8th International Conference on Time Series and Forecasting

Study of the interaction between cereal yield and hydroclimatic factors through Dynamic Factor Analysis

Vanwalleghem, T., Jiménez-Donaire M.P..
Dpto. de Agronomía, Universidad de Córdoba, Edif. Da Vinci,Ctra. Madrid km 396,14071 Córdoba. ag2vavat@uco.es

Introduction

Drought is a major natural hazards affecting agricultural crop production and food security. A large number of indicators have been proposed to monitor and evaluate drought stress, mostly based on the deviation of rainfall from long-term mean, such as SPI or SPEI. he relationship between plant greenness (NDVI) in rainfed cereal and climatic variables.

However, relatively few studies have evaluated the performance of these studies against independent yield data. The problem with plant yield is that in addition to drought, also other factor can influence strongly, such as frost during cricitical stages of plant growth, even excessive rainfall and flooding damaging crops. but also plant diseases which could be related to humidity.

This motivates a wider, more detailed study of the relation between plant response and hydroclimatic factors. The objective of this study is to use Dynamic Factor Analysis (DFA) as an alternative tool to physically based model of plant growth to explore the relation between NDVI (plant greenness) and hydroclimatic variables.

Materials and methods

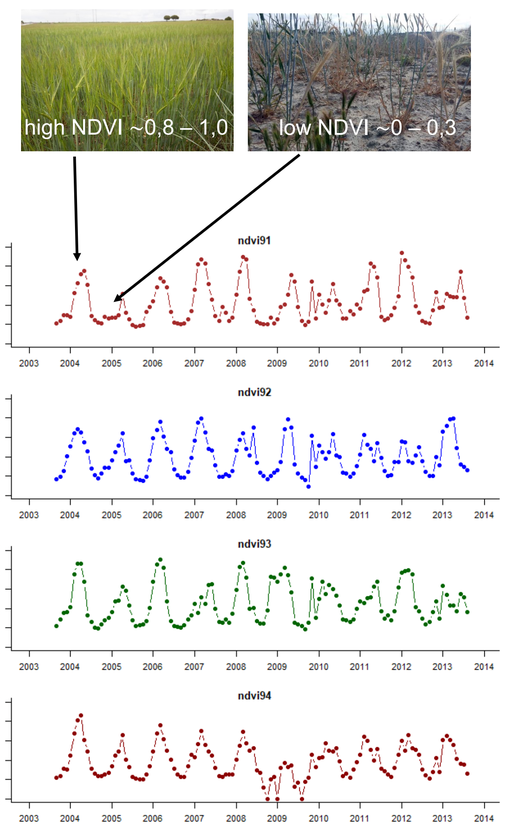
This study uses 11 years of NDVI data in 4 different cereal fields in Cordoba province (Spain), that is correlated with:

- SPI-3, giving the rainfall anomaly
- Modelled soil moisture, integrating the effect of rainfall and evapotranspiration

NDVI was converted to z-scores

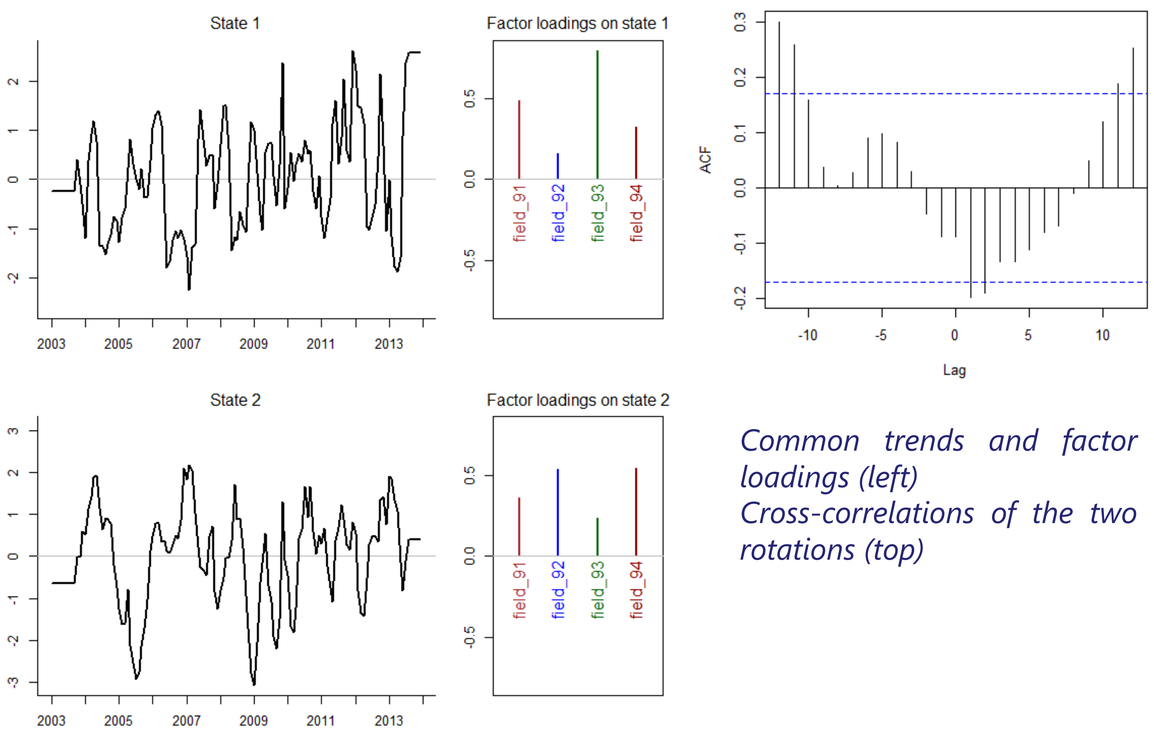
DFA analysis was done in R software, using the package "MARSS".

Location of study area (left) and temporal variation of NDVI (vegetation greenness) (right). Low values correspond to bare fields and high values to full & healthy crop cover .



Results

The common trends and canonical correlation for quantifying the correlation are shown below, together with the factor loadings for each of the four analyzed fields. There is a strong variation in the common trends, and some indication of differences between the analyzed fields.

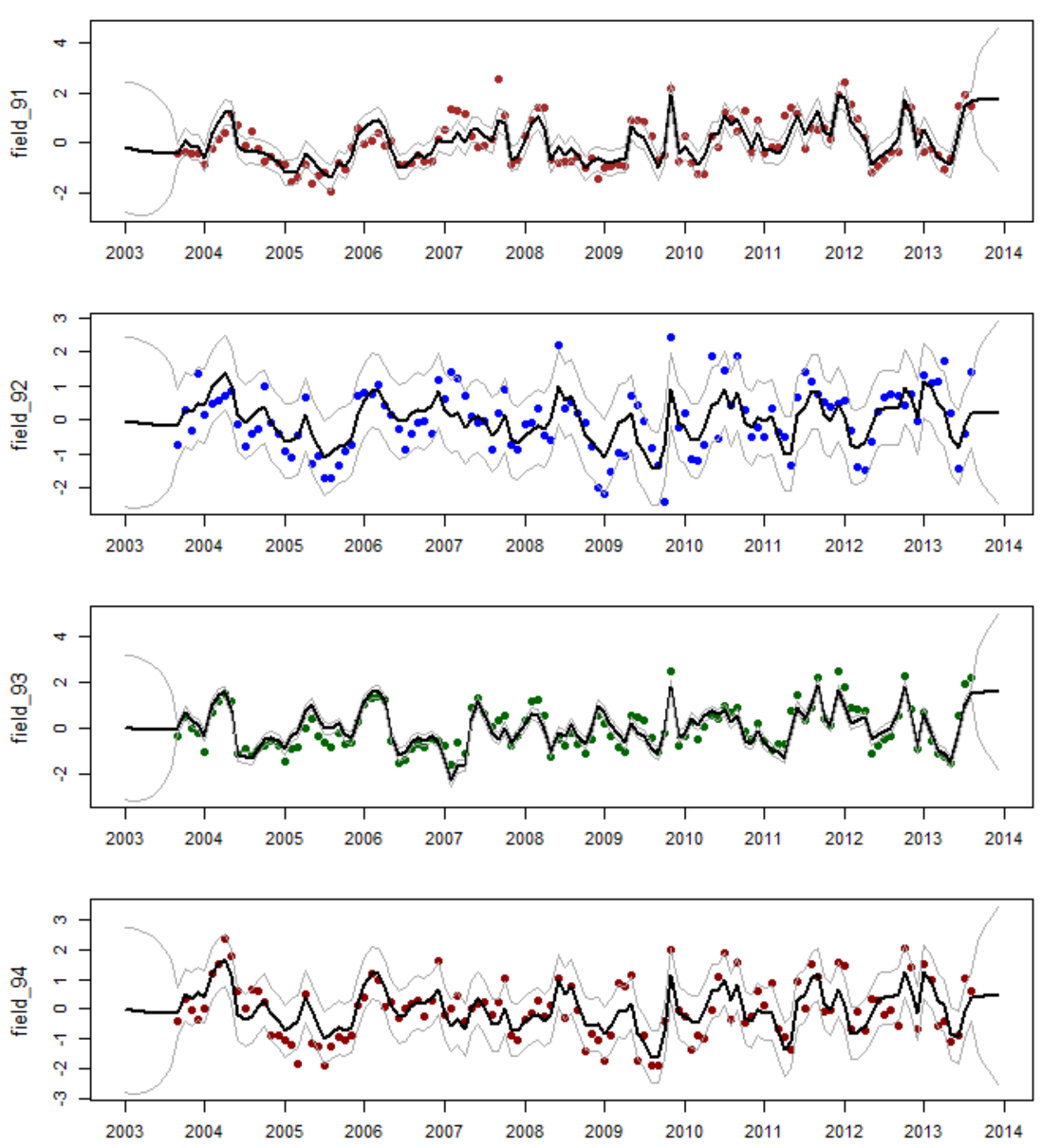


Common trends and factor loadings (left)
Cross-correlations of the two rotations (top)

Dynamic Factor Analysis (DFA) models tested and goodness-of-fit (AIC)

Model	No. of common trends	Explanatory variables	AIC
Step 1 (DFA model with K = 0)			
1	2	None	1167
2	3	None	1182
Step 2 (DFA model with K>0)			
3	2	SPI-3	1356
4	2	Soil moisture	1414
5	2	SPI-3 and soil moisture	1168

Fitted dynamic factor model and observed temporal variation of NDVI. Grey lines show model uncertainty.



Discussion & Conclusions

We developed a DFA model exploring different models with 2 to 3 common factors (since four fields were analyzed, 3 was taken as the máximum). Adding additional variables such as SPI-3 or soil moisture did not improve the model. Further research will be needed, evaluating the effect of additional covariates and extending the analyzed NDVI time series by incorporating more satellite images.

The final model satisfactorily reproduced the observed NDVI variation. This demonstrates that DFA analysis shows a high potential for modelling the behaviour of cereal and yields over time, as an alternative to traditional agronomic modelling based on rainfall/temperature inputs only.

References

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Acknowledgements

This work is funded by project H2020-SFS-2016-2017 Super-G and PID2019-109924RB-I00. Vanwalleghem thanks funding to the Department of Agronomy by the Spanish Ministry of Science and Innovation, the Spanish State Research Agency, through the Severo Ochoa and María de Maeztu Program for Centers and Units of Excellence in R&D (Ref. CEX2019-000968-M).