P1.2 RESPONSE OF WINTER CEREAL PRODUCTIVITY IN SPAIN TO CLIMATE VARIABILITY

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1. INTRODUCTION

In this study we examine how climate affects year-to-year cereal productivity in Spain. The relationships between climate and cereal productivity (wheat, rye and barley) are derived from historical records of both climate and agriculture. The interannual variations of cereal productivity in Spain have been found to be associated with monthly mean maximum temperature, precipitation and atmospheric circulation corresponding to May. We have identified the flow regimes and teleconexion indices which are favourable for cereal productivity. The results obtained in this work could be applied: for estimating the magnitude of the impact of climate change on crop productions by projecting the climate models into the future (Reilly et al., 2003; Lawror and Mitchell 2000; Adams et al. 1990); and to lessen the agricultural risk due to climate variations (Hansen 2002; Sonkas et al. 1992). The association of agricultural productions and teleconnection indices such as El Niño were analyzed by: Adams et al. 1999; Changnon S. A. and D. Winstanley, 2000; Ferreyra et al. 1999; Ogallo et al. 2000.

2. DATA AND APPROACHES

Cereal production and crop surface were taken from the *Agricultural Statistics of the Spanish Ministry of "Agricultura Pesca y Alimentacion"*. Cereal productivity (hereafter CP) is then obtained by dividing the production in tons (t) per ground area (ha) and year. The monthly precipitation and mean monthly maximum and minimum temperature are from the National Meteorological Institute of Spain and Portugal. Other data were from National Centers for Environmental Prediction/National Centers for Atmospheric Research (NNR) (Kalnay et al. 1996).The teleconexion indices were taken from http://www.cpc.ncep.noaa.gov/data/teledoc/teleconten ts.html and http://www.cru.uea.ac.uk/cru/data/pci.htm.

An increasing trend is observed in the mean and in the variability of cereal productivity (Fig. 1). Factors other than climate, such as technology, should be related to this trend, and, because at present it is not possible to separate the trends owing to climate from others factors, we have filtered the total mean trend. The standardized and detrend CP time series behave almost in Gaussian fashion.

The interannual signals of climate variability were extracted from climate data by means of Empirical Orthogonal Function (EOF) analysis using varimax rotation. CP time series were analysed together with the precipitation and temperature principal components. Both approaches, heterogeneous correlation maps between CP and climate fields, and the composite maps of climate data for years with extreme CP, allowed us to identify agro-climatic regions. The flow regimes that affect CP were obtained by correlation analysis between CP and geopotential height at 700 hPa (HGT) and composite maps for years with higher/lower CP.

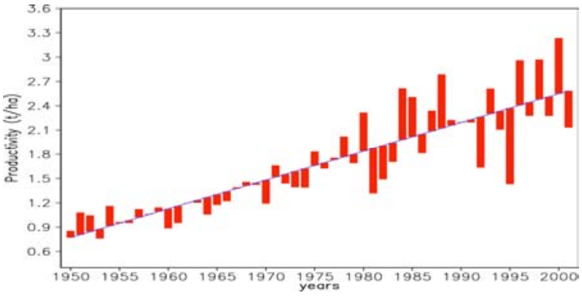

Figure 1: Time series of cereal (wheat, rye and barley) productivity (t/ha) in Spain.

3. RESULTS

Table 1 depicts the correlation between CP and the: second mode of precipitation (RPC2_PR); third mode of maximum temperature (RPC3_TX); and the first mode of minimum temperature (RPC1_TN) corresponding to May. The critical significance level for the correlation coefficient is 0.21 at 95%. The association is positive with precipitation and negative with maximum and minimum temperatures. Precipitation and temperature have opposite effects on CP, which agree with the results obtained by Chen et al. (2004) for crops in the US.

Table1: Correlation coefficients between cereal productivity (CP) and precipitation (RPC2_PR), maximum (RPC3_TX) and minimum (RPC1_TN) temperatures principal components.

	RPC2_PR	RPC3_TX	RPC1_TN
CP	0.50	-0.42	-0.34

The correlation coefficients between CP and monthly precipitation, maximum and minimum temperatures in May indicate that the proportion of the Iberian peninsula with significant correlation is 67% for precipitation, 94% for maximum temperature and 74% for minimum temperature. These correlation patterns are globally significant. There is a good correspondence between the spatial modes of precipitation and maximum temperature with the correlation patterns between CP and monthly precipitation and maximum temperature in May. The correlation maps (not shown) give us information about the most important agro-climatic regions for CP in Spain.

It is important to determine the relationships between atmospheric circulation and CP for application in climate impact studies (Changnon, 2004). We found significant correlation between CP and the North Atlantic Oscillation index (NAOI)

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corresponding to May (r = -0.43). This result is reasonable because NAOI is one of the most important teleconnection indices affecting climate over the Iberian peninsula (Hurrel, 1995). The NAOI from the Climate Research Unit (Jones et al. 1997) is more influential than any other defined NAO indices. The correlation between CP and El NIÑO3.4 of June (r= -0.31) is small but significant.

When CP is projected onto geopotential height at 700hPa (HGT) we obtained a higher correlation toward the south-western part of the Iberian peninsula (Fig. 2). The effects of atmospheric flow on CP could be represented by a regional index obtained by averaging HGT over the area: 30ºN-35ºN, 10ºW-2.5ºW. We named this index the Golf of Cadiz Index (GCAI). The correlation between CP and the GCA index is -0.53.

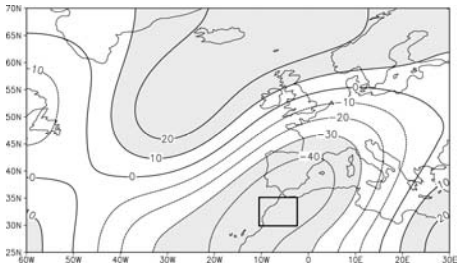
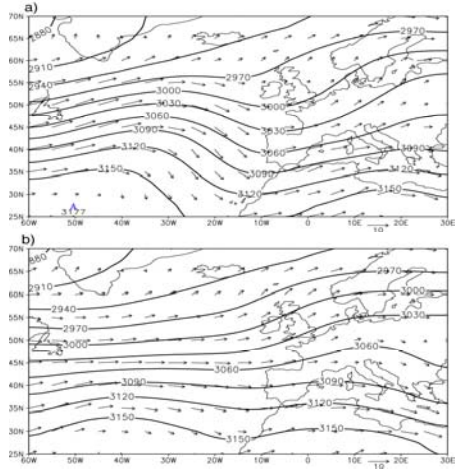


Figure 2: Heterogeneous correlation map between CP and geopotential height at 700 hPa.

Composite maps of HGT and wind for years with higher CP (2000; 1988, 1984 and 1996) inform us that meridional circulation helps to increase CP (Fig. 3a) while zonal circulation (low CP: 1995; 1992; 1981 and 2001) causes damage to CP (Fig.3b).



Figures 3: Flow regime for: a) high CP; b) low CP.

The response of cereal productivity to the climate variable is characterized by a linear model obtained using the stepwise regression method with the following independent variables: RPC2_PR, RPC3_TX, NAOI, GCAI and NINO3.4. The model selected the variables GCA and NINO3.4. The GCAI is coherent with CP at oscillations between 4 and 5 years and el NIÑO3.4 is coherent with CP at about 3 years. CGAI and NAOI are associated (r = 0.52) but GCAI better reflects the regional effects of atmospheric circulation on CP than NAOI.

The proportion of variance of CP ascribable to climate variations with respect to other causes is 34%, the F statistics value is 12.5.

4. CONCLUSIONS

Statistical approaches such as EOF, correlation and variance analyses were used to determine the interannual variability of cereal productivity (wheat, rye and barley) in Spain. We obtained a significant correlation between cereal productivity and maximum temperature, precipitation, NAOI and meridional atmospheric flow corresponding to May. El NIÑO3.4 of June indicates some influence on cereal productivity (CP). We provide a quantitative response of the CP owing to climate variables; the model represents 34% of the interannual variability of CP in Spain.

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