Global and Planetary Change 133 (2015) 65–78

Contents lists available at ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

# Wet season precipitation during the past century reconstructed from tree-rings of a tropical dry forest in Southern Ecuador

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ARTICLE INFO

*Article history:*
Received 20 February 2015
Received in revised form 31 July 2015
Accepted 4 August 2015
Available online 5 August 2015

*Keywords:*
Tree-rings
Tropical dry forest
Reconstructed precipitation
Wet season
*Bursera graveolens*
*Maclura tinctoria*

ABSTRACT

This study investigates the dendroclimatic potential of tree species in a tropical dry forest in southern Ecuador. From 10 selected tree species, *Bursera graveolens* and *Maclura tinctoria* exhibited distinct annual and cross-datable tree-rings. It was possible to synchronize individual tree-ring series and to establish two tree-ring chronologies of 203 and 87 years length, respectively. The characteristic ENSO frequency band is reflected in wavelet power spectra of both chronologies. Both species show a strong correlation between ring width and precipitation of the wet season (January–May). Strong El Niño events (1972, 1983 and 1998) lead to strong growth responses in the tree-ring chronologies, whereas 'normal' ENSO events do not trigger long-lasting growth responses. The first ring-width based wet-season precipitation reconstruction for the past 103 years was developed. Statistical and spatial correlation analysis verified the skills of the reconstructed precipitation which captures a great part of the Rainfall Index over the land area of Ecuador and the equatorial Pacific. Furthermore, teleconnections with central Pacific precipitation and SST patterns were found.

## 1. Introduction

After their initial development almost one century ago (Douglass, 1919), tree-ring studies were conducted worldwide. Currently, more than 3000 tree-ring data sets are stored in the International Tree-Ring Data Bank (ITRDB, NOAA http://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/tree-ring). In comparison to the temperate climate zones, the tropical regions are still strongly underrepresented and require much further research (Zhou et al., 2013).

A major challenge for tropical dendrochronology is the indistinct or missing formation of tree-rings in most species due to the lack of climatic seasonality (Rozendaal and Zuidema, 2011). However, as early as 1927, tropical tree species with distinct rings have first been described (Coster, 1927). In the last decades, tropical dendrochronology has been developing rapidly through identifying a considerable number of tree species with annual growth rings. The annual nature of these rings was proven by studying cambial phenology (Krepkowski et al., 2011; Volland-Voigt et al., 2011), wood anatomy (Harley, 2013; Rozendaal and Zuidema, 2011; Worbes, 1995), and stable isotopes (Anchukaitis et al., 2008; Evans and Schrag, 2004). Tree-ring formation in humid tropical forests can be an effect of the occurrence of short dry periods or of leaf phenology (Brienen and Zuidema, 2005). While tree-ring formation in inundation forests is triggered by the annual flooding cycle (Callado et al., 2001; Schöngart et al., 2005), in dry forests it is controlled by a marked annual rainfall seasonality regulating the water balance of the ecosystem (Fichtler et al., 2004; Reich, 1995; Rodríguez et al., 2005; Worbes, 1999). The lack of a comprehensive network of tree-ring chronologies in tropical ecosystems poses a deficit for a better understanding of large-scale tropical forest ecology and global carbon balances. Additional tree-ring chronologies providing species-specific information on physiological responses to the local and regional climate variability are urgently needed to get a broader picture of long-term changes and adaptations of tropical forest ecosystems (Rozendaal and Zuidema, 2011). While humid tropical forests received considerable attention by ecologists and dendrochronologists, tropical dry forests are almost understudied (Brienen and Zuidema, 2005; Chazdon et al., 2007; Mooney et al., 1995; Sanchez-Azofeifa et al., 2005).

The El Niño/Southern Oscillation (ENSO) tropical circulation system influences large parts of tropical South America and other parts of the earth via long-distance teleconnections. Existing tree-ring based climate reconstructions for the South American tropics or ENSO have often been based on moisture-sensitive chronologies from subtropical or semiarid temperate regions in Central and North America (D'Arrigo et al., 2005; Stahle et al., 1988). However, teleconnections between local moisture-sensitive proxies and ENSO are often not stable, and so correlations between proxy-derived ENSO reconstructions vary over time (D'Arrigo et al., 2005; Wilson et al., 2010). Hence, more reconstructions of local precipitation and variations of ENSO-related climate parameters from tropical areas are needed.

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http://dx.doi.org/10.1016/j.gloplacha.2015.08.003
0921-8181/

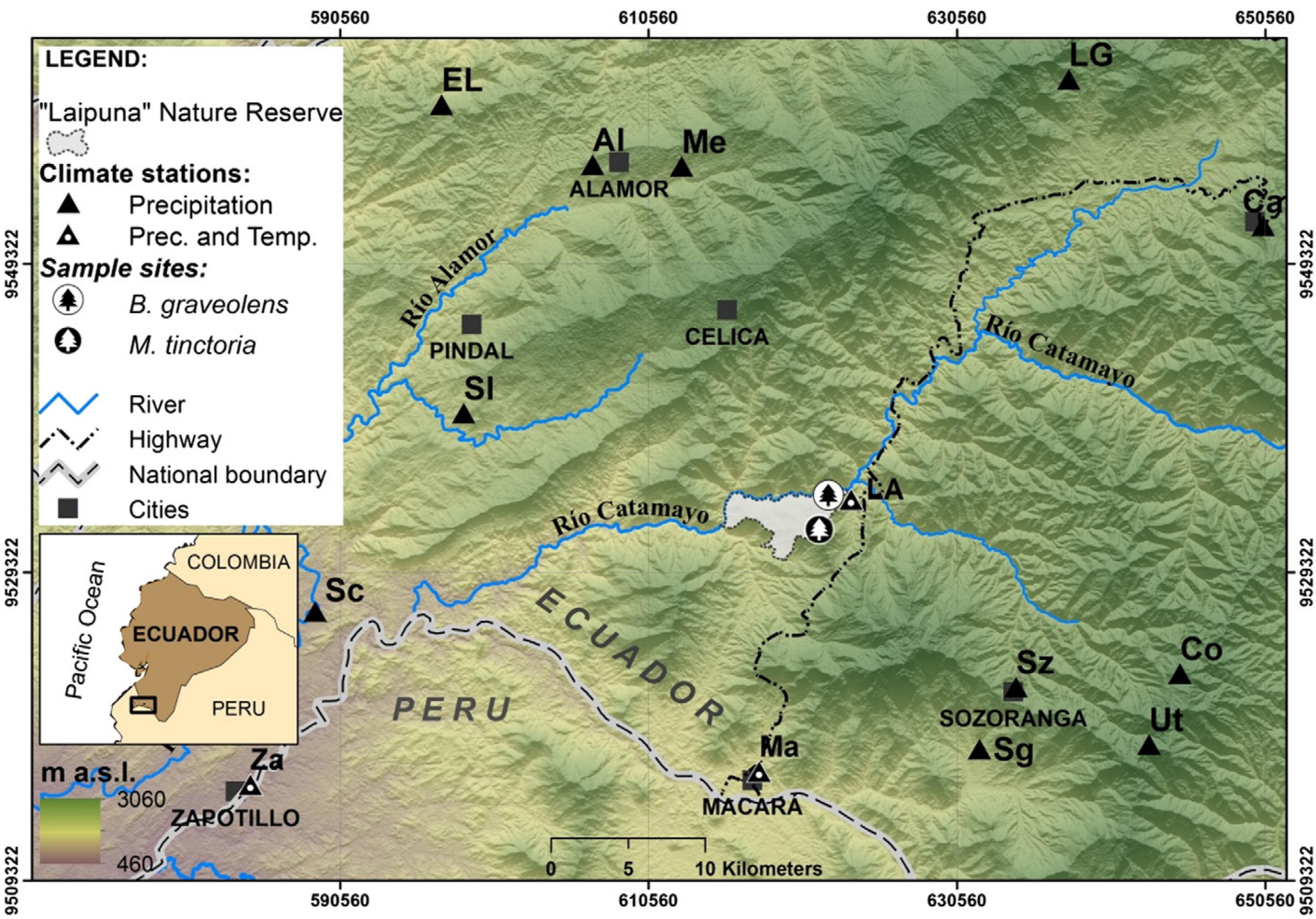

**Fig. 1.** Study area, climate stations (triangles) and sample sites (circles). For climate stations labels refer to Table 1.

For that purpose the first dendrochronological study in the semi-deciduous dry forests of southern Ecuador was conducted to generate regional knowledge on historical climate changes in the equatorial tropics, and to study the influence of climate factors on these ecosystems. The potential of new tree species for dendrochronology was evaluated in order to achieve the following aims: (1) to select and identify potential tree species for dendrochronology based on the identification of distinct annual growth rings through analyzing wood anatomy; (2) to construct local climate-sensitive tree-ring width (TRW) chronologies in order to analyze and understand the impact of the local and regional climate on the annual growth of this forest ecosystem; and (3) to develop a ring-width based precipitation reconstruction.

## 2. Materials and methods

### 2.1. Study site

This study was carried out in the dry forest Laipuna Nature Reserve (4°22′S, −79°90′W; 1.600 ha) located in the core of UNESCO “Bosque Seco” Biosphere Reserve in the Catamayo River canyon in southern

**Table 1**
Parameters of the climate stations used to build the regional precipitation and temperature series.

| No | Label | Station name | Correlation coefficient r [Prec. Laipuna] | Distance from Laipuna [km] | Altitude [m a.s.l.] | Available records [time period]/[no. years] | Annual mean precipitation [mm] |
|---|---|---|---|---|---|---|---|
| 1 | LA | Laipuna | 1.00 | 0 | 590 | 2007–2012/6 | 648 |
| 2 | LG | Lauro Guerrero | 0.97 | 30 | 1910 | 1975–2013/22 | 1522 |
| 3 | EL | El Limo | 0.95 | 34 | 1150 | 1982–2013/10 | 2140 |
| 4 | SB | Sabanilla | 0.94 | 24 | 733 | 1975–2013/24 | 730 |
| 5 | CA | Catacocha | 0.93 | 32 | 1808 | 1963–2013/50 | 907 |
| 6 | SG | Sabiango | 0.92 | 20 | 734 | 1972–2013/41 | 1234 |
| 7 | ME | Mercadillo | 0.92 | 22 | 1125 | 1975–2013/21 | 1238 |
| 8 | SO | Sozoranga | 0.92 | 18 | 1510 | 1979–2013/39 | 1208 |
| 9 | CO | Colaisaca | 0.91 | 26 | 2410 | 1963–2013/49 | 1165 |
| 10 | UT | Utuana | 0.91 | 27 | 2410 | 1982–1986/5 | 1573 |
| 11 | AL | Alamor | 0.89 | 25 | 1250 | 1963–2013/48 | 1357 |
| 12 | SC | Saucillo | 0.84 | 35 | 328 | 1967–2013/44 | 788 |
| 13 | MA | Macara[a] | 0.83 | 20 | 427 | 1958–1986/26 | 630 |
| 14 | ZA | Zapotillo[a] | 0.82 | 40 | 223 | 1963–2013/46 | 688 |

[a] Climate stations with available temperature data. All correlations are significant at the 0.01 level.