps* that presented units upper to “200” all of them have simple leaves; this characteristic may provide a better avoiding of the heat of sun, and an adequate water of control status in extended dry seasons (Apgaua et al., 2015). Nevertheless, the species *A concinnum* and *T lepidota* presented the lowest values, below “100 units”, but their composed shape can confer them a better convective cooling of the leaves (Poorter & Markesteijn, 2007). The composed leaves species *P contorta*, and *C lucens* presented low-medium values. And all the composed leaf species were the same that presented a medium and high leaf area; but the relation between the LA and LS it has not been clearly established, regarding that one is independent of the other as was stressed out by Dr. Meave (See footnote in Slenderness index).

Respect to the other species that present index between “150 and 100 units” (medium values) most all of them have simple leaves. It has to be taken in count that this trait cannot be attributed to one or many botanical groups in specific, as was studied in the lowland tropical rainforest in north-eastern Australia (Apgaua et al.,2015), where species with composed leaves as *Castanospermum australe* (Fabaceae) showed similar values of LS, as other species with simple leaves like *Endiandra microneura* (Lauraceae), *Myristica globosa* (Myristicaceae), and *Syzygium graveolens* (Myrtaceae).

On the other hand, the mechanism that explains the avoiding loss of water, and reducing the transpiration rates in narrow leaves; is by reducing the size of the "boundary layer" which is a thin layer of still air hugging the surface of the leaf. This layer of air does not interfere with the transpiration, water vapor leaving the stomata must diffuse through this motionless layer to reach the atmosphere where the water vapor will be removed by moving air (The Biomimicry Institute, 2016). This can explain why the selected species with "narrower leaves" with units between 95 and 150 units may have better control of cooling and hydric regulation.

Regarding the thickness of the leaves it is shown that all the measures in mm were between the categories A (0.005-0.15 mm) B (0.16-0.35 mm) in all the species; however, those are low categories in the whole scale considering F (> 0.66 mm) as the highest (Rangel & Velásquez, 1997), where succulent leaves can be included. It has been evidenced that across plant communities, thicker leaves are associated with evergreen plants, confirming leaf thickness as a predictor of leaf lifespan (Kitajima & Poorter, 2010 in Lohbeck, 2015), which in fact is corroborated in the species *M nigra, S verticillata* common in this biome, but also in the evergreen ombrophilous dense forest, that showed the thicker consistency among the species (> 0.20 mm), which can be considered as a conservative leaf water economy adaptation (Soudzilovskaia et al., 2013); regarding the proportion of leaf thickness in the selected species, it can be observed that most of the values of category A, confers a little medium tolerance; similar for category B a medium tolerance as well.

It has to be considered that other evolutionary and environmental drivers as shade, nutrient availability or herbivory can influence tougher and/or thicker leaves (Maréchaux et al., 2015) for that leaf thickness can be used as a proxy for estimating hydraulic vulnerability, and a potential drought adaptation (Scoffoni et al., 2014).

The sclerophyllous aspect of the leaves is generally associated with the leaf toughness and thickness, condition which reduces the leaf shrinkage and dehydration under drought

(Scoffoni et al. 2014), this may apply to evergreen species like *S verticillata;* but *A pickelii*, and *T lepidota*, are deciduous and semideciduous, and all of them have a cartaceous aspect. On the other side, the coriaceous aspect is predominant in deciduous or evergreen species. The membranaceous *P contorta, M princeps,* and *T spiritosanctense* presented the lowest values of thickness, as was expected. The use of some structural traits like leaf thickness, toughness and other leaf traits related to sclerophylly; still remains open to discussion, since the links of plant responses to water stress are needed to explore more drought tolerance patterns in tropical forests (Maréchaux et al., 2015), also to corroborate and study the grade of sclerophylly in order to set aside the subjective categories, it can be suggested to use the calculation of the sclerophylly index.

The bark thickness has a role in heat insulation protecting the plant against wildfires, and hydric regulation (Cornelissen et al.,2003; Casanoves et al., 2011) being the "roughness" the aspect to classify this trait, considering the habitat and distribution of the species. Following the used scale, it can be inferred that species like *M princeps* which present a fissured-like corky aspect, could retain more moist in the bark surface due to its irregular texture; the other species like *C lucentifolium* and *S verticillata* present the same aspect but with less deep fissures or ridges. Besides that, the species that present a plaque irregular aspect in the bark like *A pickelii,* and *M oliviformis* also shown some smooth exposed parts; the striated character present in the rest of the species has many variations that include presence of lenticels that confers a barely rough aspect, and species like *P contorta* and *C lucens* have a striated but smooth aspect, and it might be suggested that this aspect could confer less rough surface to retain moisture and probably making it prone to a greater water evaporation rate of the surface more than the species with rough bark texture.

Nevertheless, to support the role of the bark texture as water retainer there must be considered other variables associated like the access to light, water stress, also the percentage of retention of rainfall, intensity of precipitation, the degree of inclination and architecture of the branches, which is another trait to consider; besides the water storage rate of the canopy; among others (Gómez et al., 2012)

Even though lichens are not part of the bark were evidence in all the species, and can be suggested also as an annex trait for indication of environmental conditions, besides the presence of bromeliads and other epiphytes in the area, also the presence of lenticels could support this studying its density or its aspect at medium or long term as was suggested by Dr. Rodrigues in the interview.

Regarding the trichomes, is clearly known the role of this trait in plant protection against drought by hydric regulation of the plant, by reducing absorption of solar radiation, which in turn reduces the heat load minimizing the need for transpirational cooling (Espigares & Peco 1995 in Huttunen et al., 2010). They were found in the species *P contorta, A pickelii, T spiritosanctense, T lepidota* and *M princeps*, that presented with the lowest thickness values; consequently, can be suggested that this could be a compensative trait respect to the other species. These traits were more conspicuous in *A pickelli* and located in other structures besides the leaf like the branch stem than the other species that presented trichomes mainly in the leaves. It could be considered other characteristics of the trichomes (e.g. location, density, and length) in exhaustive studies that lead to a better understanding of the role of trichomes as drought adaptive trait.

Although the spinescence was not considered in the study, it was detected in some species like *Bactris* (Araceae), and other botanical groups like some Fabaceae, Rubiaceae, and Cactaceae, but in less proportion; also in woody lianas Fam. Malpighiaceae, Bignoniaceae; among others. Nevertheless, those traits were notorious and should be considered in researches for drought adaptation taken in count the representativeness and distribution of the individuals; especially in groups like lianas given their invasive character proliferating along the remnants and clearings.

Following that line, is inferred that the traits that generally presented the highest values in more proportion were the sclerophylly, leaf slenderness, and leaf area. If this valuation was made considering the species, could only reflect partially which one of them are better adapted but it has to be taken in count that there are other non-measured traits that could confer tolerance to drought conditions, additionally those are proxies that still are under research; for that, the addition of other soft and hard traits related to the density of canopy, leaf litter, stem, wood density, root biomass; among others, as was expressed by the consulted experts, is important to complement the studies in a group or traits useful to understand plant drought adaptations.

Other traits also stomatal density it would also be interesting to analyze as drought adaptive traits regarding of their changes in time and space through monitoring permanent plots of study, which could lead to formulating questions related to variations of morphological traits in species occurring in both biomes (Cerrado and Mata Atlântica), and if there are shifts in the occurrence (samples, specimens) of drought-adapted (Cerrado) species towards the Mata Atlântica biome within the last decades.

The presence of vascular epiphytes of families like Orchidaceae, Araceae and Bromeliaceae in the fragments are indicators of the environmental conditions of the area those groups are very sensitive to climate variations and other perturbations for that these fragments, which are currently protected and despite the impact to which they have been subjected still harbor diversity of flora and fauna. Nevertheless, one of the current threats is its proneness to drought events which have been occurring frequently registering hydrological drought during the last 7 years, impacting in other activities such as agriculture and livestock, which is why the government has focused on protecting these areas and bodies of water in the region as a measure of mitigation in the face of drought as natural hazard.

For instance, it has been noticed an increase in the duration of the period when plants are deciduous due to longer periods of drought, also changes in vegetation composition which causes an entry of species from other formations, and a reduction of local diversity and occurrence of other species. Changes in nutrient cycling conditions and soil impoverishment are elements that tend to increase the frequency of deciduity for instance. However, there is still missing information about the adaptive responses in evergreen as well as deciduous, and semideciduous species not only in biomes of the Cerrado and Mata Atlântica but also along the country.

According to Dr. Sattler, the characteristics of plants species under dry conditions, regarding the changes in the vegetation composition, and also the performance of foreign and native species, have to be considered, for further researches taken in count also their occurrence to provide information for potentially increasing drought and respective impacts. Hence, such data is a valuable scientific argument, together with other (climate) data, that action in terms of drought adaptation is needed. This can be done with a specific selection and plantation of more drought-adapted species public spaces and in afforestation activities in the Mata Atlântica region.

The study of functional traits is increasingly taking interest to apply them in projects or activities that aim to mitigate of drought; as an example can be stressed out the protection of watersheds and restoration of degraded areas planting pioneer species like *Cecropia sp* (Imbauba), *Inga sp* (Ingá) *Caesalpinia ferrea* (Pau de Ferro), *Cariniana legalis* (Jequitibá Rosa) carried out by EMATER-RIO in São Francisco de Itabapoana; and other projects related with monitoring and restoring degraded areas and riparian forests implemented by institutions like the UENF and UFSCAR.

Respect to the SDM for the database species has to be considered the date of the climatic variables were from 1950 to 2000; it was found that the variables that conditionate the distribution of the species considering the set which was BIO 5 the Max Temperature of Warmest Month (O'Donnell & Ignizio, 2012) this means that the maximum monthly temperature occurrence over a given year (time-series) or averaged span of years (normal) conditioned the distribution of the species *L nianga, T heteromalla, V calcarata, C biserrata, L reversa* during those five decades, and for *E citrifolium* was (BIO18-Precipitation of Warmest Quarter) which is the total precipitation during the warmest three months of the year, which can be useful for examining how such environmental factors may affect species seasonal distributions. The species that shown a better distribution from the highest (1) to the lowest (0) were *L nianga* 0.986, *T heteromalla* 0.981, *V calcarata* 0.975, *C biserrata* 0.974, *L reversa* 0.963 and *E citrifolium* 0.882

V calcarata, L nianga and *L reversa* have a low trend to be distributed to the north where there are more drought prone areas than the south. Others that shown the best pattern distribution to the south, others like *E citrifolium, C biserrata*, and *T heteromalla* are usual to find them in drought prone areas to the north and probably could be better adapted than the others.

The whole distribution of the species is focused in the southeast part specially in Rio de Janeiro and São Paulo where are the better conditions for the species occurrences. But this distribution of the species takes places, nowadays in less drought-prone areas respect to the north of the country where biomes like the Caatinga have been registered more events, as well as part of Cerrado and Mata Atlântica where are have been registered between 10 and 25 events during 2003 to 2015 (see Figure 1 Ecosystems of the Atlantic Forest) also the distribution of the species is along the main types of vegetation like biomes to of pioneer formations to the coastlines, ombrophilous dense forest, deciduous and semidecidious seasonal forests, part of highland fields and ombrophilous mixed forests, but are more distributed to the seasonal Semideciduous forest which is located in altitudes no more than 500m over the sea level and also in the evergreen ombrophilous dense forest which have characteristically vegetation with broad and perennial leaves to the south of the Mata Atlântica where are more conditions of humidity than the north of this biome.

Regarding the SDM for the selected traits in the “Mata de Tabuleiros” it can be made an estimative appreciation of the distribution of the traits in this area, taking as reference the proximimity of the main remnant Mata do Carvão to the study area is the variable (BIO15-Precipitation Seasonality) this means that species distributions can be strongly influenced by variability in precipitation, this index provides a percentage of precipitation variability where larger percentages represent greater variability of precipitation (O’Donnell & Ignizio, 2012) Not all the traits were located in the remnants as can be observed, also the occurrences of the traits apparently show a better distribution form the inner part of the area to the coast, the traits that show a better are more distributed in the area are the trichomes 0.986 and sclerophylly 0.975 ; followed by the bark texture 0.968, leaf area 0.965, leaf slenderness 0.962, and leaf thickness 0.960; nevertheless the differences between these latter four are not easy to detail. Te sum of all traits show suitable conditions in all the area as was expected; but as is mentioned more records and include other variables are required to elaborate a more accurate model. Nevertheless, usual traits as trichomes and sclerophylly which are related with dry conditions tend to show a better distribution, for this they may be considered as potential drought traits.

Considering the time of the climatic variables analyzed is expected for the future to develop a model with different predictor variables and more recent; including more records in a better pronounced and visible gradient, which will allow to do a SDM for past and the future that it would be an important next stage to do a SDM, and find a trend or pattern in distribution of indicator species, over time. Also, mention that can be used methods with a smaller sets of species data using different resolution if information is missing or if is to heterogeneous to work with it (Raedig et al., 2010).

9.CONCLUSIONS

Studies in the Atlantic forest regarding functional and morphological traits that consider aspects such as ecological restoration, physiognomy, are important, since can also be guidelines to a good exploitation and management of forestry resources, but studies on functional features in relation to climate conditions are always required to be made at small scale in order to compare along a gradient orand also.

The functional traits used are the product of compile several protocols, which can be included new traits to measure that give more accurate information respect to the influence of climate based on plant responses. This type of studies must be done also considering the representativeness of the species in the field to have more records to assess and also for modeling.

The elaborated set of indicators included usual measured traits as spines, trichomes related with dry conditions, but by including other pool of traits as leaf slenderness or bark texture can give a hint of the response of the vegetation to cope with adverse climate conditions. Also the measures more specific for some trits e.g. sclerophyly index or SLA Specific Leaf Area; among others can be considered to complement the analysis enhancing the obtention of the information to study.

Due to the drought proneness of the area of Mata de Tabuleiros it is important to carry out studies directly in the field and species modeling in order to know the distribution of the species. The measurements of the obtained traits can be done more precise by including more records through monitoring plots in n that allow to make comparisons over a time scale (e.g months or years).

The species mentioned by the interviewed which are resistant to drought, also the most sensitive and foreign and naturalized should be subject of study for futher analysis that led to evidence how they could be distributed

Information such as the JABOT database and field protocols are basic inputs that allow selecting the traits to be evaluated depending on the habitat, the species and its ease or access to them to be analyzed.

To elaborate the SDM it should be considered the temporality of climate variables, which also allows models to be made of future distribution of species conditioned by different recently recorded climatic factors.

Other traits to consider are the semideciduousness and evergreen characteristics of some species, but in a biome like the Mata de Tabuleiros some species modulate and delay the leaf shedding, this is currently subject of some researchs in the north of Rio de Janeiro.

The developed methods in the field were adapted considering the characteristics of the vegetation, and are available to be updated and improved, including new methodologies of collection or another characteristics of the traits that have not been studied in detail.

Further studies can consider also traits or species like epiphytes as indicators of environmental conditions, at different levels of stratification, in order to study which of them could present resistant to drought conditions.

This set of indicators can be also an input for other projects that consider actions aimed to ecological restoration or recovery of degraded areas, also regarding the distribution of species with the SDM that can predict which areas are suitable for drought resistant species that could be protected as a measure of mitigation against drought.

REFERENCES

- Abreu, K. (2013). *Estrutura, Florística e Diversidade de Fragmentos de Floresta Estacional Semidecidual no Norte-Noroeste Fluminense*. State University of North Fluminense “Darcy Ribeiro”

- Abreu, K., Braga, J. M. A., Nascimento, M. T. M. T., Maria, K., Abreu, P. De, Marcelo, J., … Nascimento, M. T. M. T. (2014). Tree Species Diversity of Coastal Lowland Semideciduous Forest Fragments in Northern Rio De Janeiro State , Brazil Diversidade De Espécies Arbóreas Em Fragmentos De Floresta Semidecidual De Terras Baixas Costeiras No Norte Do Estado Do Rio De Janeiro , Br. *Bioscience Journal*, *30*(5), 1529–1550.

- Afonso, J. A. C. (2010). Floresta Estacional Semidecidual. Sèrie Ecosistemas Paranaenses, 8. Retrieved from http://www.meioambiente.pr.gov.br/arquivos/File/cobf/V5_Floresta_Estacional_Semidecidual.pdf

- Ahmad, P., & Mohd, R. W. (2014). *Physiological Mechanisms and Adaptation Strategies in Plants | Parvaiz Ahmad | Springer*. (P. Ahmad, S. Pratap, M. R. Wani, & G. D. College, Eds.) (Vol. 1). New York: Springer Science. Retrieved from http://www.springer.com/de/book/9781461485995

- Al-tawaha, A. R. M. R., Turk, M. A., Abu-Zaitoon, Y. M., Hmoud, S., Al-rawashdeh, I. M., Alnaimat, S., … Wedyan, M. (2017). Plants adaptation to drought environment. *Bulgarian Journal of Agricultural Science*, *23*(3), 381–388.

- Amissah, L. (2014). Functional Traits, Drought Performance, and the Distribution of Tree Species in Tropical Forests of Ghana. Wageningen University.

- Apgaua, D. M. G., Ishida, F. Y., Tng, D. Y. P., Laidlaw, M. J., Santos, R. M., Rumman, R., … Laurance, S. G. W. (2015). Functional Traits and Water Transport Strategies in Lowland Tropical Rainforest Trees. *Plos One*, *10*(6), e0130799. https://doi.org/10.1371/journal.pone.0130799

- Araus, J. L. (2002). Plant Breeding and Drought in C3 Cereals: What Should We Breed For? *Annals of Botany*, *89*(7), 925–940. https://doi.org/10.1093/aob/mcf049

- Baptista, A. (2009). Mata atlântica: uma abordagem geográfica. Nucleus, 6(1), 27–53

- Barradas, D., & Novo, G. (1999). Plant functional types and ecosystem function in Mediterranean shrubland. Journal of Vegetation Science, 10, 709–716.

- Beguería, S., Latorre, B., Reig, F., Serrano, S. (2018). SPEI Global Drought Monitor. Retrieved July 17, 2018, from http://spei.csic.es/map/maps.html#months=1%23month=5%23year=2018

- Berger, B., Parent, B., & Tester, M. (2010). High-throughput shoot imaging to study drought responses. Journal of Experimental Botany, 61(13), 3519–3528. https://doi.org/10.1093/jxb/erq201

- Bravo, A. (2013). Modelos para la predicción de la distribución de especies. Retrieved August 13, 2018, from https://es.slideshare.net/MrAngelBravo/modelos-para-la-prediccin-de-la-distribucin-de

- Broggio, I. S., Menezes, L. F. T. de, Peixoto, A. L., José, O., & Pereira, E. (2011). *Florìstica de um Trecho da Floresta Atlântica de Tabuleiro no Municipio de Pinheiros - ES*

- Brooks, T. M., Mittermeier, R. a, Mittermeier, C. G., Da Fonseca, G. a B., Rylands, A. B., Konstant, W. R., … Hilton-Taylor, C. (2002). Habitat Loss and Extinction in the Hotspots of Biodiversity\rPérdida de Hábitat y Extinciones en Áreas Críticas para la Biodiversidad. Conservation Biology, 16(4), 909–923. https://doi.org/10.1046/j.1523-1739.2002.00530.x

- Cabido, M., & Díaz, S. (1997). Plant functional types and ecosystem function in relation to global change. Journal of Vegetation Science, 8(4), 463–474. https://doi.org/10.2307/3237198

- Cabrera, V., & Tillett, S. (2016). Morphological glossary of the indument of leaves and stems of angiosperms in Venezuela. *ACTA BOT. VENEZ.*, *39*((1)), 37–65.

- Câmara, I., & Galindo-Leal, C. (2003). The Atlantic Forest of South America: Biodiversity Status, Threats, and Outlook. Electronic Green Journal, Issue #15, 1(19).

- Canosa, G. A., & Moraes, L. F. D. de. (2016). Atributos funcionais de espécies da Mata Atlântica: ferramentas para o planejamento ambiental e econômico., 168. Retrieved from https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1056021/atributos-funcionais-de-especies-da-mata-atlantica-ferramentas-para-o-planejamento-ambiental-e-economico

- Casanoves, F., Pla, L., & Di Rienzo, J. A. (2011). Valoración y análisis de la diversidad funcional y su relación con los servicios ecosistémicos. Centro Agronómico Tropical de Investigación y Enseñanza, CATIE.Turrialba, Costa Rica.

- Castellanos-castro, C., & Newton, A. C. (2015). Leaf and stem trait variation and plant functional types in 113 woody species of a seasonally dry tropical forest. Colombia Forestal, 18(50), 117–138.

- CGEE. (2016). Secas no Brasil : Política e gestão proativas. (Centro de Gestão e Estudos Estratégicos; Banco Mundial, Ed.) (Aline Adolphs). Brasilia-DF.

- Chapin, F. S., Sala, O. E., Burke, I. C., Grime, J. P., Hooper, D. U., Lauenroth, W. K., … Tilman, D. (1998). Ecosystem Consequences of Changing Biodiversity. *BioScience*, *48*(1), 45–52. https://doi.org/10.2307/1313227

- Chapin, F. S., Matson, P. a, & Mooney, H. a. (2002). Principles of Terrestrial Ecosystem Ecology. System (Vol. 21). Springer-Verlag New York, Inc. https://doi.org/10.1007/978-1-4419-9504-9

- Chaturvedi, R. K. (2010). PLANT FUNCTIONAL TRAITS IN DRY Thesis Submitted for the Degree of Doctor of Philosophy i n Botany Ravi Kant Chaturvedi. *Thesis*, (January 2013). https://doi.org/10.13140/RG.2.1.4343.1444

- Chaturvedi, R. K., Raghubanshi, A. S., & Singh, J. S. (2011). Plant functional traits with particular reference to tropical deciduous forests: A review. *Journal of Biosciences*, *36*(5), 963–981. https://doi.org/10.1007/s12038-011-9159-1

- Chaves, M. M., Maroco, J. P., & Pereira, J. S. (2003). Understanding plant responses to drought - From genes to the whole plant. *Functional Plant Biology*, *30*(3), 239–264. https://doi.org/10.1071/FP02076

- Chaves, M. M., & Oliveira, M. M. (2004). Mechanisms underlying plant resilience to water deficits: Prospects for water-saving agriculture. Journal of Experimental Botany, 55(407), 2365–2384. https://doi.org/10.1093/jxb/erh269

- Chelli, S. (2013). *Plant Functional Traits and Environmental Variations*. Department of Life Sciences.University of Camerino.

- College of Arts and Sciences Miami University. (2009). Final Leaf Blade Width jpg.jpg (2500×1250). Retrieved June 23, 2018, from http://www.cas.miamioh.edu/~meicenrd/MUDESCd/Xidw/Working Paint Images/Final Images/Final Leaf Blade Width jpg.jpg

- Comas, L. H., Becker, S. R., Cruz, V. M. V., Byrne, P. F., & Dierig, D. A. (2013). Root traits contributing to plant productivity under drought. Frontiers in Plant Science, 4(November), 1–16. https://doi.org/10.3389/fpls.2013.00442

- Conservation International do Brasil. (2000). Avaliação e ações prioritárias para a conservação da biodiversidade da Mata Atlântica e Campos Sulinos. Ministério do Meio Ambiente, Brasília. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:AVALIA??O+E+A??ES+PRIORIT?RIAS+PARA+A+CONSERVA??O+DA+BIODIVERSIDADE+DA+MATA+ATL?NTICA+E+CAMPOS+SULINOS#0

- Cornelissen, J. H. C., Lavorel, S., Garnier, E., Díaz, S., Buchmann, N., Gurvich, D. E., … Poorter, H. (2003). A handbook of protocols for standardised and easy measurements of plant functional traits worldwide. Aust. J. Bot. 51, 335-380. *Aust. J. Bot.*, *51*(51), 335–380. https://doi.org/10.1071/BT02124

- Danielsen, K., & White, S. (2003). *Field Methods Guide Characteristics of Wiigwaasi-mitig Field Methods Guide Characteristics of Wiigwaasi-mitig (Paper Birch, Betula papyrifera Marsh .)* (Vol. 1). USDA Forest Service. Odanah.

- Dantas, H. G. (2005). Paisagem e Vegetação do Município de Armação dos Búzios, Rio de Janeiro. Escola Nacional de Botânica Tropical.Instituto de Pesquisas Jardim Botânico do Rio de Janeiro.

- Department of Agronomy, I. S. U. (2018). Leaf Size and Shape. Retrieved July 18, 2018, from http://agron-www.agron.iastate.edu/courses/Agron541/classes/541/lesson11a/11a.3.html

- Dias, E., & Siddique, I. (2014). *ATRIBUTOS FUNCIONAIS PREDIZEM SOBREVIVÊNCIA E Florianópolis*. Universidade Federal de Santa Catarina. https://doi.org/10.1658/1100-9233(2003)014[0307:PFTIRT]2.0.CO;2

- Díaz, S., & Cabido, M. (2001). Vive la différence: Plant functional diversity matters to ecosystem processes. *Trends in Ecology and Evolution*, *16*(11), 646–655. https://doi.org/10.1016/S0169-5347(01)02283-2

- Diaz, S., Cabido, M., & Casanoves, F. (1998). Plant functional traits and environmental filters at a regional scale. *Journal of Vegetation Science*, *9*(1), 113–122. https://doi.org/10.2307/3237229

- Díaz, S., Hodgson, J. G., Thompson, K., Cabido, M., Cornelissen, J. H. C., Jalili, A., … Zak, M. R. (2004). The plant traits that drive ecosystems: Evidence from three continents. *Journal of Vegetation Science*, *15*(3), 295–304. https://doi.org/10.1111/j.1654-1103.2004.tb02266.x

- Diémé, J. S. (2016). Respuesta adaptativa de especies leñosas a las variaciones climáticas y ambientales en el noroeste de Senegal. Universidad de Almería. https://doi.org/10.7818/ECOS.2013.25-1.14

- DPI-INPE. (2018). AMBDATA Grupo de Modelagem para Estudos da Biodiversidade. Retrieved July 5, 2018, from http://www.dpi.inpe.br/Ambdata/download.php#var_ind

- Duarte, E., Júnior, L. C. R., Vefago, M. B., & Aguiar, J. T. De. (2017). *Influência de atributos funcionais sobre a distribuição geográfica de espécies arbóreas da floresta com araucária frente às mudanças climáticas - etapa: impacto de mudanças climáticas*. Santa Catarina-Brasil.

- Engelbrecht, B. M. J., Comita, L. S., Condit, R., Kursar, T. A., Tyree, M. T., Turner, B. L., & Hubbell, S. P. (2007). Drought sensitivity shapes species distribution patterns in tropical forests. *Nature*, *447*(7140), 80–82. https://doi.org/10.1038/nature05747

- Engle, N., De Nys, E., & Magalhäes, A. R. (2017). *Drought in Brazil: Proactive Management and Policy* (CRC Press). Boca Raton-Florida.

- Farooq, M., Wahid, A., Kobayashi, N., & S.M.A. Fujita, D. B. (2009). Review article Plant drought stress : effects , mechanisms and management. *Agronomy for Sustainable Development*, *29*(1), 185–212. https://doi.org/10.1051/agro

- Fernández Carballo, R. (1998). La entrevista en la investigación cualitativa. *Revista Pensamiento Actual*, 21 p.

- Frazer, G., Trofynow, J., & Lertzman, K. (1997). A method for estimating canopy opennes, effective leaf area index, and photosynthetically active photon flux density using hemispherical photography and computerized image analysis techniques. (P. F. Centre, Ed.). Victoria, British Columbia: Canadian Forest Service.

- Garay, I., Rizzini, C. M., Kindel, A., Agarez, F. V., Louzada, M. A. P., Santos, R. D. dos, & Vincens, R. S. (2003). A Floresta Atlântica de Tabuleiros-Diversidade Funcional da Cobertura Arbórea. *Editora Vozes Ltda*, (January), 56. Retrieved from internet: http://www.vozes.com.br%5CnBrasil

- Goldstein, G. H., & Santiago, L. S. (2016). Tropical tree physiology: adaptations and responses in a changing environment. Retrieved from https://books.google.de/books?id=goWuCwAAQBAJ&pg=PA248&lpg=PA248&dq=During+annual+seasonal+drought,+the+deciduousness+may+also+be+an+advantage+during+extreme+droughts+by+providing+an+ability+to+maintain+dormancy+while+minimizing+resources+expenditure&source=bl&ots=e7NcOm-L7o&sig=6fOTVkwoZEJlOD9yOMLaGAGyn-M&hl=es&sa=X&ved=2ahUKEwis08WduMrcAhXQEVAKHVSNAp0Q6AEwAHoECAAQAQ#v=onepage&q=During annual seasonal drought%2C the deciduousness may also be an advantage during extreme droughts by providing an ability to maintain dormancy while minimizing resources expenditure&f=false

- Gómez, J., Declerck, F., Ibrahim, M., Rush, G., Casanoves, F., Casals, P., & Jiménez, F. (2012). *Efecto de las características de las plantas y rasgos funcionales de la copa de árboles del neotrópico seco, sobre la transferencia de la lluvia y la captura de nutrientes*. Centro Agronómico Tropical de Investigación y Enseñanza, CATIE.

- Gonçalves, R. S., Ivanauskas, N. M., Rodrigues, R. R., Nascimento, M. T., Gomes, J. M. L., Folli, D. A., & Couto, H. T. Z. do. (2006). Composição Florística do estrato arbóreo da Floresta Estacional Semidecidual na Planície Aluvial do rio Doce, Linhares, ES, Brasil. *Acta Botanica Brasilica*, *20*(3), 549–561. https://doi.org/10.1590/S0102-33062006000300005

- Gonçalves, S. R., Ivanauskas, N. M., & Engel, V. L. (2016). As florestas de tabuleiro do norte do Espírito Santo São ombrófilas ou estacionais? *Floresta Atlântica de Tabuleiro: Diversidade E Endemismo Na Reserva Natural Vale*, (September), 47–60.

- Google Earth Pro. (2018). Fragment Fazenda Imburi. Retrieved June 17, 2018, from https://www.google.com/maps/@-21.3270958,-41.1029772,778m/data=!3m1!1e3

- Google Earth Pro. (2018). Fragment Fazenda Santana. Retrieved June 19, 2018, from https://www.google.com/maps/@-21.3361513,-41.1401115,1427m/data=!3m1!1e3

- Google Earth Pro. (2018). Fragment Fazenda Santo Antonio. Retrieved May 16, 2018, from https://www.google.com/maps/@-21.2982887,-41.0933672,872m/data=!3m1!1e3

- Gorne, R. A. (2010). Atributos funcionais e a distribuição de espécies do cerradão e da floresta estacional semidecidual. Instituto de biologia. Universidade Estadual de Campinas. https://doi.org/10.1007/s13398-014-0173-7.2

- Haak, D. (2003). Functional Ecology: Definition & Concepts | Study.com. Retrieved June 22, 2018, from https://study.com/academy/lesson/functional-ecology-definition-concepts.html

- Herz, K., Dietz, S., Haider, S., Jandt, U., Scheel, D., & Bruelheide, H. (2017). Predicting individual plant performance in grasslands. Ecology and Evolution, (July), 1–8. https://doi.org/10.1002/ece3.3393

- Huttunen, P., Kärkkäinen, K., Løe, G., Rautio, P., & Agren, J. (2010). Leaf trichome production and responses to defoliation and drought in Arabidopsis lyrata (Brassicaceae). *Annales Botanici Fennici*, *47*(3), 199–207. https://doi.org/10.5735/085.047.0304

- IBGE. (2012). *Manual Técnico da Vegetação Brasileira*. *Instituto Brasileiro de Geografia e Estatística - IBGE*. (2 Ed) Rio de Janeiro.https://doi.org/ISSN 0101-4234
- INMET. (2018). BDMEP - Banco de Dados Meteorológicos para Ensino e Pesquisa: Retrieved July 17, 2018, from http://www.inmet.gov.br/portal/index.php?r=bdmep/bdmep

- Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). (2018). ICMBio - Reserva Biológica de Sooretama - Aspectos Físicos e Biológicos. Retrieved June 22, 2018, from http://www.icmbio.gov.br/rebiosooretama/aspectos-fisicos-e-biologicos.html

- INDE. (2018). Instituto Estadual do Ambiente.Visualizador da INDE. Retrieved June 25, 2018, from http://www.visualizador.inde.gov.br/

- JBRJ. (2017). INSTITUTO DE PESQUISAS JARDIM BOTÂNICO DO RIO DE JANEIRO. Rodriguésia, 68(2), 291–795. Retrieved from https://rodriguesia.jbrj.gov.br/FASCICULOS/rodrig68-2/00-sumario 68-2.pdf

- Joly, C. A., Metzger, J. P., & Tabarelli, M. (2014). Experiences from the Brazilian Atlantic Forest: Ecological findings and conservation initiatives. *New Phytologist*, *204*(3), 459–473. https://doi.org/10.1111/nph.12989

- Kattge, J., Díaz, S., Lavorel, S., Prentice, I. C., Leadley, P., Bönisch, G., … Wirth, C. (2011). TRY - a global database of plant traits. *Global Change Biology*, *17*(9), 2905–2935. https://doi.org/10.1111/j.1365-2486.2011.02451.x

- Kohtari Shan. (2015). What are functional trait-based approaches to plant ecology and why are they important? - Quora. Retrieved June 22, 2018, from https://www.quora.com/What-are-functional-trait-based-approaches-to-plant-ecology-and-why-are-they-important

- Kursar, T. A., Engelbrecht, B. M. J., Burke, A., Tyree, M. T., El Omari, B., & Giraldo, J. P. (2009). Tolerance to low leaf water status of tropical tree seedlings is related to drought performance and distribution. *Functional Ecology*, *23*(1), 93–102. https://doi.org/10.1111/j.1365-2435.2008.01483.x

- Lasley, A. L. (2013). Evaluation of Root Traits Associated with Drought Tolerance. Crop and Soil Sciences.Michigan State University.

- Lavorel, S., & Garnier, É. (2002). Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. *Functional Ecology*, *16*(5), 545–556.

- Lebrija-trejos, E., Pérez-garcía, E. A., Meave, J. A., Bongers, F., & Poorter, L. (2010). Functional traits and environmental filtering drive community assembly in a species-rich tropical system Published by : Ecological Society of America Functional traits and environmental drive community filtering in a species-rich tropical system assembly. *Ecology*, *91*(2), 386–398. https://doi.org/10.1890/08-1449.1

- Lohbeck, M., Poorter, L., Lebrija-Trejos, E., Nez-Ramos, M. M., Meave, J. A., Paz, H., … Bongers, F. (2013). Successional changes in functional composition contrast for dry and wet tropical forest. *Ecology*, *94*(6), 1211–1216. https://doi.org/10.1890/12-1850.1

- Lohbeck, M., Lebrija-trejos, E., & Martínez-ramos, M. (2015). Functional Trait Strategies of Trees in Dry and Wet Tropical Forests Are Similar but Differ in Their Consequences for Succession. PLoS ONE, 10(4), 1–15. https://doi.org/10.1371/journal.pone.0123741

- Lopez-iglesias, B., Villar, R., & Poorter, L. (2014). Acta Oecologica Functional traits predict drought performance and distribution of Mediterranean woody species. *Acta Oecologica*, *56*, 10–18. https://doi.org/10.1016/j.actao.2014.01.003

- López-Roldán, P., & Fachelli, S. (2015). Metodología De La Investigación Social Cuantitativa. (U. A. de Barcelona, Ed.), Metodología De La Investigación Social Cuantitativa (first). Barcelona-Spain: Commons, Creative. Retrieved from http://ddd.uab.cat/record/129382

- Machado, F., Higuchi, P., & Silva, A. C. da. (2016). *Influência de atributos funcionais sobre a distribuição geográfica de espécies arbóreas da floresta com araucária frente as mudanças climáticas: etapa 1 – caracterização de atributos funcionais.* Santa Catarina-Brasil.

- Mahdavi, P., & Bergmeier, E. (2016). Acta Oecologica Plant functional traits and diversity in sand dune ecosystems across different biogeographic regions. *Acta Oecologica*, *74*, 37–45. https://doi.org/10.1016/j.actao.2016.06.003

- Maréchaux, I., Bartlett, M. K., Sack, L., Baraloto, C., Engel, J., Joetzjer, E., & Chave, J. (2015). Drought tolerance as predicted by leaf water potential at turgor loss point varies strongly across species within an Amazonian forest. *Functional Ecology*, *29*(10), 1268–1277. https://doi.org/10.1111/1365-2435.12452

- Marengo, J. (2007). *Mudanças Climáticas Globais e seus Efeitos sobre a Biodiversidade: Caracterização do Clima Atual e Definição das Alterações Climáticas para o Território Brasileiro ao Longo do Século XXI*. (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Ed.), *Série Biodiversidade* (Biodiversi, Vol. 26). Brasilia. https://doi.org/10.1017/CBO9781107415324.004

- Markesteijn, L. (2010). Drought tolerance of tropical trees species: Functional Traits, Trade-offs and Species Distribution. Wageningen University.

- Martínez-Sánchez, O. (n.d.). *Droughts: Definitions, Monitors and Causes*. San Juan. UPRRP Environmental Sciences, NOAA, National Weather Service USA

- Martins-da-Silva, R. C. V., Silva, A. S. L. da, Fernandes, M. M., & Margalho, L. F. (2014). Noções morfológicas e taxonômicas para identificação botânica. Brasilia-DF: 114 p. Embrapa.

- Meira-Neto, J. A. A., & Martins, F. R. (2002). Composição florística de uma Floresta Estacional Semidecidual Montana no município de Viçosa- MG. *Revista Árvore*, *26*(4), 437–446. https://doi.org/10.1590/S0100-67622002000400006

- Micco, V. De, & Aronne, G. (2012). Plant Responses to Drought Stress. In R. Aroca (Ed.) (pp. 37–62). Naples, Italy: Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-642-32653-0

- Ministério do Meio Ambiente. (2005). Programa de Ação Nacional de Combate à Desertificação e Mitigação dos Efeitos da Seca PAN-Brasil. (E. MMA, Ed.). Brasilia-DF.

- Ministério do Meio Ambiente. (2018). *Impactos da Mudança do Clima na Mata Atlântica*. (DPMC/SMCF/MMA/GIZ, Ed.). Brasilia-DF.

- Missouri Botanical Garden., Herbario Nacional de Bolivia., Universidad Autónoma de Madrid.(2012). Protocolo para la medición de características funcionales Proyecto Inventario Florístico de la Región Madidi. Retrieved from http://www.mobot.org/mobot/research/madidi/protocolos/ProtocoloCaracterFuncionales.pdf

- Mittermeier, R. A., van Dijk, P. P., Rhodin, A. G. J., & Nash, S. D. (2004). Hotspots Revisited: Earth's Biologically Richest and Most Endangered Ecoregions. Chelonian Conservation and Biology, 14(1), 200. https://doi.org/10.2744/ccab-14-01-2-10.1

- Morellato, L. P. C., & Haddad, C. F. B. (2000). Introduction : The Brazilian Atlantic Forest. Biotropica, 32(4), 786–792.

- Niinemets, Ü. (2001). Global-scale climatic controls of leaf dry mass per area, density, and thickness in trees and shrubs. *Ecology*, *82*(2), 453–469. https://doi.org/10.1890/0012-9658(2001)082[0453:GSCCOL]2.0.CO;2

- Niinemets, Ü., Portsmuth, A., & Tobias, M. (2007). Leaf shape and venation pattern alter the support investments within leaf lamina in temperate species: A neglected source of leaf physiological differentiation? *Functional Ecology*, *21*(1), 28–40. https://doi.org/10.1111/j.1365-2435.2006.01221.x

- Nock, C. A., Vogt, R. J., & Beisner, B. E. (2016). Functional Traits. In eLS (pp. 1–8). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470015902.a0026282

- O'Donnell, M. S., & Ignizio, D. A. (2012). Bioclimatic Predictors for Supporting Ecological Applications in the Conterminous United States. U.S Geological Survey Data Series 691.

- Olivero Lora, S. (2011). Functional trait approach to assess the ecological processes of drought tolerance and water use efficiency in silvopastoral systems in Rivas Department, Nicaragua. Centro Agronómico Tropical de Investigación y Enseñanza.Turrialba Costa Rica.

- Passioura, J. B. (1996). Drought and drought tolerance. *Plant Growth Regulation*, *20*(2), 79–83. https://doi.org/10.1007/BF00024003

- Pellegrini, A. F. A., Franco, A. C., & Hoffmann, W. A. (2016). Shifts in functional traits elevate risk of fire-driven tree dieback in tropical savanna and forest biomes. *Global Change Biology*, *22*(3), 1235–1243. https://doi.org/10.1111/gcb.13110

- Pérez-Harguindeguy, N., Diaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., … Cornelissen, J. H. C. (2013). New Handbook for standardized measurment of plant functional traits worldwide. *Australian Journal of Botany*, *61*(34), 167–234. https://doi.org/http://dx.doi.org/10.1071/BT12225

- Phillips, S. J.; Anderson, R. P. & Schapire, R. E. (2006).Maximum entropy modelling of species geographic distributions. *Ecological Modeling*, vol. 190, p. 231-259.

- Phillips, S. (2008). A Brief Tutorial on Maxent. AT&T Research. https://doi.org/10.4016/33172.01

- Poorter, L., & Markesteijn, L. (2007). Seedling Traits Determine Drought Tolerance of Tropical Tree Species Author(s): Lourens Poorter and Lars Markesteijn Source: *Biotropica*, *40*(3), 321–331. https://doi.org/10.1111/j.1744-7429.2007.00380.x

- Preiskorn, G. M., & Couto, H. T. Z. (2009). *Quantificação e monitoramento de biomassa e carbono em plantios de áreas restauradas*. *Pacto pela restauração da mata atlântica: referencial dos conceitos e ações de restauração florestal*.

- Rabelo, G. R., Vitória, Â. P., da Silva, M. V. A., Cruz, R. A., Pinho, E. I. B., Ribeiro, D. R., … Da Cunha, M. (2013). Structural and ecophysiological adaptations to forest gaps. Trees - Structure and Function, 27(1), 259–272. https://doi.org/10.1007/s00468-012-0796-2

- Raedig, C., Wirth, C., Prance, G. (2010). Distribution patterns of Neotropical angiosperm species: tackling difficulties of large-scale research. Universität Leipzig.

- Rangel, J. O., & Velázquez, A. (1997). Metodos de estudio de la vegetacion. In Universidad Nacional de Colombia (Ed.), Colombia Diversidad Biótica II (1st ed., pp. 59–87). Bogotá- Colombia: Instituto de Ciencias Naturales.100.Ramirez, B. (2016). Botánica . Generalidades , Morfología y Anatomía de plantas superiores. (U. del Cauca, Ed.) (1st ed.). Popayán-Colombia: Cargraphics.

- RBMA Conselho Nacional Reserva da Biosfera da Mata Atlântica. (2004). RBMA - Reserva da Biosfera da Mata Atlântica. Retrieved June 5, 2018, from http://www.rbma.org.br/anuario/mata_02_baciashidro.asp

- Rosado, B. H. P., & Mattos, E. A. de. (2007). Variação temporal de características morfológicas de folhas em dez espécies do Parque Nacional da Restinga de Jurubatiba, Macaé, RJ, Brasil. Acta Botanica Brasilica, 21(3), 741–752. https://doi.org/10.1590/S0102-33062007000300020

- Ribeiro, M. C., Paul, J., Camargo, A., Jorge, F., Metzger, J. P., Martensen, A. C., … Hirota, M. M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, *142*(6), 1141–1153. https://doi.org/10.1016/j.biocon.2009.02.021

- Romero-Saritama, J. M., & Pérez Ruiz, C. (2016). Rasgos morfológicos de semillas y su implicación en la conservación ex situ de especies leñosas en los bosques secos tumbesinos. *Ecosistemas*, *25*(2), 59–65. https://doi.org/10.7818/ECOS.2016.25-2.07

- Rosado, B. H. P., & Mattos, E. A. de. (2007). Variação temporal de características morfológicas de folhas em dez espécies do Parque Nacional da Restinga de Jurubatiba, Macaé, RJ, Brasil. *Acta Botanica Brasilica*, *21*(3), 741–752. https://doi.org/10.1590/S0102-33062007000300020

- Ruíz Molina, J. (2015). *Grupos funcionales de plantas con potencial para la restauración ecológica de manantiales de agua en la microcuenca de la Laguna de Pedro Palo y sus alrededores, Cundinamarca-Colombia*. Universidad Nacional de Colombia. Retrieved from http://www.bdigital.unal.edu.co/53423/

- Salgado Negret, B. (2015). La Ecología Funcional como aproximación al estudio, manejo y conservación de la biodiversidad: protocolos y aplicaciones. (B. Salgado-Negret, Ed.), La ecología funcional como aproximación al estudio, manejo y conservación de la biodiversidad: protocolos y aplicaciones. Bogotá- Colombia: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. https://doi.org/10.7818/ECOS.2015.24-3.10

- Sanaphre-Villanueva, L., Dupuy, J. M., Andrade, J. L., Reyes-García, C., Paz, H., & Jackson, P. C. (2016). Functional diversity of small and large trees along secondary succession in a tropical dry forest. *Forests*, *7*(8), 1–15. https://doi.org/10.3390/f7080163

- Sansevero, J. B. B. (2013). Classificação de grupos funcionais e caracterização de trajetórias sucessionais na Floresta Atlântica. Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. Retrieved from http://www.jbrj.gov.br/enbt/posgraduacao/resumos/2013/jernimo_sansevero_pos_defesa.pdf

- Santos, Martins Cristiano, R. (2010). Mata Atlântica: Características, Biodiversidade E a História De Um Dos Biomas De Maior Prioridade Para Conservação E Preservação De Seus Ecossistemas. Trabalho De Conclusão De Curso No Colegiado Do Curso De Ciências Biológicas. Centro Universitário Metodista Izabela Hendrix.

- Scheer, M. B., & Blum, C. T. (2009). Arboreal Diversity of the Atlantic Forest of Southern Brazil : From the Beach Ridges to the Paraná River. *The Dynamical Processes of Biodiversity - Case Studies of Evolution and Spatial Diversity*, 109–134.

- Scoffoni, C., Vuong, C., Diep, S., Cochard, H., & Sack, L. (2014). Leaf Shrinkage with Dehydration: Coordination with Hydraulic Vulnerability and Drought Tolerance. *Plant Physiology*, *164*(4), 1772–1788. https://doi.org/10.1104/pp.113.221424

- SEA / INEA. (2011). O Estado do Ambiente: Indicadores Ambientais do Rio de Janeiro 2010. Rio de Janeiro: SEA / INEA.

- Silva, G. C., & Nascimento, M. T. (2001). Fitossociologia de um remanescente de mata sobre tabuleiros no norte do estado do Rio de Janeiro (Mata do Carvão). *Revista Brasileira de Botânica*, *24*(1), 51–62. https://doi.org/10.1590/S0100-84042001000100006

- Sivakumar, M. V. K., Wilhite, D. a., Svoboda, M. D., Hayes, M., & Motha, R. (2010). *Drought risk and meteorological droughts*. ISDR, WMO, USDA, University of Nebraska-Lincoln

- Soboleski, V. F., Higuchi, P., Carolina, A., Loebens, R., Souza, K., Junior, F. B., … Dallabrida, J. P. (2017). Variação de atributos funcionais do componente arbóreo em função de gradientes edáficos em uma floresta nebular no sul do Brasil. Rodriguésia, 68(2), 291–300. https://doi.org/10.1590/2175-7860201768201

- Sobrado, M. A., & Medina, E. (1980). General Morphology, Anatomical Structure, and Nutrient Content of Sclerophyllous Leaves of the “Bana” Vegetation of Amazonas. Oecologia, 45(3), 341–345. https://doi.org/10.1007/BF00540202

- Sobrado, M. A. (1997). Embolism vulnerability in drought-deciduous and evergreen species of a tropical dry forest. *Acta Oecologica*, *18*(4), 383–391. https://doi.org/10.1016/S1146-609X(97)80030-6
- Sobral, M., & Stehmann, J. R. (2009). An analysis of new angiosperm species discoveries in Brazil (1990-2006). Taxon, 58(1), 227–232. https://doi.org/10.2307/27756836

- SOSMA e INPE. (2011). Fundação SOS Mata Atlântica Instituto Nacional de Pesquisas Espaciais ATLAS DOS REMANESCENTES FLORESTAIS DA MATA ATLÂNTICA PERÍODO 2008- 2010 São Paulo. São Paulo- Brazil.

- Soudzilovskaia, N. A., Elumeeva, T. G., Onipchenko, V. G., Shidakov, I. I., Salpagarova, F. S., Khubiev, A. B., … Cornelissen, J. H. C. (2013). Functional traits predict relationship between plant abundance dynamic and long-term climate warming. *Proceedings of the National Academy of Sciences*, *110*(45), 18180–18184. https://doi.org/10.1073/pnas.1310700110

- Speck, T., & Burgert, I. (2011). Plant Stems: Functional Design and Mechanics. *Annual Review of Materials Research*, *41*(1), 169–193. https://doi.org/10.1146/annurev-matsci-062910-100425

- Stehmann, J. R., Forzza, R. C., Salino, A., Sobral, M., Pinheiro, D., Kamino, H. Y., (2009). Plantas da F loresta Atlântica. (S. Bittencourt & C. Molinari, Eds.). Rio de Janeiro: Instituto de Pesquisas Jardim Botânico do Rio de Janeiro.

- Subbarao, G. V., Johansen, C., Slinkard, A. E., Rao, N., Saxena, N. P., & Chauhan, Y. S. (1995). Strategies For Improving Drought Resistance In Grain Legumes. Critical Reviews in Plant Sciences, 14(6), 469–523. https://doi.org/10.1080/713608125

- Suding, K. N., & Goldstein, L. J. (2008). Testing the Holy Grail framework: Using functional traits to predict ecosystem change. New Phytologist, 180(3), 559–562. https://doi.org/10.1111/j.1469-8137.2008.02650.x

- Tabarelli, M., Venceslau, A., Cezar, M., Paul, J., & Peres, C. A. (2010). Prospects for biodiversity conservation in the Atlantic Forest : Lessons from aging human-modified landscapes. *Biological Conservation*, *143*(10), 2328–2340. https://doi.org/10.1016/j.biocon.2010.02.005

- The Biomimicry Institute. (2016). Small leaves buffer ambient temperature : Sacred Datura - AskNature. Retrieved July 24, 2018, from https://asknature.org/strategy/small-leaves-buffer-ambient-temperature/#.W1dlENIzbIV

- Universidad de La Plata. (2004). La Hoja De Las Plantas : Morfología Y Adaptaciones. Curso de Morfología Vegetal (Vol. 6). La Plata Argentina.

- Valliyodan, B., & Nguyen, H. T. (2006). Understanding regulatory networks and engineering for enhanced drought tolerance in plants. *Current Opinion in Plant Biology*, *9*(2), 189–195. https://doi.org/10.1016/j.pbi.2006.01.019

- Villela, D. M., Nascimento, M. T., Aragao, L. E. O. C., & da Gama, D. M. (2006). Effect of selective logging on forest structure and nutrient cycling in a seasonally dry Brazilian Atlantic forest. *Journal of Biogeography*, *33*(3), 506–516. https://doi.org/10.1111/j.1365-2699.2005.01453.x

- Violle, C., Navas, M. L., Vile, D., Kazakou, E., Fortunel, C., Hummel, I., & Garnier, E. (2007). Let the concept of trait be functional! *Oikos*, *116*(5), 882–892. https://doi.org/10.1111/j.2007.0030-1299.15559.x

- Wagner, F., Rossi, V., Baraloto, C., Bonal, D., Stahl, C., & Hérault, B. (2014). Are commonly measured functional traits involved in tropical tree responses to climate? *International Journal of Ecology*, *2014*(June). https://doi.org/10.1155/2014/389409

- Weiher, E., van der Werf, A., Thompson, K., Roderick, M., Garnier, E., & Eriksson, O. (1999). Challenging Theophrastus: A common core list of plant traits for functional ecology. *Journal of Vegetation Science*, *10*(5), 609–620. https://doi.org/10.2307/3237076

- Westoby, M., Falster, D. S., Moles, A. T., Vesk, P. A., & Wright, I. J. (2002). Plant Ecological Strategies: Some Leading Dimensions of Variation Between Species. *Annual Review of Ecology and Systematics*, *33*(1), 125–159. https://doi.org/10.1146/annurev.ecolsys.33.010802.150452

- Wilhite, D., & Glantz, M. (1985). Understanding the Drought Phenomenon: The Role of Definitions. WATER INTERNATIONAL, 10, 37–41.

- Wilhite, D. A. (2000). Drought as a natural hazard: Concepts and definitions. Drought: A Global Assessment. University of Nebraska-Lincoln.

- Williamson Graham. (2015). Dog rose - Breamish Valley. Retrieved June 24, 2018, from https://www.breamishvalley.com/dog-rose/

- WMO. (2014). *Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes*. *WMO No. 1123*. https://doi.org/ISBN 978-92-63-11123-4

- Xiao, K., Mao, X., & Lin, Y. (2016). Trichome, a Functional Diversity Phenotype in Plant. *Molecular Biology*, *s1*(1), 1–6. https://doi.org/10.4172/2168-9547.1000183

- Xu, F., Guo, W., Xu, W., Wei, Y., & Wang, R. (2009). Leaf morphology correlates with water and light availability: What consequences for simple and compound leaves. *Progress in Natural Science*, *19*(12), 1789–1798. https://doi.org/10.1016/j.pnsc.2009.10.001

- Yamazaki, K., & Ohsaki, N. (2006). Willow leaf traits affecting host use by the leaf-gall-forming sawfly. *Population Ecology*, *48*(4), 363–371. https://doi.org/10.1007/s10144-006-0002-8

ANNEX

Tables with the measured traits per species

Traits measured for the species *Alseis pickelii* . Source (Guarín Diego, 2018)

Place: Fazenda Imburi	**Parcel N° 46**	**DBH(cm):** **8.75**	**Height of the Tree:** **8.5m**	**Date:** **DD** 09 **MM** 05 **YY** 2018 **Hour of the day:** 14:30	**Coordinates:** **Lat: 21°19'38.16"S** **Long: 41° 6'1.39"W**	**Elevation (M.A.S.L) 57 m**
Species: *Alseis pickelii*	**Ind N°: 1182**					

Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **5 m**															
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm^2)	46.89	44.52	28.33	78.02	47.31	29.47	60.59	62.41	46.91	49.29	70.29	44.96	33.61	43.86	42.48	**728.92**
Slenderness Index (Ratio Leaf Length/Leaf width)	16.26	16.03	13.83	19.31	15.73	12.42	18.31	17.72	15.2	15.91	19.44	15.66	13.66	15.63	14.05	**239.16**
Thickness (mm)	3.35	3.35	3.71	2.78	3.07	3.00	3.21	2.84	2.80	2.79	2.81	2.85	3.01	3.05	2.53	**45.15**

Leaf surface	Type of leaf: Simple (**x**) Composed ( )
	Natural occurrence of trichomes: Yes (**X**) No ( ) — If yes: Presence of trichomes: Beam __ back _**X**_ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __**x**_ Coriaceous_ __ papiraceous__ Membranaceous___
Bark-Rind aspect	Striated___ Fissured__ Papiraceous ___ Plaques_**x**__Scales__ smooth___
Trunk or Branch Stem surface	Trichomes: Yes _**X**_ No__
	Absence of thorns, spines or prickles __**x**__
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __

Individual	**Leaf área mm^2**	**Slenderness index**	**Thickness (total mm)**
1182	**728.92**	**45.15**	**1.73**
Ap2	619.221	44.23	1.87
Ap3	397.322	48.90	1.88
Ap4	731.92	44.02	1.87
Ap5	616.11	42.49	1.88
TOTAL	**3093.493**	**224.79**	**9.23**

Traits measured for the species *Astronium concinnum* . Source (Guarín Diego, 2018)

Place: Fazenda Imburi	**Parcel N° 46**				**DBH(cm):** 9.25		**Height of the Tree:** 9 m		**Date:** DD 09 MM 05 YY 2018 **Hour of the day:** 9:30		**Coordinates:** Lat: 21°19'37.96"S Long: 41° 6'1.47"W		**Elevation (M.A.S.L) 59 m**		
Species: *Astronium concinnum*	**Ind N°: 1151**														
Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **7 m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm^2)	99.60	38.42	84.57	111.6	36.90	67.42	37.70	85.42	95.09	107.4 9	66.90	38.65	86.51	97.10	106.38	**1159.80**
Slenderness Index (Ratio Leaf Length/Leaf width)	1.17	1.57	1.25	1.13	1.03	1.06	1.47	1.31	1.49	1.04	1.08	1.55	1.26	1.45	1.09	**18.95**
Thickness (mm)	0.12	0.13	0.16	0.15	0.16	0.15	0.13	0.15	0.12	0.13	0.16	0.13	0.12	0.13	0.15	**2.09**
Leaf surface		Type of leaf: Simple ( ) Composed (**x**)														
	Natural occurrence of trichomes: Yes ( ) No (**X**)	If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)														
leaf consistency		Sclerophyllous: Rigid___ Cartaceous __**x**_ Coriaceous_ __ papiraceous__ Membranaceous___														
Bark-Rind aspect		Striated_**x**__ Fissured__ Papiraceous ___ Plaques___Scales__ smooth___														
Trunk or Branch Stem surface		Trichomes: Yes __ No_**X**_														
		Absence of thorns, spines or prickles __**x**__														
		Presence of thorns, spines or prickles: <5mm long __ >5mm long __														

Individual	Leaf área mm^2	Slenderness index	Thickness (total mm)
1151	**1159.798**	**18.95**	**2.09**
Ac2	1352.509	20.98	1.95
Ac3	1162.798	18.84	1.78
Ac4	1159.498	18.91	2.11
Ac5	1162.50	18.83	2.12
TOTAL	**5997.101**	**96.51**	**10.05**

Traits measured for the species *Copaifera lucens* . Source (Guarín Diego, 2018)

Place: Fazenda Santo Antonio	**Parcel N° 63**	**DBH(cm):** **9.3**	**Height of the Tree:** **9m**	**Date:** **DD** 11 **MM** 05 **YY** 2018 **Hour of the day:** 11:40	**Coordinates:** **Lat: 21°17'58.02"S** **Long: 41° 5'38.77"W**	**Elevation (M.A.S.L) 57 m**
Species: *Copaifera lucens*	**Ind N°: 474**					

Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **8 m**															
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	103.5	84.76	80.27	81.65	96.25	130.9	103.79	84.96	80.47	81.85	96.45	103.69	84.86	80.37	81.75	**1375.63**
Slenderness Index (Ratio Leaf Length/Leaf width)	1.51	1.40	1.79	1.54	1.19	1.71	1.50	1.40	1.77	1.53	1.19	1.50	1.40	1.78	1.54	**22.76**
Thickness (mm)	0.13	0.12	0.13	0.12	0.11	0.12	0.13	0.12	0.13	0.12	0.12	0.13	0.14	0.13	0.13	**1.88**

Leaf surface	Type of leaf: Simple ( ) Composed (**X**)	
	Natural occurrence of trichomes: Yes ( ) No (**X**)	If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous_**x** __ papiraceous__ Membranaceous___	
Bark-Rind aspect	Striated_**x**__ Fissured__ Papiraceous ___ Plaques___Scales__ smooth___	
Trunk or Branch Stem surface	Trichomes: Yes __ No_**x**_	
	Absence of thorns, spines or prickles __**x**__	
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __	

Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1881	1500.672	27.6304388	1.87
1126	1597.124	27.3507636	2.02
244	1554.62	18.5592731	2.04
276	1433.104	22.0538885	2.04
474	**1375.632**	**22.7556624**	**1.88**
TOTAL	**7461.152**	**118.350026**	**9.85**

Traits measured for the species *Chrysophyllum lucentifolium* . Source (Guarín Diego, 2018)

Place: Fazenda Santo Antonio	**Parcel N° 61**	**DBH(cm):** 8.75	**Height of the Tree:** 8.40	**Date:** DD 10 MM 05 YY 2018 Hour of the day: 10:15	**Coordinates:** Lat: 21°17'51.29"S Long: 41° 5'43.84"W	**Elevation (M.A.S.L) 52 m**									
Species: *Chrysophyllum lucentifolium*	**Ind N°: 309**														
Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **7.5 m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	16.15	20.40	14.92	14.41	12.52	20.02	15.61	13.31	19.67	19.26	18.73	13.46	18.87	15.92	16.78	**250.02**
Slenderness Index (Ratio Leaf Length/Leaf width)	2.29	2.26	2.16	2.74	2.35	2.32	2.73	2.58	1.95	2.09	2.03	2.21	2.32	2.43	1.91	**34.36**
Thickness (mm)	0.22	0.23	0.21	0.23	0.21	0.18	0.23	0.21	0.16	0.16	0.22	0.18	0.22	0.16	0.18	**3**
Leaf surface	Type of leaf: Simple (**X**) Composed ( )															
	Natural occurrence of trichomes: Yes ( ) No (**X**)	If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)														
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous_**x** __ papiraceous__ Membranaceous___															
Bark-Rind aspect	Striated___ Fissured_**X**_ Papiraceous ___ Plaques___Scales__ smooth___															
Trunk or Branch Stem surface	Trichomes: Yes __ No_**X**_															
	Absence of thorns, spines or prickles __**x**__															
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __															

Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1062	174.061	38.6756585	2.49
1091	183.008	37.119066	2.64
1164	177.061	35.4765111	2.79
2616	240.263	34.6773581	2.93
309	**250.022**	**34.36101**	**3**
TOTAL	**1024.415**	**180.309604**	**13.85**

Traits measured for the species *Melicoccus oliviformis subsp. Intermedius.* Source (Guarín Diego, 2018)

Place: Fazenda Santana	**Parcel N° 52**	**DBH(cm):** 9,2	**Height of the Tree:** 10 m	**Date:** DD 06 MM 05 YY 2018 **Hour of the day:** 15:00	**Coordinates:** **Lat: 21°20'11.25"S** **Long: 41° 8'23.48"W**	**Elevation (M.A.S.L) 49 m**
Species: *Melicoccus oliviformis subsp. Intermedius*	**Ind N°: 2676**					

Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **8.5 m**															
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm^2)	9.56	6.56	8.767	11.63	13.17	11.85	8.80	14.34	9.23	5.57	9.83	10.89	14.26	17.63	21.00	**173.08**
Slenderness Index (Ratio Leaf Length/Leaf width)	1.53	2.13	1.98	1.81	1.91	1.53	2.07	1.66	1.81	2.37	2.06	2.26	1.88	1.62	1.42	**28.03**
Thickness (mm)	0.19	0.13	0.15	0.2	0.21	0.21	0.23	0.13	0.19	0.2	0.18	0.11	0.13	0.15	0.2	**2.61**

Leaf surface	Type of leaf: Simple (**X**) Composed ( )	
	Natural occurrence of trichomes: Yes ( ) No (**X**)	If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous_**x** __ papiraceous__ Membranaceous___	
Bark-Rind aspect	Striated___ Fissured__ Papiraceous ___ Plaques_**X**__Scales__ smooth___	
Trunk or Branch Stem surface	Trichomes: Yes __ No_**X**_	
	Absence of thorns, spines or prickles __**x**__	
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __	

Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1293	675.91	35.455073	2.97
1825	678.91	34.6217817	2.82
1829	476.556	30.8016568	2.47
2676	**173.079**	**28.0288546**	**2.61**
2640	176.079	27.1067066	2.58
TOTAL	**2180.534**	**156.014073**	**13.45**

Traits measured for the species *Metrodorea nigra*. Source (Guarín Diego, 2018)

Place: Fazenda Imburi	**Parcel N° 45**		**DBH(cm):** 8.7		**Height of the Tree:** 9 m		**Date:** DD 08 MM 05 YY 2018 Hour of the day: 9:00			**Coordinates:** Lat: 21°19'40.09"S Long: 41° 6'4.31"W			**Elevation (M.A.S.L) 50 m**		
Species: *Metrodorea nigra*	**Ind N°: 1077**														
Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **7 m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	23.74	37.79	22.92	10.80	25.46	17.08	14.72	12.37	14.02	22.92	12.39	22.74	36.80	24.92	11.20	**309.88**
Slenderness Index (Ratio Leaf Length/Leaf width)	2.24	2.39	2.48	3.07	2.32	2.68	2.78	2.90	3.05	2.48	2.80	2.25	3.61	2.94	2.21	**40.22**
Thickness (mm)	0.27	0.18	0.25	0.22	0.21	0.19	0.23	0.22	0.21	0.24	0.25	0.26	0.19	0.24	0.24	**3.4**
Leaf surface	Type of leaf: Simple (**X**) Composed ( )														
	Natural occurrence of trichomes: Yes ( ) No (**X**)	If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)													
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous_**X** __ papiraceous__ Membranaceous___														
Bark-Rind aspect	Striated_**x**__ Fissured_ _ Papiraceous ___ Plaques___Scales__ smooth___														
Trunk or Branch Stem surface	Trichomes: Yes __ No_**X**_														
	Absence of thorns, spines or prickles __**x**__														
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __														

Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1085	**309.88**	**40.22**	**3.4**
1077	475.97	34.63	3.35
1095	380.07	38.29	3.59
Metn	706.48	43.19	3.48
1105	331.17	27.03	3.46
TOTAL	**2203.57**	**183.35**	**17.28**

Traits measured for the species *Metternichia princeps.* Source (Guarín Diego, 2018)

Place: Fazenda Imburi	**Parcel N° 46**			**DBH(cm):** 6.5		**Height of the Tree:** 8 m		**Date:** DD 10 MM 05 YY 2018 **Hour of the day:** 11:00			**Coordinates:** Lat: 21°19'40.29"S Long: 41° 6'1.47"W			**Elevation (M.A.S.L) 52 m**	
Species: *Metternichia princeps*	**Ind N°: 4838**														
Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **5 m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	14.11	13.12	14.46	12.16	18.97	8.53	17.45	27.97	18.42	17.85	32.39	27.97	28.39	28.82	29.24	**309.84**
Slenderness Index (Ratio Leaf Length/Leaf width)	3.58	3.49	3.38	2.49	3.41	3.49	2.24	2.56	2.91	3.39	3.12	3.04	2.94	2.85	2.77	**45.69**
Thickness (mm)	0.20	0.14	0.13	0.15	0.12	0.13	0.13	0.15	0.20	0.14	0.14	0.15	0.15	0.12	0.15	**2.20**
Leaf surface	Type of leaf: Simple (**X**) Composed ( )															
	Natural occurrence of trichomes: Yes (**X**) No ( )		If yes: Presence of trichomes: Beam __ back _**X**_ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)													
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous___ papiraceous__ Membranaceous__**x**_															
Bark-Rind aspect	Striated___ Fissured_ **x**_ Papiraceous ___ Plaques___Scales__ smooth___															
Trunk or Branch Stem surface	Trichomes: Yes _**X**_ No__															
	Absence of thorns, spines or prickles __**x**__															
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __															

Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
4830	262.43	39.74	2.27
4838	**309.84**	**45.69**	**2.20**
Mp3	454.63	41.68	2.07
Mp4	441.75	44.14	2.19
Mp5	382.13	39.56	2.25
TOTAL	**1850.77**	**210.81**	**10.98**

Traits measured for the species *Pseudopiptadenia contorta.* Source (Guarín Diego, 2018)

Place: Fazenda Santo Antonio	**Parcel N° 61**		**DBH(cm):** 6.5		**Height of the Tree:** 8 m		**Date:** DD 07 MM 05 YY 2018 **Hour of the day:** 13:15			**Coordinates:** Lat: 21°17'51.15"S Long: 41° 5'43.96"W			**Elevation (M.A.S.L) 58 m**		
Species: *Pseudopiptadenia contorta*	**Ind N°: 4849**														
Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: 5 **m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	71.80	69.82	69.25	44.25	70.46	53.18	60.39	40.90	47.08	21.22	53.82	50.99	48.17	45.35	42.52	**789.18**
Slenderness Index (Ratio Leaf Length/Leaf width)	1.35	1.74	1.44	1.44	1.81	1.17	1.62	1.80	1.85	1.63	1.78	1.84	1.89	1.94	1.99	**25.30**
Thickness (mm)	0.04	0.04	0.05	0.05	0.03	0.05	0.03	0.03	0.05	0.04	0.03	0.05	0.05	0.04	0.03	**0.61**
Leaf surface	Type of leaf: Simple ( ) Composed (**x**)															
	Natural occurrence of trichomes: Yes (**x**) No ( )	If yes: Presence of trichomes: Beam __ back __ both __none __ (Presents in the leaf rachis _**X**_) *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)														
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous___ papiraceous__ Membranaceous__**x**_															
Bark-Rind aspect	Striated_**x**__ Fissured_ _ Papiraceous ___ Plaques___Scales__ smooth___															
Trunk or Branch Stem surface	Trichomes: Yes _**X**_ No__															
	Absence of thorns, spines or prickles __**x**__															
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __															

Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1882	787.68	25.41	0.57
526	786.18	25.49	0.59
4849	**789.18**	**25.30**	**0.61**
486	786.33	25.48	0.61
333	789.93	25.25	0.56
TOTAL	**3939.31**	**126.93**	**2.94**

Traits measured for the species *Senefeldera verticillata*. Source (Guarín Diego, 2018)

Place: Fazenda Imburi	Parcel N° 45	DBH(cm): 5.5	Height of the Tree: 9 m	Date: DD 09 MM 05 YY 2018. Hour of the day: 14:00	Coordinates: Lat: 21°19'39.94"S Long: 41° 6'4.52"W	Elevation (M.A.S.L) 59 m									
Species: *Senefeldera verticillata*	Ind N°: 1119														
Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **6 m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm^2)	49.71	53.97	28.25	85.35	69.89	6.79	38.66	53.64	21.03	19.36	16.77	28.22	45.77	50.66	36.52	**604.58**
Slenderness Index (Ratio Leaf Length/Leaf width)	2.49	2.43	2.80	2.36	2.49	2.32	3.15	2.29	2.94	2.02	3.34	2.37	2.88	2.29	2.38	**38.54**
Thickness (mm)	0.19	0.18	0.23	0.22	0.19	0.18	0.25	0.18	0.25	0.23	0.22	0.22	0.23	0.22	0.23	**3.22**
Leaf surface	Type of leaf: Simple (**x**) Composed ( )															
	Natural occurrence of trichomes: Yes ( ) No (**X**)	If yes: Presence of trichomes: Beam __ back __ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)														
leaf consistency	Sclerophyllous: Rigid___ Cartaceous _**x**_ Coriaceous___ papiraceous__ Membranaceous__															
Bark-Rind aspect	Striated___ Fissured_ **X**_ Papiraceous ___ Plaques___Scales__ smooth___															
Trunk or Branch Stem surface	Trichomes: Yes __ No_**x**_															
	Absence of thorns, spines or prickles __**x**__															
	Presence of thorns, spines or prickles: <5mm long __ >5mm long __															

Individual	Leaf área mm^2	Slenderness index	Thickness (total mm)
1119	**604.58**	**38.54**	**3.22**
1116	468.38	38.43	2.97
1118	370.03	40.38	3.03
1102	655.08	33.85	2.97
1084	589.58	46.96	2.71
TOTAL	**2687.64**	**198.16**	**14.9**

Traits measured for the species *Trichilia lepidota.* Source (Guarín Diego, 2018)

<table>
<tr><td>Place: Fazenda Santana</td><td colspan="4">Parcel N° 54</td><td colspan="2" rowspan="2">DBH(cm):
7.6</td><td colspan="2" rowspan="2">Height of the Tree:
8.5 m</td><td colspan="3" rowspan="2">Date:
DD 06 MM 05 YY 2018
Hour of the day: 9:30</td><td colspan="3" rowspan="2">Coordinates:
Lat: 21°20'2.80"S
Long: 41° 8'23.00"W</td><td colspan="2" rowspan="2">Elevation (M.A.S.L) 62 m</td></tr>
<tr><td>Species:
Trichilia lepidota</td><td colspan="4">Ind N°: 2777</td></tr>
<tr><td rowspan="2">Dimensions of exposed leaves to sunlight</td><td colspan="16">Estimated Height where leaves were collected: 5 m</td></tr>
<tr><td>Leaf 1</td><td>Leaf 2</td><td>Leaf 3</td><td>Leaf 4</td><td>Leaf 5</td><td>Leaf 6</td><td>Leaf 7</td><td>Leaf 8</td><td>Leaf 9</td><td>Leaf 10</td><td>Leaf 11</td><td>Leaf 12</td><td>Leaf 13</td><td>Leaf 14</td><td>Leaf 15</td><td>Total</td></tr>
<tr><td>Leaf Area LA (mm²)</td><td>97.31</td><td>91.99</td><td>168.71</td><td>320.08</td><td>129.35</td><td>182.86</td><td>183.78</td><td>139.28</td><td>181.95</td><td>107.28</td><td>101.02</td><td>134.64</td><td>179.48</td><td>65.81</td><td>48.36</td><td>2131.89</td></tr>
<tr><td>Slenderness Index (Ratio Leaf Length/Leaf width)</td><td>1.35</td><td>1.71</td><td>0.16</td><td>1.42</td><td>1.42</td><td>1.45</td><td>1.51</td><td>1.73</td><td>1.08</td><td>1.29</td><td>1.34</td><td>1.31</td><td>1.40</td><td>1.29</td><td>1.46</td><td>19.92</td></tr>
<tr><td>Thickness (mm)</td><td>0.12</td><td>0.12</td><td>0.09</td><td>0.13</td><td>0.11</td><td>0.11</td><td>0.11</td><td>0.11</td><td>0.12</td><td>0.13</td><td>0.13</td><td>0.09</td><td>0.12</td><td>0.11</td><td>0.11</td><td>1.71</td></tr>
<tr><td rowspan="2">Leaf surface</td><td colspan="16">Type of leaf: Simple ( ) Composed (x)</td></tr>
<tr><td colspan="3">Natural occurrence of trichomes: Yes (x) No ( )</td><td colspan="13">If yes: Presence of trichomes: Beam __ back _x_ both __none __
*none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)</td></tr>
<tr><td>leaf consistency</td><td colspan="16">Sclerophyllous: Rigid___ Cartaceous _x_ Coriaceous___ papiraceous__ Membranaceous__</td></tr>
<tr><td>Bark-Rind aspect</td><td colspan="16">Striated__x_ Fissured_ _ Papiraceous ___ Plaques___Scales__ smooth___</td></tr>
<tr><td rowspan="3">Trunk or Branch Stem surface</td><td colspan="16">Trichomes: Yes _X_ No__</td></tr>
<tr><td colspan="16">Absence of thorns, spines or prickles __x__</td></tr>
<tr><td colspan="16">Presence of thorns, spines or prickles: <5mm long __ >5mm long __</td></tr>
</table>

Individual	Leaf área mm²	Slenderness index	Thickness (total mm)
1296	2130.39	19.95	1.56
2777	**2131.89**	**19.92**	**1.71**
2754	2135.64	19.51	1.71
Tl4	2132.64	20.27	1.64
Tl5	2160.39	20.26	1.66
TOTAL	**10690.93**	**99.91**	**8.28**

Traits measured for the species *Trigoniodendron spiritosanctense.* Source (Guarín Diego, 2018)

Place: Fazenda Santana	**Parcel N° 52**	**DBH(cm):**	**Height of the Tree:**	**Date:** DD 12 MM 05 YY 2018	**Coordinates:**	
Species: *Trigoniodendron spiritosanctense*	**Ind N°: 2639**	**8.45**	**10 m**	**Hour of the day:** 10:30	**Lat: 21°20'11.24"S** **Long: 41° 8'23.17"W**	**Elevation (M.A.S.L) 60 m**

Dimensions of exposed leaves to sunlight	Estimated Height where leaves were collected: **7 m**														
	Leaf 1	**Leaf 2**	**Leaf 3**	**Leaf 4**	**Leaf 5**	**Leaf 6**	**Leaf 7**	**Leaf 8**	**Leaf 9**	**Leaf 10**	**Leaf 11**	**Leaf 12**	**Leaf 13**	**Leaf 14**	**Leaf 15**	**Total**
Leaf Area LA (mm²)	16.08	18.68	22.31	18.04	23.41	20.26	18.63	16.21	16.12	12.42	22.74	23.99	17.03	17.33	16.86	**280.10**
Slenderness Index (Ratio Leaf Length/Leaf width)	2.51	2.46	2.53	2.75	2.46	2.63	2.50	2.86	2.38	2.38	2.23	2.13	2.15	2.45	2.11	**36.53**
Thickness (mm)	0.11	0.12	0.13	0.10	0.13	0.12	0.13	0.10	0.12	0.12	0.11	0.12	0.13	0.12	0.12	**1.78**

Leaf surface	Type of leaf: Simple (**x**) Composed ( )	
	Natural occurrence of trichomes: Yes (**x**) No ( )	If yes: Presence of trichomes: Beam __ back _**x**_ both __none __ *none refers to the loss or undevelop trichomes due to conditions like (disease, adverse climate conditions, etc.)
leaf consistency	Sclerophyllous: Rigid___ Cartaceous __ Coriaceous___ papiraceous__ Membranaceous_**X**_	
Bark-Rind aspect	Striated__**x**_ Fissured__ Papiraceous ___ Plaques___Scales__ smooth___	
Trunk or Branch Stem surface	Trichomes: Yes _**x**_ No__	
	Absence of thorns, spines or prickles ____	
	Presence of thorns, spines or prickles: <5mm long _**x**_ >5mm long __	

Individual	**Leaf área mm²**	**Slenderness index**	**Thickness (total mm)**
1094	125.19	36.10	1.60
1848	128.19	34.27	1.76
2639	**280.10**	**36.53**	**1.78**
2719	283.40	35.16	1.75
312	139.07	43.72	1.77
TOTAL	**955.96**	**185.79**	**8.66**

Elaboration of Interviews

Other part of the work included the elaboration of semi-structured interviews which consist in open questions in this case aimed to the subject of study, where the interviewed can express their opinion in order to complement the answer in a natural and flexible form. (Fernández Carballo, 1998; López-Roldán & Fachelli, 2015) as was mentioned in the part 6.1.1 Selection of Drought-Related tolerance Traits, the questions were aimed to know the current state of drought-prone areas in the Mata Atlântica in relation to the plant adaptive traits of the species in this biome. There were elaborated three types of interviews, as follows:

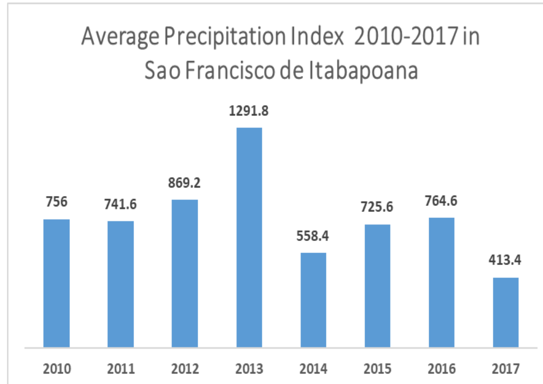
Interview N°1

The first interview was conducted with local people of the municipality, aimed to 10 persons in total between local inhabitants-agricultors, personnel of EMATER-RIO São Francisco de Itabapoana, and the Secretary of Environment of the same municipality. This interview was developed considering the recent reports were events like fires and logging are considered as factors that may increase the drought risk in the region; in this case, part the answers from the people mentioned above were obtained through a meeting of some of them where they compiled the answers in just one interview. Other answers where obtained extracting them through provided documents or reports. The formulated questions were the following.

Interview N°1

1. **When did you noticed the last longer period of dryness in this region? Do you consider that the frequency of these periods in the region is accelerating the response of the vegetation characteristics to drought conditions?**

The last effects of drought were during July-September 2017 but at least during the last three years the precipitation has decreased significantly, when at least the indexes in the region should be between 1200 and 1500 mm for a good mainteinance of the crops



Since 1980 it has been noticed the decrease of some representative pioneer and secondary species maybe due to the effects of drought see answer 6.

And currently in the municipality the drought is considered a natural hazard being evidenced a hydrological drought (water courses interrupted and low level of the flow in water bodies) which have led to declare an emergency situation.

Adapting the municipality plan of water reserves that states to make use and extent water reservoirs for agriculture and livestock an others for rainfall water captation this is stressed out by the civil defense department and the local municipality in decree N°56 Nov 10 -2017 decree of identification of emergency situation-Hydrological Drought

2. **Do you consider that there are invasive plant species that best adapt to the drought conditions in this area? What are these species?**

Cactaceae like the Rabo de macaco *Hildewintera colademononis* Castanheiras no sertão Cipós guaxumo vassoura, Baleeira *Cordia verbenacea* mata pasto dente de traira, pico preto, chifre de garrote, tiririca ,etc are native plants easily propagated by animals, and wind.

3. **How can the functional characteristics of the plant be used to guide the restoration of the areas affected by drought in in this region for the conservation of the Atlantic Forest?**

By vegetative propagation of pioneer species like *Cecropia sp* (Imbauba), *Inga sp* (Ingá) *Caesalpinia ferrea* (Pau de ferro), *Cariniana legalis* (Jequitibá Rosa), *Talisia esculenta* (Pitomba) *Melanoxylon brauna* (Brauna preta), *Peltogyne lecointei* (Roxinho), *Dalbergia nigra* (Jacarandá)

4. **Which plants in the region do you think are most affected by drought?**

Cecropia sp (Imbauba), Calophyllum brasiliense (Guanandi), Mimosa bimucronata (Maricá),

5. **Which plants of the region do you consider the most resistant to drought?**

Trees like the Monjolo, peroba, Paullinia *cupana,* Guaraná, guaratáia, Guarapoca, Fabaceae Sucupira, *Goniohachis marginata* Itapecuru, café do mato, *Pachystroma longifolium* induaçu. Etc.

6. There are some characteristics of plants such as stem, root, leaves, fruits, etc., that over time allow detecting if they changed their characteristics like size, color, shape due to the effects of drought? Can you describe it?

In some plants as the angico, monjolo sabão, monjolo alho, monjolo teta de porca, monjolo cabelo de negro, sapucaia , araça do mato, cajá do mato can be detected less growth, the leaves may have a "grayish" aspect and the tips of twigs are dry; but these aspects can be also attributed may be to the acidity or alcalinity of the soil not necessarly to drought

7. Are there any plant species that you noticed that have diminished your presence in the region?

Probably it has been noticed the decrease of some representative pioneer and secondary species like *Aspidosperma polyneuron* (Peroba rosa), *Handroanthus albus* (Ipê amarelo), *Handroanthus impetiginosus* (Ipê Roxo), *Cariniana legalis* (Jequitibá Rosa), *Lafoensia glyptocarpa* (Mirindiba rosa) and others like *Goniohachis marginata* (Itapicuru) and sapucaia *Lecythis sp*.

8. Are there projects or studies being carried out to study the relationship of plant characteristics to ecological restoration plans in the Atlantic Forest region? Do you know what these projects are?

Meanwhile The Protection of water springs in the ciliary forest in the Microbasin of Guaxindiba river.

Interview N°2

This interview was conducted to specialized and expert personnel in the subject. In this case, professors and researchers from the UENF, which have been developed many studies in the region, the Prof. Dr. Marcelo Nascimento Trinidade, and the Ph.D. Student Igor Broggio; and Prof. Dr. Fatima Pina Rodrigues of the UFSCAR. There were elaborated questions aimed to answer if the distribution of plants is already showing signs of drier climatic conditions; whether native or foreign species are better adapted to drought, and if certain morphological characteristics or attributes of the species show adaptations to climate change. The questions are described as follows.

1. **In what functional characteristics of woody species of plants can be observed adaptations at morphological level in response to drought conditions in regions such as the Cerrado and Atlantic Rain Forest? Please, mention the attributes or characteristics that you consider important to measure**.

- Information provided by UFSCAR:

a) Attributes of the leaf (shape, thickness, size, etc.):

Field: Collecting leaf samples (This is why you need to sample leaves (3 at the base, 3 at the middle and 3 at the top)
Office and laboratory:
• IAF = leaf area index (calculated in office)
• LMA - Foliar mass per unit area (laboratory) - is negatively related to the plant's shadow tolerance and ability to harvest light. Therefore, it will be necessary to sample leaves (3 at the base, 3 at the middle and 3 at the top)
• CMSF- Leaf dry matter content (laboratory) - obtained directly from the material collected for the LMA. They are related to nutrient rich environments. The CMSF is also positively related to leaf longevity and protection against physical damage and negatively with the relative growth rate.

b) Attributes of the stem (cork thickness, wood density, etc):
• Bifurcation - in the perennial form of life is a strong indicator of the potential for vegetative branching along the edaphic environment. We make this classification considering the location of the height of the soil of the bifurcation. The great problem of this method is to distinguish, in the field, what is bifurcation and what is canopy. We have seen that in areas subject to seasonal and dry variations, the presence of bifurcations (number) is much greater.

c) Underground attributes (eg Root):
• This attribute is very difficult to achieve, but an indirect measure is to measure the water potential of the leaf. For this attribute can be used a pressure pump: http://www.agriexpo.online/en/prod/p-m-s-instrument-company/product-173955-49732.html#product-item_49714
• Thus, we compare the populations / individuals of different dry / wet conditions or wet and dry season and we have references.

- Information provided by UENF:

a) Leaf attributes (shape, thickness, size, etc.): leaf area, limb width, clean height, thickness, petiole size, presence of roughness, type of boron etc.
b) Attributes of the stem (cork thickness, wood density, etc.): specific wood density, presence of lenticels, bark adhesion, presence of lichens, etc.
c) Underground attributes (eg Root):

d) Other characteristics to consider: sometimes some species or genera have the same herbivory patterns, this may be a characteristic of identification ... type of herbivory example: chewers, miners, gall makers, leaf rollers, etc.

2. **Is there a collection of data of plant characteristics in the region (Cerrado - Atlantic Forest) that may suggest changes in the dry conditions? If yes, how is it elaborated? If not, how relevant should they be included in the drought studies in the region.**

- Information provided by UFSCAR:

There are some researches, but not structured. We are trying to do this with our team. And we consider relevant these data to include them in projects related to restoration of degraded areas.

- Information provided by UENF:

There are some information but still under research and could be included in researches or actions for degraded areas and protection of some areas in the region

3. **Do you consider that the table of characteristics of the indicators proposed (see tables of indicators in the results), has adequate characteristics that can be evaluated directly in the field, for example: that they demonstrate a response to drought conditions over a period of time (eg in the last 30 years?) What other traits can be included? Please explain your answer.**

- Information provided by UFSCAR:

Density of canopy in period (dry and wet season). This data has been relevant in the selection of species adapted to drier areas. Architecture of canopy considering its density or sparse

- Characterization of the crown

a) Height: total (Ht) and crown (Hc)
b) Cup diameter (measured north-south and east-west) or only the largest dimension
c) Canopy format: we use here the concepts used in urban afforestation (see: http://www.pma.es.gov.br/arquivos/downloads/Manual_Arborizacao.pdf) Figure 15
d) Position in Canopy: we only assign note by the visualization of the individual: note 1 (subcanopy), 2 (canopy position), 3 (emergent)

- Deciduity of the species (present or absent),
- Natural occurrence of the species. We consider that species with a wide natural distribution are more associated to environments of different characteristics, which leads to greater plasticity and potential to adapt to more drastic climate conditions. Thus we classify them in: note 1 (one) - occurrence in large areas in different ecosystems; 2- occurrence restricted to an ecosystem; 3- endemic species.
- Above ground biomass (leaf litter) - indicator of the functioning of the areas and plants. The evaluation has been very simple. We use a 0.5 x 0.5 m frame) that is thrown under the canopy and out of the canopies at least 3 times and note the% of litter covered area (each square of 0.25 cm represents 25%). We used the average cup data (to evaluate litter production) and outside the canopy (environment). Measuring time: 10 minutes / 10 x 10 m plot. Evaluation: drier areas tend to have less stock biomass.

4. **What is the relation of these characteristics of plants to adaptation to drought with foliar or perennial habits? Do these characteristics occur more in deciduous or perennial species?**

- Information provided by UFSCAR:

The suggested characteristics occur in both but need to be compared. In Brazil, long-term data are still missing

5. **Are there known traits that can show physical changes faster than others in response to drought conditions over a period of decades, for example? What are these traits?**

- Information provided by UFSCAR:

It can be considered the reduction the specific leaf area, leaf blade measurements (width and length), thickness for example would be good biometric attributes to consider, also stomatal density it would also be interesting to analyze. Besides the others thet I mentioned in the first answer

6. **Can you notice longer periods of dryness in the area? If so, do you consider that the frequency of these periods in the region is accelerating the response of the characteristics to drought conditions, and why?**

- Information provided by UFSCAR:

It has been noticed an increase in the duration of the period when plants are deciduous due to longer periods also changes in vegetation composition which cause a Entry of species from other formations. Reduction of local diversity and occurrence of other species. Changes in climate and nutrient cycling conditions and soil impoverishment are elements that increase the frequency.

7. Is there an increase in invasive plant species in the area, and can this be related to drier periods? What could be the reason for that?

- Information provided by UFSCAR:

Yes. The presence of some species like *Dodonaea* (Sapindaceae) has increased, the same with the different Asteraceae (vassorinhas) *Scoparia dulcis* that have increased and the presence of bamboos (Poaceae) is noticed.

- Information provided by UENF:

Some plants like *Hildewintera colademononis*, vassoura *Scoparia dulcis* , Baleeira *Cordia verbenacea* and bamboos (Poaceae) is noticed

8. Do you consider that the distribution of some families or species has been changed or reduced due to the effects of drought? If so, could you mention some taxons or botanical groups at which this phenomenon is evidenced.

- Information provided by UFSCAR:

It can be noticed the increase of Fabaceae species, also species we call "opportunists" some *Croton*. In areas of seasonal forest, near to beach regions is increased the presence of many Cactaceae species**.**

- Information provided by UENF:

Since 2008 in the Seasonal Semideciduous Forest in Guaxindiba for instance there is not noticed a increasing or reduction of some botanical groups but due to the changes is a probablity that at long term certain families may dominate

9. What projects or studies are being carried out to study the relation of functional characteristics to ecological restoration in this area of the Atlantic Forest?

- Information provided by UFSCAR:

Currenty our students are performing the functional traits monitoring , using protocols of Sandra Lavorel for this work by comparing:

a) Planting area of the same age (7 years) planted in a model that simulates the Atlantic forest in an area of seasonal forest; (highly densely planted with 142 species). Periodic monitoring, which is currently carried out in the dry and humid season.
b) Seasonal forest natural area (comparative model) - initial successional stage - periodic evaluation (not all attributes), but biomass contribution
c) Area of planting of restoration of 7 years, planted with 80 species, spacing 3 x 2 m.
d) Restoration areas in different models and ages (monitoring has been irregular and related to the characteristics of the environment x species) - focus on biomass contribution above the soil.

- Information provided by UENF:

- Temporal variation of Atlantic forest arboreal biomass at Biological Reserve União: Effect of Fragmentation Climate in 2017 baesd on collected data from 2000-2012 with the aim to predict potential impacts of climate changes on carbon storage in this area
- Impact of anthropic action on establishment of seedlings of tree species in riparian forest areas with 20 species
- Technical projects for the management of recovery of riparian forest protection in São Francisco

Interview N°3

For the elaboration of this interview were considered the observations of personnel of the JABOT which through Dr. Dietmar Sattler from the University of Leipzig provided a database of some collected exsiccates along a gradient from the Cerrado to the Mata Atlântica. The elaboration of this interview was conducted directly to him, considering the following criteria:

- It was found that 21 botanical families have exsiccates with entries with at least than two or three morphological recorded characteristics that could be considered as drought adaptive; including the biomes according to the IBGE classification.
- The families with more entries in the biomes were Asteraceae, Leguminosae, Acanthaceae, and Melastomataceae. The biomes with more entries were the Ombrophilous Forest, Restinga, Semideciduous Seasonal Forest and Savanna.

Next, the questions are presented considering the recorded species in the IBGE biomes and the description of some morphological characteristics of the exsiccates.

BIOMAS IBGE	Características		Familia	Especie
Campo Cerrado	, Arbusto com cerca de 1,5m de altura. Botões florais		ASTERACEAE	Pseudobrickellia brasiliensis (Spre
Campo Cerrado	, Arbusto de aproximadamente 1m de altura, flores r		CLUSIACEAE	Kielmeyera neriifolia Cambess.
Campo Cerrado	, Arbusto até 2m, foliolos papiraceos, calice verde e (		LEGUMINOSAE	Aeschynomene
Campos de altitude	, Arbusto, terrícola, heliófila. Folhas discolores. Inflo		ASTERACEAE	ASTERACEAE
Campos de Altitude	Subarbusto, Terrícola, heliófila. Pecíolo vinoso, folha		ERICACEAE	Gaultheria eriophylla (Pers.) Sleur
Floresta Montana	, Arbusto, terrícola, umbrófilo. Folhas glabras. Cálice		MALPIGHIACEAE	Byrsonima myricifolia Griseb.
Floresta Montana	Arbusto, Terrícola, heliófila. Arbusto 2 m, Folhas glab		OCHNACEAE	Ouratea vaccinioides (A.St.-Hil. & T
Floresta ombrofila	arbusto, Heliófila, caule ereto, pardo-esverdeado. Fo		MONIMIACEAE	Mollinedia schottiana (Spreng.) Pe
Floresta Ombrófila	arbusto, Ciófila, Caule esverdeado a arroxeado nas e		ACANTHACEAE	Justicia nervata (Lindau) Profice

. Example of botanical families recorded in the IBGE biomes Source (JABOT database, 2018)

Botanical families with traits considered as drought adaptive. Source modified from (JABOT database, 2018)

Family	Types of Biomes based on the IBGE classification, recorded on the provided database											
	Cerrado	Highland fields	High mountainous Forest	Semideciduous Seasonal Forest	Mountainous Forest	Ombrophilous Forest	Submountainous Forest	Riparian Forest	Riparian Forest in transition with Cerrado	Clouded Forest	Restinga	Savanna With trees
Acanthaceae				X		X	X			X		
Annonaceae						X						X
Apocynaceae						X						X
Aquifoliaceae												X
Arecaceae				X								
Asteraceae	X	X		X	X	X					X	
Begoniaceae					X	X						
Bignoniaceae						X	X					
Cactaceae											X	
Clusiaceae	X				X							
Ericaceae		X										
Euphorbiaceae			X									
Leguminosae	X						X				X	X
Malphigiaceae					X						X	
Melastomataceae	X			X		X					X	
Myrtaceae				X							X	
Piperaceae						X			X			
Rubiaceae								X			X	
Salicaceae						X						
Solanaceae						X						
Sapindaceae												x

Based on the previous information the following questions were elaborated:

Interview N°3

1. **Which of these families do you think they present morphological adaptations to drought conditions regarding the habitat where they are found?**

First, I think that the botanical family level is far to rough for identifying morphological or functional adaptions to drought conditions, especially in such broad and species rich families like Asteraceae, Fabaceae (Leguminosae) and Melastomataceae. They all have some woody species with drought adaptions. To my opinion, ecological evidence of drought adaption is only meaningful at species level and in combination with habitat of occurrence.

For example, there are many Asteraceae and Fabaceae species from the Atlantic Forest Biome restricted to moist ombrophilous (mountain) forest (e.g. Piptocarpha), but others are indeed adapted to drought like e.g. Hymenaea courbaril (as this species is semideciduous) but it is still occurring both in the Cerrado and Mata Atlântica biome. On the other hand, the Fabaceae species Acosimum dasycarpum, Enterolobium gummiferum and Andira paniculata show drought and fire adaptions like deciduousness and suberose bark and are restricted to the Cerrado.

Even the Cactaceae family, famous for being drought adapted, comprises Atlantic forest species (e.g. Pereskia aculeata, Rhipsalis spp.) and of course Cerrado species (e.g. Melocactus spp.). Hence, for further analysis I suggest focusing on the traits and distribution of species or smaller, ecologically +/- uniform genera.

2. **Which other general characteristics of the plants in the database that you know, could be considered to be taken into account as indicators in studies related to drought?**

I suggest not restricting the search for drought indicators in plants to the recent occurrence of adapted woody species. More important is the change (decline/increase) of such species in a given area. This could be detected either by repetitive floristic data from permanent plots or by field validation of species occurrences documented in older JBRJ records.

Additionally, there are for example many epiphytes in the Atlantic forest, depending on moist environmental conditions and more or less regular precipitation. Their decline or absence in forests or forest fragments formerly showing high epiphyte diversity can be used as an indicator for increasingly dry environmental conditions too.

3. **Could some of these characteristics change over time at anatomical or morphological level due to the effect of drought conditions? if so, in which ones could these changes be evidenced?**

Many adaptations to drought are addressed using physiological traits, which are not accessible via the JBRJ database or the plant specimens. Hence, I think it is important to mention that woody plants leaf traits (size, quantity, cuticular waxes etc.) and other morphological indicators of drought adaption should be investigated with regard of their changes in time and space.

Key questions to be addressed while searching the JBRJ database could be i) are there species occurring in both biomes and if so, do they significantly vary in leaf (and other e.g. bark) morphological traits? ii) are there shifts in the occurrence (samples, specimens) of drought adapted (Cerrado) species towards the MA biome within the last decades?

4. **According to the morphological characteristics recorded in the JABOT database; how those, could be used to guide actions or programs aimed to mitigate the impacts of drought?**

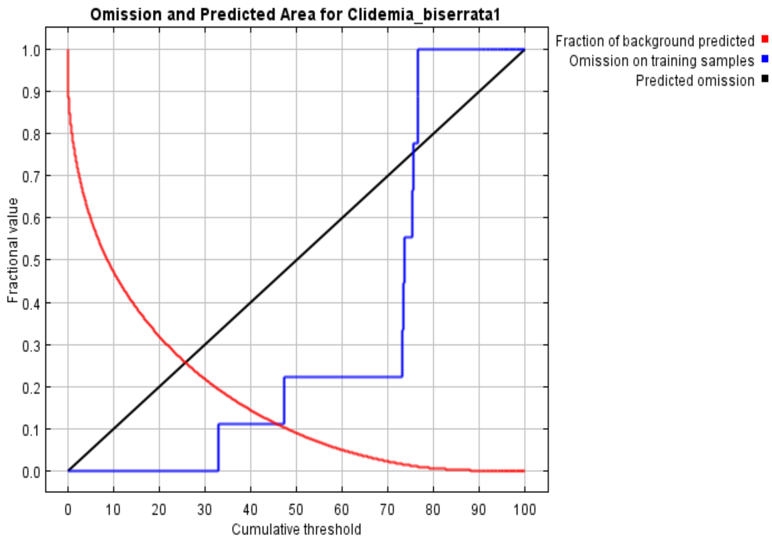
Only separately looking for morphological characteristics in the JABOT database does not help guiding actions or programs to mitigate the impacts of drought. A spatio-temporal analysis of the occurrences of plants possessing such traits can at least provide some evidence for potentially increasing drought and respective impacts. Hence, such data is a valuable scientific argument, together with other (climate) data, that action in terms of drought adaption is needed. This can be done with a specific selection and plantation of more drought adapted species in urban public spaces and in afforestation activities in the Mata Atlântica region.

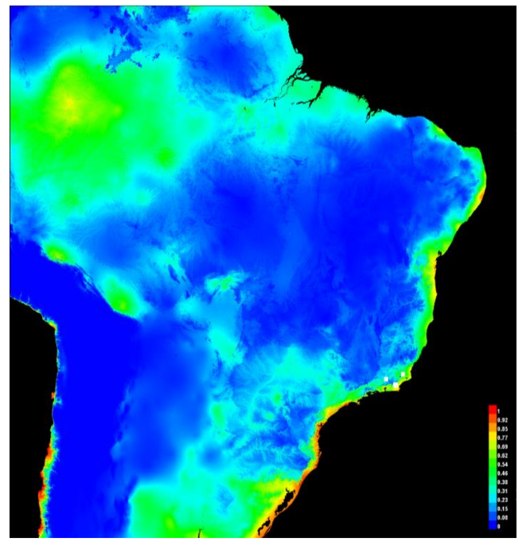
5. **Do you consider that certain morphological adaptations that some plants can present in case of drought, can be better evidenced in native or foreign species**?

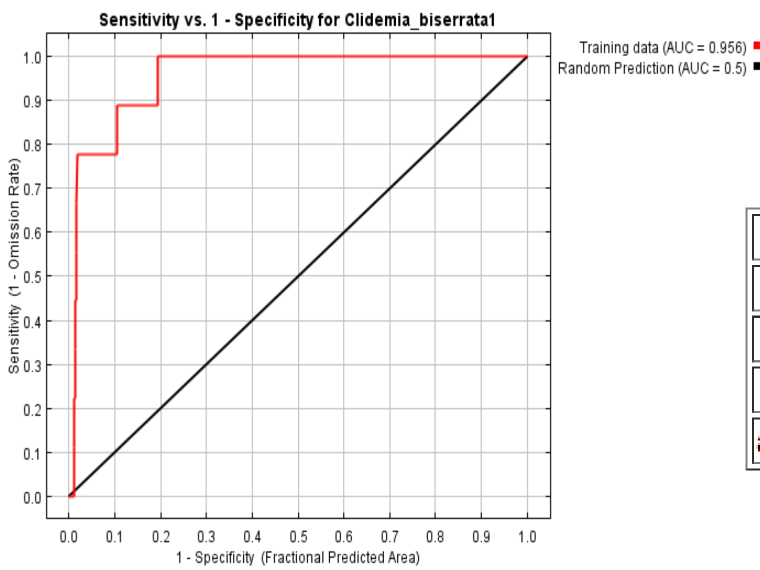
I do not think that origin of plant species plays a key role in morphological adaptions to drought. The only indicator aspect could be the change in the occurrence and degree of naturalization of exotic, drought adapted plants (e.g. Sansevieria trifascicata, some Cereus species) in Atlantic Forest (fragments) indicating more favourable (dryer) environmental conditions for competing out the native understorey flora.

Maxent modeling SDM for the selected database species

Clidemia biserrata

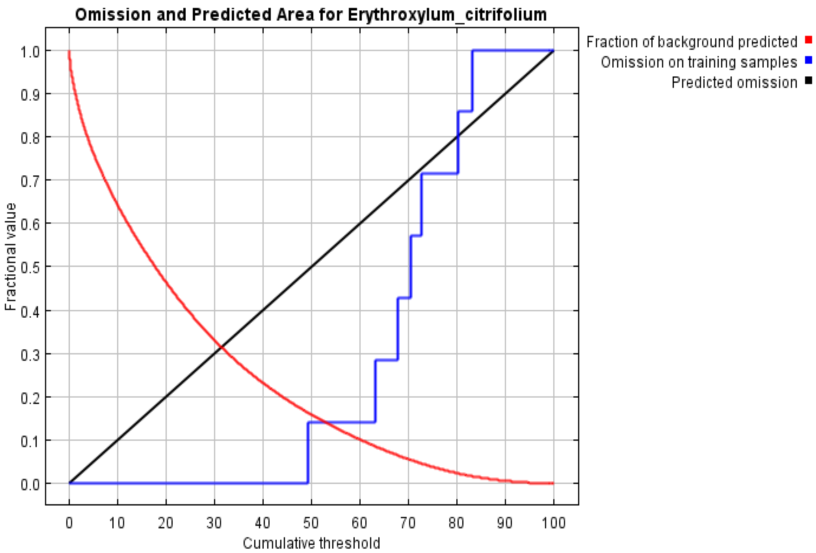


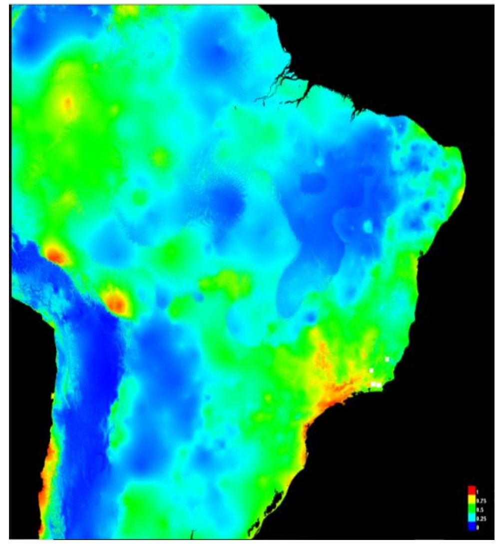


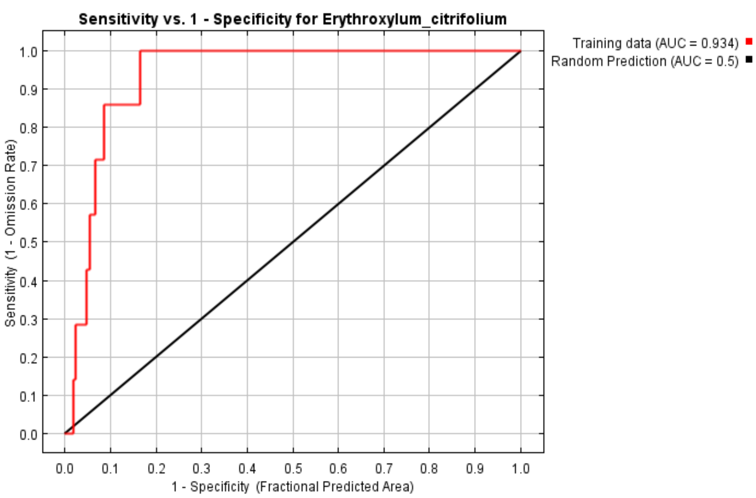


Variable	Percent contribution
bio5_br	89.6
bio18_br	10
bio15_br	0.3
altitude_br (1)	0

Erythroxylum citrifolium

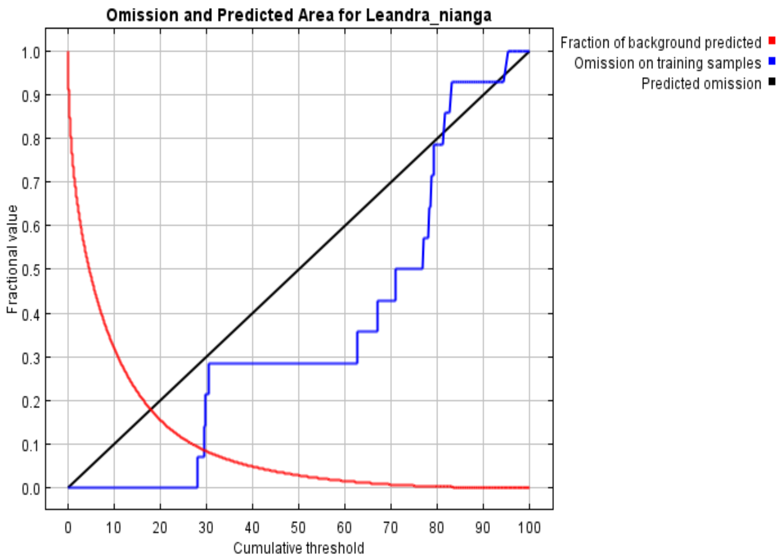


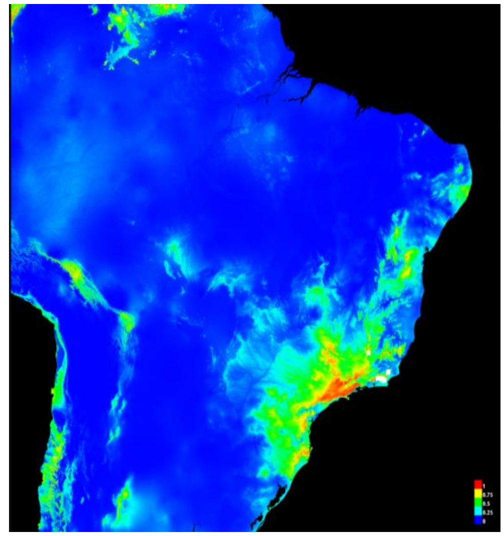


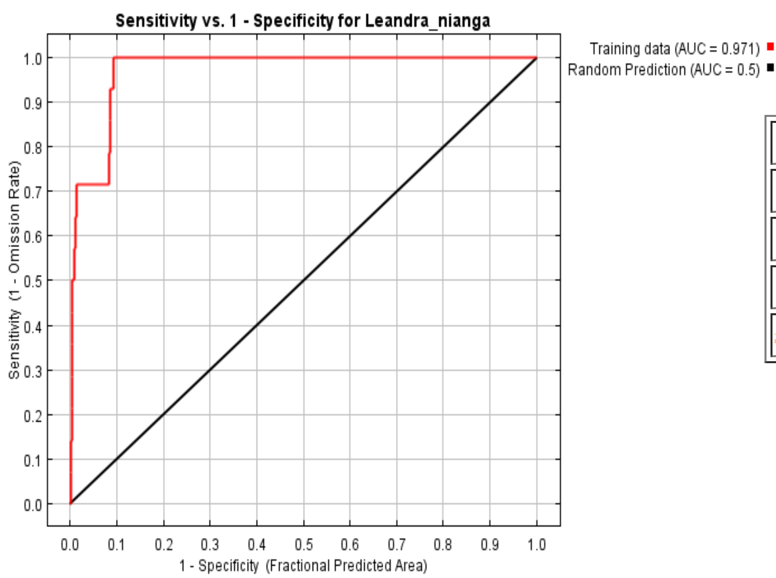


Variable	Percent contribution
bio18_br	53.4
bio5_br	39.8
bio15_br	6.9
altitude_br (1)	0

Leandra nianga

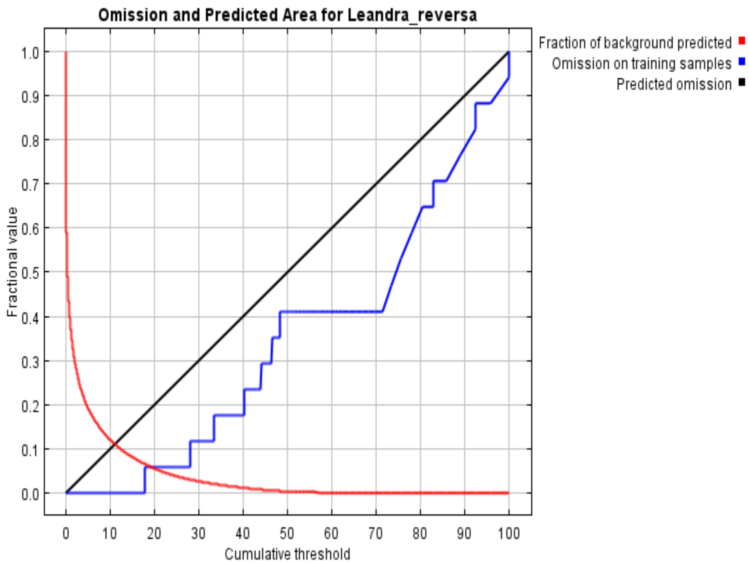


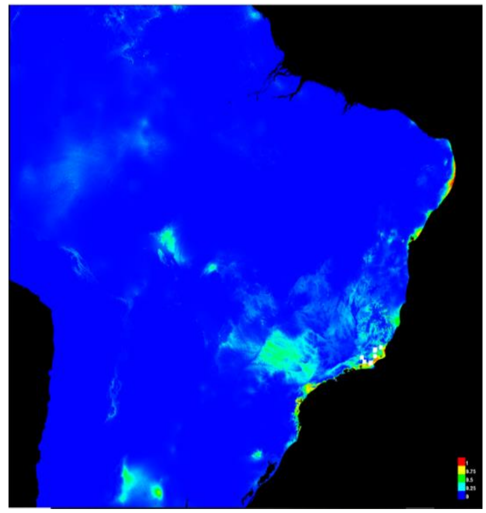


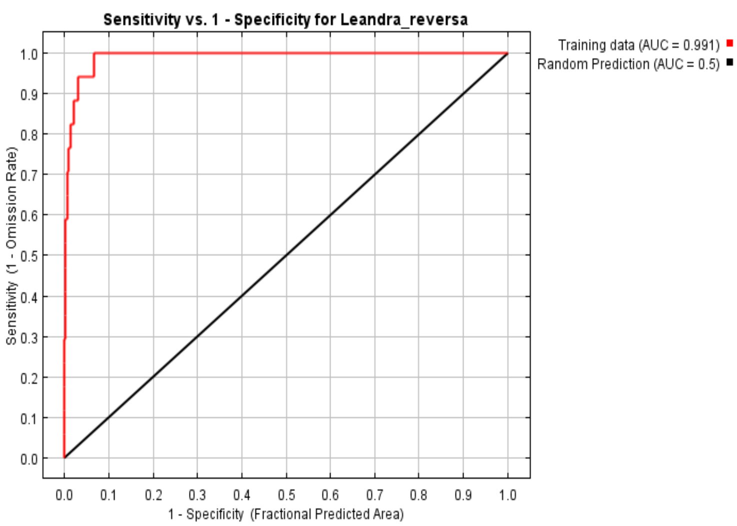


Variable	Percent contribution
bio5_br	55.8
bio18_br	34.8
bio15_br	9.3
altitude_br (1)	0

Leandra reversa

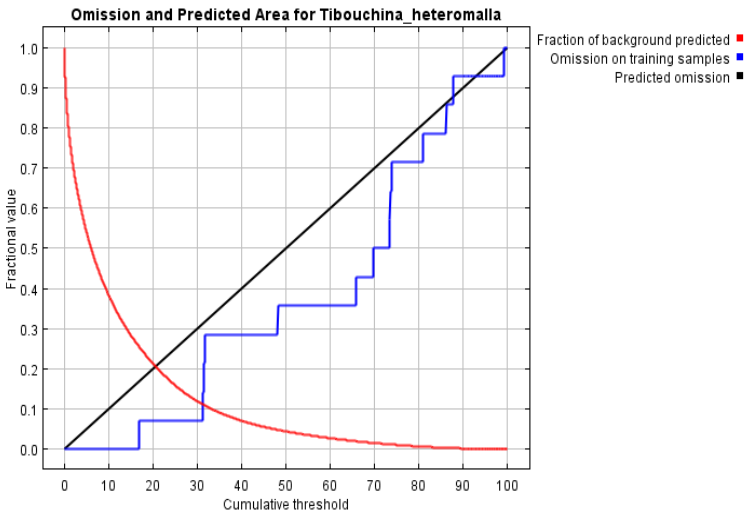


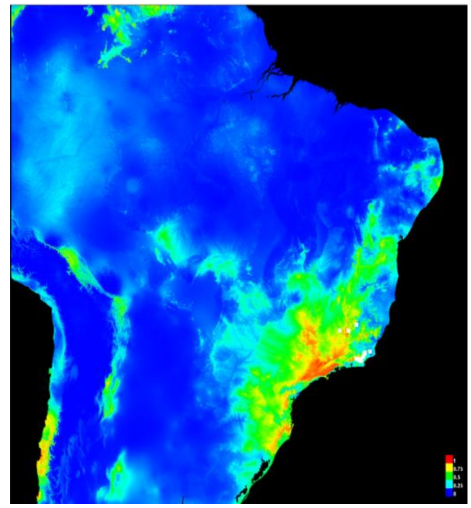


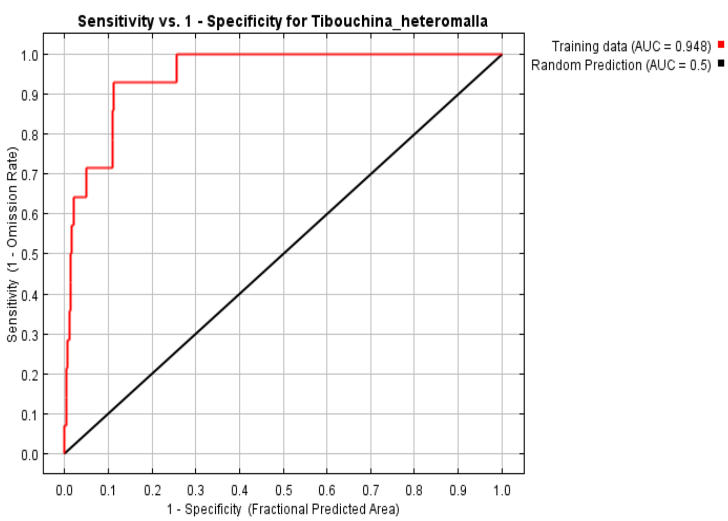


Variable	Percent contribution
bio5_br	57.5
bio15_br	21.7
bio18_br	20.8
altitude_br (1)	0

Tibouchina heteromalla

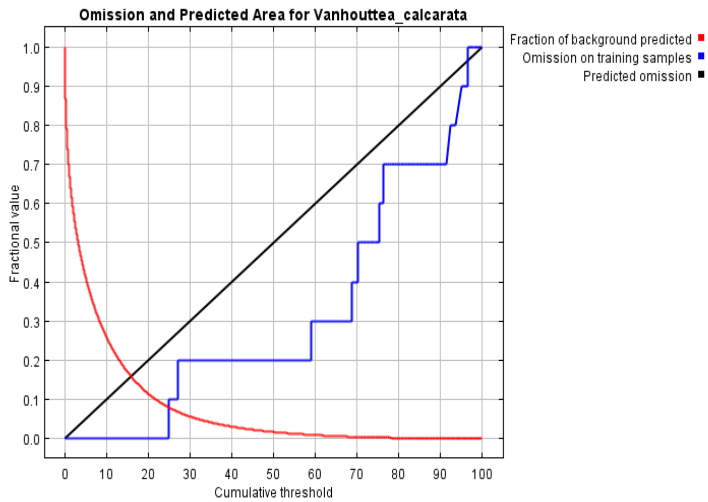


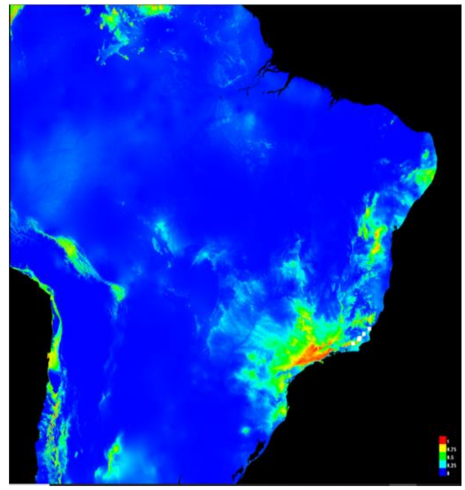


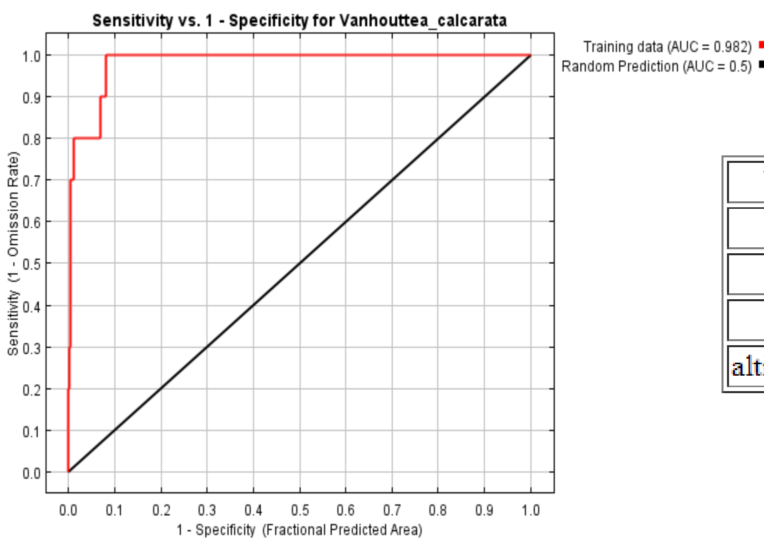


Variable	Percent contribution
bio5_br	65.2
bio18_br	30.7
bio15_br	4.1
altitude_br (1)	0

Vanhouttea calcarata



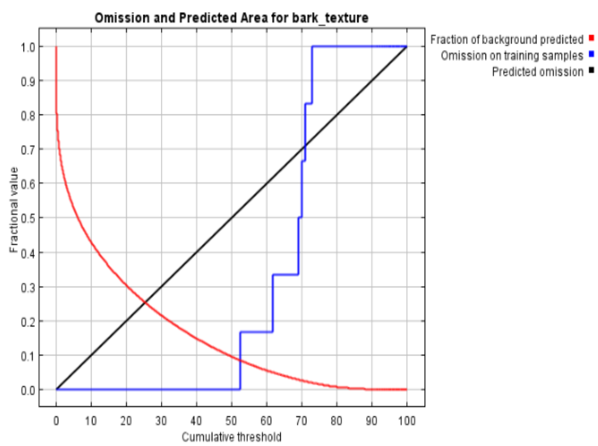


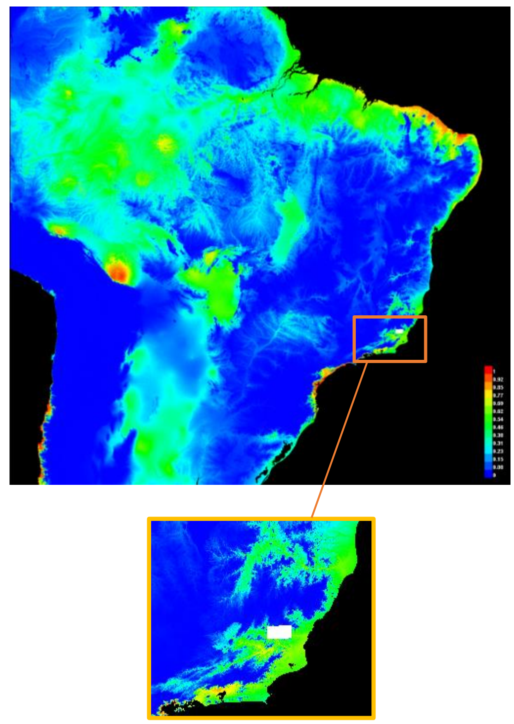


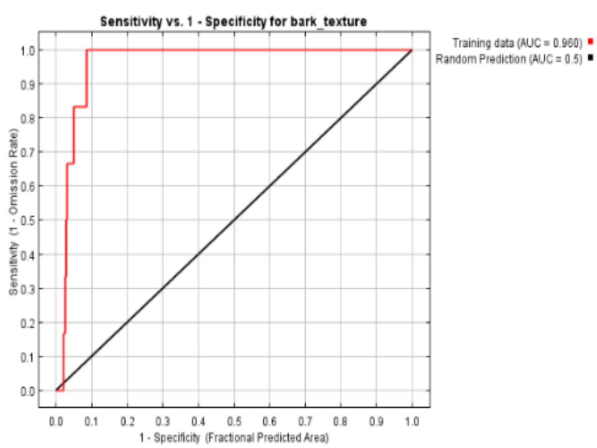
Variable	Percent contribution
bio5_br	53.3
bio15_br	26.2
bio18_br	20.4
altitude_br (1)	0

Maxent modeling SDM for the selected traits for the species in the field

Bark texture

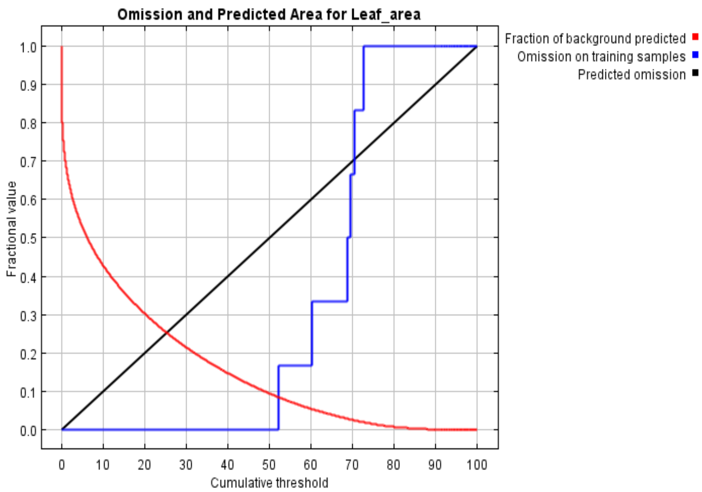


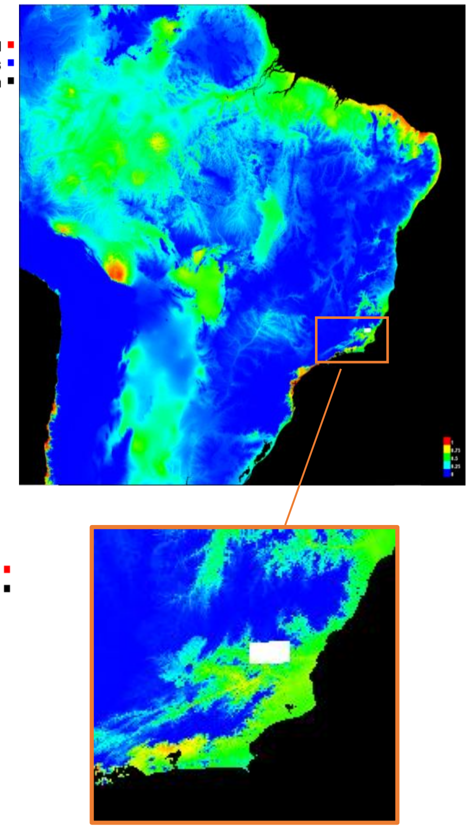


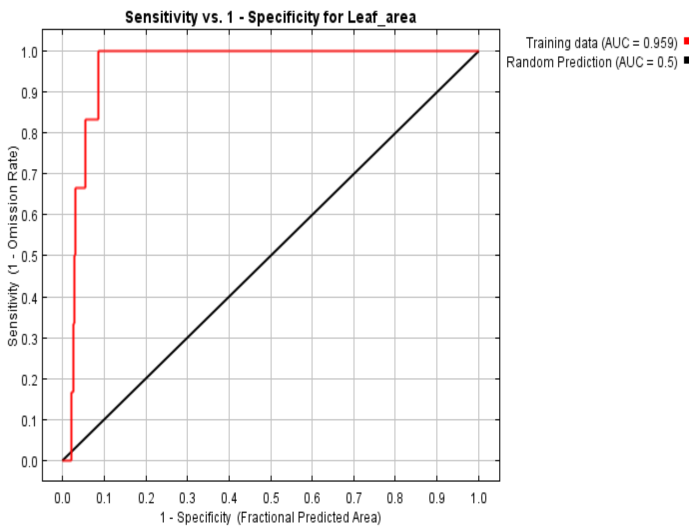


Variable	Percent contribution
bio15_br	43.2
bio18_br	34.8
bio5_br	22
altitude_br (1)	0

Leaf Area

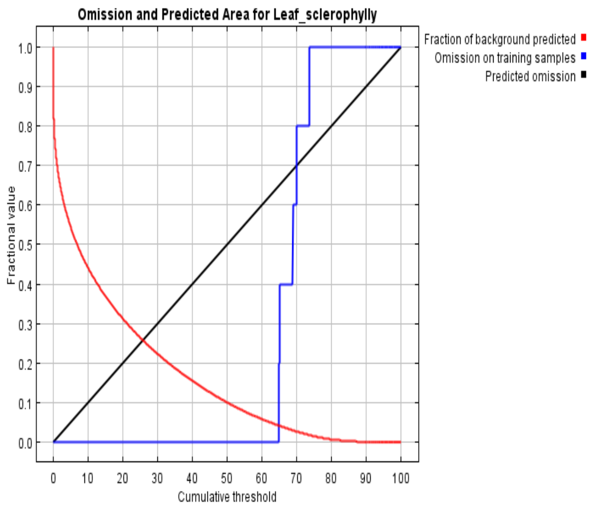


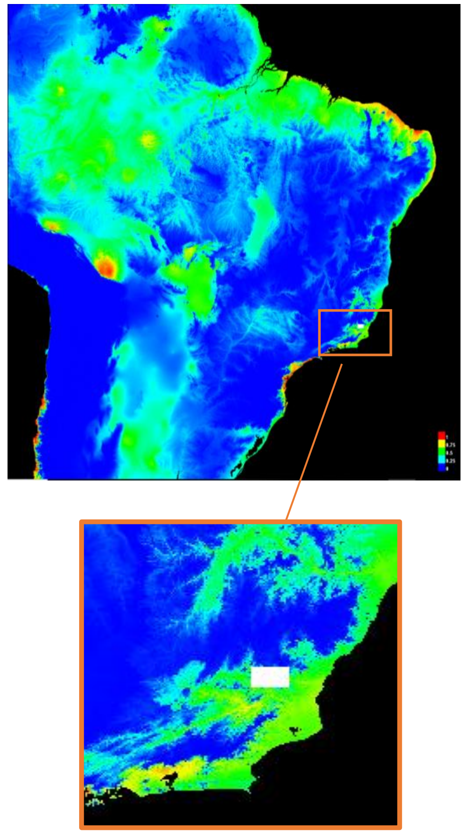


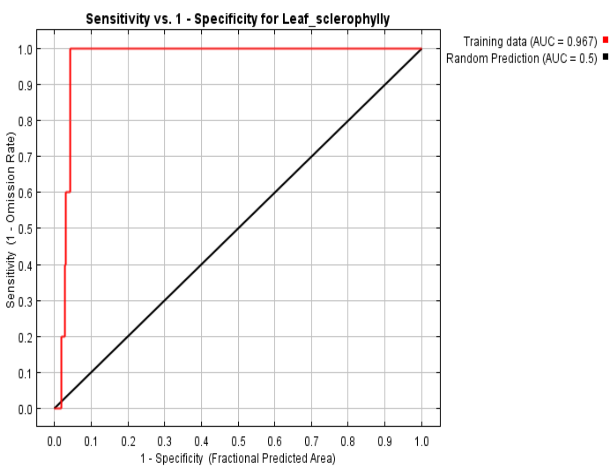


Variable	Percent contribution
bio15_br	44.7
bio18_br	34.7
bio5_br	20.6
altitude_br (1)	0

Leaf Sclerophylly

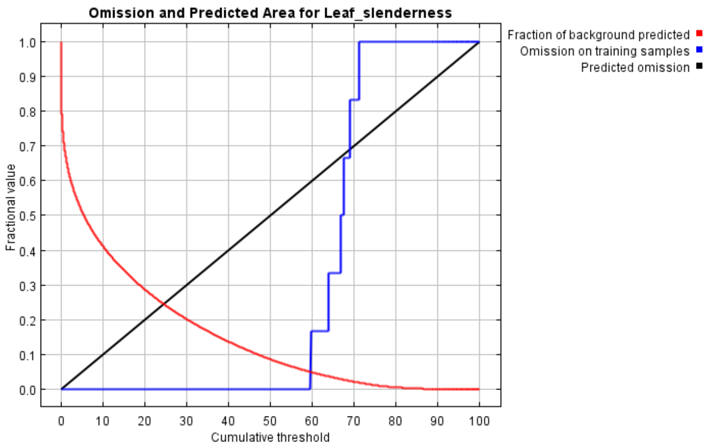


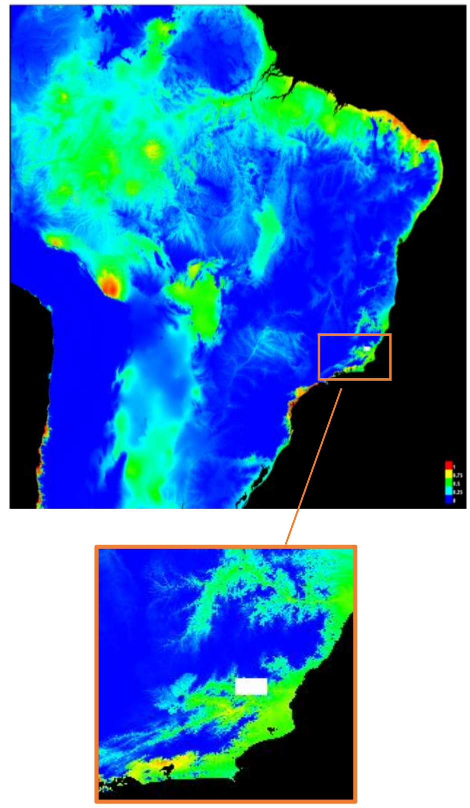


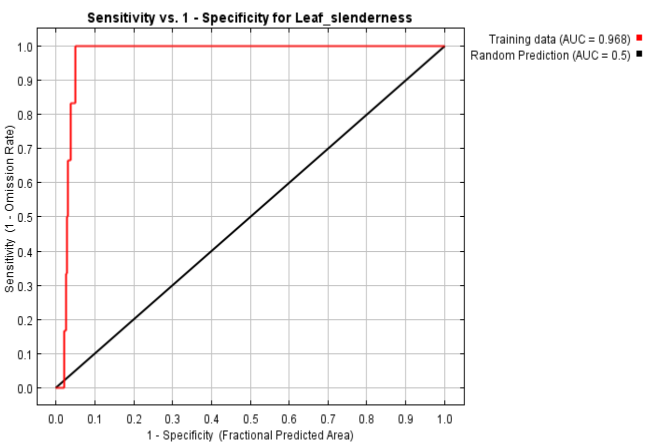


Variable	Percent contribution
bio15_br	36.7
bio18_br	34.5
bio5_br	28.8
altitude_br (1)	0

Leaf Slenderness

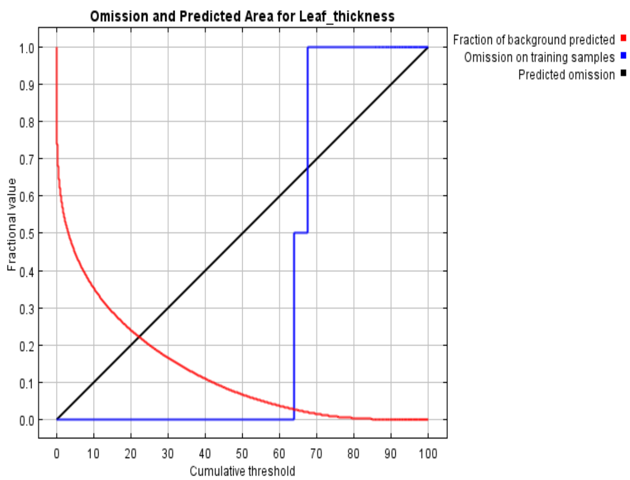


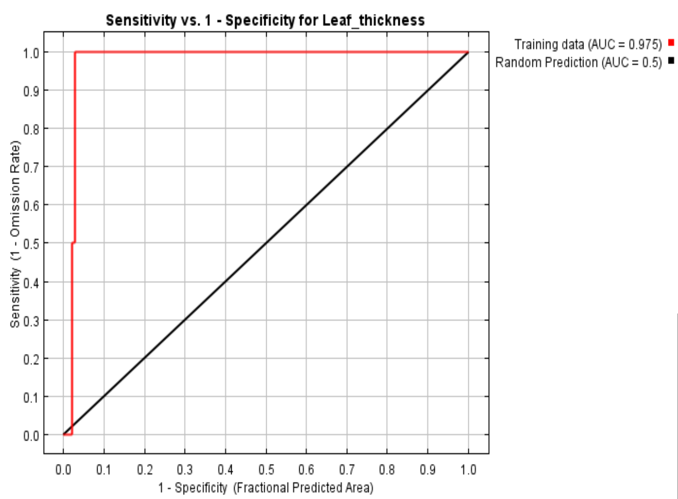


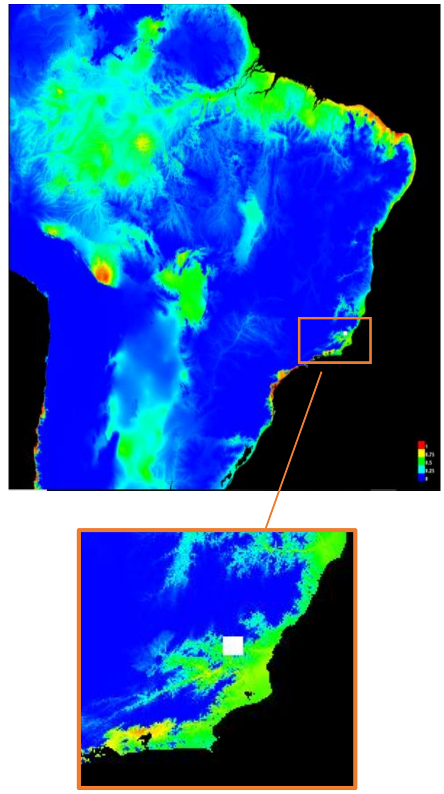


Variable	Percent contribution
bio15_br	48
bio18_br	29.1
bio5_br	22.9
altitude_br (1)	0

Leaf Thickness

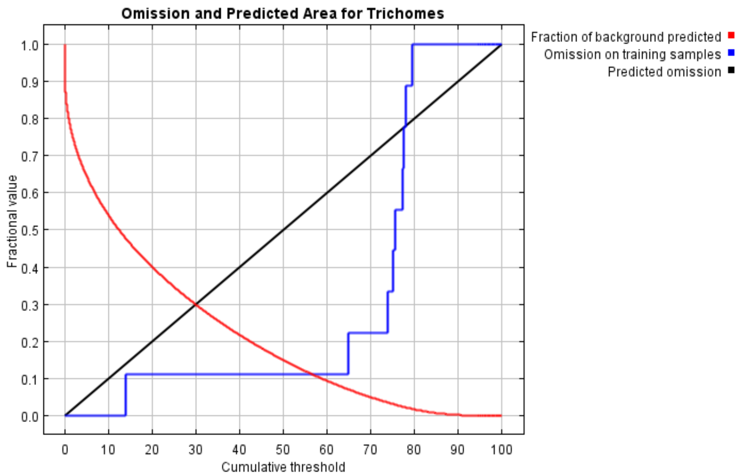


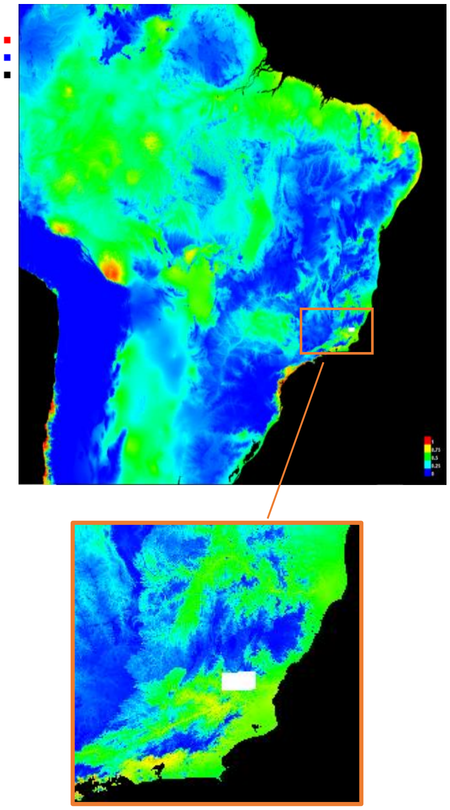


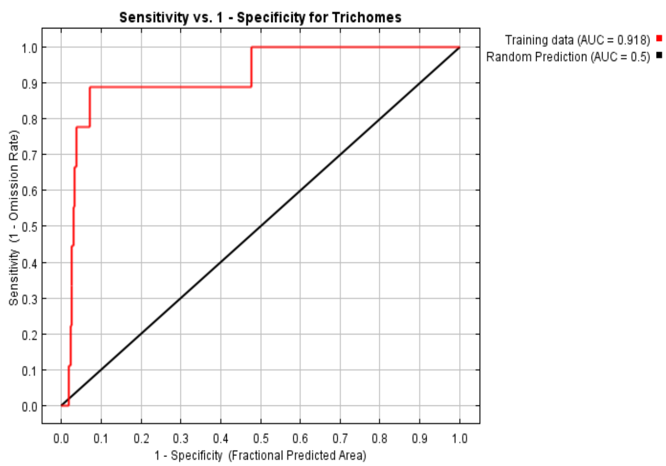


Variable	Percent contribution
bio15_br	43.4
bio18_br	29.2
bio5_br	27.4
altitude_br (1)	0

Trichomes







Variable	Percent contribution
bio15_br	37.9
bio18_br	34.8
bio5_br	27.3
altitude_br (1)	0