Nitrogen deposition increases sensitivity to drought observed in Swiss forests

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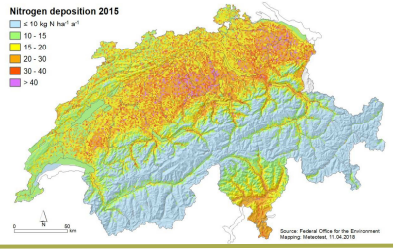
Conclusions

- N deposition decreased the growth of European beech in long-term forest observation sites in Switzerland.
- Mortality rates of both beech and Norway spruce trees were increased with N deposition.
- Drought increased the growth reduction of beech at high N deposition.
- N deposition increased the drought sensitivity of Norway spruce mortality.
- Low foliar P concentrations increased the drought sensitivity of beech mortality, which may explain why beech was strongly affected by the drought of 2018/2019 in some regions of Switzerland.
- Diversity and biomass of ectomycorrhizal fungi (EMF) were strongly reduced with increasing N deposition.

IAP 2019: Drought damages to beech trees in Ajoie, Jura mountains, Switzerland

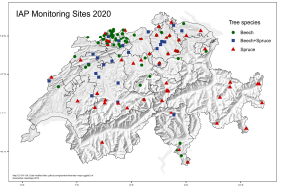
Total deposition of N calculated on a ha raster in Switzerland (Rihm and Künzle 2019)



Methods

Long-term forest monitoring in Switzerland since 1984

Health, growth and nutrition of trees are monitored in 95 beech (*Fagus sylvatica*) and 75 spruce (*Picea abies)* sites that are part of the long-term Intercantonal Forest Observation Program in Switzerland (Braun et al. 1999). Foliar nutrient concentrations and stem increments were measured at intervals of 4 years. Mortality was observed every year and related to the population of the preceding year.



Nitrogen deposition

Total nitrogen (N) deposition per year was modelled at a spatial resolution of 1 ha (Rihm and Künzle 2019). Nitrogen deposition in the plots varied between 8.5 and 81 kg N ha^{-1} yr^{-1}.

Ectomycorrhizal communities

Ectomycorrhizal fungal (EMF) communities were analyzed on both root tips and in mesh bags in 15 sites on a N deposition gradient.

Drought

Drought was calculated using a hydrological model (WaSiM-ETH) on a daily basis. It was quantified either as minimum site water balance of a year (SWB_{min}) or as average ratio between actual and potential evapotranspiration during the first 90 days of the season (ETa/ETp) (see Braun et al. 2015).

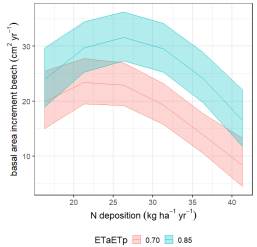
Statistical analysis

Data were analyzed using generalized linear mixed effect models (GLMEM) with site and year as random factors. Significant predictors were tested systematically for interactions and linearity. The importance of the lagged time effects of drought indicators were tested with a polynomial distributed lag model. Thereafter an average drought effect was calculated taking into account the cumulated drought effect of 3 years for beech and spruce.

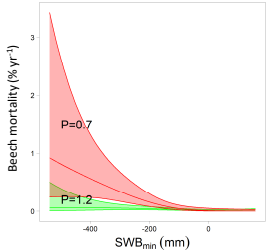
Results

Beech

Stem increment showed a bell shaped relation with N deposition, with increment decreasing at N deposition >25 kg N $ha^{-1}yr^{-1}$. The significant interaction suggests that the decrease starts at lower N deposition when it is dry (ETa/ETp=0.7). Shaded areas show the 95% confidence interval.

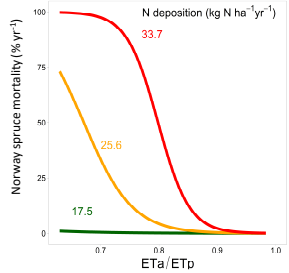


Mortality was increased with the cumulative drought effect (SWB_{min}). The relation was stronger when foliar P concentrations were low.



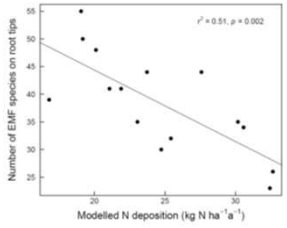
Norway spruce

Mortality was increased by drought and modified by N deposition. Mortality was also increased when foliar K was low which is an indirect N deposition effect.



Ectomycorrhiza in beech

Increased N deposition lead to a decrease in EMF diversity and abundance in beech, and probably to a loss of functionally important EMF. Thereby soil carbon, water and nutrient cycles are changed.



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