Prediction of agricultural drought in Chile from multiple spatio-temporal data sources

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November 26, 2022

Abstract

Global food security is negatively affected by drought. Climate projections show that drought frequency and intensity may increase in different parts of the globe. Early season forecasts on drought occurrence and severity could help to better mitigate the negative consequences of drought. The objective of this study was to assess if interannual variability in agricultural productivity in Chile can be accurately predicted from freely-available, near real-time data sources. As the response variable, we used the standard score of seasonal cumulative NDVI (zcNDVI), based on 2000-2017 data from Moderate Resolution Imaging Spectroradiometer (MODIS), as a proxy for anomalies of seasonal primary productivity. The predictions were performed with forecast lead-times from one- to six-month before the end of the growing season, which varied between census units in Chile. Predictor variables included the zcNDVI obtained by cumulating NDVI from season start up to prediction time; standardised precipitation indices, derived from satellite rainfall estimates, for time-scales of 1, 3, 6, 12 and 24 months; the Pacific Decadal Oscillation and the Multivariate ENSO oscillation indices; the length of the growing season, and latitude and longitude. We used two prediction approaches: (i) optimal linear regression (OLR) whereby for each census unit the single predictor was selected that best explained the interannual zcNDVI variability, and (ii) a multi-layer feedforward neural network architecture, often called deep learning (DL), where all predictors for all units were combined in a single spatio-temporal model. Both approaches were evaluated with a leave-one-year-out cross-validation procedure. Both methods showed good prediction accuracies for small lead times and similar values for all lead times. The mean R2cv values for OLR were 0.95, 0.83, 0.68, 0.56, 0.46 and 0.37, against 0.96, 0.84, 0.65, 0.54, 0.46 and 0.38 for DL, for one, two, three, four, five, and six months lead time, respectively. Given the wide range of climates and vegetation types covered within the study area, we expect that the presented models can contribute to an improved early warning system for agricultural drought in different geographical settings around the globe.

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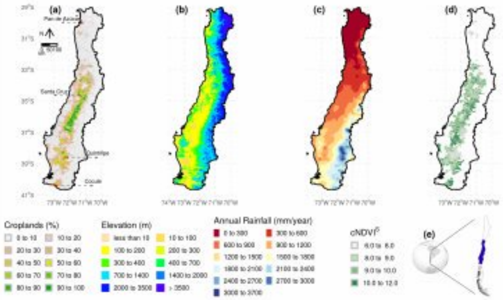
Motivation: Although there is debate whether drought frequency has increased in recent years (Dai, 2012;), climate change is expected to exacerbate the phenomenon and lead to more frequent and intense drought periods, which may even occur in regions where overall precipitation increases are expected (IPCC, 2013). Planning for effective adaptation strategies is thus crucial to mitigate future impacts (Roco et al., 2014). In addition, the ability to anticipate the impact of drought early in the season and take in-season mitigation measures such as more targeted irrigation, or reducing stand density (Bodner et al., 2015) could help to reduce crop losses (Pulwarty and Sivakumar, 2014).

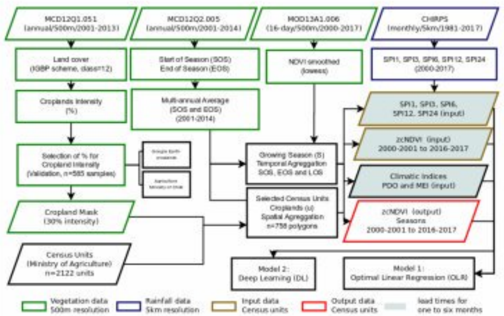
Goal: The main goal of this study is to assess if interannual variability in crop biomass productivity can be accurately predicted using freely-available, near real-time data sources.

Methods

Study area: main agricultural land of Chile



Workflow: for predictions at 1 to 6 months lead times



Proxy for crop biomass productivity

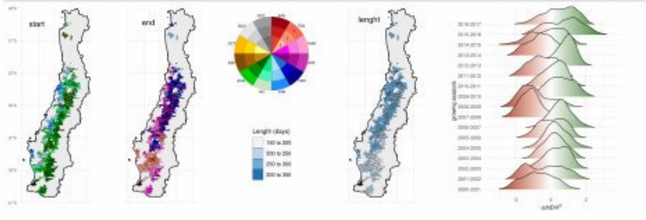
$$zcNDVI^S = \frac{cNDVI^S - \overline{cNDVI^S}}{\sigma(cNDVI^S)}$$

the standardized anomaly of cumulative NDVI over the growing season

Results

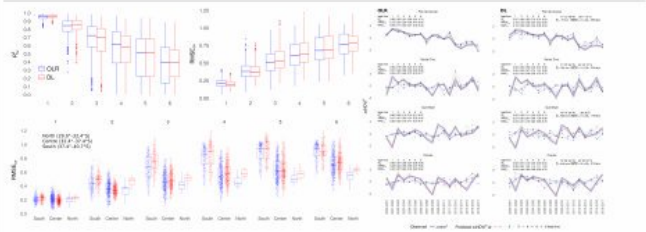
Proxy for seasonal crop biomass productivity

Growing season **Proxy for crop biomass**

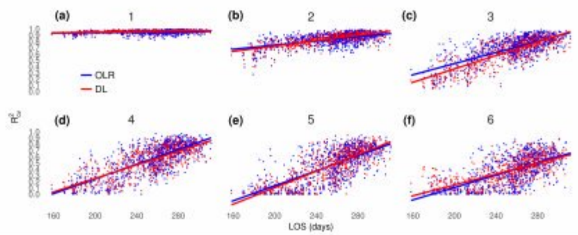


Cross-validated accuracy measures

Overall **Four units**



Accuracies vs. length of growing season for 1 (a) to 6 (f) lead times



Discussion

1. Spatially explicit crop calendar information for Chile would better define this seasonality, allowing for better proxies of agricultural productivity, and more relevant timing of drought prediction
2. Although $zcNDVI$ at lead times was in general the best predictor of seasonal $zcNDVI$, the prediction accuracy strongly depended on the prediction lead time for both OLR and DL with poor predictive power early during the season.
3. Our study shows that complex global models do not always yield better results than simple models that carefully select the best predictors on a case-by-case basis.
4. Our current results are encouraging given that they reach similar or better accuracy compared to existing studies.

Future outlook

1. Additional spatio-temporal predictors such as soil moisture, evapotranspiration, and existing multi-scalar drought indices can be incorporated into future implementation of both OLR and DL approaches.
2. While a few challenges remain, we believe that the models presented in this study can constitute a solid basis for improved operational drought warnings.

Acknowledgements

Work funded by CONICYT, Chile Scholarship/National Ph.D. 21141028. Additional funding was provided by the Hémera Centro de Observación de la Tierra from the Universidad Mayor, Chile.

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References

Dai, A. (2012). Increasing drought under global warming in observations and models. Nature Climate Change, 3(1), 52–58. https://doi.org/10.1038/nclimate1633

Vrieling, A., Meroni, M., Mude, A. G., Chantarat, S., Ummenhofer, C. C., & de Bie, K. (2016). Early assessment of seasonal forage availability for mitigating the impact of drought on {E}ast {A}frican pastoralist. Remote Sensing of Environment, 174, 44–55.

Zambrano, F., Vrieling, A., Nelson, A., Meroni, M., & Tadesse, T. (2018). Prediction of drought-induced reduction of agricultural productivity in Chile from MODIS, rainfall estimates, and climate oscillation indices. Remote Sensing of Environment, 219, 15–30.