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Climate change and grain production

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Summary. — Climate change is a matter of fact, and it is expected to have non-negligible effects on food security. 50 year-long time series of wheat and maize Italian average productions have been compared to the Western Mediterranean Oscillation Index, and to Sun Spot Number (SSN). Data trends and fluctuations are denoised by EMD and SSA, and analysed by wavelet transform. The analysis shows that SSN oscillations can be recognized into regional scale dynamics, and both signals significantly related to 7–16 years fluctuations of considered crops.

1. – Introduction

In a climate change scenario, understanding the relation between climate and yields has gained a large interest. Climate indicators are commonly investigated as time series, whose analysis tool set includes an extended collection of methods. A classical approach is represented by the Fourier Analysis (FA), assuming the underlying system is linear and quasi-stationary. For non-stationary signals local approaches have been developed including Wavelet Analysis (WA). On the other hand non-parametric methods have been developed to analyse signals from non-linear systems. Popular methods are represented by Empirical Mode Decomposition (EMD), and the Singular Spectrum Analysis (SSA). WA has been used to study the impact of weather factors on yields [1]. SSA has been used to characterize ecosystem-atmosphere interactions from short to inter-annual time scales [2], while EMD for denoising satellite data for crop yield prediction [3]. A clear proof and perception of effects of climate change on crop productions is still lacking though. The present analysis is aimed at investigating trends and fluctuations of country average crop yields comparing them to other climate indicators.

2. – Data and method of analysis

50 years Italian yields (1967–2017) of two main crops, wheat and maize [4], have been compared to two climatic indicators —the Western Mediterranean Oscillation index

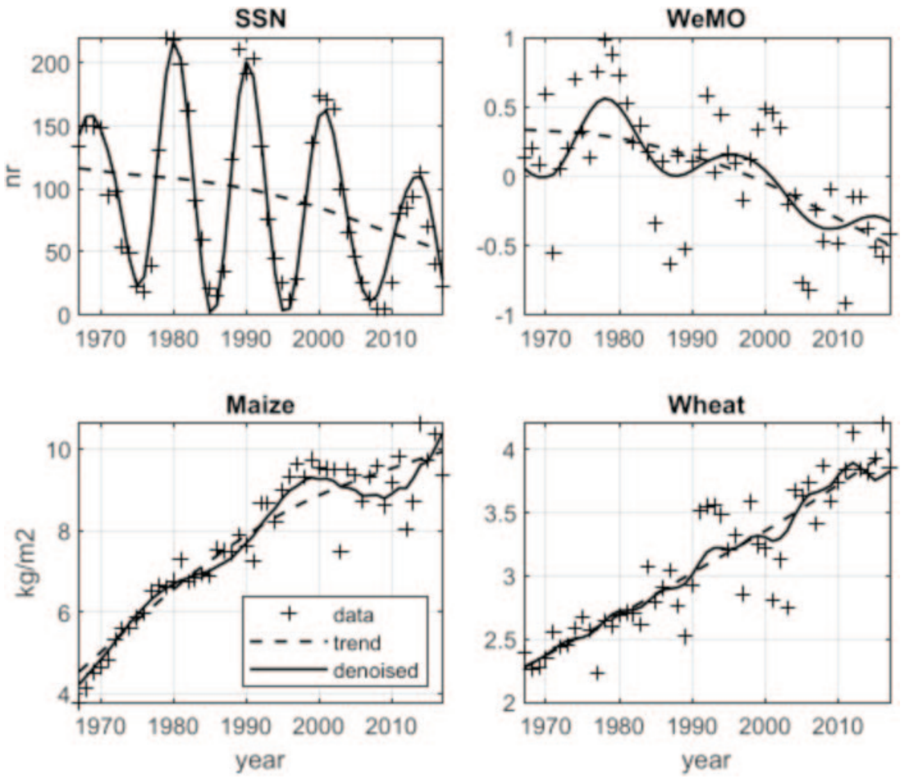

Fig. 1. – Time series considered in the analysis, SunSpot Number (SSN), Western Mediterranean Oscillation Index (WeMO) and Italian averaged yields of maize and wheat. Each series is displayed as cross points, trends as dashed lines and denoised signal as continuous lines.

WeMO [5], and the Sun Spot Number SSN [6]. The first has been selected for its regional valence, the latter as a global climate indicator, already related to yields [7]. Series analysed are shown in fig. 1 (cross points). As considered signals (indicators) are expected to be non-linear and non-stationary, a trade-off between two non-parametric methods EMD and SSA has been used to identify the denoised signal (continuous line in fig. 1). Both EMD and SSA have been applied on spline-detrended signals (dashed line in fig. 1) retaining the sum of SSA principal components matching the best with one of the modes produced by sifting process. Finally each denoised-detrended-normalized (ddn) signal has been Wavelet-transformed (Morlet function) to perform a frequency analysis on each signal, while the Cross Wavelet Transform has been used to estimate common periods of two time series.

3. – Results

Trends of SSN and WeMO (fig. 1) are comparable, being stable in the first decades and decreasing in the last period. A regression between the two trends ($R^2 = 0.99$) suggests a strong dependence of regional climate on solar activity. Clear trends appear in yields, showing the effects of the so-called "green revolution" due, after the WWII,

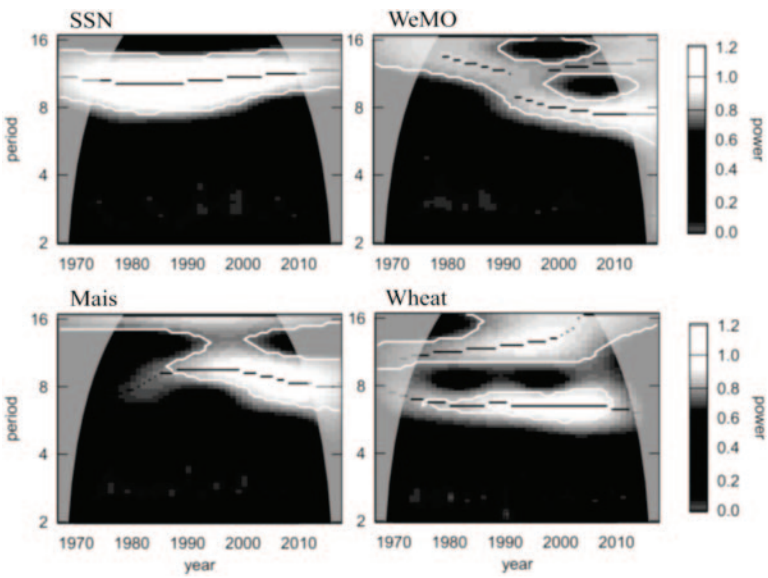

Fig. 2. – Wavelet Transform of the 4 ddn time series - whiter tones represent higher power values.

to a big adoption of technology in agriculture. In WT (fig. 2) it is easy to recognise the well-known $\sim$ 11 year cycle [8]. In WeMO the passage from a rather quiescent zone of the first 3 decades to oscillations with a period of 7–16 years for the last two decades is more evident. Variable fluctuations with a period greater than 5 years emerge in maize

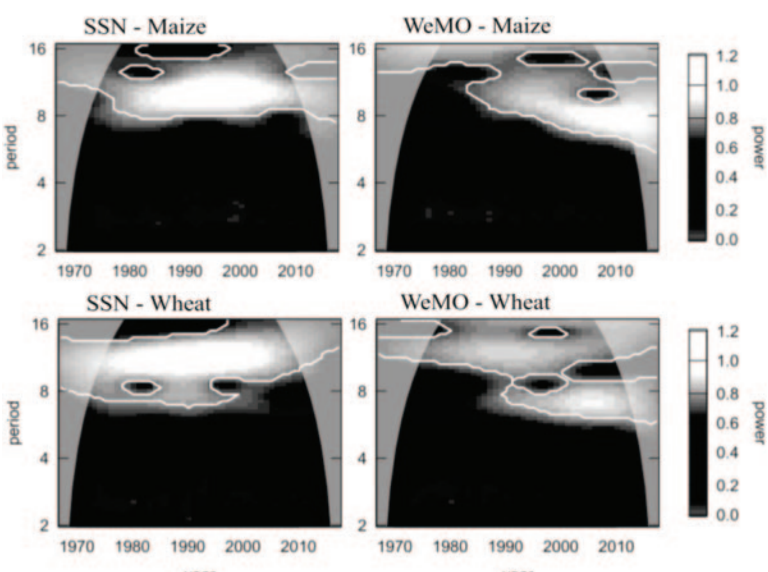

Fig. 3. – Cross Wavelet Transform of the SSN (left side) and WeMO (right side) ddn time series crossed respectively with maize (top row) and wheat (lower row) ones; whiter tones represent higher power values.

and wheat yields. More insightful are periodograms obtained from cross Wavelet analysis (fig. 3). SSN and WeMo fluctuations, not readily recognizable in crops, here appear more evident.

4. – Discussion and conclusions

Climate change is a matter of fact, and it is expected to have non-negligible effects on food security [9]. Trends are however often emphasized because of impacts they have on communication media, stakeholders and decision makers. Fluctuations, often neglected because of the complexity and difficulty to eliminate noise components, may contain information far from common perception but helpful to understand teleconnections, with a strategic importance for the agro-environmental system. Though the analysis suffered the small size of time series (50 years), it has shown how SSN oscillations affect regional scale dynamics as WeMO, the latter's behaviour reflecting on the yield of wheat and maize.

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