How dry is too dry? Quantifying the adverse effects of droughts for European forests across the last two decades (project start: Nov 2020)

Jan-Peter George[1], Matthias Neumann[2], Jürgen Vogt[3], Carmelo Cammalleri[3], Mait Lang[1,4]

[1] University of Tartu-Tartu Observatory; [2]University of Applied Life Sciences Vienna (BOKU); [3]European Drought Observatory; [4]Estonian University of Life Sciences

UNIVERSITY OF TARTU Tartu Observatory

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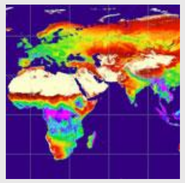
Project Aims

Forests are currently experiencing an unprecedented period of progressively drier growing conditions around the globe, which is threatening many of the functions forest ecosystems need to fulfill for human society. Yet, our understanding of how long and how severe a drought needs to be in order to provoke substantial decline in net primary productivity or even lead to ultimate death of trees is still poorly understood. Here, we combine remotely sensed data (MODIS EURO) with observations on tree mortality (ICP level I forest observations) throughout the last two decades (2000-2019). The project aims at unraveling the complex relationship between drought duration/intensity and forest growth and mortality for entire Europe at 1x1Km resolution. For this, we will apply the random forest algorithm as well as Cox proportional hazard models, both permitting us to additionally test for the effects of important co-variables (e.g. tree age, pre-drought climate, etc.).

i) Is drought response equal among forest types and geographical regions in Europe?
ii) Which combination of drought intensity and duration has the strongest effect on productivity and mortality and can we distinguish spatial clusters showing similar response patterns?
iii) How much of the spatiotemporal variation in drought response can be explained by using drought intensity and duration as predictors?
iv) What is the effect of biological and climate co-variates (e.g. tree age, drought-preceding productivity and climate conditions prior to drought) for productivity and mortality?
v) How are productivity and mortality related to each other in the context of increased forest background mortality?

Datasets

Satellite data



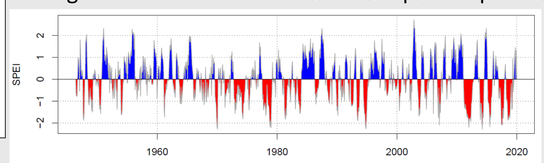
MODIS EURO & MOD17 A3
Annual NPP for Europe at 1Km resolution
2000-2020
(e.g. Neumann et al. 2016)

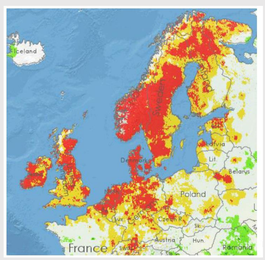
Ground observations

ICP Level I Forest damage survey
13,630 observation plots at
16x16Km raster
2000-2020
(Eichhorn et al. 2016)
> 1Million observations

Climate Data

Standardized precipitation evapotranspiration index (SPEI) calculation based on daily 1x1 Km Climate data (Moreno & Hasenauer 2016) for Europe using the Thornthwaite model for evapotranspiration

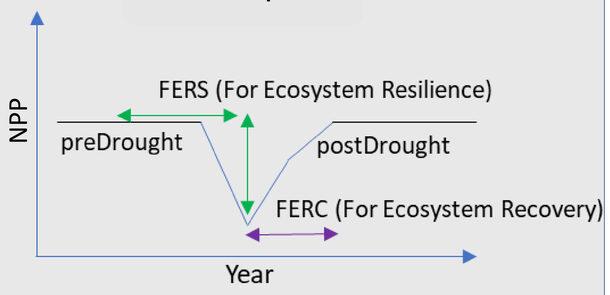




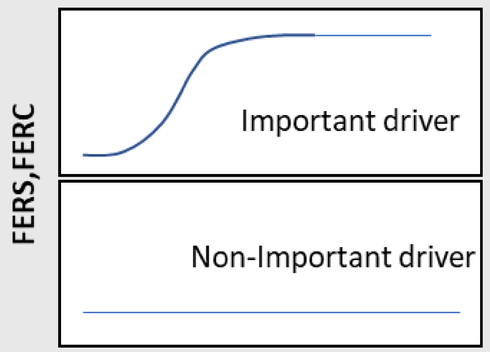
Soil moisture anomaly with 5Km resolution and one retrieval every 10 days from 1995-2020 (Spinoni et al. 2017) from the **European Drought Observatory (EDO)**

Models

Growth Response Indices

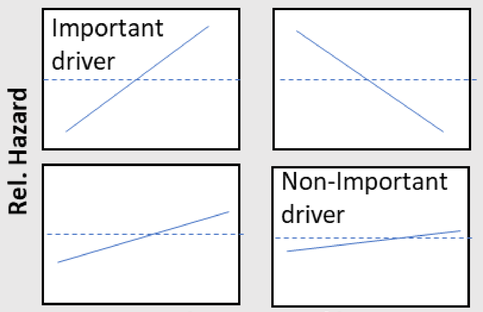


Random Forest (Growth)



Drought intensity/duration
+Explanatory co-variates (Age, preDrought NPP (FER), preDrought SPEI)

Cox Hazard Models (Mortality)



Drought intensity/duration
+co-variates (Age, preDrought SPEI)

Why is drought research timely?

The drought in 2018 was a unique phenomenon among the last 500 years with unprecedented dry climatic conditions in the Boreal North. Approximately 140,000 km² coniferous forest as well as 20,000 km² deciduous forests in Europe significantly suffered from the 2018 drought and many regions in Europe experienced forest productivity losses of around 40%. Even after this drought had terminated, tree mortality remained (and still remains) at a high level in subsequent years due to so-called carry-over effects (i.e. drought effects that are carried-over across years due to a `legacy` of the drought). Recent simulations showed that temperature and rainfall conditions such as in 2018 could become a common occurrence as early as 2043 under high-end emission climate scenario projections in Europe which will have significant impacts for our forest landscapes.

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