Links between Meteorological Drought Indices and Major European Crop Yields, 1979 – 2009

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Introduction

Agriculture is one of the most important sectors that humans rely on and can be significantly affected by droughts. Impact in some areas already dealing with water scarcity will increase in the expected climate change scenarios, especially in Southern Europe. Since Europe is one of the most productive food suppliers it is important to explore how anomalies in observed crop yield can be detected by meteorological drought indices and to see when the crops are more sensitive during the growing season.

Previous research on European scale seldom include details about the crop type and drought timing. The distinction within crops is needed since yields might react on droughts in different manners across regions and therefore a comprehensive pan-European study is required. The lack of enough spatial and temporal scale data sets made it hard to tackle the research question in the past. Currently the data sets are expanded to a European and 30-year lasting scale, allowing, by explaining past yield trends and variability, to contribute for increasing awareness (early warning system) thus helping mitigate future drought impacts. To do so, we tested the hypotheses:

- Crop yield anomalies and drought indices will be higher correlated when social-economic effects are controlled by (different methods of) de-trending;

- The meteorological drought indices Standardised Precipitation Index (SPI) and Standardised Precipitation-Evapotranspiration Index (SPEI) are able to explain crop yield losses on European scale;

- The SPEI takes into account evapotranspiration and therefore we expect higher correlations between SPEI and crop yield anomalies;

- For each crop the accumulation periods affect differently;

- Crop yield anomalies and drought indices correlations might be better explained by accounting differences between biogeographical regions within Europe.

Data

- Eurostat yearly crop yield (1975 – 2009) (see Figure 1)
  - Crop yield data of at least 10 years
  - Average yield > 10th percentile of total

- Monthly SPI and SPEI (1979 – 2009) (WATCH project) incl. accumulation periods 1, 2 and 3

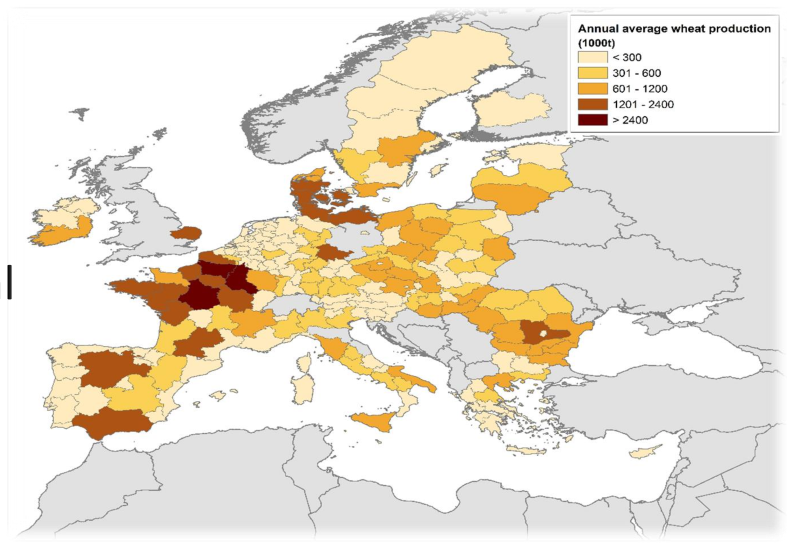

Figure 1: Annual average wheat production (1000 tons) for the period 1979 – 2009 at NUTS2 level.

- Both data sets on NUTS2 scale

- Five annual crops were selected based on: *i)* data availability, *ii)* spreading over Europe, *iii)* variability in growing season (winter and summer) and *iv)* water needs
  → Barley, wheat, potato, sugar beet and maize

Statistical approach

Three (de-trended) data sets tested
- Raw data
- De-trended by moving average
  - PACF estimated the suggested best moving average to de-trend (period)
  - R^2 to select the best approach, de-trending window (2 years before and after %)
- De-trended by linear regression

Linear regression modelling (stepwise forward)
Four spatial scales: Europe, Atlantic, Continental and Mediterranean regions (Figure 2)

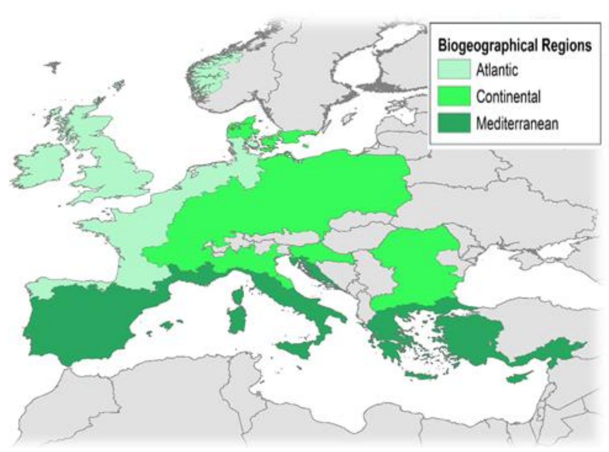

Figure 2: Map of Europe and the three largest biogeographical regions: Atlantic, Continental and Mediterranean.

Results

There were evident linkages between four crop yield anomalies and the two drought indices, both at European and biogeographical region levels, with relevance in the different periods of the growing season (sowing, early growing season, mid growing season/flowering, late flowering and harvest). Figure 3 shows for each crop the results in case of de-trended by moving average.

Figure 3: left; Average Pearson correlation (r), between European crop yield anomalies and drought indices SPI (solid line) and SPEI (dashed line) for accumulation period 1,2 and 3 months separated for wheat (a), barley (b), potato (c), sugar beet (d) and maize (e). The stars indicate a significant predictor variable included in the model (p <0.05). Right; Contribution of predictor to model for the spatial scales of Europe (red), Atlantic (blue), Continental (green) and Mediterranean climate regions (yellow) over five periods of the growing season. A positive contribution refers to losses by drier than average periods (or droughts) and a negative contribution suggest crop yield losses in case of higher than normal precipitation. .

Discussion & Conclusion

- The three (de-trending) methods give, in general, the same relation between crop yield and drought indices. Correlation for de-trending by moving average gave the highest scores.

- SPI and SPEI give about the same correlations and patterns. SPEI gives only higher correlations during the end growing season for wheat, probably due to the large foliage contribution to evapotranspiration a few months before harvest. Sugar beet on the other hand produces a minimum of foliage, which could explain the similarity of results for both indices.

- Barley and wheat: accumulation period 3 months gives best results. Those two crops seem less sensitive to droughts on a small temporal scale, but they show significant predictor variables after a summation of a few months.

- Potato, sugar beet and maize: accumulation period 1 and 2 months are more important, indicating that these crops are probably more sensitive to droughts on already a small temporal scale.

- All crops show a deviating response on droughts during various periods within the growing season, concluding that it was correct to separate the crop analysis.

- Impacts of droughts on crop yield at European scale is visible, but regional differences within biogeographical regions exist due to variations in climate.

Further steps

- Include simulated soil moisture indices to account for the top soil properties
- Improving moving average de-trending approach by individual NUTS2 region

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