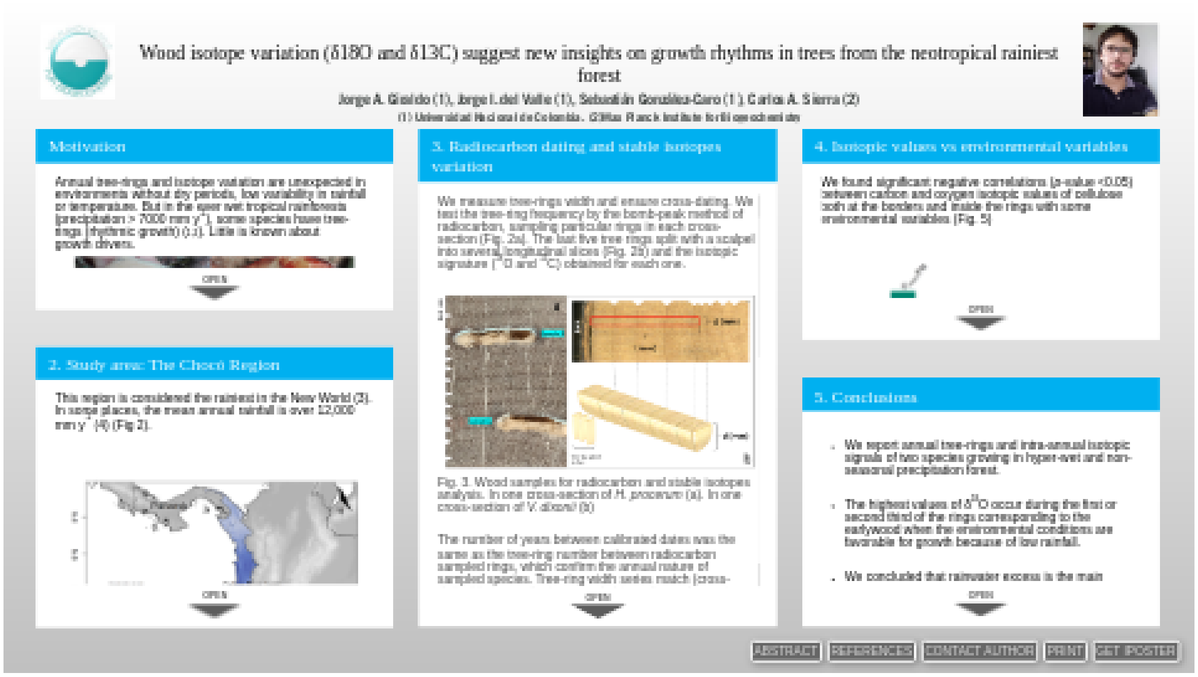
Wood isotope variation (δ18O and δ13C) suggest new insights on growth rhythms in trees from the neotropical rainiest forest



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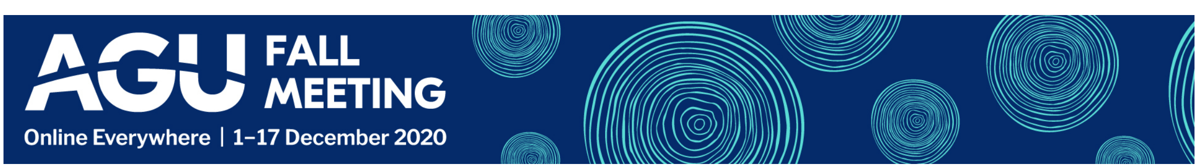


MOTIVATION

Annual tree-rings and isotope variation are unexpected in environments without dry periods, low variability in rainfall or temperature. But in the ever wet tropical rainforests (precipitation > 7000 mm y^{-1}), some species have tree-rings (rhythmic growth) (1,2). Little is known about growth drivers.

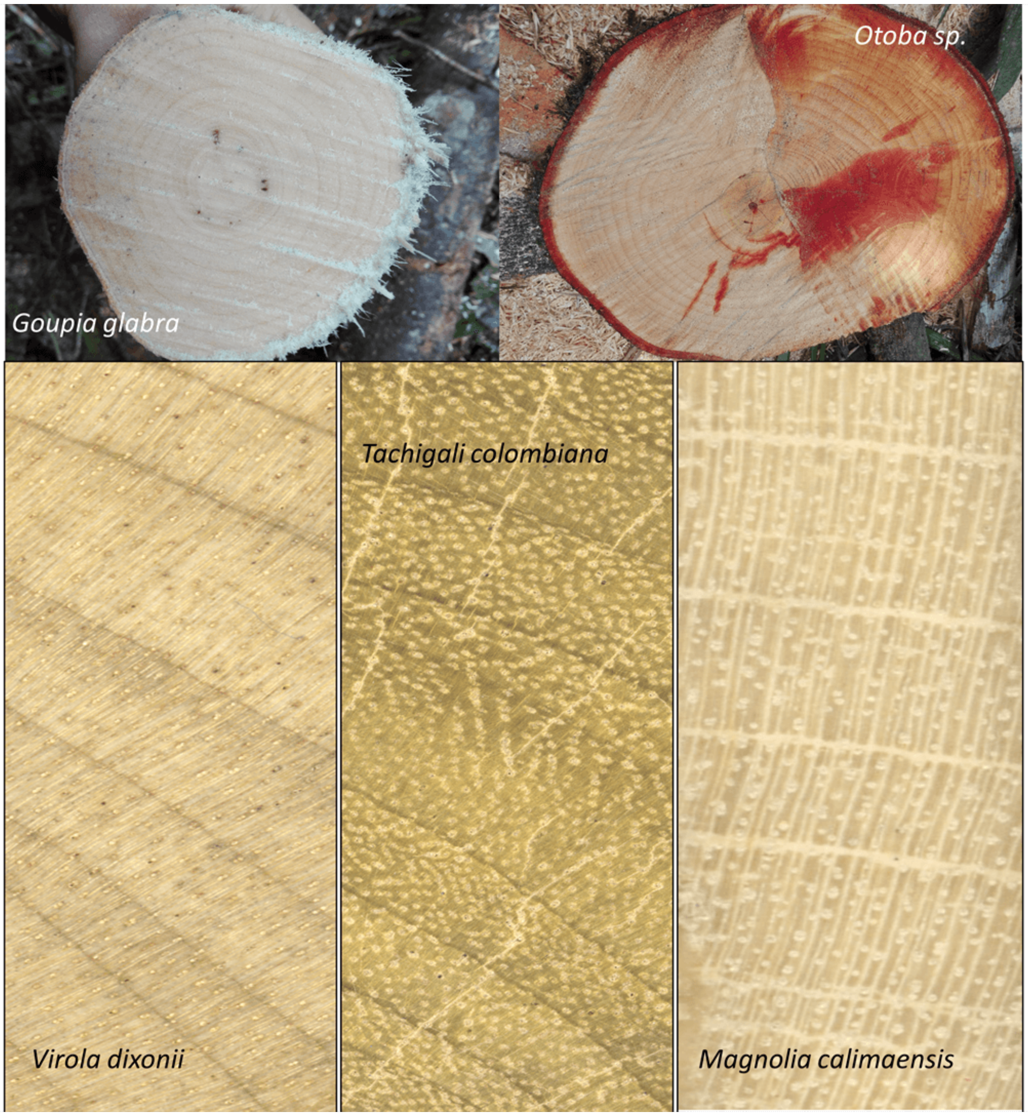


Fig. 1. Tree-rings evidence from Chocó region (2).

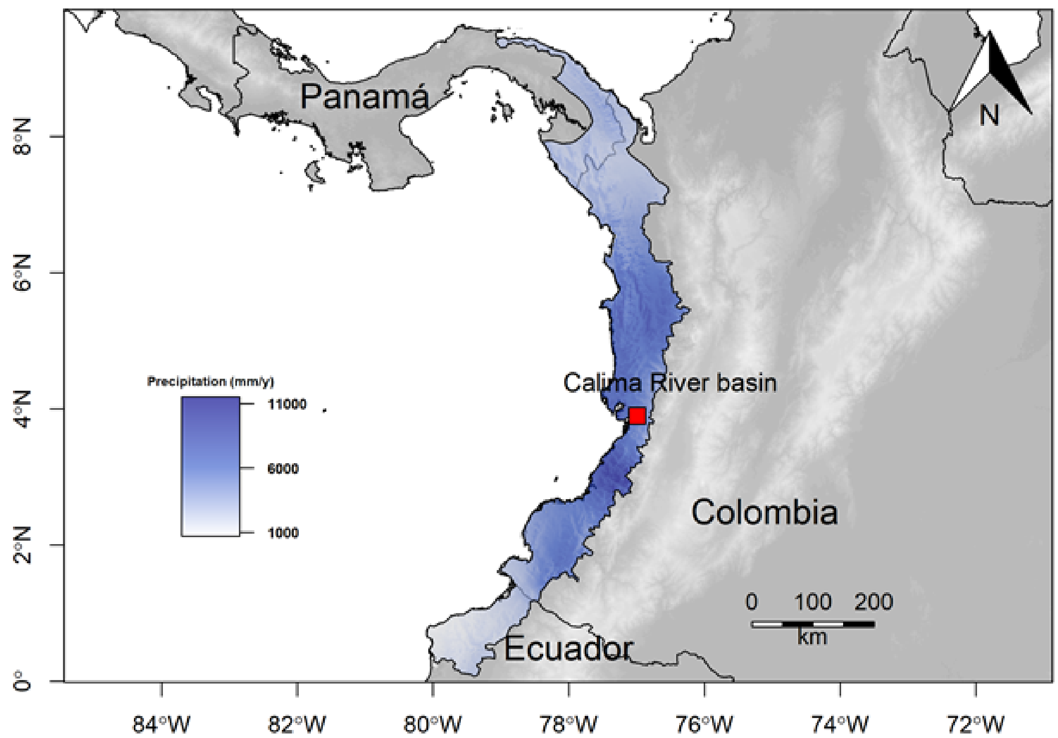
We hypothesize water excess is the main limiting factor for tree growth which is evidenced by the isotopic record in tree rings.

Our aim

To establish tree-ring frequency in two tree species from a non-seasonal tropical hyper-humid forest. To test the intra-annual variability of $\delta^{13}C$ and $\delta^{18}O$ in tree rings and explore the relationships between isotope composition in tree rings with environmental variables.

2. STUDY AREA: THE CHOCÓ REGION

This region is considered the rainiest in the New World (3). In some places, the mean annual rainfall is over 12,000 mm y^{-1} (4) (Fig 2).



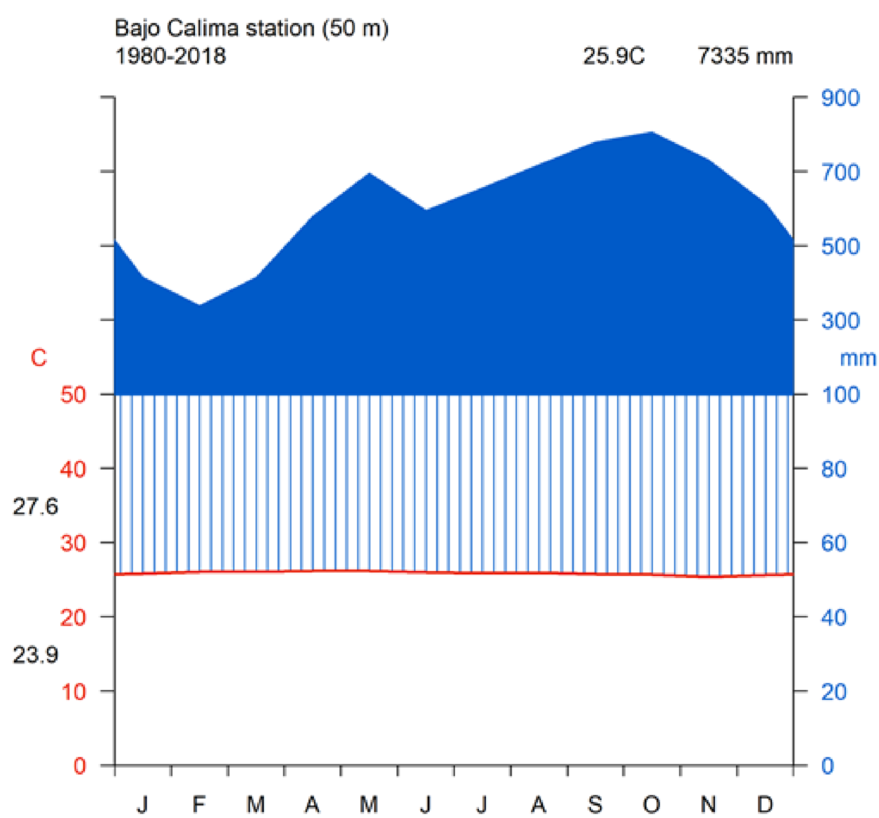


Fig. 2. Study area within the Chocó Region with explicit precipitation gradient and climate diagram.

In the study area on average, there are dry months. The least rainy month of the year is February with an average of 370 mm, the mean annual temperature is 25.9°C, and is almost constant during all months (Fig. 2)

We sampled four cross-sectional disks: two from *Humiastrum procerum* and two from *Virola dixonii* tree species growing under similar conditions as dominant trees. Both shed their leaves between August to October. New leaves occur between November to February.

3. RADIOCARBON DATING AND STABLE ISOTOPES VARIATION

We measured tree-rings width and ensured the exact year of wood formation by cross-dating. We tested the tree-ring frequency by the bomb-peak method of radiocarbon, sampling particular rings in each cross-section (Fig. 2a). The last five tree rings were splitted with a scalpel into several longitudinal slices (Fig. 2b), and their isotopic signatures (^{18}O and ^{13}C) were measured.

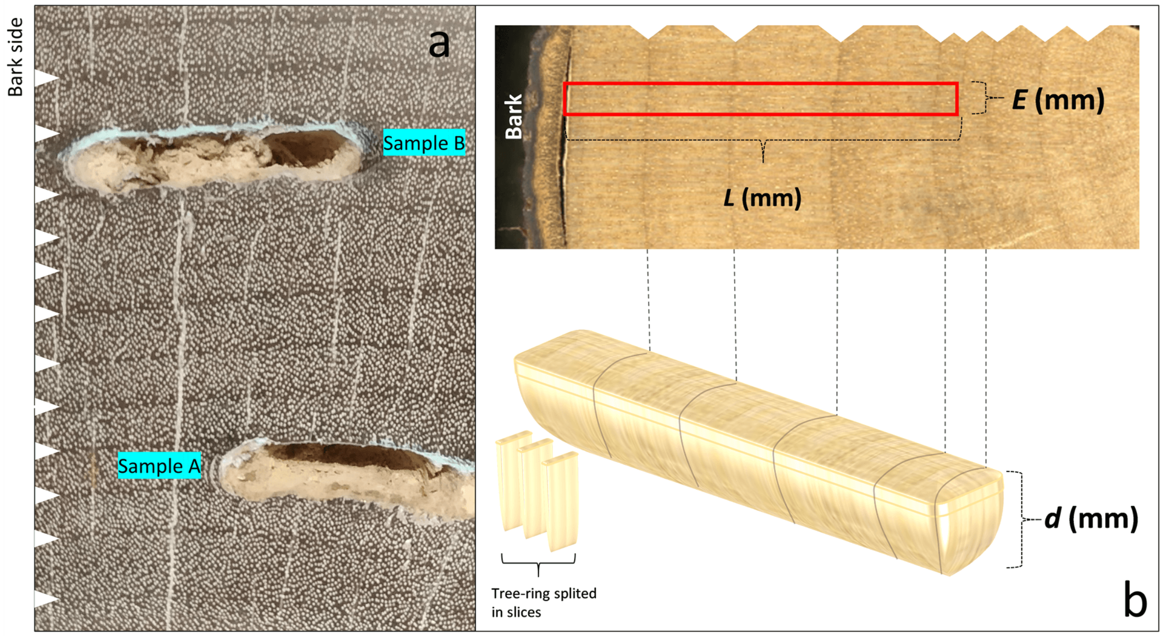


Fig. 3. Wood samples for radiocarbon and stable isotopes analysis. In one cross-section of *H. procerum* (a). In one cross-section of *V. dixonii* (b)

The number of years between calibrated dates was the same as the tree-ring number between radiocarbon sampled rings, which confirm the annual nature of sampled species. Tree-ring width series match (cross-dating) between the two sampled trees for each species. Serial intercorrelation: *H procerum* was 0.57 and 0.40 for *V. dixonii* (p-value <0.05).

We observed a cyclic pattern in δ^{18}Ocellulose values in the tree rings, which coincides with the ring boundaries (Fig. 4a-c), Such variation is conspicuous in *H. procerum*; but not clear in *V. dixonii* a (Fig. 4e-h). Low values of δ^{13}Ccellulose appear (greater discrimination of δ^{13}C), but the pattern is not obvious.

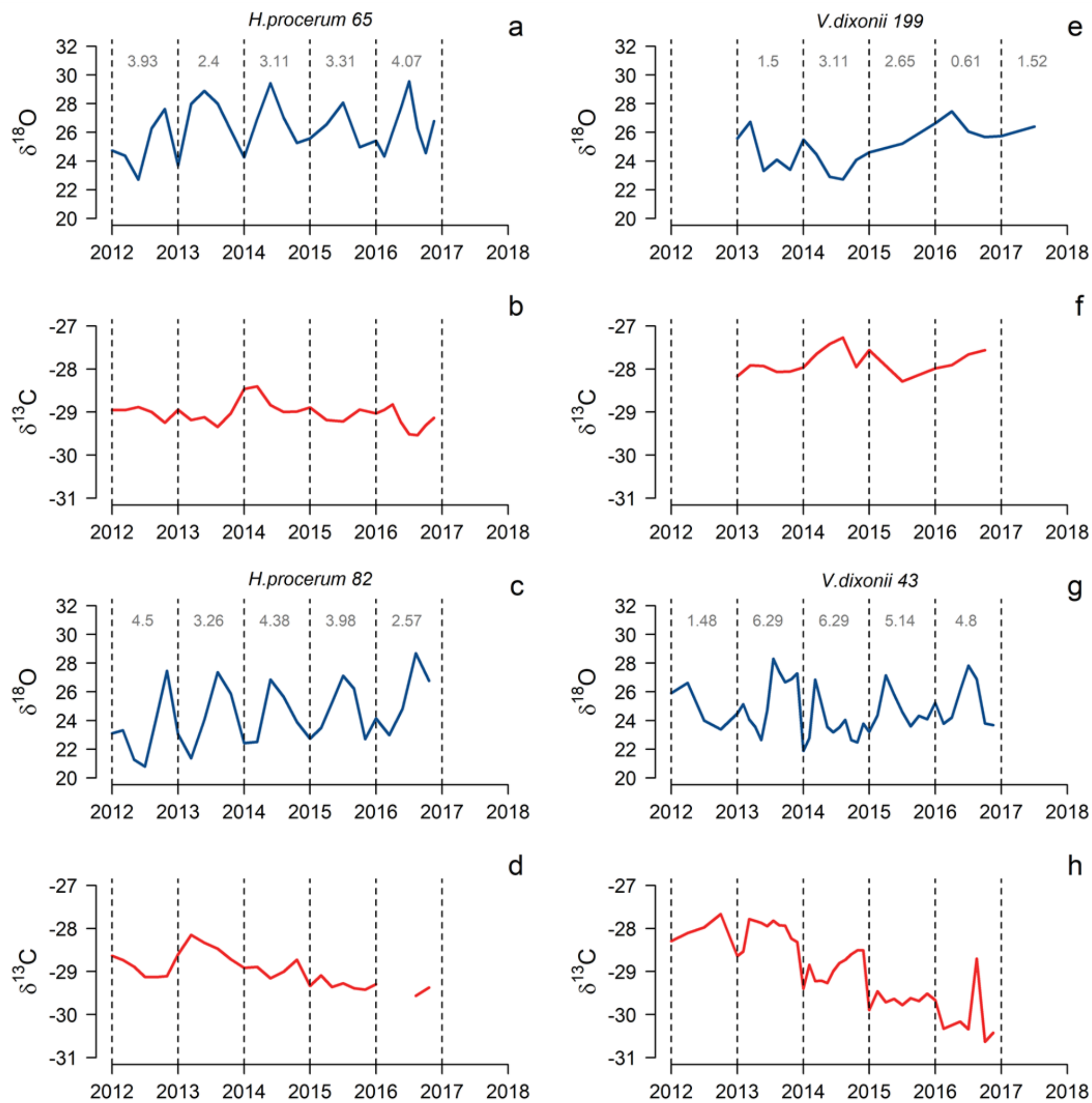


Fig. 4 Radial variation of $\delta^{18}O_{cellulose}$ (blue), $\delta^{13}C_{cellulose}$ (red). Values at the top panels indicate tree-ring widths in mm. The vertical lines indicate the limits of the annual rings

4. ISOTOPIC VALUES VS ENVIRONMENTAL VARIABLES

We found significant negative correlations (*p*-value <0.05) between carbon and oxygen isotopic values of cellulose both at the borders and inside the rings with some environmental variables (Fig. 5)

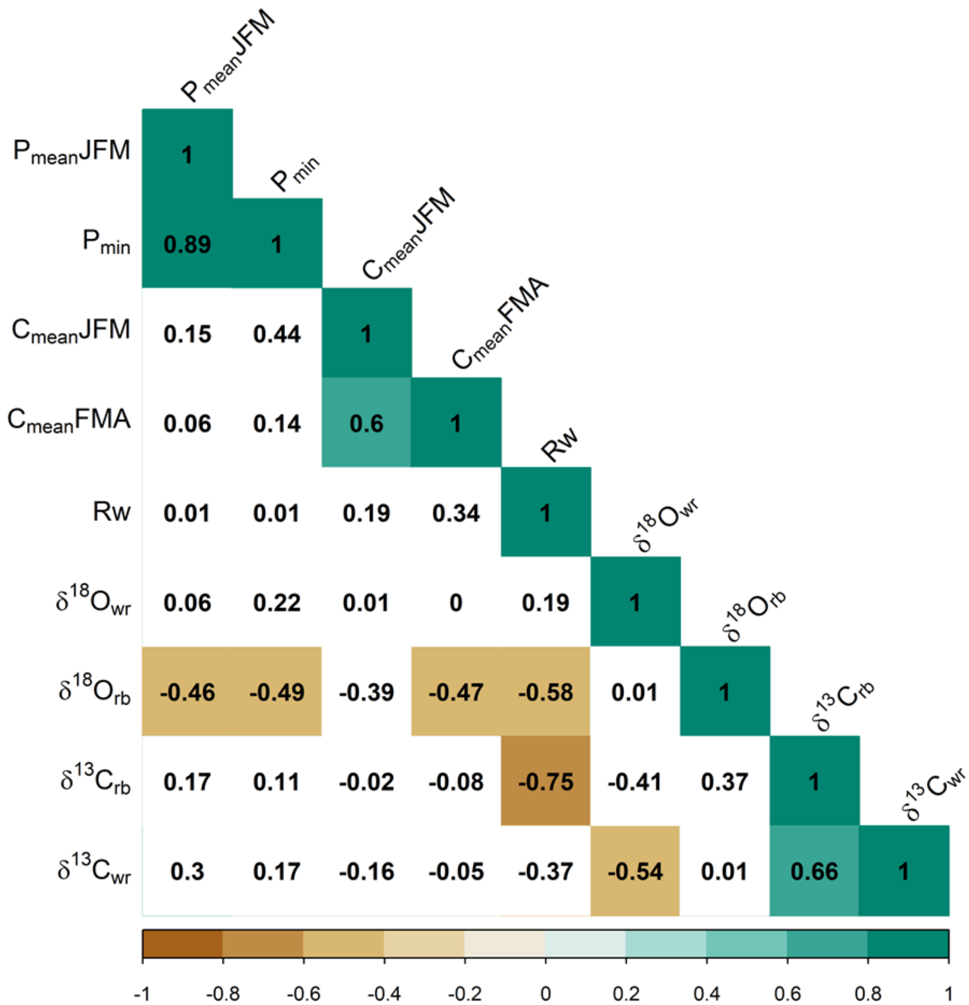


Fig. 5 Pearson´s correlation matrix of the $\delta^{18}O$ and $\delta^{13}C$ values observed in the tree rings versus environmental variables (*p*-value <0.05, n=20).

A negative correlation was observed between the $\delta^{18}O$ at ring boundary ($\delta^{18}O_{rb}$) with precipitation of the driest month and quarter direst months. $\delta^{18}O_{rb}$ correlates with ring width (Rw) and mean cloudiness during the quarter of February-March-April (C_{mean}FMA). We also found significant correlations between isotopes: $\delta^{13}C$rb versus the maximum value of $\delta^{13}C_{cellulose}$ within the ring ($\delta^{13}C_{wr}$) (the only positive), and $\delta^{13}C$wr versus the maximum value of $\delta^{18}O_{cellulose}$ within the ring ($\delta^{18}O_{wr}$) (Fig. 5). No significant correlations were found between the other variables (Solar radiation and temperature).

5. CONCLUSIONS

- We report annual tree-rings and intra-annual isotopic signals of two species growing in hyper-wet and non-seasonal precipitation forest.

- The highest values of $\delta^{18}O$ occur during the first or second third of the rings corresponding to the earlywood when the environmental conditions are favorable for growth because of low rainfall.

- The isotopic signature of $\delta^{18}O$ provided strong evidence for our initial hypothesis of the annual formation of tree rings related to low precipitation levels

ABSTRACT

The drivers of tree growth are one critical question in forest ecology and conservation. However, the measurement of tree growth is a difficult task that requires novel methods to improve accuracy and broaden the understanding of the effect of climate on tree metabolism and carbon accumulation. In this context, isotopes variation along woody tissues is a strong tool that provides new information about tree metabolism, growth rate, and the effect of climatic variation on these processes at high temporal resolution. Here, we obtained woody samples of two tree species two individuals per species (n = 4) from the Biogeographic *Chocó* Region in Colombia, one of the most humid regions of the planet without dry periods (mean annual temperature 25.9°C and rainfall >7200 mm). We measured ^{18}O and ^{13}C on these samples across some rings in each one to obtain intra-annual variation. Using these data, we assessed if isotopes variation in wood is correlated with climatic variation, explicitly precipitation regimen indicators employing Pearson correlation and linear mixed effect models. We found that both isotopes are correlated negatively with ring width. We also found that ^{18}O is high negative correlated with precipitation indicators, rather than ^{13}C. Our results suggest that isotopes variation are surrogates of tree growth in humid and non-seasonal forests. Besides, the ^{18}O accumulation, which is strongly related to rainfall during the less rainy month (February: 370 mm on average), could be a better indicator of the effect of precipitation on the woody tissue rate change. However, ^{13}C is more related to tissue formation processes. In conclusion, we found evidence of intra-annual variation in isotopes and tree growth in one hyper-humid forest challenging the effect of the dry season of tree growth and potentially suggesting the water excess as an additional limiting factor controlling growth rhythms in tropical trees.

REFERENCES

1 Fiihtler E, Clark D, Worbes M (2003) Age and long-term growth of trees in an old-growth tropical rain forest, based on analyses of tree rings and 14C. Biotropica 35:306–317. doi: 10.1646/03027

2 Giraldo JA, del Valle JI, Sierra CA, Melo O (2020) Dendrochronological potential of trees from America's rainiest region. In: Pompa-García M, Camarero JJ (eds) Latin American Dendroecology Combining tree-ring sciences and ecology in a megadiverse territory. Springer International Publishing, AG, pp 79–119

3 Poveda GG, Mesa OJ (2000) On the existence of Lloró (the rainiest locality on Earth): enhanced ocean-land-atmosphere interaction by a low-level jet. Geophys Res Lett 27:1675–1678. doi: 10.1029/1999GL006091

4 Mesa OJ, Rojo JD (2020) On the general circulation of the atmosphere around Colombia. Rev la Acad Colomb Ciencias Exactas, Físicas y Nat 44:857–875. doi: 10.18257/raccefyn.899