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Original Article

Impact of Site Conditions Changes on the Tree Ring Records Suitability as Climate Proxies in the Brazilian Amazon

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ABSTRACT

The increment zones width in the xylem of *Swietenia macrophylla* King was investigated by dendrochronological methods in an undisturbed and a strongly disturbed tropical site near Aripuanã, Mato Grosso, Brazil (10°09' S, 59°26'W). The study aimed to assess the impact of forest disturbance on the relationship between precipitation and the cambial growth of this species. Tree-ring width chronologies were developed for both sites from cross-dated increment curves. Simple correlations were computed between monthly precipitation records and the annual increment of Swietenia for the period between 1870 and 2000. Logging activities and altered land use caused a significant decrease of the water supply of the Swietenia trees grown in the disturbed area compared to trees grown in the undisturbed area. Consequently, the precipitation of almost the total growing season had a significant influence on the tree ring width of Swietenia grown in the disturbed area, while in the undisturbed forest area the significant correlation between monthly precipitation and the tree ring width of Swietenia was restricted to the beginning of the growing season (November to January). However, the reconstruction of monthly precipitation data from the tree ring width records was more precise using the chronology developed from tree ring width records of undisturbed trees compared to the chronology developed from tree ring widths from the disturbed area. It was concluded that the use of the tree ring widths of Swietenia as climate proxies is restricted to certain months of the year and requires tree ring width chronologies developed from trees grown in undisturbed or only slightly disturbed forest areas without severe anthropogenic changes in microclimate.

Keywords: climate change, tropics, dendroclimatology, forest disturbance, microclimate, *Swietenia macrophylla*.

1. INTRODUCTION

Long-term meteorological records proved the increase of the mean global surface air temperature during the last decades and recent climate models predict a further increase of the mean surface air temperature in the forthcoming years (IPCC, 2014). Changing air temperatures also have a strong impact on main components of the hydrologic cycle like the precipitation, the evapotranspiration and the transport of water vapour (Nepstad et al., 1994; Costa & Foley, 2012). However, there is a strong spatial and temporal variation in these global climatic disturbances. Due to a dense net of meteorological stations with long-term data sets, these disturbances are documented very well in some parts of the world, while in other regions of the world long-term meteorological records are missing. In particular, in wide parts of the humid tropics meteorological records are rare (Vincent et al., 2005), although the humid tropics are considered to be one of the key regions for the global climate (Malhi & Wright, 2004; Makarieva & Gorshkov, 2006; Anhuf, 2008).

Therefore in these regions climate proxies might be useful for the reconstruction of missing meteorological data in the past. Due to the strong correlation between climatic factors, namely temperature (Denne, 1971; Briffa et al., 1990, 1995) and precipitation (Hughes et al., 1994), and tree growth, in temperate and boreal regions, tree ring records were used successfully as proxy data for the reconstruction of meteorological situations over monthly and annual time scales (Briffa, 1995). Due to the lack of strong seasonality in the humid tropics, the suitability of tropical trees for dendrochronology has been questioned for many years, even though the pioneering investigations by Coster (1927, 1928) indicated a regular pattern in wood formation of some tropical tree species related to a distinct rainfall periodicity in some tropical areas. In particular, studies on *Tectona grandis* (teak), growing under the Asian monsoon climate, showed that wood formation is correlated with the seasonal course of precipitation (Berlage, 1931; Priya & Bhat, 1999). Studies on the climate-tree growth relationship of some *Meliaceae* species from the neotropics (Worbes, 1999; Dünisch et al., 2002a; Dünisch et al., 2003; Schöngart et al., 2002) also proved the annual formation of tree rings and the strong influence of the water supply on the tree ring width in *Swietenia macrophylla* (true mahogany). Due to the formation of annual tree rings, to the wide natural distribution Pennimgton et al., 1981), and to the maximum lifespan covering up to some hundred years (Mayhew & Newton, 1998), *Swietenia macrophylla* is considered to be one of the most promising tree species for climate reconstruction from tree ring width records in the neotropics.

However, the reconstruction of meteorological data from tree ring records requires almost constant correlations between the meteorological input and the tree ring width during the calibration period and during the reconstruction period of the statistical model. In particular, during the last 30 years the Amazon basin was subject to strong anthropogenic impacts like severe logging and agricultural activities, which might have a significant impact on the microclimatic conditions of the forests (Ray et al., 2005).

Therefore this study was designed to establish tree-ring width chronologies of *Swietenia macrophylla* King grown in undisturbed and in strongly disturbed forests of the Brazilian Amazon in order to investigate the impact of changing site conditions and divergent microclimates on the reconstruction of precipitation from tree ring records as climate proxies in this key region for the global climate.

2. MATERIAL AND METHODS

2.1. Study site and experimental trees

The study sites are located close to the city of Aripuanã, Mato Grosso, Brazil (10°09' S, 59°26'W; 190 m above sea-level). The soil is of a xanthic ferralsol type (FAO 1990). The mean air temperature is 22.9 °C, and the annual precipitation is approximately 3,000 mm (Lisboa et al., 1976). Whereas the mean monthly temperature and the relative humidity of the air show low intra-annual variation, the precipitation is distributed unequally over the year. From May until October the precipitation is significantly reduced compared to the other months of the year (Figure 1).

According to the classification of the Amazon Institute of People and the Environment (IMAZON, 2012), the region of Aripuanã is located in the "Logging zone 3", where significant legal and illegal logging activities and land use change took place during the last 10 to 30 years (Figure 2). For the comparison

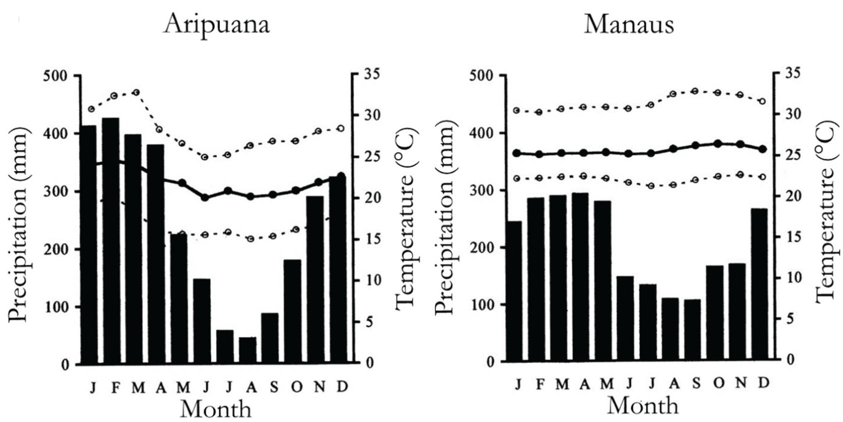

Figure 1. Mean monthly air temperature (°C) and precipitation (mm) of the study site Aripuanã, Mato Grosso (10°09' S, 59°26'W; 1978-2013, 13 missing years) and Manaus, Amazônia (03°08' S, 59°52'W; 1978-2013, 2 missing years).

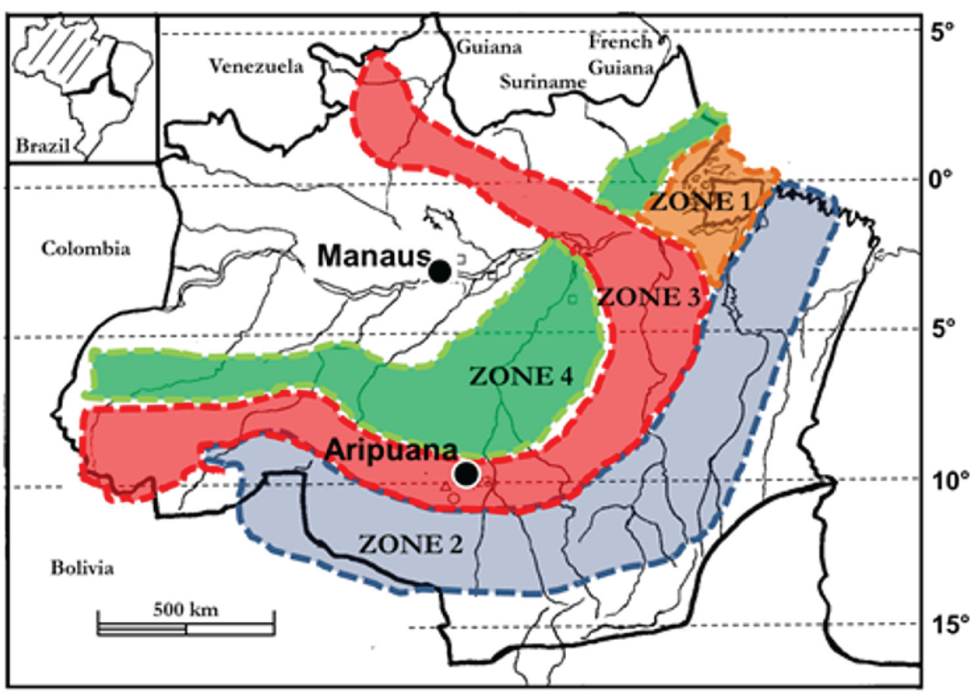

Figure 2. Logging zones in the Brazilian Amazon according to IMAZON – Amazon Institute of People and the Environment (IMAZON, 2012). Zone 1: Logging for more than 300 years; Zone 2: Logging for more than 30 years; Zone 3: Logging during the last 10 to 30 years; Zone 4: Logging during the last 10 years: Experimental site Aripuanã, Mato Grosso (10°09' S, 59°26'W) located in logging zone 3. Long-term meteorological data from stations in Manaus, Amazônia (03°08' S, 59°52'W).

of tree ring width records of old-grown *Swietenia* trees grown in almost undisturbed forest areas and in strongly disturbed areas, stem discs were sampled directly after felling of 41 trees grown in the indigenous forest reserve "Rio Branco" (undisturbed forest area; Figure 3a) located 50 km north of Aripuanã; and of 37 trees grown at a private farm (disturbed forest area; Figure 3b) located 8 km southwest of Aripuanã (breast height diameter: 0.41 to 1.07 m; tree height: 19 to 41 m). The intensive logging started in 1973 at the strongly disturbed area. In the subsequent years logging was followed by pasture and spontaneous

Figure 3. (a) Undisturbed area with native *Swietenia* trees in the indigenous reserve "Rio Branco" close to the city of Aripuanã, Mato Grosso. (b) Disturbed area with remaining native *Swietenia* trees close to the city of Aripuanã, Mato Grosso. Significant disturbance started in 1973 due to logging activities and pasture.

secondary vegetation with some single remaining primary grown trees leading to a strong degradation of the area. Soil analyses revealed a lower content of phosphorus and potassium and an increase of nitrogen in the upper soil layer (0-20 cm depth) of the disturbed area compared to the undisturbed area (unpublished data). From 1996 to 1999 the temperature and the relative humidity of the air (one meter above soil level) was measured in 30-minutes intervals in both areas by Testostor 175 data loggers (Testo GmbH Germany). Sixteen data loggers each were installed with a grid size of 25 m x 25 m in the undisturbed and disturbed areas. During the same experimental period the soil water potential was measured weekly in a soil depth of 20 cm by means of tensiometer measurements (UP GmbH, Germany). Measurements were carried out in the root zone of 10 *Swietenia* trees, each grown in the undisturbed and disturbed areas.

2.2. Tree ring width measurements

Annual growth increments in the adult xylem of *Swietenia* are marked by terminal parenchyma bands. The wood anatomy and the width of increment zones were studied on polished stem discs (sampled at a tree height of 50 to 100 cm) along 4 to 6 radii. In preparation for the increment measurements, the markers of each increment zone were identified by light microscopy of the discs or in microtome cross sections of the xylem blocks (Reichert, Austria; section thickness approximately 20 µm). The width of the increment zones was obtained by means of a measuring ocular lens (accuracy 0.1 mm).

2.3. Development of increment chronologies and study of the response to precipitation

In order to study the relationship between the monthly precipitation and the width of the increment zones of the *Swietenia* trees, ring width chronologies were developed. The increment curves were visually cross-dated within and between trees according to Fritts (1976) using percentage of parallel run and Student´s t-test as statistical tools (Briffa, 1995). The synchronized increment curves were standardized by fitting logarithmic regression lines. The individual standardized increment curves were then averaged to establish the corresponding chronologies for *Swietenia* grown in the undisturbed and disturbed areas. Linear trends within the chronologies were calculated for the periods 1870 to 1920 (period I), 1910 to 1960 (period II), 1950 to 2000 (period III), and 1870 to 2000.

Linear correlations were computed between the chronologies, and the monthly precipitation during the annual growth period, which starts in the region of Aripuana in September as the earliest and finishes in August of the subsequent year as the latest (Dünisch et al., 2002a). The standardized annual increment of *Swietenia* of the undisturbed and disturbed areas was correlated with the precipitation data from Manaus (03°08' S, 59°52'W) for the periods I, II, and III. (years with missing meteorological data were excluded).

In order to prove the suitability of this statistical model for the reconstruction of the precipitation in the past, the correlations obtained for the time period III (1950 to 2000) served for calibration. For validation of the model, precipitation data were calculated for the period I (1870 to 1920). The calculated data were compared with the precipitation measured at the meteorological station in Manaus.

Statistics on the properties of the tree ring width chronologies and on the relationship between precipitation and tree growth were calculated using the program packages ARSTAN and COFECHA (Holmes, 1994).

2.4. Analyses of meteorological data

Meteorological data for "Aripuanã" are only available for the timespan 1978 to 2013, while long-term meteorological data (since 1866 with missing values) for the Central Amazon are available from different meteorological stations in Manaus (03°08' S, 59°52'W; Figure 1; INMET, 2001). Therefore, for correlation analyses of the relationship between precipitation and tree growth of *Swietenia*, monthly precipitation values measured in Manaus were used. To prove the suitability of the precipitation records from Manaus for the analyses, the linear correlation between the precipitation in Manaus and Aripuanã was calculated (Table 1). Linear trends in precipitation were calculated for the periods 1870 to 1920 (period I), 1910 to 1960 (period II), 1950 to 2000 (period III), and 1870 to 2000.

Table 1. Linear regression and correlation coefficient (R^2) for the relationship of the monthly precipitation (mm) of the study site Aripuanã, Mato Grosso (10°09' S, 59°26'W) and the monthly precipitation (mm) of Manaus, Amazônia (03°08' S, 59°52'W; 1978-2013, 13 missing years).

Period	Linear regression	r^2
January	0.7825x + 127.18	0.87
February	0.6769x + 163.93	0.76
March	0.7866x + 120.70	0.73
April	1.1335x + 41.04	0.96
May	1.2303x + 1.29	0.88
June	1.3552x + 21.81	0.91
July	1.2515x – 24.81	0.60
August	0.5664x – 55.77	0.98
September	0.5056x + 7.73	0.59
October	1.1828x + 54.36	0.83
November	0.6281x + 103.29	0.76
December	0.9290x + 49.46	0.57

3. RESULTS

3.1. Long-term trends in precipitation and microclimate of undisturbed and disturbed forest areas

The meteorological data from the stations in Manaus revealed a slight increase of the mean monthly precipitation in April and October during the time period 1950 to 2000 (period III) compared to the period 1910 to 1960 (period II), while no significant differences in monthly precipitation between the two periods were found in the other months (Table 2). In contrast, in the period from 1870 to 1920 (period I), the mean monthly precipitation in April/May and from August to November was significantly lower compared to the periods II (1910 to 1960) and III (1950 to 2000) causing a significant lower mean annual precipitation in period I compared to period II and III.

Linear trend analyses indicated only a very slight decrease of the mean monthly precipitation in April and November (-4.7 and -3.4 mm, respectively) during the period I (1870 to 1920) and a very small increase of mean monthly precipitation in September (+1.4 mm) during the period III (1870 to 2010), while all other monthly mean precipitation values did not show any trend during the periods under investigation.

The relative humidity of the air and the soil water potential in the undisturbed and disturbed areas were

Table 2. Monthly precipitation (mm) and its linear trend (mm; correlation coefficient r^2) during the periods I (1870-1920), II (1910-1960), III (1950-2000), and I-III (1870-2000) in Manaus, Amazônia (03°08' S, 59°52'W).

Period I (1870-1920) – 13 years missing													
Prec.	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**
Mean (mm)	235^{a}	268^{a}	290^{a}	266^{a}	191^{a}	130^{a}	91^{a}	74^{a}	58^{a}	78^{a}	108^{a}	213^{a}	2002^{a}
Trend (mm)	−0.6	+0.9	−1.1	−4.7*	−0.3	−1.4	+1.5	+1.1	+0.8	−1.1	−3.4*	−2.5	−12.5
r^2	0.03	0.02	0.04	0.33*	0.01	0.04	0.07	0.06	0.16	0.16	0.63*	0.12	0.11
Period II (1910-1960) – 9 years missing													
Prec.	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**
Mean (mm)	276^{a}	281^{a}	279^{a}	270^{a}	254^{b}	149^{a}	87^{a}	85^{a,b}	92^{b}	127^{b}	151^{b}	250^{a}	2301^{b}
Trend (mm)	+2.2	−0.5	+1.1	−0.7	−0.2	+0.5	+0.1	−0.9	+0.2	+0.1	−0.4	+1.8	+1.0
r^2	0.28	0.06	0.12	0.02	0.06	0.01	0.01	0.10	0.05	0.02	0.01	0.14	0.07
Period III (1950-2000) – 3 years missing													
Prec.	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**
Mean (mm)	270^{a}	303^{a}	299^{a}	316^{b}	268^{b}	163^{a}	111^{a}	106^{b}	110^{b}	167^{c}	187^{b}	247^{a}	2547^{b}
Trend (mm)	+3.5	+1.6	+1.6	+3.4	−1.0	+2.6	−1.9	+1.7	+1.2	−0.8	+2.7	−1.0	+9.2
r^2	0.12	0.02	0.03	0.19	0.01	0.17	0.14	0.07	0.06	0.01	0.09	0.01	0.11
Period I-III (1870-2000) – 25 years missing													
Prec.	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**
Mean (mm)	261^{a}	283^{a}	289^{a}	281^{a,b}	240^{b}	145^{a}	94^{a}	89^{a,b}	89^{b}	132^{b,c}	155^{a,b}	238^{a}	2298^{a,b}
Trend (mm)	+1.0	+1.5	+0.2	+0.6	+1.6	+1.0	+0.8	+1.3	+1.4*	+1.4	+1.0	+0.1	+11.2
r^2	0.06	0.07	0.01	0.02	0.12	0.09	0.09	0.18	0.35*	0.17	0.07	0.01	0.21

Mean values followed by different letters differ significantly between the periods I, II, III, and I-III at $p<0.05$ (Student's t-Test). Significance ($p<0.05$, Fisher´s F-Test) of linear trends in monthly precipitation during the periods I, II, III, and I-III are marked by asterisks (*).

correlated with the seasonal course of precipitation, while on all sites the intra-annual variation of the air temperature was relatively low (Figure 4). However, during the experimental period from 1996 to 1999 the mean air temperature measured in the undisturbed forest area (24.7 °C) was significantly lower than in the disturbed area (27.1 °C). In the disturbed area the mean relative humidity of the air (81%) was lower than in the undisturbed forest (96%), while the amplitude of intra-annual variation significantly increased. In both areas, the reduced precipitation from May until October caused a decrease of the soil water potential in the root zone of the *Swietenia* trees, but the decrease was more pronounced in the disturbed area (minimum soil water potential 20 cm soil depth –673 hPa to –839 hPa) compared to the undisturbed area (minimum soil water potential 20 cm soil depth –167 hPa to –253 hPa).

3.2. Establishment of master chronologies for Swietenia macrophylla grown in undisturbed and disturbed forest areas

The increment curves of 36 out of 41 *Swietenia* trees grown in the undisturbed area and of 31 out of 37 trees grown in the disturbed area were included in the increment chronologies covering the time period 1870 to 2000 (Table 3, Figure 5). However, due to the high number of false rings and missing rings in the juvenile wood (first 10 to 15 tree rings counted from the pith) of *Swietenia* (Dünisch et al., 2002a) tree ring width records from the innermost part of the stem discs were not suitable for the establishment of the master chronologies. Consequently, the age of the sampled *Swietenia* trees could only be dated in good approximation. The tree age of the trees grown in the undisturbed and disturbed areas varied between 95-170 years and 80-150 years, respectively. Consequently, the part of the master chronologies covering the time period I (1870-1920) are based on tree ring records from less trees (undisturbed area 32 trees, disturbed area 25 trees) than the master chronologies covering the periods II and III (1910-2000; 36 and 31 trees, respectively).

The parallel run between the standardised increment curves included in the two chronologies varied between 87 and 99%. The linear correlation of the standardised tree-ring records of *Swietenia* trees grown in the same area was significant, while the correlation between tree ring records from trees grown in the undisturbed and disturbed areas was not significant, indicating somewhat low common signals within the trees grown in the two different areas. The high standard deviation of the chronologies indicates a high sensitivity of both chronologies.

In period I (1870-1920) and II (1910-1960) the mean annual radius increment of the *Swietenia* trees was between 3.35 and 3.55 mm. No significant differences in radius increment were found between

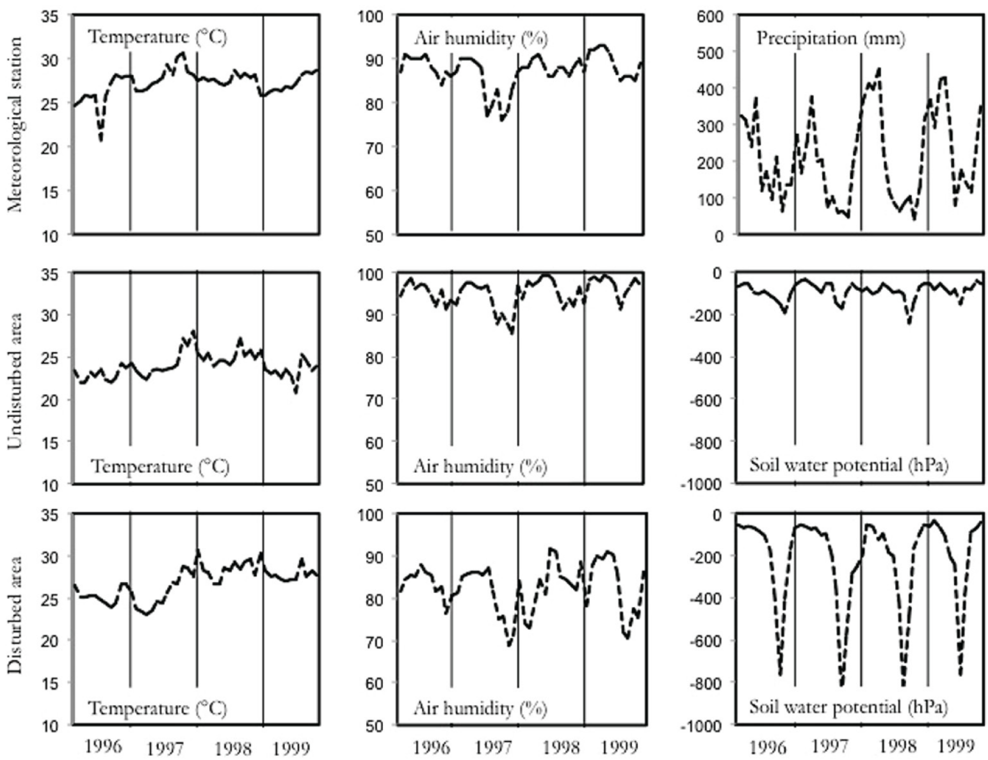

Figure 4. Mean monthly air temperature (°C), relative humidity of the air (%), and precipitation (mm) measured at the meteorological station in comparison to mean monthly air temperature (°C), relative humidity of the air (%), and soil water potential (hPa, soil depth 20 cm) measured in the undisturbed and in the disturbed experimental areas. Measuring period 1996-1999.

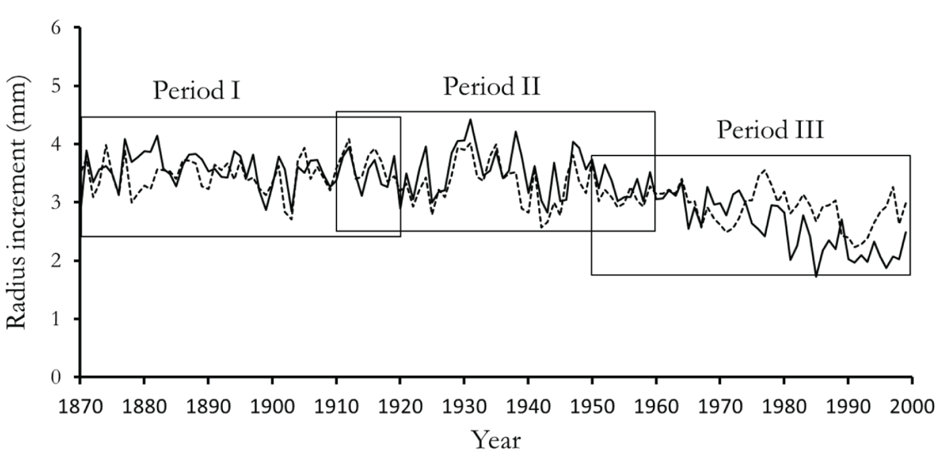

Figure 5. Chronologies (1870-2000) of mean annual radius increment (mm) of *Swietenia macrophylla* sampled in undisturbed (dotted line) and disturbed (bold line) areas near Aripuanã, Mato Grosso.

Table 3. Dendrochronological properties of the master chronologies for *Swietenia macrophylla* from undisturbed and disturbed areas on the study site Aripuanã, Mato Grosso (10°09' S, 59°26'W).

Master chronology	*Swietenia* Undisturbed area	*Swietenia* Disturbed area
No. of trees investigated	41	37
No. of trees included	36	31
Tree age (years)	95-170 (approx.)	80-150 (approx.)
Mean annual radius increment 1870-2000 (mm)	3.26 ± 0.31	2.95 ± 0.39
Period I, 1870-1920 (mm)	3.44 ± 0.28	3.55 ± 0.31
Period II, 1910-1960 (mm)	3.35 ± 0.38	3.48 ± 0.38
Period III, 1950-2000 (mm)	2.94 ± 0.32	2.72 ± 0.52
Standardised master chronology	Undisturbed area	Disturbed area
Correlation between trees	0.37	0.28
Standard deviation	0.21	0.26
First order autocorrelation	0.063	0.057

trees grown in the undisturbed and disturbed areas (Table 3). In period III (1950-2000) the mean annual radius increment of the trees grown in the disturbed area decreased significantly compared to period I and II (–23%), while the slight decrease in increment (–14%) of trees grown in the undisturbed area in period III was not significant. The standard deviation of the annual radius increment of trees grown in the disturbed area increased in period III compared to period I and II, indicating an increase in sensitivity of these trees.

The linear trend analysis indicated a very a slight decrease of the annual radius increment of trees growing in the undisturbed area during the growth period III (1950-2000), while during the same period the annual radius increment of trees growing in the disturbed area strongly decreased (–0.2 mm a^{-1}; Figure 5). No trend in radius increment of the *Swietenia* trees was found during the growth periods I (1870-1920) and II (1910-1960).

3.3. Relationship between precipitation and the tree ring width of Swietenia macrophylla grown in undisturbed and disturbed forest areas

Simple correlations between the tree-ring width chronologies and the monthly precipitation records of Manaus revealed a significant influence of the precipitation, from October/November until January of the current growth season, on the width of the increment zones in *Swietenia* trees growing in the undisturbed area during the periods I, II, and III (Figure 6). During the periods I and II, similar correlations were found for the trees grown in the disturbed area, while in period III the tree ring width was significantly correlated with the precipitation in September (negative correlation) and the precipitation from December until June (positive correlation).

However, the correlation coefficients between the precipitation of individual months and the annual radius increment of the trees were low (0.09 to 0.43), while the correlation coefficients between the total precipitation of the months, which had a significant influence on the tree ring width, and the annual increment were quite high (0.59 to 0.77).

3.4. Reconstruction of precipitation from tree ring width records

In order to reconstruct the total precipitation for the periods November to January, September, and December to June from the tree ring widths records of the *Swietenia* trees grown in the undisturbed and disturbed areas, respectively, the highly significant correlations between the precipitation in these months and the tree ring width in period III (1950-2000; undisturbed area r^2=0.63, disturbed area r^2=0.77) were used for calibration of the statistical model (Figure 7). In the validation period from 1870 to 1920 the precipitation from November to January reconstructed from the tree ring records of the trees grown in the undisturbed area was highly correlated with the meteorological data measured at the station in Manaus (r^2=0.71). In contrast, during the validation period 1870 to 1920 reconstruction of precipitation in September, and from December to June from the tree

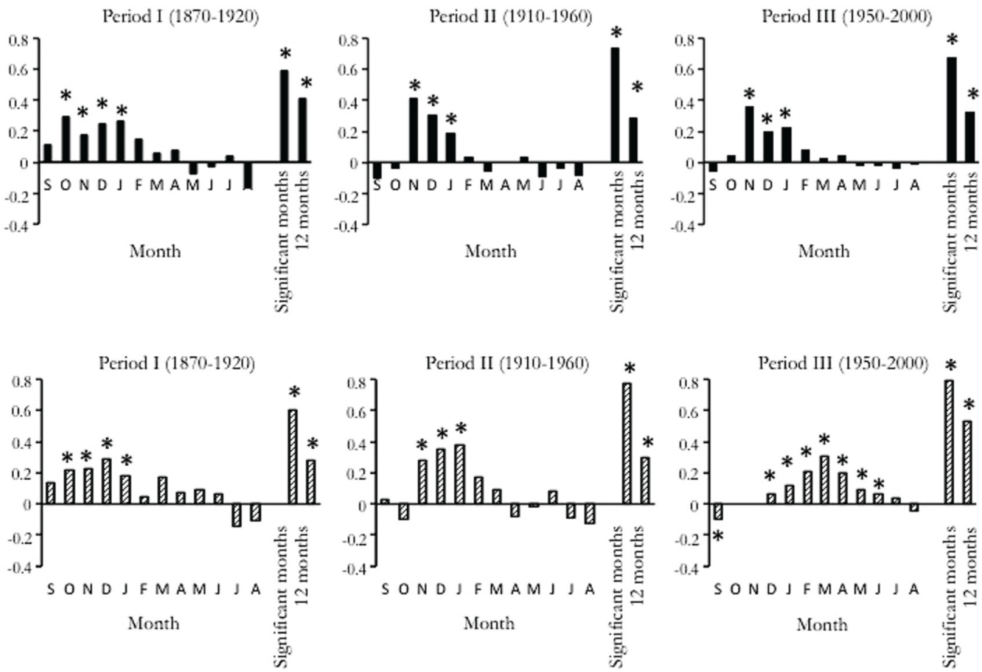

Figure 6. Correlation coefficients between the standardized monthly precipitation of Manaus, Amazônia (03°08' S, 59°52'W) and the standardized growth increment of (a) *Swietenia macrophylla* King grown near Aripuanã, Mato Grosso in undisturbed (shaded columns) and disturbed (dotted columns) areas during the periods I (1870-1920), II (1910-1960), and III (1950-2000). Significant correlations (p<0.05, Fisher's F-Test) are indicated by asterisks.

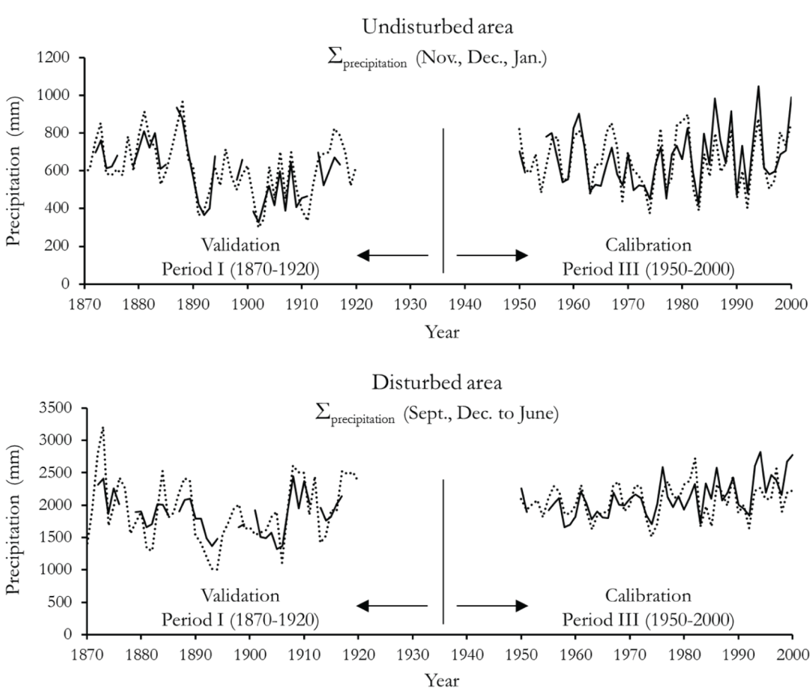

Figure 7. Measured (bold line) and calculated (dotted line) monthly precipitation from November to January from tree ring records of *Swietenia macrophylla* grown in undisturbed areas and monthly precipitation in September and from December to June from tree ring records of *Swietenia macrophylla* grown in disturbed areas during the calibration period 1950-2000 and the validation period 1870-1920.

ring width of *Swietenia* grown in the disturbed area was less precise (r^2=0.35). In particular, precipitation extremes were more pronounced in the reconstructed records than in reality.

4. DISCUSSION

Studies on the ecophysiology (Dünisch et al., 2002b) and on the wood anatomy (Fujii et al., 1998) of *Swietenia macrophylla* proved the high sensitivity of this tropical tree species to changing water supply, which makes this species extremely interesting for dendroclimatology with special regard to the reconstruction of the hydrological situation in former times (Fichtler & Worbes, 2012). However, the reliability of climate reconstructions from tree ring records depends on the quality of the meteorological data as well as on the quality of the tree ring records.

Statistical analysis of the relationship between the monthly precipitation and the annual tree ring width requires long-term data sets covering a timespan of at least 40 to 50 years (Fritts, 1976). Due to the lack of long-term meteorological observations close to our study site "Aripuanã", meteorological data of Manaus (approximately 800 km distant from Aripuanã) had to be used for the correlation analysis. On the other hand no old-growth of *Swietenia* is available near Manaus as to overcome the problem and correlate the tree growth with meteorological parameters recorded far from the study site (Pennimgton et al., 1981). Although the monthly meteorological records of Manaus show similar tendencies to those near Aripuanã, in the Aripuanã region the annual precipitation is higher and shows a more seasonal pattern than in the region of Manaus. Thus, the correlation between precipitation in Manaus and the tree ring width of trees grown close to Aripuanã leads to a slight overestimation of the impact of precipitation on the annual increment of the trees (Hietz et al., 2005; Poorter et al., 2010).

In addition, changes in the sampling methodology and of the sites of the rainfall collectors in Manaus during the period 1870 to 2000 (INMET, 2001) as well as missing data also might have an impact on the quality of the meteorological data used for the correlation analyses (Santer et al., 2008; Boulanger et al., 2010). In particular, it is not quite clear, how far the slight decrease of precipitation monitored in the period from 1870 to 1920 compared to the period 1920 to 2000 is affected by changes in the sampling method.

The high parallel run and the significant correlation between the annual tree ring widths of the trees included in the master chronologies for the undisturbed and for the disturbed area indicate a high quality of the cross-dated tree ring records and distinct common signals within the chronologies. However, the development of master chronologies is restricted to tree ring records from old grown trees. Consequently, the number of trees covering the timespan 1870 to 1920 in the master chronologies is slightly reduced compared to the period from 1920 to 2000, which leads to a slight increase of uncertainty of the results obtained for the relationship between precipitation and growth of *Swietenia* during the period 1870 to 1920 (Fritts, 1976; Briffa, 1995).

In agreement with studies on long-term trends in meteorological records in the Amazon, the meteorological data used for this study did not indicate strong alterations in precipitation in the Central Amazon during the last 130 years (Victoria et al., 1998; Malhi & Wright, 2004; Vincent et al., 2005; Costa & Foley, 2012). However, as also reported from other sites in the Amazon, changes in land use during the last 30 years on the disturbed experimental site had a strong impact on the vapor saturation deficit of the atmosphere and on the availability of water in the upper soil layer (Schroth et al., 1999). Investigations of Noldt et al. (2001) lead to the expectation of a high sensitivity of *Swietenia* towards precipitation due to their root system in the upper soil, while many other tropical tree species withdraw a high amount of water from deep soil water storages (Nepstad et al., 1994). This is confirmed by the strong decrease of the annual increment and the increase of the sensitivity of the tree ring width chronology to precipitation during the last 30 years in the disturbed area compared to the undisturbed area.

Regarding the suitability of the tree ring records of *Swietenia* for climate reconstruction, the shift in correlations between monthly precipitation and tree ring width after the disturbance is of main interest. In the undisturbed forest the significant influence of precipitation on the tree ring width is restricted to the beginning of the growing season (November to January). In contrast, in the disturbed area the growth of *Swietenia* was significantly correlated with the precipitation during the entire growing season (but less significant correlations of individual months), which underlines the strong limitation of the tree growth by the changed microclimatic conditions.

Thus, the reconstruction of monthly precipitation from the tree ring records is only possible for months, which had a highly significant influence on the tree ring width, which strongly limits the use of tree ring width records of *Swietenia* for the reconstruction of missing precipitation data.

A further serious problem for the use of tree ring records of *Swietenia* as climate proxies is that only trees from areas without significant alterations in microclimate can be considered for the establishment of master chronologies. This study showed that the precision of the reconstruction of precipitation from tree ring width records strongly decreased, when tree ring records from trees, which grew in disturbed forest areas with significant changes in microclimate, were included in the analyses. Due to the strong exploitation of mahogany trees in the past (Free at al., 2014), the natural distribution of the trees, and the strong disturbances by anthropogenous impacts in many parts of the Amazon, the establishment of *Swietenia* chronologies becomes more and more difficult. However, in further studies the degree of forest disturbance, which leads to significant alterations in microclimate relevant for the climate - tree growth relationship of *Swietenia* has to be studied in more detail.

From the results of this study, it was concluded that only for very restricted regions and for distinct periods of the year tree ring width records of *Swietenia macrophylla* might serve as suitable proxies for the reconstruction of precipitation in the neotropics.

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