



Original article

Climate affects the structure of mixed rain forest in southern sector of Atlantic domain in Brazil



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ABSTRACT

This study aimed to analyze the influence of environmental factors in determining the variation in forest structure. We obtained the data through sampling units placed regularly in a grid of 10 km × 10 km in the state of Santa Catarina, southern Brazil. The axes of Detrended Correspondence Analysis summarized the vegetation structure and we used these as response variables in ordinary least square models, and environmental variables as predictors. Moran Eigenvector Maps were used as spatial predictors, enabling the variance partitioning. The results revealed influence of climatic factors, especially thermal and rainfall in determining the vegetation structure. The physical geography (high plateaus) and positioning below the Tropic of Capricorn line are the main static elements influencing the climate and therefore the vegetation.

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1. Introduction

Since Alexander Von Humboldt's pioneer work, exposing influence of climate and altitude on species distribution, plant forms and vegetation types variation, similar ideas have filled textbooks and scientific papers proving to be a general rule to explain why vegetation changes along latitudinal and topographical ranges (e.g. Holdridge, 1967; Walter, 1979; Whittaker, 1967). Altitude affects local and regional climate and vegetation in many ways (Lüttge, 2008; McCain and Grytnes, 2010; Ohsawa, 1995) influencing not only vegetation form, but also plant diversity (Gasper et al., 2015; Givnish, 1999; McCain and Grytnes, 2010; Saiter et al., 2015). As could be expected, climatic factors, especially thermal and precipitation ones, are associated to the plant development and global distribution of growth forms which results in changes in vegetation

structure along gradients and in delimitation of different forest types (Oliveira-Filho et al., 2013; Saiter et al., 2015).

While at a local level, both climatic and soil variables have been suggested as the main predictor of the structure of tree communities (Maçaneiro et al., 2016; Toledo et al., 2011), at regional scales, several studies have revealed the climate as the main predictor of tropical and subtropical forest structure (Engelbrecht et al., 2007; Gasper et al., 2015; Oliveira-Filho et al., 2005; Saiter et al., 2015; Scudeller et al., 2001).

The elevation and the associated lower temperatures are strongly correlated with structure variation of forests from Atlantic Forest domain (Oliveira-Filho and Fontes, 2000), that gives rise to distinct vegetation types. In the Atlantic Forest domain, a major division is related to altitude and to proximity from Atlantic ocean margin: (1) areas with better rainfall distribution at low and medium altitudes located between the ocean margins and the eastern mountain chains (the “Serra do Mar” and “Serra Geral”), and (2) areas in moderately high interior plateaus that have somewhat variable dry season (Morellato and Haddad, 2000). The first area is covered by the Atlantic Rain Forest, and the second by the forests typical of interior plateaus, like the Deciduous Seasonal Forest, that

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¹ In memoriam.

occupies lower and dissected areas surrounding the major river basins, and the Mixed Rain Forest (MRF) in the higher altitudes (Eisenlohr and de Oliveira-Filho, 2015; Oliveira-Filho et al., 2013).

From a phytogeographical point of view, the MRF, along with the seasonal forests, makes up the whole of Paraná province of Cabrera and Willink (1980) and the Paranaense biome of Spichiger et al. (2006). The MRF should be better understood as an expression of a continuum of variation of the South American Atlantic Forest domain, which is strongly influenced by the annual distribution of rainfall, in the Northern sector, and temperature, in Southern section (Giehl and Jarenkow, 2012; Oliveira-Filho et al., 2013).

Particularly, the MRF is marked by the strong presence of Brazilian pine or araucaria tree (*Araucaria angustifolia* (Bertol.) Kuntze), above the forest canopy (Klein, 1960) and is distinct if compared with deciduous or rain forest (Eisenlohr and de Oliveira-Filho, 2015). Furthermore, other species are commonly associated with this formation, such as *Dicksonia sellowiana* Hook., *Ocotea porosa* (Nees & Mart.) Barroso, *Ilex paraguariensis* A. St.-Hil. and *Podocarpus lambertii* Klotzsch ex Endl. (Klein, 1978; Leite and Klein, 1990; Maack, 1947; Vibrans et al., 2011). The characteristic flora of MRF results from the combination of temperate genera, including *Araucaria* Juss., *Podocarpus* L'Hér. ex Pers. and *Drimys* J.R.Forst. & G.Forst (Leite, 2002; Waechter, 2002), and typical elements of the Paraná Core flora (Spichiger et al., 2004).

The MRF spreads over large geographic area in southern Brazilian plateau, which includes large topographic projections over an extensive altitudinal, longitudinal and latitudinal range. Particularly, the Santa Catarina state in Brazil encompasses a wide range of climatic variation and counts with an excellent database derived from an extensive survey of forests structure recently concluded, which makes it as a good place to test some hypothesis linking environmental and forest structure variation. Thus, it is expected that major climate parameters variations could influence vegetation structure. Based on the data from an extensive survey conducted through the Floristic and Forest Inventory of Santa Catarina (IFFSC – <http://www.iff.sc.gov.br>), we want to address the following question: can the effects of altitude and its climatic variations influence major changes in forest structure in the MRF? The MRF was chosen as the focus taking into account that recent works have a wider perspective (e.g. Oliveira-Filho et al., 2013; Rezende et al., 2015). Thus, the aim of this study is to clarify specific MRF patterns.

2. Material and methods

2.1. Study area

The Santa Catarina State, in the Southern Brazil, lies completely below the Tropic of Capricorn over wide expanses of plateaus that could reach up to 1800 m (Fig. 1). Subtropical climate types predominate, with a certain frequency of frost and even snow during winters in the highlands, but with evenly annual distribution. The average annual rainfall varies approximately from 1500 to 2100 mm (Nimer, 1979; Pandolfo et al., 2002; Wrege et al., 2011). In the high and cold plateaus predominates Cfb climate type of Köppen (temperate, humid with warm summer), which is gradually replaced by Cfa type (temperate and humid, but with hot summer) towards the west, far from ocean margin, in the lower and dissected areas of the Parana river and Uruguay river basins (where the Seasonal Deciduous Forest occur), as well as along the valleys and coastal plains facing east (where Atlantic Rain Forest predominates) (Kottek et al., 2006).

The average annual 16 °C isotherm relates to altitudes between 750 and 1000 m, identifying the beginning of the *Araucaria* forests occurrence zone, also known as Mixed Rain Forest (MRF) (Gasper et al., 2012; Veloso et al., 1991). The study area includes mainly the perimeter of MRF and Grasslands (the later vegetation type occurs at high altitudes, mainly above 1200 m, where MRF follows the river channels, and the interfluves are dominated by grasslands) as defined by Klein (1978). We include some other areas within the perimeter of other formations based on field observations (Fig. 2). In Santa Catarina state, the MRF covered nearly 50% of the territory, especially in the highlands and relict areas, at altitudes ranging between 500 and 1800 m (Backes, 2009; Reitz and Klein, 1966). Its area of dominance borders to the east with the cliffs of the “Serra Geral” and “Serra do Mar”, interweaving to the grasslands (Leite, 2002) at the higher portions in the southeast and central north of the state. It internalizes to the west, covering areas that extend beyond state boundaries and establishes contact with the flora of the Deciduous Seasonal Forest along the banks of the Uruguay River and its tributaries at southwestern region of Santa Catarina state (Klein, 1978; Leite, 2002) (Fig. 2).

The average annual temperatures ranges between 12 and 20 °C, while in the higher parts of the “Espigão” and “Aparados da Serra” mountain chains, which constitutes the major elevations of the

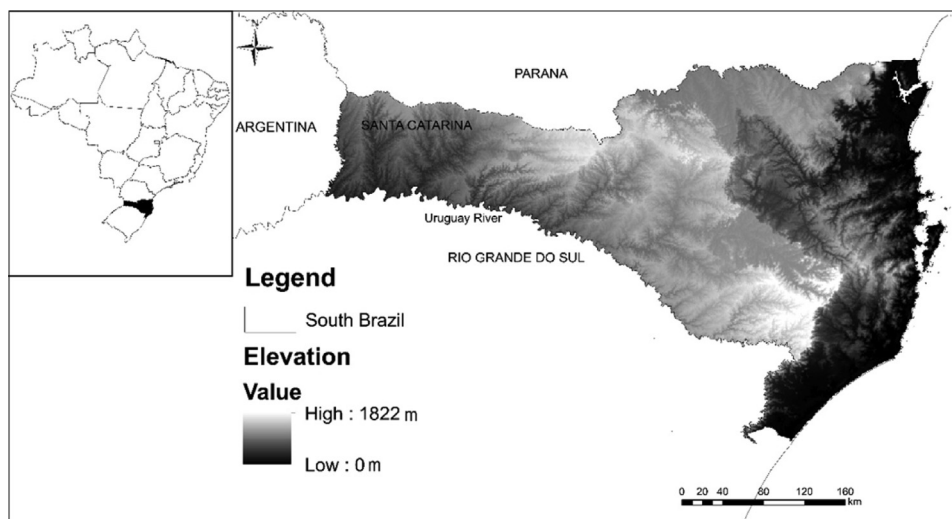


Fig. 1. Position of Santa Catarina State in Southern Brazil and its altimetric profile.

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