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ORIGINAL ARTICLE

An assessment of *Schinopsis brasiliensis* Engler (Anacardiacea) for dendroclimatological applications in the tropical Cerrado and Chaco forests, Bolivia

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ABSTRACT

Given the scarcity of instrumental climatic data in the South American tropics, it is valuable to explore the dendrochronological potential of the numerous tree species growing in the region. In this paper, we assessed for the first time the dendrochronological characteristics of *Schinopsis brasiliensis*, an arboreal species from the dry-tropical Cerrado and Chaco forests in Bolivia and adjacent countries. Similar to most woody species in the Cerrado and Chaco regions, growth rings of *S. brasiliensis* are delimited by the presence of thin but continuous lines of marginal parenchyma. Based on 22 samples from 15 trees, we present the first ring-width chronology for this species covering the period 1812–2011 (200 years). Additionally, a 106-year floating chronology from *S. brasiliensis* was developed using cores from four columns from the church of San Miguel, Santa Cruz, built in the period 1720–1740. Standard dendrochronological statistics indicate an important common signal in the radial growth of *S. brasiliensis*. The comparison of variations in regional climate and ring widths shows that tree growth is directly related to spring-summer rainfall and inversely related to temperature. Following the winter dry season, rainfall in late spring and early summer increases soil water supply, which activates tree growth. In contrast, above-average temperatures during the same period increase evapotranspiration, intensify the water deficit and reduce radial growth. The dependence of *S. brasiliensis* growth on water supply is evidence of its dendrochronological potential for reconstructing past precipitation variations in the extensive tropical Cerrado and Chaco forest formations in South America. Using wood from historical buildings opens the possibility of extending the chronologies of *S. brasiliensis* over the past 400–500 years.

1. Introduction

Dendrochronological studies in tropical and subtropical regions of South America have advanced dramatically over the last 10–20 years (Boninsegna et al., 2009; Rozendaal and Zuidema, 2011). Most investigations have focused on determining the ages of trees, rates of radial growth, biological rotation ages and the influences of regional climate variables on tree growth (Brienen and Zuidema, 2005; Lopez and Villalba, 2011; Lopez et al., 2013; Schöngart, 2008; Zuidema et al., 2012). In addition, a small number of initiatives have explored the potential of new tree species for dendroclimatological and dendrohydrological applications. Presently, most dendrochronological studies in tropical South America deal with approximately 15 species, representing a small percentage of the total available species (Lopez et al., 2012a; Rozendaal and Zuidema, 2011; Rozendaal, 2010), which may number up to 300 different tree species per hectare (Gentry, 1988). The relatively low number of species whose annual bands have been described with certainty usually corresponds to the limited number of tree species exploited by large-scale timber companies (Brienen and Zuidema, 2005; Lopez and Villalba, 2015; Lopez et al., 2013; Schöngart, 2008). In most cases, opportunistic samplings from these species at the local cutting areas have allowed for the collection of relatively large numbers of cross sections.

In the tropical Bolivian forests, which are dominated by hardwood trees of considerable size, logging operations provide a unique opportunity to access remote areas and to collect a large number of cross sections for dendrochronological studies (Lopez et al., 2012a). The high density and hardness of most woods in dry tropical forests impede the use of traditional increment borers, designed for low-density woods, for the collection of a large number of samples (Lopez et al., 2012a). The collection of

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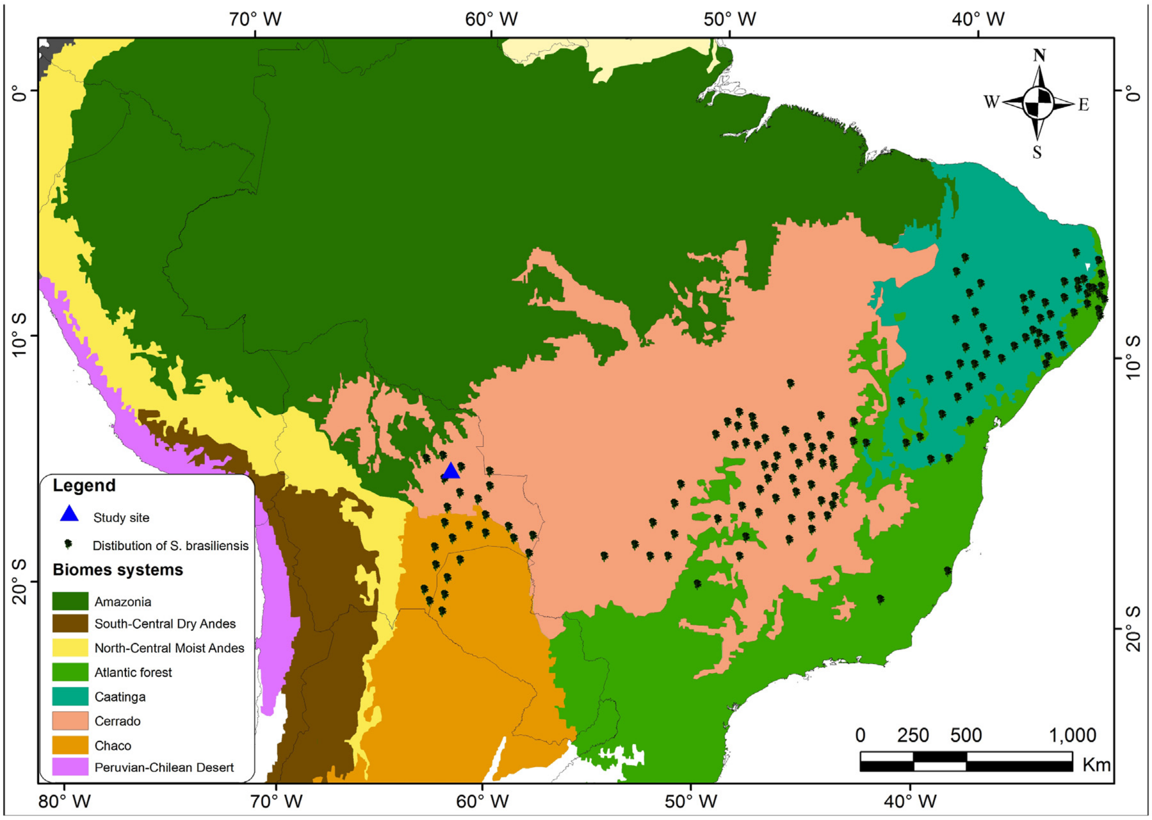

Fig. 1. Location of the study site (blue triangle) and the distribution of *Schinopsis brasiliensis* across tropical-dry biomes in South America (black dots). The Cerrado phytogeographical province extends from SE Bolivia into NE Brazil. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

complete cross sections allows establishing the presence of irregular or false bands facilitating the cross-dating of different radii in a cross section.

Since most dendrochronological samplings in tropical dry forests of Bolivia are opportunistic (Lopez et al., 2013, 2012b), our permanent monitoring of forest activities in the region has enabled us to access new sampling sites and to increase the number of species that are useful for dendrochronological research. This study presents the first dendrochronological assessment of *Schinopsis brasiliensis* Engler, a valuable timber species from the biogeographic provinces of the Cerrado and Chaco in tropical South America. Based on the exact dating and precise measurement of ring widths, we develop the first tree-ring chronology for *Schinopsis brasiliensis* and describe its response to regional climate. The potential to develop tree-ring chronologies of *S. brasiliensis* from historical buildings is also briefly evaluated.

2. Methods

2.1. Description and distribution of the species

In South America, the genus *Schinopsis* (family Anacardiaceae) includes eight species distributed across the tropical and subtropical dry forests that extend from Peru and north-central Brazil to northern Argentina. Five species have been identified in Bolivia (Killeen et al., 1993). *Schinopsis brasiliensis* Engler is mainly found in the Chaco and Cerrado forests of Bolivia, Brazil and Paraguay (Fig. 1) and is a characteristic species of these dry deciduous to semideciduous forests. Locally known as “soto”, *S. brasiliensis* trees can reach up to 20 m in height and have diameters larger than 1 m (Killeen et al., 1993; Mostacedo et al., 2003). They have straight and cylindrical trunks with a bark pattern of square plates. There is no specific information on *S. brasiliensis* population densities. According to the Inpa forest inventory (Mostacedo et al., 2009), this species is not abundant, with just one to two trees larger than 40 cm in diameter per every five hectares.

S. brasiliensis wood is very hard, with a specific density of 1.04 g/cm^3. The sapwood is yellowish-white and the heartwood is a light reddish brown (Fig. 3c). Highly resistant to decay, even when in contact with the ground, *S. brasiliensis* is used for parquet and floors, rural construction, rustic furniture and railroad ties. During the Jesuit colonization of the Chiquitania region in Bolivia, long, almost cylindrical *S. brasiliensis* trunks were employed in church construction, including the columns in the main building and their campaniles.

2.2. Study area

The study area is located in the Chiquitano botanical district in the biogeographic province of the Bolivian Cerrado (Navarro and Maldonado, 2004). This phytogeographic province is one of the largest vegetation domains in South America, extending from north-central Brazil to eastern Bolivia and northeastern Paraguay (Cabrera and Willink, 1973). In Bolivia, this province includes different forests from the transitional areas adjacent to tropical humid formations (Chiquitano-Amazonia) to the wet savannah of the Pantanal and the dry deciduous forests in the southern Bolivian Chaco (Killeen et al., 1993). The Chiquitano district covers a large territory characterized by a rich biodiversity that is typical of the seasonal tropics. Most forests are dominated by species of the genus Fabaceae and have an upper canopy that exceeds 25 m in height (Killeen et al., 1993).

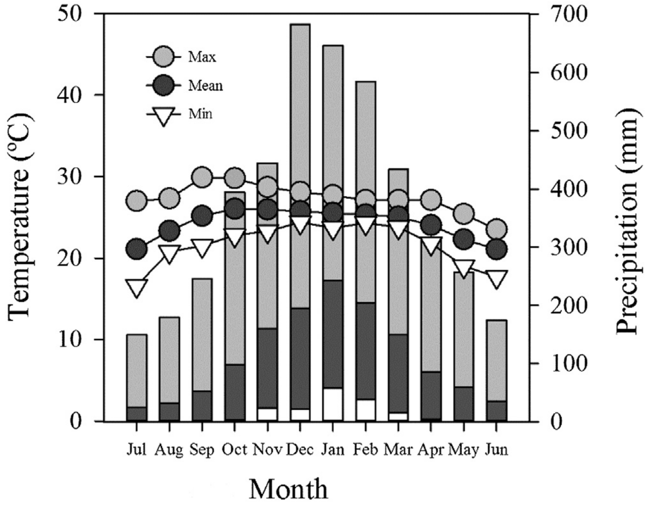

Fig. 2. The climate diagram from the Concepción weather station is illustrated for the period 1948–2010. Monthly mean, maximum and minimum temperature and precipitation values are plotted for the hydrological year starting in July.

Source: Servicio Nacional Meteorológico e Hidrológico de Bolivia (SENAMHI–Bolivia).

Precipitation in the Chiquitano district is largely concentrated in summer. The winter dry season has a mean duration of 6 months from April to September (Fig. 2). Mean annual temperature at the meteorological station of Concepción, located next to the sampling site, is 24.2 °C for the interval 1948–2010 (Fig. 2). The total annual precipitation varies between 1090 and 1270 mm over the same period (1948–2010). Dominated by small hills and plateaus, the Chiquitano district has very stony and shallow soils (Navarro, 2011).

2.3. Sample collection

The sampling site is situated in the locality of Inpa (16° 21′ 28′S, 61° 48′ 50″ W), Ñuflo de Chavez, Santa Cruz, Bolivia. Fifteen cross sections were collected at the time the timber company was conducting logging activities. In general, most trees showed good morphological characteristics, with diameters greater than 100 cm and heights around 20 m. Sampling heights varied according to the cutting practices, but all cross sections were cut from the lower (<1 m) part of the stem, avoiding heart rot. Five radii were also measured on four columns salvaged from the church of San Miguel de Velasco, Departamento Santa Cruz, Bolivia (Fig. 2). According to historical information from the town council, this church was built in the early 18th century (approx. 1720–1740) during the period of the Jesuit Missions in the Bolivian Chiquitania. The San Miguel church was restored between 1980 and 1983 as part of a restoration program of the Jesuit Churches in the Bolivian Chiquitanía sponsored by UNESCO.

2.4. Sample processing and chronology development

Cross sections were polished with progressively finer sandpaper (from 80 to 1200) to allow clear microscopic visualization of the minute wood anatomy (Fig. 3b). Tree rings were dated visually under a binocular microscope using a high quality cold-type light. Samples were illuminated from different angles to achieve the best contrast. Following the Southern Hemisphere convention, annual rings were assigned to the year in which their formation began (Schulman, 1956). Two or more radii were dated on each cross section. Following the visual cross-dating of the different radii on each cross section, the ring widths were measured with a precision of 0.001 mm using a Velmex UniSlide Tablet connected to a digital counter (Metronics Quick-Chek QC – 10 V).

The quality of the visual dating and measurement was checked with the computer program COFECHA (Holmes, 1983). This program calculates correlation coefficients between individual ring-width series and the master chronology by averaging all other dated samples at a particular site. This procedure helps to identify incorrectly dated specimens or segments of specimens, and provides a statistical basis to help identify absent or false rings on the measured radii. Following the sample cross-dating, all correctly dated series were standardized by fitting negative exponential curves or straight lines to the raw ring width measurement time series using the program ARSTAN 0.41 (Cook et al., 2007; Cook and Holmes, 1999). The objective of ring-width standardization is to remove long-term growth trends due to the increasing size

Fig. 3. Macroscopic structure of *Schinopsis brasiliensis* wood (*a*). Arrows indicate the boundary between consecutive rings marked by a thin line of marginal parenchyma (*b*). The restored Jesuit church of San Miguel Velasco, Velasco, Santa Cruz, Bolivia (*c*). Original *S. brasiliensis* columns salvaged from the church are stored in a local sawmill and were sampled for dendrochronology.

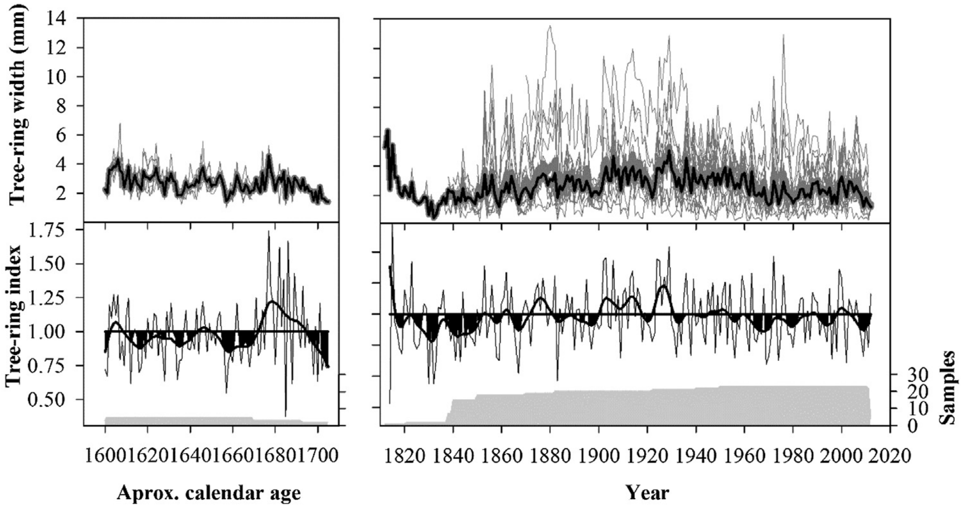

Fig. 4. Annual ring width measurements (upper graph) and standard tree-ring index chronologies (lower graph) are illustrated for *Schinopsis brasiliensis* cross sections from trees collected at Inpa (right) and from old columns removed from the church of San Miguel de Velazco (left). To emphasize the long-term variations, the chronologies are shown with a cubic smoothing spline that highlights low frequency variations near 15 years (Cook and Peters, 1981). Variation in sample size over time is shown at the bottom of each chronology in light gray.

and age of the tree, as well as to differences in the absolute growth rates among trees. In consequence, standardization maximizes the percentage of common variance in ring width variations between samples in the chronology (Cook and Peters, 1981; Cook and Holmes, 1999). The standardized ring-width indices for each radius are dimensionless as a result of dividing the observed ring width value by the value of the fitted curve in each year.

Several statistics used routinely in dendrochronology were calculated to estimate the quality of the derived chronology, including the standard deviation, the first-order autocorrelation and the mean sensitivity, a measure of the relative change in ring-width from one year to the next, commonly related to growth responses to variations in climate (Fritts, 1976). Other statistics used in dendrochronological studies, such as the RBAR and EPS, were also calculated. The RBAR is a measure of the common signal in tree-ring variations, calculated as the average correlation coefficient between all possible pairs of segments of a given length (50 years in our study) included in the chronology (Briffa, 1995). The EPS (or expressed population signal) is a measure of the total signal present in the chronology (e.g., 50 years) in comparison to a fully replicated chronology. EPS values > 0.85 indicate that the number of radii included in a particular segment of the chronology is large enough to capture an adequate percentage of the theoretical signal present in the fully replicated chronology. EPS values < 0.85 indicate that replication in that particular segment of the chronology is low and that the number of samples should be increased to strengthen the common signal (Briffa, 1995).

2.5. Climate-growth relationships

In order to determine the climate influences on the growth of *Schinopsis brasiliensis,* interannual variations in ring widths were compared with monthly temperature and precipitation records from the Concepción weather station using correlation function analysis (Blasing et al., 1984). This method estimates the correlation coefficients between ring-width indices and monthly climate variables. Because growth in a given year can be influenced by climatic conditions of the previous year, the comparison period used in our study included 29 months, from the January two years previous to the growing season until May of the year in which the rings were formed. In addition, variations in *Schinopsis brasiliensis* and in the Palmer Drought Severity Index (PDSI) were compared over the interval 1948–2010. The PDSI data for the 0.5° grid located over the sampling site were obtained from the Climatic Research Unit (CRU), University of East Anglia.

3. Results

The identification, dating and measurement of growth rings in *Schinopsis brasiliensis* relies on the careful polishing of the cross sections. The vessel distribution is diffuse, with no clear earlywood/latewood pore arrangement. Vessels are arranged from solitary to radial multiples (up to 4–5 vessels) surrounded by vasicentric to aliform parenchyma (Fig. 3c). Growth rings are indicated by the presence of a thin but continuous band of marginal parenchyma (Fig. 3c). The marginal parenchyma acts as the growth-ring indicator, as annual growth boundaries would otherwise be indistinguishable due to the diffuse-porous nature of *S. brasiliensis* wood.

The chronology from *S. brasiliensis*, which is based on 22 radii from 15 trees, covers the period 1812–2011 and is well replicated (>10 trees) after 1840. Tree rings from opposite radii on seven complete cross sections were measured; the remaining nine trees were dated and measured using the available partial cross sections. The mean diameter growth for *S. brasilienses* over the full period 1812–2011 is 2.57 mm/year. However, most samples show larger ring widths during the first decades (1870–1940) and a gradual reduction in width over the most recent 50 years (Fig. 3).

A preliminary floating chronology was also developed based on five radii from four damaged columns that were salvaged from the church of San Miguel de Velasco, Department of Santa Cruz, Bolivia. This church was restored in the 1980s by an international collaborative program sponsored by UNESCO. During the restoration, some columns were replaced and stored in local sawmills. The floating chronology covers 106 years and the average correlation between samples is r = 0.48 (Fig. 4).

The statistics commonly used in dendrochronology to assess the quality of tree ring records indicate that the *S. brasiliensis* chronology is of good quality. A mean sensitivity value of 0.37 suggests a relatively high interannual variability in ring widths. This value is consistent with a standard deviation of 0.45 and a relatively low autocorrelation of 0.46. In addition, the mean RBAR and EPS (1812–2010) for the whole chronology are 0.42 and 0.89, respectively (Fig. 5). EPS values above the 0.85 threshold span the interval

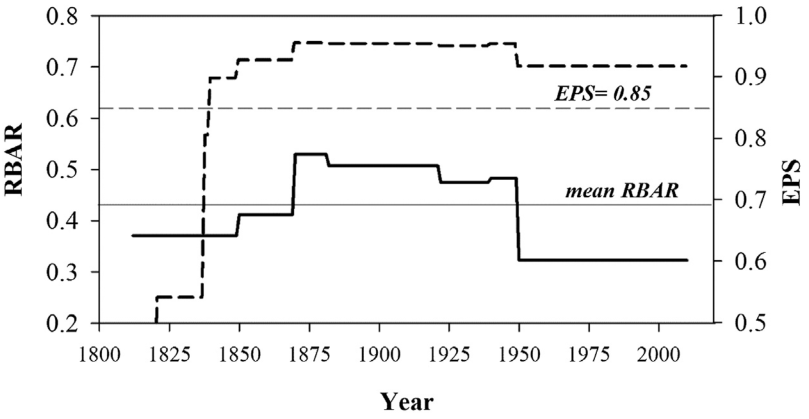

Fig. 5. Interannual variations in RBAR (solid line) and EPS statistics (dashed line) for the *S. brasiliensis* chronology from Inpa, Concepción, plotted for 50-year window intervals with 25-yr overlap. The mean RBAR and the EPS threshold of 0.85 are also shown.

1830–2010. The chronology exhibits marked inter-annual variability in ring-width indices, and there are periods dominated by low and high rates of growth. From approximately 1870 until 1930, the tree-ring indices indicate generally above-average growth, especially during the 1920s. Below-average radial growth is computed for the 1960s and after 2005 (Fig. 4). The low average growth rates from 1820 to 1840 may be biased by the small sample size for this period (Fig. 4).

Schinopsis brasiliensis growth is favored by late spring-summer precipitation (Fig. 6). Radial growth is significantly related to precipitation from October to January (except December) during the period of active tree growth. In contrast, radial growth is inversely related to temperature during the same period, though the correlation coefficients are not significant (Fig. 7). This is a common correlation pattern between climate and tree growth recorded at moisture-stressed forest stands around the world (Fritts, 1976; Villalba and Veblen, 1997). This moisture signal is consistent with relatively modest annual precipitation totals and long seasonal dry periods in the Bolivian Cerrado. Above-average temperatures from October to January presumably increase the summer water deficit during the growing season and are negatively related to growth.

Based on these results, seasonal precipitation and temperature records were used to estimate the strength of the relationships between climate and tree growth. Fig. 7 compares the inter-annual variations in S*chinopsis brasiliensis* growth at Inpa with a seasonal record of precipitation (October, November, January and February) from Concepción over the 1948–2010 interval. Although the positive relationship between precipitation and tree growth is statistically significant over this period ($r = 0.41$, $p < 0.01$), we noted a five-year interval (1979–1983) with opposite trends (Fig. 7). Indeed, the correlation coefficients between precipitation and tree growth are much stronger over the intervals preceding (1948–1979; $r = 0.67$) and following (1984–2010; $r = 0.47$) the period 1979–1983. The relationship between *S. brasiliensis* radial growth and late spring-early summer temperature (October to January) is weaker, although significant over the interval 1948–2006 ($r = -0.27$, $p < 0.05$). Late spring-summer seasons with significantly above-average temperatures, such those recorded in 1953, 1962, 1971, 1996 and 2002, were concurrent with extremely narrow tree rings. Higher temperatures during these growing seasons, concurrent in most cases with scarce precipitation, increased evapotranspiration and reduced soil water available for tree growth. These results suggest that moisture balance indices, such as the Palmer Drought Severity Index (PDSI) or the Standardized Precipitation Evapotranspiration Index, might be suitable for climate reconstruction using *Schinopsis brasiliensis* tree-ring chronologies. Indeed, the comparison between the *S. brasiliensis* chronology and the gridded PDSI reveals correlation patterns similar to those found for precipitation (Fig. 7).

4. Discussion and conclusions

Schinopsis brasiliensis, a valuable timber species from the semiarid regions of tropical South America, has been used to develop an exactly dated tree-ring chronology covering the period 1812–2011 (Fig. 1). This is the first accurately dated, well-replicated and statistically reliable chronology of *S. brasiliensis* yet developed. Previous studies in subtropical (25°S) South America by Ferrero and Villalba (2009) have reported the development of a tree-ring chronology from *Schinopsis lorentzii*, a dominant species in the semi-arid Chaco in Argentina and Paraguay. In both species, tree rings are defined by more abundant fibers at the end of the growing season, and particularly by the presence of a lighter and continuous band of two-to-three cell thick of marginal parenchyma.

Statistics traditionally used in dendrochronology indicate that the *Schinopsis brasiliensis* chronology is of good quality and contains an important common growth signal. The mean RBAR value of 0.42 is comparable with those reported for chronologies in other regions of South America, including trees from temperate or cold sites with a marked seasonality in temperature. For example, RBAR values for *Nothofagus pumilio*, the dominant sub-alpine species in Patagonia, range between 0.25 and 0.41 (Lara et al., 2008). For *Polypepis tarapacana,* which grows above 4300 m elevation in the Bolivian Altiplano, RBAR values range from 0.23 to 0.50 (Solíz et al., 2009). The mean RBAR from the *S. brasiliensis* chronology is also similar to or higher than those recorded for tropical species in the Cerrado, including *Centrolobium microchaete* (RBAR from 0.22 to 0.31; (Lopez and Villalba, 2011)). EPS values above 0.85, the critical threshold for a robust common signal in the chronology (Wigley et al., 1984), are registered from 1840 to present. Our chronology statistics are very similar to those reported for the *S. lorentzii* chronology in subtropical northwestern Argentina (mean RBAR = 0.52 and mean EPS = 0.97 from 1880 to 2004; Ferrero and Villalba, 2009).

The radial growth of *Schinopsis brasiliensis* at the Inpa site in the Chiquitano district is modulated by soil moisture conditions, as indicated by the positive correlations with precipitation and the negative correlations with temperature during the period 1948–2010 (Fig. 6). Following the winter-early spring dry season, precipitation from October to February favors tree growth. In particular, October rainfall that ends the long dry season appears to be most strongly related to radial growth (Fig. 6). As indicated by the correlation coefficients, rainfall in December does not appear to be related to *S. brasiliensis* growth. We are suspicious on the homogeneity of the Concepción precipitation record

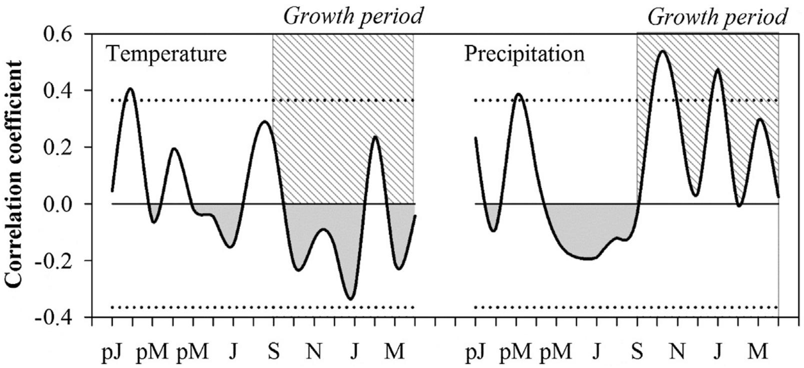

Fig. 6. The correlation function for the *Schinopsis brasiliensis* chronology at Inpa showing the relationships with monthly temperature (left) and precipitation (right) records. The relationships are shown for the period extending from January of the previous growing season to April of the current growing season. Correlations greater than $r = 0.24$ (dotted lines) are statistically significant ($p < 0.05$). The timing of the growing season for *S. brasiliensis* is highlighted.

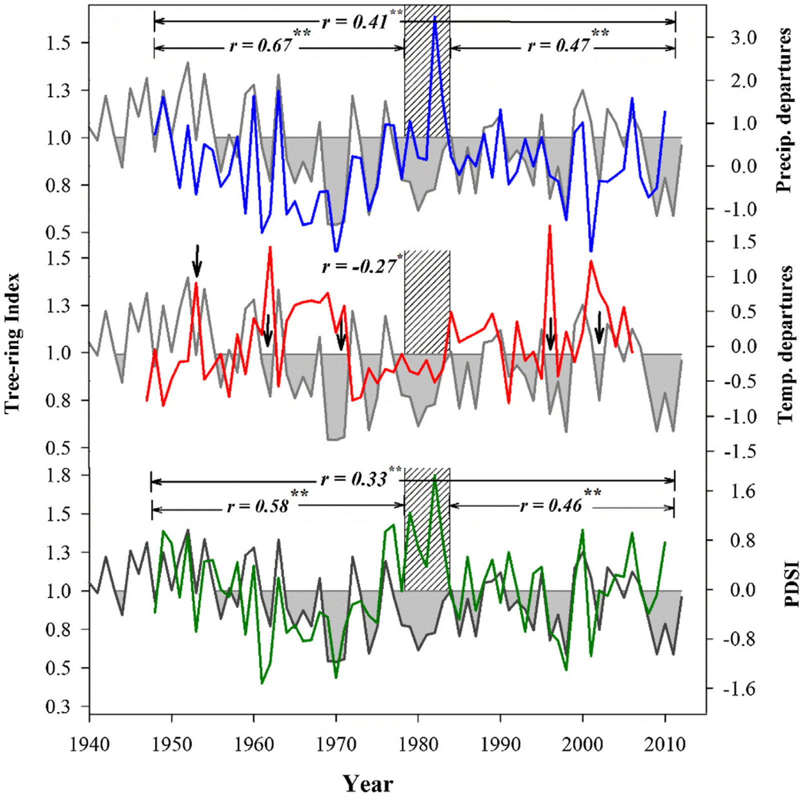

Fig. 7. Comparisons between interannual variations in the radial growth of *Schinopsis brasiliensis* at Inpa (black line) and normalized seasonal (October, November, January and February) precipitation, seasonal (October to January) temperature and seasonal (October, November, January and February) Palmer Drought Severity Index (PDSI) over the past six decades. Note that both the precipitation and PDSI relationships with tree growth are stronger before and after the anomalous 1979–1983 interval. Above-average temperatures appear to be associated with below-average tree growth (arrows).

in December, however, particularly during the decade of 1960. December is the month with the largest year-to-year variability (SD = 93.5 mm) at the Concepción weather station. December precipitation ranges from 21 to 488 mm over the period 1943–2010. Rainfall in December 1967 reached 488 mm, 103 mm more than that of December 2005, the second wettest December in the record. Just two years before 1967, December precipitation during the two consecutive years of 1964 and 1965 recorded surprisingly similar amounts of 22.5 mm, less than 5% of the total precipitation recorded in December 1967. Although this large variability in precipitation could explain the weak relationship between December rainfall and tree growth, problems in the precipitation records are very likely. Nevertheless, the Concepción precipitation record is the longest available in the region and is close to our sampling site. Only a few instrumental climatic records are available from the Bolivian lowlands and most are sparsely distributed. It may be difficult to build a consistent regional precipitation record given the large spatial variability in regional precipitation and the low inter-site correlation among the available instrumental records.

Despite of this limitation, interannual variations in the *Sichinopsis brasiliensis* chronology are significantly correlated with rainfall from October to February (excluding December) over the period 1948–2010 (Fig. 7). This relationship is stronger over the interval 1948–1978, when late spring-summer precipitation accounts for almost 45% of the interannual variations in *S. brasiliensis* radial growth at Inpa (Fig. 7). These relationships between *S. brasiliensis* and climate are consistent with those reported for *S. lorentzii* (Ferrero and Villalba, 2009). In this species, tree growth is favored by abundant precipitation and below-average temperatures during late spring and summer. The relationship between November to April rainfall and *S. lorentzii* tree growth (r = 0.69) is stronger than that recorded for *S. brasiliensis* (r = 0.41; Fig. 7) over a similar period of comparison. However, the poor quality of the Concepción precipitation record might account for this weaker relationship.

In addition to the similarities in climate-tree growth responses between different species of the genus *Schinopsis* growing in tropical and subtropical South America, our results show that *S. brasiliensis* shares common response patterns with other species from the dry tropical forest, including *C. microchaete* in the Bolivian Cerrado (Lopez and Villalba, 2011). Interannual variations in the radial growth of *C. microchaete* have a significant and positive correlation with precipitation during spring and summer (November to January). Rainfall at the end of the dry season gradually increases the water stored in the soil and promotes the initiation of tree growth. For *C. microchaete*, above-average temperatures in spring and summer increase water deficit and reduce tree growth (Lopez and Villalba, 2011). Since variations in precipitation and temperature in the Cerrado dry forest are related to each other, it is difficult to separate the particular influence of rain vs. temperature on tree growth. Consistent with these observations, previous studies in the Bolivian Cerrado (Lopez and Villalba, 2011) suggest that water deficit estimates such as the moisture index, an indirect measure of the regional water balance, may be a better predictor of tree growth than precipitation or temperature alone. Our results show a weak but significant inverse relationship between October-January temperatures and *S. brasiliensis* radial growth. However, reductions in tree growth were common during spring-summer seasons with comparatively higher temperatures (Fig. 7). Conversely, wider rings were recorded during spring-summer seasons with relatively cool conditions, such as in 1949, 1954, 1963 and 1972 (Fig. 7). In contrast to these observations, the relationships between *Schinopsis brasiliensis* radial growth and the PDSI, an index of water deficit that integrates precipitation and temperature variations, were similar to or even weaker than those based solely on precipitation from Concepción. Given the scarcity of meteorological records in the region, the relationship between tree-growth and PDSI resembles that of tree-growth and precipitation (Fig. 7 upper and lower parts). Indeed, the anomalies in the climate-growth relationships reported for the period 1979–1983 based on precipitation still remain in the comparison based on the PDSI. This suggests that, due to the scarcity of instrumental records in the region, the gridded PDSI from CRU are largely based on the Concepción records.

The dependence of tree growth on climate variations in the Bolivian Cerrado region suggests that future climate change could significantly influence the growth of tropical dry forests during the 21 st century. Presently, inferences regarding the nature of these effects are complicated by factors related to uncertainties in precipitation simulations and the establishment of precise relationships between climate and tree growth at regional scales (Clark, 2007). Depending on emission scenarios, temperature in the Bolivian Cerrado is projected to increase by 3–4.5 °C during this century (Urrutia and Vuille, 2009; Vicente-Serrano et al., 2014). Higher temperatures may increase evaporation rates, aggravate water loss associated with lower rainfall (Lean and Warrilw, 1989), and reduce tree growth. Our preliminary results with *S. brasilensis* show the feasibility of developing climate-sensitive chronologies covering the past two centuries along the dry tropical forest in South America. The use of *S. brasiliensis* samples from historical buildings can even extend the tropical dendrochronological records over the past three to four centuries. Additional sites and species should be studied to increase our confidence in regional tree growth trends and to develop past hydroclimate reconstructions based on tropical tree-ring records.

Acknowledgments

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