Reconstruction of Aridity for the Sierra de la Laguna, Baja California Sur, Mexico

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Introduction

A well-documented history of past climatic conditions is needed to understand and resolve some ecological problems, but the existing climatological records are too short to detect long-term climatic variability and changes. Some trees, such as pines, produce annual tree rings with different widths depending on prevailing environmental conditions, such as climate. Tree-ring analysis of long-lived trees can be used to estimate past variations in climate.

The principal aim of this study is to reconstruct aridity for the southern portion of the Baja California Peninsula, by means of dendroclimatologic techniques.

The study was carried out in the Sierra de la Laguna, a mountain range in the southern part of the Baja California Peninsula (Figure 1). The altitudinal range of the Sierra de la Laguna shows marked climatic differences, as well as life forms, different from the rest of the state. At higher altitudes are the only oak-pine woodlands of the state where an endemic conifer, *Pinus lagunae*, grows. This species was the subject of the present study.

Methodology

Within the Sierra de la Laguna oak-pine forest, 80 pines were selected to obtain two increment cores from each tree with a standard increment borer. Dendrochronology procedures and techniques for analyzing radial growth in trees included the following steps:

- Increment core samples were cross-dated by the skeleton plot to synchronize variations in ring width of the different trees and assign them to the correct time sequence.
- Ring widths were measured on a sliding-stage micrometer. Measurements were transformed to growth indices by fitting curves to the series and dividing the ring widths by the values of the fitted curves.
- A master dendrochronology time series was created by simply averaging the core indices with a computer program (Holmes 1992).

In: C.M. Isaacs and V.L. Tharp, Editors. 1995. *Proceedings of the Eleventh Annual Pacific Climate (PACLIM) Workshop, April 19-22, 1994*. Interagency Ecological Program, Technical Report 40. California Department of Water Resources.

The regional instrumental climatic series was obtained from Díaz *et al* (1994). They based the analysis on climatologic recordings of total monthly rainfall and monthly mean temperatures of stations in low and middle altitudes of the Sierra de la Laguna, at an average of 451 meters above sea level. The aridity index was calculated from these data using Martonne's (1926) formula. In addition, from the climatologic data of Díaz *et al* (1994), we constructed annual instrumental rainfall and temperature time series.

Dendrochronologic and aridity data were compared over a period of time called the "calibration period". With the resulting model, aridity was reconstructed from dendrochronologic data for the pre-instrumental period.

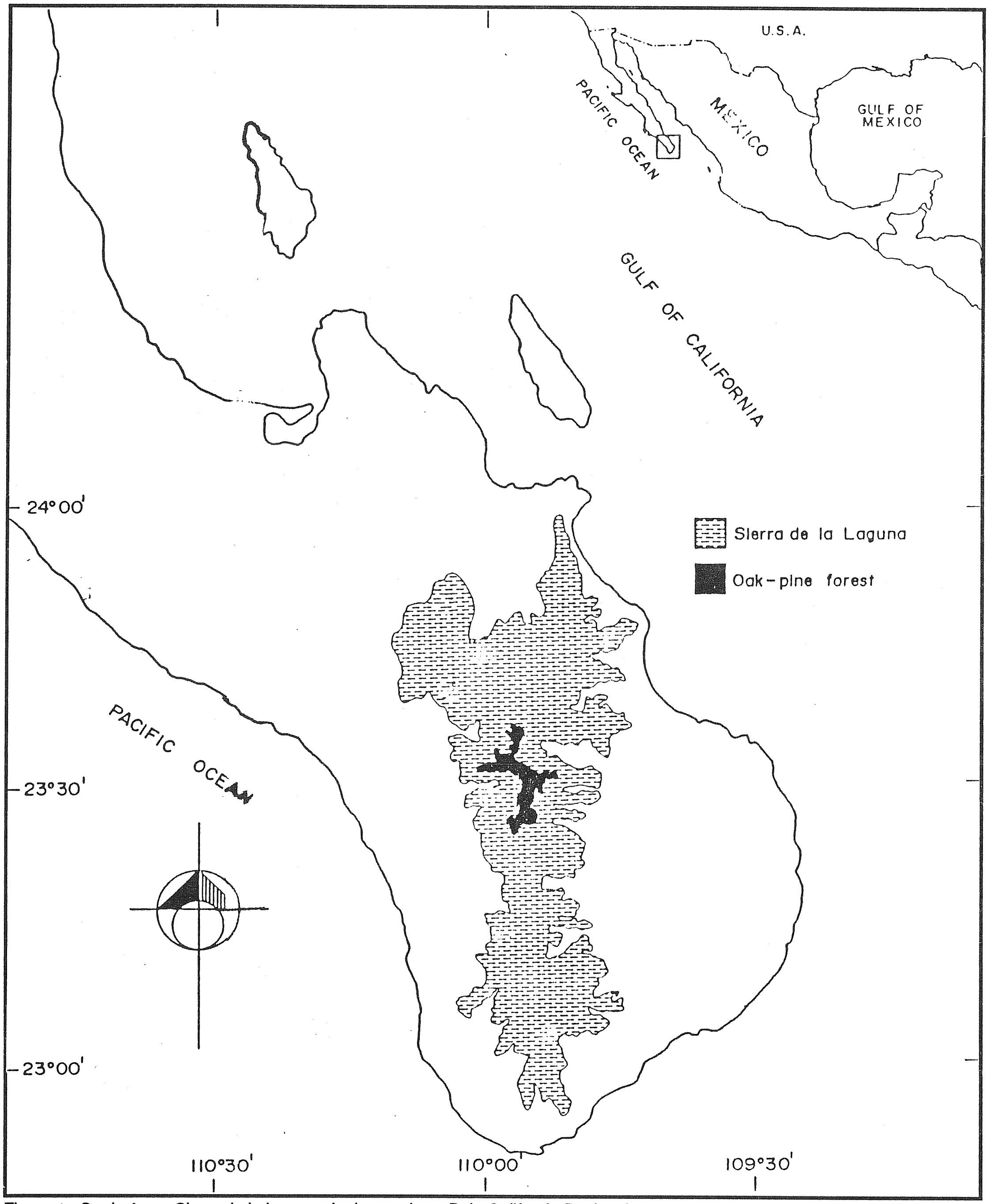

Figure 1. Study Area, Sierra de la Laguna, in the southern Baja California Peninsula.

Results and Discussion

For the calibration period, the dendrochronology time series and estimated rainfall and temperature time series were used to search for possible relationships between tree growth and meteorological variables. Since linear regression models were to be used, series were first tested for normality. For the aridity series, the five upper outliers deviated significantly from the general fitted normal distribution (Figure 2). These values were replaced with their corresponding five terms unweighted moving averages. No other transformation of data was done.

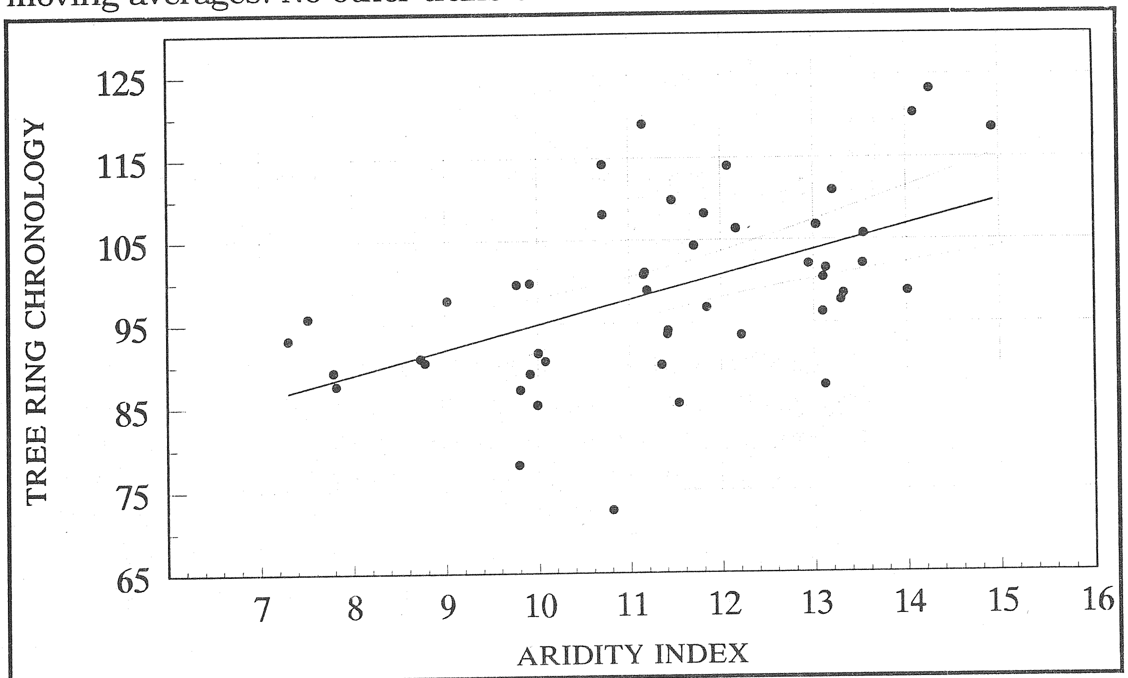

Figure 2. INSTRUMENTAL ARIDITY INDEX VERSUS TREE-RING WIDTH FOR THE FOLLOWING YEAR
The equation for the best-fit regression line is $Y = 2.988X + 65$; $r = 0.523$ (**).

Single and multiple regression between dendrochronology (dependent variable) and temperature, precipitation, and aridity for the previous year (independent variables) were tested. Only precipitation and aridity ($r=0.523$) were significantly correlated with the dendrochronology. However, multiple correlation showed that the two variables were highly redundant ($r=0.524$). The regression coefficient (beta) for precipitation was not significant under the multiple linear regression model. Thus, simple linear regression between aridity and dendrochronology was selected for the reconstruction.

Since the applied regression model assumes a linear relationship between normally distributed variables, standardized residuals were tested for these assumptions using normal probability plots (residuals *vs* expected normal value). No indications were found of severe violations to the model assumptions. In addition, we plotted residuals *vs* deleted residuals (*ie*, the residual for a particular value when regression is performed without that value; Figure 3). Regression was not seriously biased by outliers, since there is not a great difference between residual and deleted residual for any value.

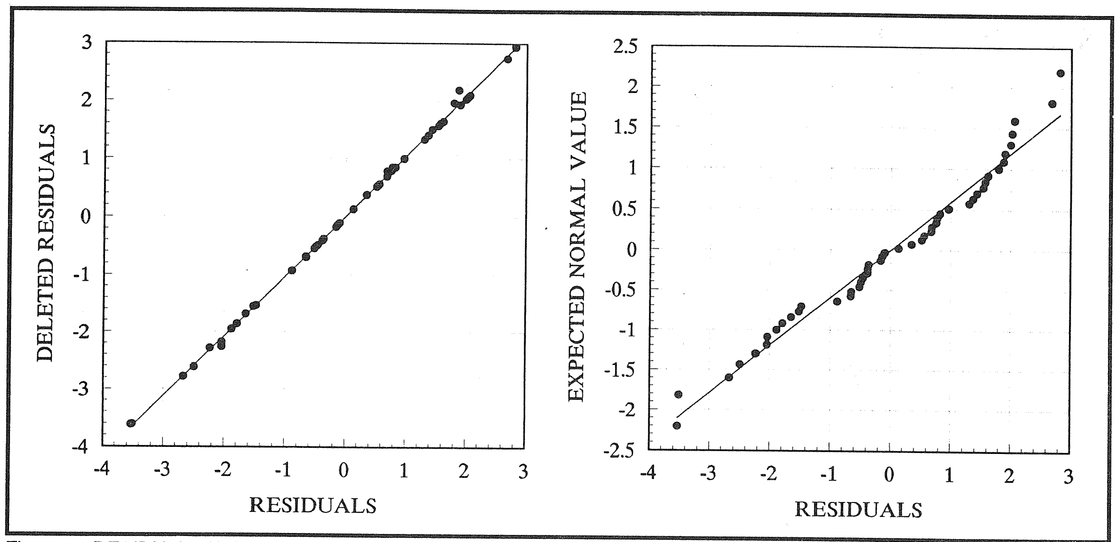

Figure 3. RESIDUAL ANALYSIS
Left: Residuals versus Deleted Residuals: Regression is not seriously biased by outliers.
Right: Normal Probability of Residuals: The assumption of a linear relationship between variables and the normal underlying distributions seems reasonable.

The aridity index was calculated from the regression equation, and these values were compared to the actual aridity index values. For 1940 to 1989 (Figure 4), the dendrochronology/aridity relationship was not very close. However, aridity reconstruction at an interdecadal scale is promising. The upward trend between the mid-1940s and the early 1960s, the downward trend up to 1970, the upward trend up to 1983, and the downward trend up to 1989 are all evident in both series.

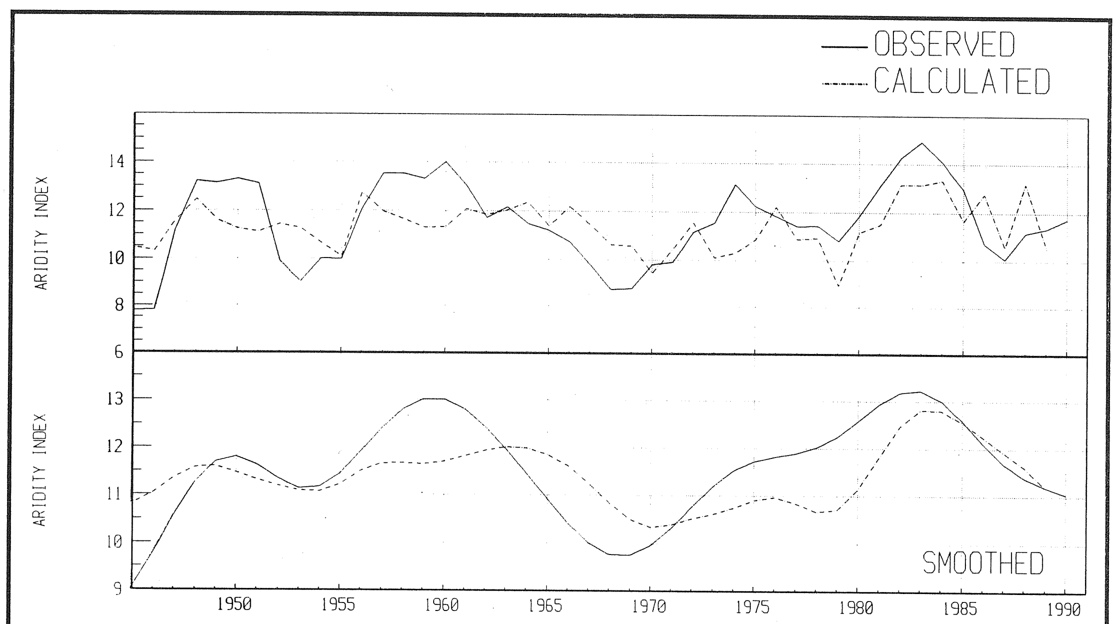

Figure 4. ARIDITY RECONSTRUCTION FOR THE CALIBRATION PERIOD

The aridity reconstruction series shows some interesting features:

- From 1810 to 1890, a period of high variability and high aridity occurred, interrupted by a few years of very low aridity during the mid-1840s.
- From 1900 to the mid-1950s, there was a remarkably stable period of intermediate aridity.
- Recent years have been highly variable, with minimum aridity in the mid-1960s, a maximum during the early 1970s, and another minimum during the mid-1980s.

Conclusions

Dendrochronology does not correlate highly with aridity at an interannual scale. Possible reasons include:

- There are no long precipitation/temperature records for the woodland area, so nearby meteorological stations had to be used. These stations are at much lower altitude than the woodland area.
- Although water availability should be a limiting factor on tree growth, the biological response to interannual variability in aridity may be "filtered" if physiological compensation is to be expected. If so, dendrochronology may reflect sustained trends much better than interannual variations, as observed.
- Dendrochronology is much more closely correlated with aridity at an interdecadal scale. Accordingly, we reconstructed aridity for the last two centuries based on dendrochronology data (Figure 5).
- Recent-year trends for the reconstructed aridity are also present in the meteorological records for nearby areas. It is concluded that the species *Pinus lagunae* is sensitive to climatic changes.

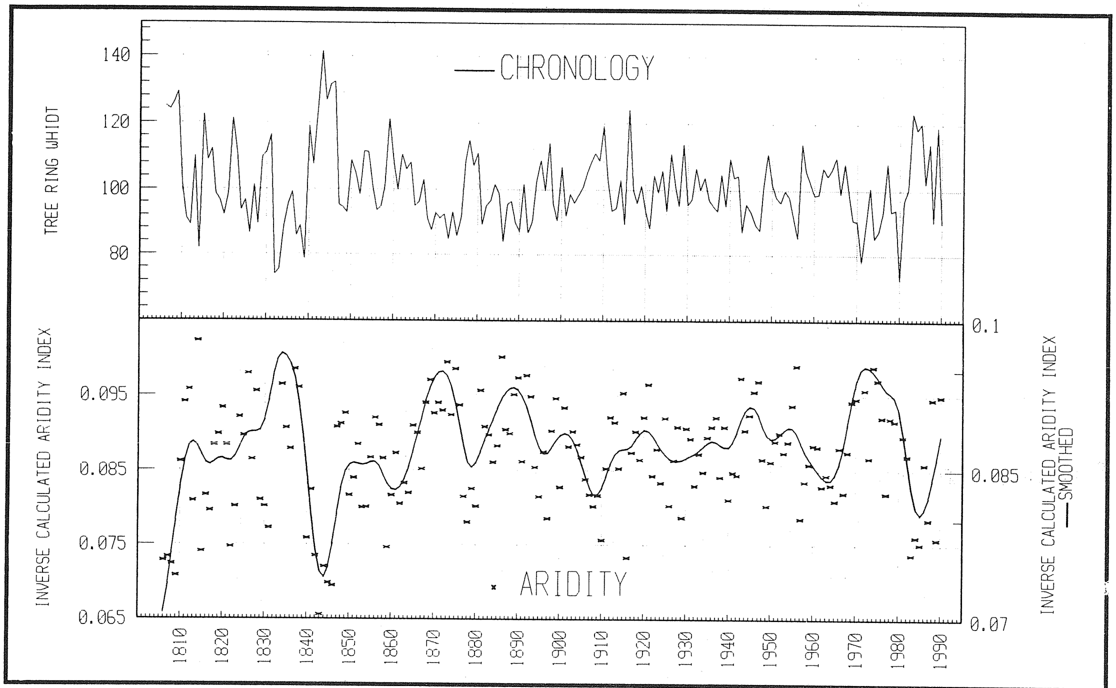

Figure 5. ARIDITY TRENDS FOR THE LAST TWO CENTURIES IN SIERRA DE LA LAGUNA

References

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