Ecology, Conservation and Management of Mediterranean Climate Ecosystems

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Drought patterns and its ecological effects in east Spain during the second half of 20th century

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ABSTRACT: We have compared Standardized Precipitation Index (SPI at 6 months resolution level) with tree growth series of different forests in Mediterranean coastland / inland area of the E of Iberian Peninsula to analyze the effects of short-term drought on natural systems. Such relationships seem to be variable in the study area, so we analyzed the spatial distribution patterns of SPI at subregional level from a very dense monthly rainfall database (1 observatory per 150-200 km²). Spatial and temporal analyses of droughts from 1950-2000 were performed using PCA analysis. As general result, in the whole area, the last two decades of XX century have been suffered the more severe droughts. Moreover, we identify five different areas with different drought patterns where drought trends show significant differences in time.

1 INTRODUCTION

Drought are considered as the most negative climatic risk along the twenty century (Obasi 1994), their losses sum billions of USA dollars (Bruce, 1994) and they have been considered as extreme climatic events (Changnon et al. 2000). Climate models suggest an increment of drought related to precipitation decrease in different areas (Jones et al. 1996). Particularly in Mediterranean climate areas, if precipitation decreasing were confirmed (see New et al. 2002), regional consequences would be extremely dangerous because these landscapes are under specifically climatic conditions, particularly water stress produced by paucity and seasonality of rainfall and high potential evapotranspiration values.

The Mediterranean region of the Iberian Peninsula is an adequate area for drought impact analysis. It is located in transitional climatic area, under Mediterranean conditions. Except in northern and western areas, precipitations are scarce and very irregular in time and space. An especial case is the NE inland-coastland area where droughts manifest as a recurrence event, with high temporal and spatial variability (Estrela et al. 2000, Vicente-Serrano and Beguería-Portugués 2003).

In this paper we have analyzed the spatial and temporal patterns of short droughts during the second half of the 20th century in NE of Iberian Peninsula (Spain) from coastland Valencia Region to NE inland Middle Ebro basin. We have included landscapes under different Mediterranean climatic conditions. Paper is organized in four sections. In section 2 study area is presented. Database and methods are described in section 3. We present the results in section 4 comparing the SPI evolution with different TRI (Tree Ring Index) series. Finally we discuss the spatial gradients of drought natural systems response.
2 STUDY AREA

The study area is located in the western Mediterranean basin from east coastland (Valencia Region) to NE inland (Middle Ebro Basin, Fig. 1), and comprises an area extending between 38° and 41° N (c. 40,000 km²).

Precipitation varies from less than 250 mm in the southern areas and 350 mm in the middle Ebro basin to 800 mm in the Valencia central mountain areas and in the Pre-Pyrenees (see Fig. 1.2.). PET is over 1000 mm yr⁻¹, and can reach more than 1400 mm yr⁻¹ in the driest areas (Middle Ebro and south of Valencia). In many sectors of the study area annual rainfall show a general increase in variability (Serrano et al. 1999, De Luis 2000) and seasonal changes (De Luis et al. 2000, González Hidalgo et al. 2001). However, a high spatial heterogeneity exists, which makes difficult to establish a global pattern. Also torrentially is characteristic of precipitation in this area and the extremely dependence of annual mean precipitation value from few rainy days let us to presents the hypothesis that drought probability would be increasing.

Water demand is high in this area because of human activities: in the inland area (Middle Ebro basin) due to irrigation agricultural practices, and in coastland furthermore by tourist activities (more than 2,000,000 visitors per years).

3 DATA AND METHODS

Monthly database from 141 observatories has been used. Database comprises from January of 1950 to December of 1999. The rain gauges are distributed irregularly throughout the area (see Fig. 1.1). The overall density is 1 observatory per 200 km².
Droughts are ever promoted by accumulated precipitation deficits, and precipitation methods are nice tools for their identification and reasonable way to analyze its different spatial effects (Guttman et al. 1991, Oladipo 1995, Komuscu 1999, Redmond 2002, Fowler and Kilsby 2002). As a consequence, in environments with high spatial and temporal variability of precipitation it is reasonable to expect the same variability in droughts. Standardized Precipitation Index (SPI, McKee et al. 1993 and 1995) has been considered as the most reliable ones for measuring the intensity, duration and spatial extent of droughts (Guttman 1998, Keyantash and Dracup 2002).

We have calculated drought index (Standardized precipitation Index, SPI, Guttman 1999) after quality and homogeneity control of original data. In this paper, the SPI series were computed from January of 1951 to December of 1999 and temporal scale 6 months (see Vicente and Cuadrat 2002 for details).

Temporal series of SPI indices from different areas were compared with Tree Ring Index from database of Project (REN2003-07453): “Variabilidad climática y dinámica forestal en ecosistemas de ecotono”. The database is at present is in progress, so we only show 5 TRI series from different areas, as a provisional approach. Forest site locations are shown in Fig. 2. Such SPI local series were computed from nearest rainfall data point.

Principal Components Analysis (PCA) in S-mode was applied to SPI individual values to produced the most general patterns of drought evolution in the area. To determine the spatial extent of each component series we mapped the factorial matrix values by using the correlation between each component and the original SPI series of each station. We note that because the SPI series are normalized, the different component values show the SPI representative of certain area (Serrano et al. 1999). Components selection has followed the criteria of Briffa et al. (1994), using a rotation of components (Varimax) (Richman 1986) (see Figure 2). Spatial distribution of components was performed by mapping the factorial matrix values by means of splines with tension (Vicente-Serrano et al. 2003) using the ArcView 3.2 SIG.

4 RESULTS

The relationship between SPI and TRI from different forest are shown in Table 1. Values express the monthly correlation value from monthly SPI local series and TRI. Monthly correlation values differ spatially in magnitude.

<table>
<thead>
<tr>
<th>Forest</th>
<th>E</th>
<th>F</th>
<th>MZ</th>
<th>AB</th>
<th>MY</th>
<th>JN</th>
<th>JL</th>
<th>AG</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>Prec</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZORITA</td>
<td>0.52</td>
<td>0.50</td>
<td>0.51</td>
<td>0.40</td>
<td>0.36</td>
<td>0.33</td>
<td>0.28</td>
<td>0.29</td>
<td>0.21</td>
<td>0.10</td>
<td>0.04</td>
<td>-0.21</td>
<td>615</td>
</tr>
<tr>
<td>ALCOI</td>
<td>0.39</td>
<td>0.47</td>
<td>0.48</td>
<td>0.50</td>
<td>0.50</td>
<td>0.45</td>
<td>0.30</td>
<td>0.29</td>
<td>0.25</td>
<td>0.29</td>
<td>0.10</td>
<td>-0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>BIAR</td>
<td>0.09</td>
<td>0.15</td>
<td>0.20</td>
<td>0.30</td>
<td>0.37</td>
<td>0.44</td>
<td>0.44</td>
<td>0.47</td>
<td>0.50</td>
<td>0.26</td>
<td>0.10</td>
<td>0.17</td>
<td>413</td>
</tr>
<tr>
<td>MAIGMO</td>
<td>0.26</td>
<td>0.39</td>
<td>0.42</td>
<td>0.45</td>
<td>0.51</td>
<td>0.56</td>
<td>0.52</td>
<td>0.45</td>
<td>0.37</td>
<td>0.18</td>
<td>0.05</td>
<td>0.11</td>
<td>378</td>
</tr>
</tbody>
</table>
| C: EOF associated (see Fig. 2). Prec.: Mean annual precipitation (in mm). See Figure 2 for forest site location

Five main components of PCA explain >70% of total variance and there exist a break point with values of variance of 5th and 6th components. We have selected these components for subsequent commentaries and analysis (Fig. 2).

The first Empirical Orthogonal Function (EOF) explains 22.9 % of total temporal variance, and represents the droughts evolution of middle coastland areas (Fig. 2). The second EOF (20.9 % of total variance) is mainly representative of Northern coastland. Middle Ebro basin is represented by 3th EOF (19.8 % variance), while 4th (5.4% variance) is the transition between 2nd and 3rd. Finally southern EOF is located at southern area (4.8 % of variance).

Figure 3. Temporal series of SPI Components 1, 2, 3, 4 and 5.
All of these aforementioned patterns are clearly spatially distributed, do not overlap between them, and show different evolution (Fig. 3). As a consequence, the series of each component represents the temporal evolution of droughts in specific areas at temporal resolution of six months. Transitional areas between different EOF are also identified by other components (not shown), but they represent low values of explained variance. Also such areas are local ecotones under high uncertainty because the high probability to be affected by more than one main EOF pattern.

The temporal evolutions of the EOF 1 to 5 are shown in Figure 3. EOF 1 shows different drought episodes: beginning of 1980´and the end of 1990´. These episodes were prolonged in time with critical and extreme situations. Short events are found during 1950´, 1960´and middle of the 1970´. The behavior of EOF 2 and 3 show more extreme droughts than EOF 1, nevertheless, the 1980´and 1990´are dominant dry in the whole area, and 1950´and 1960´decades mainly in south (EOF 5).

Forest series are located in different EOF patterns (Alcoi, Biar and Maigmo in the area represented by EOF 1, Zorita forest in EOF 4 and Crevillente forest in EOF 5), and forest from others EOF pattern are at present under study (see Figure 2).

5 FINAL REMARKS

Different studies have shown that in Mediterranean areas there is a general decrease in precipitation (Briffa et al. 1994, Lana et al. 2001), and increase of extreme events. By the other hand climatic models show a general increase of droughts in the Mediterranean region (Jones et al. 1996) and the increment of precipitation variability (Houghton et al. 2001). Nevertheless, there is no consensus in the drought trends in the Mediterranean region. Lloyd-Hughes and Saunders (2002) have analyzed drought trends over the whole of Europe (1901 – 1999) using the SPI and they do not find significant trends in long term. Similar results are reported in the analysis of annual precipitation trends (Brunetti et al. 2001, Quereda et al. 2000, New et al. 2002). The global results show a very high degree of variability.

The relationships of tree growth (evaluated by *Pinus halepensis* TRI), and drought conditions (evaluated by SPI at 6 month) is significant and seems to be related to spatial variability of drought. Spatial distribution of drought at 6 months in the coast-NE inland of Iberian Peninsula is represented by five spatial patterns of SPI that differentiate inland from coastland areas and divide littoral areas from N to S. Relief distributions seems to be one of the most important factor in such spatial pattern. Their temporal behavior seems to be different, suggest the high spatial variability of drought, and indicated the spatial heterogeneity of ecosystems conditions. Research in progress in other sites let us to know in future more about such spatial variability.

At local scale, tree ring growth and forest dynamics seems to be closely related to the frequency and magnitude of droughts events and SPI represent a adequate index in order to evaluate this relations. Thus, SPI index, usually applied to evaluate drought incidence from a agricultural and water resources point of view, could be either used as to evaluate ecological consequences of droughts. Moreover, observed close relationship between TRI and SPI values at local scale indicate that obtains chronologies in the study area (covering 1820-2000 period) could be used to reconstruct SPI values for periods with not instrumental records available. To do this at regional scale, new tree-ring chronologies must be built. We do this the objectives of future research.

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