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Forest growth response to cumulative drought

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***Abstract*—Drought is a phenomenon that threatens forest ecosystems. However, the cumulative effect of drought on tree growth is unknown for the forest ecosystems of Mexico. This study conducted a correlation analysis, under a dendrochronological approach, to determine the effect of multiscale droughts at 1,3,6,12,24, and 36 months with the growth of one of the most commercially valuable conifers in the north of Mexico. Correlation analyzes showed that the cumulative drought at six months is the best associated to tree growth. These results highlight the importance of monitoring the intensity of drought in the months before the period of growth. In particular, dry winters will have serious impacts on forest decline.**

Keywords—multiscale droughts; conifers; north of Mexico; Pinus cooperi; tree-radial growth

I. INTRODUCTION

The Sierra Madre Occidental in the north of Mexico forms a large region that integrates different ecosystems and is home to numerous species of wild flora and fauna, and provides many goods and services [1]. However, in recent years, global climate change has become a phenomenon that modifies drought levels worldwide [2]. To understand the ecological processes in forests with the interaction of drought is an issue that has regained great interest in our time [3]. It is necessary to consider possible scenarios of response to this phenomenon, since it has been reported that trees are sensitive to spatial and temporal variations of drought [4], [5], [6]. In order to deepen and know the cumulative effects of drought, [2] SPEI drought index data have been published. This is a reliable tool in evaluating drought since unlike traditional indices evaluating drought, the SPEI includes the effect of temperature, coupled with its multiscale character to differentiate types of drought [7]. Although the climate-tree relations have been explored in the north of Mexico [8], [9], [10], [11] and its impact on large-scale phenomena [12], up to now, the effect of cumulative drought on forest ecosystems is unknown. Therefore, this study evaluates the response of forest to drought cumulative in an ecosystem of the north of Mexico to improve the understanding of the mechanisms of response to changes in moisture availability.

II. MATERIALS AND METHODS

The study was conducted in the Sierra Madre Occidental (SMO) of the state of Durango (Fig. 1). The climate varies from temperate to tropical, total annual precipitation varies from 443 to 1,452 mm, an average of 917 mm. The average annual temperature ranges from 8.2 to 26.2 °C, with an average of 13.3 °C. In the SMO, the altitude ranges between 363 and 3,190 m (average 2,264 m). The predominant types of forests are irregular (unevenly aged) of pine-oak, often mixed with *Pseudotsuga menziesii*, *Arbutus spp*., *Juniperus spp*. and other tree species [1].

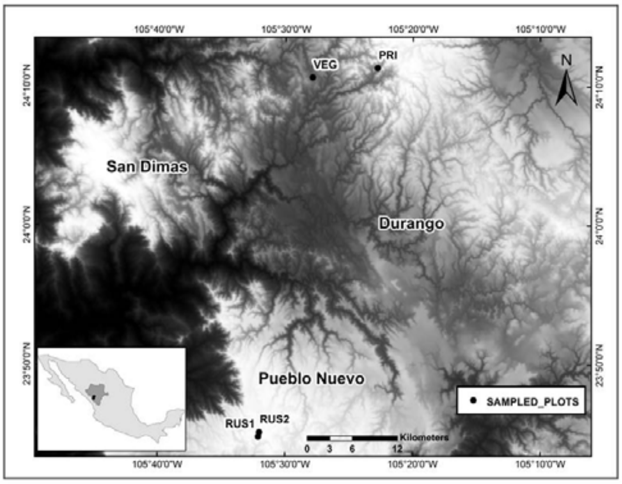

Fig. 1. Location of the study sites in the Sierra Madre Occidental.

To perform this study, four sampling sites in coniferous forest, located at different altitudes (Table 1) were defined. From 6-10 trees of *P. cooperi* were selected at each site, a dendrochronological study was conducted to each tree using the methodology described by [13], which resulted in standardized residual series with the information on tree-ring index (TRI).

TABLE I. SAMPLING SITES

Site	Geographic coordinates		Altitude (msnm)	Number of trees
	W (°)	N (°)		
RUS1	105.534944	23.747306	2905	10
RUS2	105.533583	23.752605	2813	10
PRI	105.379611	24.189083	2424	10
VEG	105.464778	24.177583	2375	6

The relations between tree-ring index (TRI) and drought through temporary records at 1, 3, 6, 12, 24 and 36 months of SPEI (available at http://sac.csic.es/spei/database.html) were analyzed from the standardized residual series. Relations between TRI and SPEI were obtained by correlation analysis [14]. This procedure allowed obtaining those months of cumulative drought with greater effect on TRI.

III. Results and Discussion

Only those values with high level of significance (α = 0.05) were presented as results. Results of both positive and negative correlation ranging from -0.1 for RUS2 up to 0.69 for PRI (Figure 2) were found. In all cases, the cumulative drought behaved similarly in all sites.

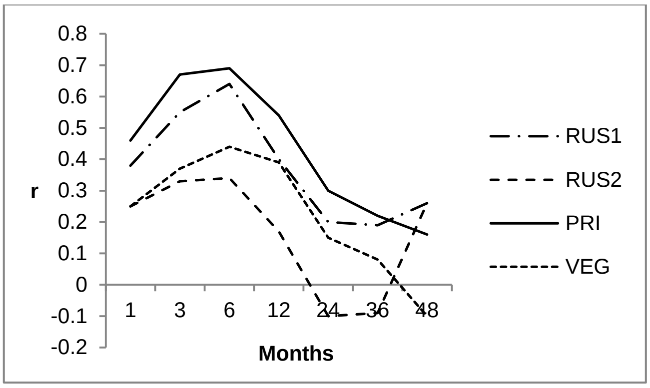

Fig. 2. Variation of correlation r (Spearman coefficient) with cumulative drought at the study sites.

These results agree with [15], who mentioned that the ring growth of forest species showed significant and positive relationship with the humidity of the previous year growth.

From the graphic analysis of multiscale correlation, the highest values were obtained for short drought periods. That is, for all sites, cumulative six-month drought is the greatest influence on the ring growth compared to the other drought periods (1, 12, 24 and 36).

The results reveal that the months that more should monitor the intensity of drought, are those corresponding to the immediate previous season to the growth period; this dry season typically spans from December to June in most of the country [16], [17], [18], [19].

Although beyond the objective of the study, these results may have influence as mitigation strategies to climate change [20]. It is important to mention that besides climatic variables, there are other factors that determine the growth of forests, such as season quality of the site, nutrient availability, competition indices and genetic adaptations of trees sampled, among others [21], [22], [23], [24], [25], [26].

IV. Conclusions

The cumulative 6-month drought has greater effect on trees ring growth. Thus, previous winter precipitation contributes to explain tree growth. This finding supports the hypothesis that wet winters contributed to tree growth. Winter rains storage during the tree latency period is useful to break bud dormancy and hence start tree growth for the next growing season.

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