THE LATE 80s BREAKPOINT OF EUROPEAN CLIMATE AND THE CONSEQUENT CHANGE IN THE SPATIAL DISTRIBUTION OF RELEVANT CROPS

LA DISCONTINUITÀ CLIMATICA EUROPEA DI FINE ANNI 80 E LE CONSEGUENTI VARIAZIONI NEGLI AREALI DELLE PRINCIPALI COLTURE

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Abstract
The quantity and quality of agro-ecosystems production is strongly linked to the behavior of atmospheric driving variables. As a consequence the analysis of climate variability in its gradual and discontinuous components is particularly relevant for agro-ecosystems dynamics. This study focuses on the analysis of surface air temperature in Europe during the 1951-2010 period. Thermal resources useful for plant development have been obtained by means of the Normal Heat Hour approach with reference to three main groups of plants, group I – C3 plants adapted to cold temperatures, group II – C3/C4 plants adapted to high temperatures and group III, C3/C4 plants adapted to mild temperatures. This study, highlighting an increase of thermal resources for groups II and III all over Europe and a decrease for group I in the Mediterranean area, defines a change of the potential latitudinal limits for the three groups, representing an interesting operative tool for crops adaptation to climate change.

Keywords: Climatic change, Europe, Breakpoint, Temperature, Normal Heat Hours, Circulation indexes, Crops
Parole chiave: Cambiamento climatico, Europa, breakpoint, Temperatura, Ore normali di caldo, Indici circolatori, Colture

Introduction

The variability of climate can be approached in terms of gradual and abrupt changes with these latter playing a relevant role both in remote and recent time series. At the beginning of 90s an important abrupt change characterized the Euro-Medieterrannean area (Werner et al. 2000), causing an increase of Temperature all over Europe (Mariani et al, 2012). Therefore, the study of abrupt changes could be an useful tool for the characterization of the behaviour of atmospheric variables with relevant aftermaths for the European agricultural operative context where the discrimination between abrupt and gradual components could be extremely important in allowing the timely adoption of proper adaptation strategies.
In this context, the effects of climate change and variability on agricultural productions can be effectively studied focusing on surface air temperature behaviour (Mariani et al. 2008), due to its strict relation with plants production and phenological development. This work focuses on the detection of relevant abrupt changes in the European time series of temperature for the period 1951-2010 and consequently on the definition of homogenous sub-periods to develop suitable agro-climatic indexes to describe the availability of thermal resources for relevant European crops.

Matherials and Methods

This work is based on 171 time series of maximum and minimum temperatures gathered by the European Climate Assessment and Dataset (ECA&D - Klein Tank et al., 2002) for the 1951–2010 period. Time series have been chosen on the base of the entirety of the series and of synoptic representativeness. ECA&D blended time series have been adopted to minimize the occurrence of missing data. 24 stations have been chosen for their macroscale representativeness avoiding stations located in big cities or in depressions affected by stagnation of cold air.
The detection of abrupt changes has been based on the Bai and Perron test (2003), applied to the 24 time series of surface maximum and minimum temperature. The detection of break points has determined the definition of homogenous sub-periods.
The effects of climatic change on European agriculture have been analysed considering three main groups of European crops (Doorenboos and Kassam, 1979) and their needs in terms of thermal resources. Plants thermal needs have been approached with a response curve which translates each hour spent at a given temperature into a Normal Heat Hour (NHH) value in the range 0-1. The response curve is given by a beta function (Wang and Engel, 1998) parameterized with the cardinal temperatures Tb, To and Tm (base, optimal and maximum respectively) with NHH assuming values of 0 outside the Tb-Tm range, increasing values from 0 to 1 as temperature goes from Tb to To, 1 at To and decreasing values from 1 to 0 as temperature goes from T0 to Tm. Group I – cold adapted C3 plants – is characterized by cardinal values of 2, 18 and 30 °C; Group II – hot adapted C3/C4 plants by 12, 28 and 40 °C and Group III – intermediate C3/C4 plants by 8, 25 and 36 °C. The response curve works on hourly temperatures obtained with the Parton-Logan algorithm (1981) on the base of daily measured data.

Results and Discussion

The Bai and Perron test has detected significant breakpoints in for seventeen stations in the maximum temperature time series and for 15 in the minimum temperature ones in the 1987–1988 biennium, defining a clear continental breakpoint with a consequent increase of temperature (figure 1). Hence, two homogeneous periods 1951-1988 and 1989-2010 have been defined for the European area. For each period the mean yearly thermal resources (NHH) for the three crop groups have been obtained and mapped (group X maps are shown in

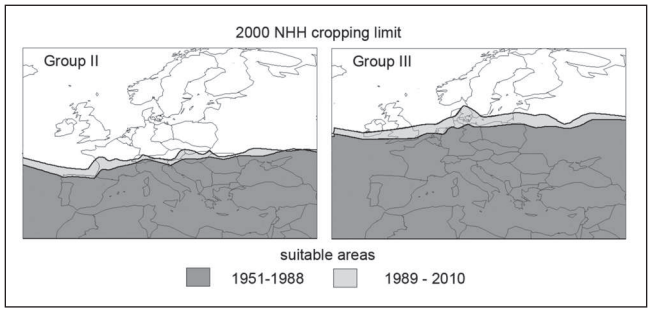

Fig. 1 - Breakpoint analysis for the mean yearly continental temperature calculated on the base of the selected 24 stations.
Fig.1 - Analisi di breakpoint sul dato di temperatura media annua continentale calcolata sulle 24 stazioni selezionate.

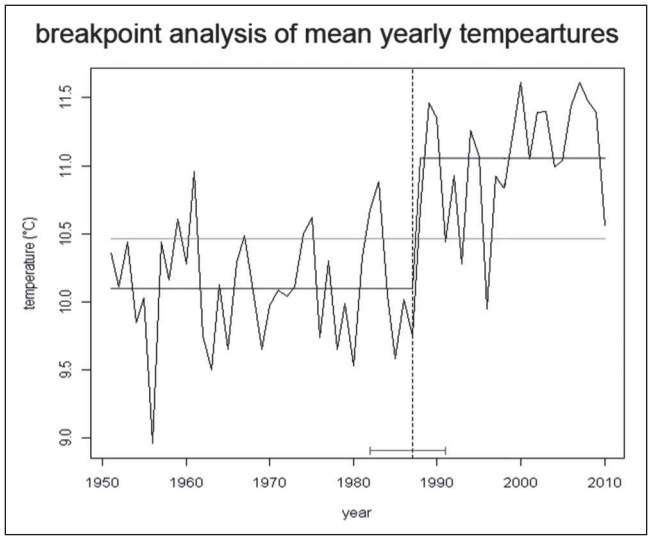

Fig. 2 - Northward shift of cropping limit for group II and group III plants as a consequence of the 1988 climate breakpoint
Fig. 2 - Spostamento a Nord del limite di coltivazione per le colture dei gruppi II e III a seguito del breakpoint climatico del 1988.

figure X). In the new period Group I shows an decrease of resources (minus100-300 NHH) in the Mediterranean area due to an increase of over optimal temperatures.
Furthermore it is evident a moderate increase of availability in Central and North-Eastern Europe and a greater availability in Central and North Western areas (maximum gain 300-500 NHH). The increase of resources is generalized for Group II and III with maximum values in Western Europe (plus 300-500 NHH) gradually declining toward East.

As a consequence of the abovementioned changes, the thermal cropping limit for rice (group II – 2000 NHH) has moved 150/250 Northward while the limit for grapevine and maize (group 3 – 2000 NHH) has gained 200-300 km. The cropping limit for high temperature demanding crops such as banana (group 2 - 5000 NHH) has reached Southern Sicily.

Conclusions

Surface air temperature plays a relevant role in the determination of crop productions. For this reason it is particularly important to early detect climatic change and discriminate between its abrupt and gradual components in order to efficiently design the proper adaptation strategies to drive the use of agrotechniques and the adoption of species/varieties. The analysis of this work highlights that in Europe, with the new climatic phase started in 1989, more thermal resources have become available for plants of Group II and III while Group I has faced a reduction of availability in the Mediterranean area. Nevertheless Group I is still the more adapted for cultivation in the European area with a mean availability of more than 4000 NHH a year.

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