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Dendrochronological Study of Manilkara Huberi (Ducke) A. Chev. (SAPOTACEAE) in a Upland Forest of Central Amazonia using High-Frequency Densitometry

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INTRODUCTION & AIM

This study aims to evaluate the correlation between climate variables, such as local precipitation and sea surface temperature in the tropical Pacific Ocean regions related to El Niño 1+2, 3, 3+4, and 4, as well as the North and South Atlantic Ocean regions. These correlations are explored using tree-ring chronologies of the species *Manilkara huberi* (Ducke) A. Chev. (Sapotaceae), found in upland forests of Central Amazonia. Sixteen samples were collected from a forest management area and analyzed using dendrochronology, specifically the high-frequency density technique. A chronology was developed, yielding an indexed average curve that was correlated with climate variables. The Amazon lacks sufficient instrumental climate data to fully capture the natural variability of rainfall patterns and their connection to major ocean-atmosphere interactions, such as the El Niño-Southern Oscillation (ENSO). In this study, we present a dendroclimatic signal from *Manilkara huberi*, a commercially significant species in the upland forests of Central Amazonia, which forms annual growth rings in response to seasonal rainfall. These rings are characterized by alternating fiber tissues and parenchyma, with a fiber band marking the annual growth limit, though it can be difficult to detect macroscopically. To reliably mark the growth rings, the high-frequency (HF) densitometry technique was used. This method measures variations in wood density at high resolution based on its dielectric properties. Transverse sections from 16 trees were prepared, and 10 parallel rays spaced 0.5 mm apart were measured using densitometry on each section. Median values were calculated for each series to eliminate density variations caused by wood vessels and to identify the maximum densities at the ring boundaries. The ring width was determined by measuring the distance between the wood density peaks. Eight of the series showed good cross-dating results. The mean indexed chronology demonstrated a significant correlation with rainfall data from the study area and with sea surface temperature anomalies in the Tropical North Atlantic and traditional El Niño regions. Remarkably, the chronology also closely aligned with the teak chronology from *Berlage* (1931) in Java, Indonesia, for the period of 1725 to 1929, despite the 18,000 km distance between these regions. This could be explained by teleconnections between regional precipitation patterns and ENSO. The study highlights the potential of dendrochronology, specifically HF density, as a powerful tool for exploring past climate conditions in the tropics using tree species' annual growth rings.

METHOD

The study was carried out in the area covered by the Sustainable Forest Management Plan of the company Precious Woods Amazon - PWA, located on the boundaries of the municipalities of Itacoatiara, Silves and Itapiranga, in the mesoregion of Centro Amazonense, state of Amazonas, Brazil.

Wood density in tree species varies along the trunk in the radial-longitudinal direction, with the most significant variation occurring within the annual growth rings. This variation is due to the formation of early and late wood, which differ in width and density. The difference in wood density between growth rings remains consistent within trees of the same species. This variation in wood density provides valuable climatic information and is linked to environmental factors such as air temperature, rainfall, and flood pulses in floodplains. In tropical tree species, intra-annual variations in density are particularly useful in identifying the boundaries of annual growth rings, especially when these boundaries are not easily visible with the naked eye. The high-frequency densitometry method was developed by the Institut für Waldwachstum - IWW (Institute of Forest Growth) at the University of Freiburg, Germany, and is based on the dielectric properties of the different wood parts (SPIECKER; HANSEN; SCHINKER, 2003).

The study aimed to obtain the density variation profile of *Manilkara huberi* (Ducke) A. Chev. by testing several probes. The 34x80 µm probe showed the best sensitivity for identifying density variation in this species due to its dimensions matching the anatomical structures of the wood. Initially, the density variation profile did not show a clear pattern, but it was discovered that dielectric constant values beyond the equipment's range were due to variation in the wood structure along the probe's measuring line. A modified density measurement process was implemented, measuring 10 lines along the radius of the cross-section, to obtain a better profile. The curves with maximum, minimum, mean, and median values were analyzed, and the median was chosen to define the profile. A moving average filter was used to remove noise and isolate the climate signal. The result was a sigmoidal curve, identifying the annual growth rings. The thickness of the rings was measured to construct a chronology. The density variation profile showed that growth rings may be associated with patterns of parenchyma and tissue fibers, and there was a coincidence between density peaks and the formation of latewood. Similar behavior was found in other studies using densitometry.

The study focused on investigating the correlation between growth ring thickness and various climatic variables. These variables included Pacific and Atlantic Ocean surface temperatures, as well as precipitation. The data for sea surface temperature was obtained from reputable sources such as the Climatic Research Unit and the Climatic Prediction Center. The study also utilized monthly data from the Tropical Pacific Ocean regions and the North and South Atlantic Ocean regions. Additionally, precipitation and temperature data were obtained from the Global Precipitation Climatology Centre, which provides free access to its data for climate monitoring and research purposes. The study compared the growth ring thickness curve with the rainfall record for the specific region where the samples originated. Finally, the study analyzed the correlation between the growth ring curve and temperature anomalies in the Pacific and Atlantic Oceans, as well as El Niño Southern Oscillation Indices. The data analysis covered the period from 1951 to 2009.

Standard dendrochronology techniques were used to cross-date the annual growth ring series of the different trees combined with a time series correlated to a master chronology (SCHÖNGART et al., 2004). The statistics relating to the annual growth rings, which describe the similarity of the individual curves to each other, was carried out using the TSAP program (Time Series Analysis and Presentation, Rinntech, Heidelberg, Germany) (RINN, 2012). The similarity measures used were the T-Student values and the percentage of parallel runs indicating the year-to-year agreement in the oscillation of two curves within the overlap interval. The program also processes the absolute curves of the annual growth rings by transforming them into indexed curves, thus removing individual and long-term trends using a 5-year moving average. The residuals from this process are normally distributed, which is a basic condition for correlation with climate data (SCHÖNGART et al., 2004).

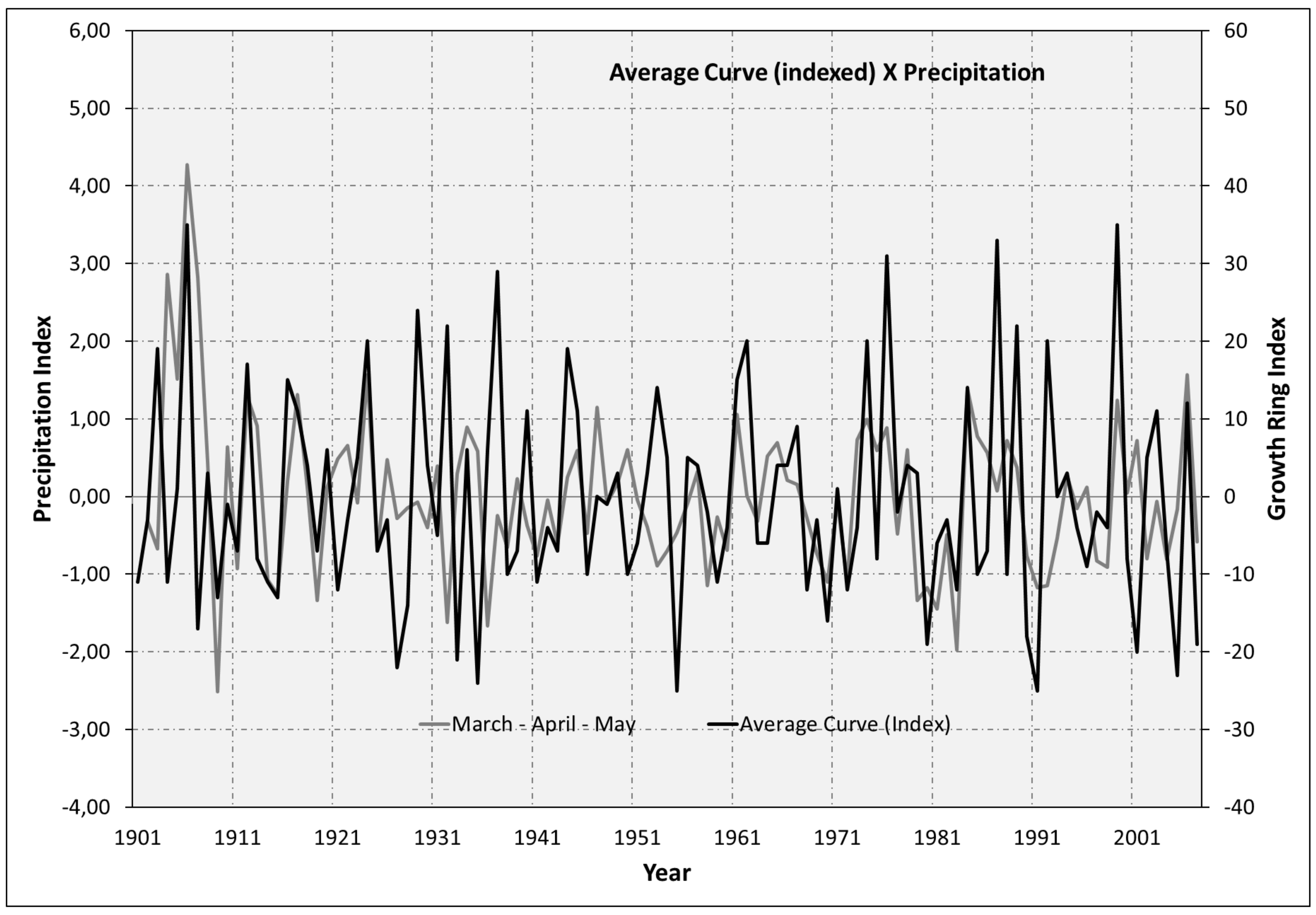
RESULTS & DISCUSSION

The trees sampled were 41.0 cm and 67.4 cm in diameter, respectively. The age of the trees investigated ranged from 174 years for the youngest to 325 years for the oldest. The thickness of the annual growth rings ranged from 1.02 to 3.72 mm, with an average annual growth of 1.07 mm.

The individual curves of the annual growth rings have patterns that show good similarities with an average percentage of overlap of 58% and maximum values of 60%. The statistical analysis process produced eight curves with good cross-dating, which were then visually analyzed to correct any possible errors. The curves were then analyzed two by two, resulting in an average curve which was used to analyze the correlation with climatic factors. The longest series was 325 years, dating back to 1685, and the shortest was 174 years. The composition of the chronology used data from the samples from 1836, where all the curves were present.

The analysis of data shows that there is no correlation between South Atlantic Sea Surface Temperature anomalies and the thickness of the annual growth ring. However, there is a low correlation between North Atlantic Sea Surface Temperature anomalies and the growth ring thickness during specific months, such as January, February, and March. The correlation is statistically significant, with a correlation coefficient (r) of -0.27 and a significance level (p) of 0.04. Similar low, statistically significant correlations are observed between Pacific Sea Surface Temperature anomalies and the growth ring thickness. The El Niño 1+2 region, El Niño 3 region, El Niño 4 region, and El Niño 3+4 region all exhibit correlations with the growth ring thickness, with varying months and values. Additionally, the El Niño Southern Oscillation Index (ENOS) shows correlations with the growth ring thickness, both in the previous year and the current year, with specific months showing significant correlations. Overall, this analysis suggests that sea surface temperatures in different regions have a low but statistically significant impact on the thickness of annual growth rings.

The correlation analysis of the growth of *Manilkara huberi* (Ducke) A. Chev. indicates that this species responds positively to rainfall, i.e. when there is more rainfall there is more growth, and vice versa



Graphical representation of the relationship between the indexed mean curve of *Manilkara huberi* (Ducke) A. Chev. compared with precipitation indices from the Global Precipitation Climatology Center (GPCC), from 1901 to 2007.

CONCLUSION

A study conducted in the Central Amazonian forest utilized high-frequency densitometry to determine the density variation profile of the *Manilkara huberi* tree species. The study found that the limits of the tree's annual growth rings aligned with the peaks of density variation. By measuring the distance between these peaks, researchers were able to estimate the thickness of the growth rings and establish a chronology for the species. This methodology also allowed for the identification and measurement of the annual growth rings, enabling the assessment of their correlation with climatic variables. The study revealed significant correlations between the obtained chronology and factors such as local rainfall and oceanic temperature variations, particularly in the Atlantic and Pacific regions during El Niño events. Overall, the hypothesis that a correlation exists between the growth ring thickness and climatic factors was confirmed, with statistically significant results at a 95% probability level.

FUTURE WORK / REFERENCES

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