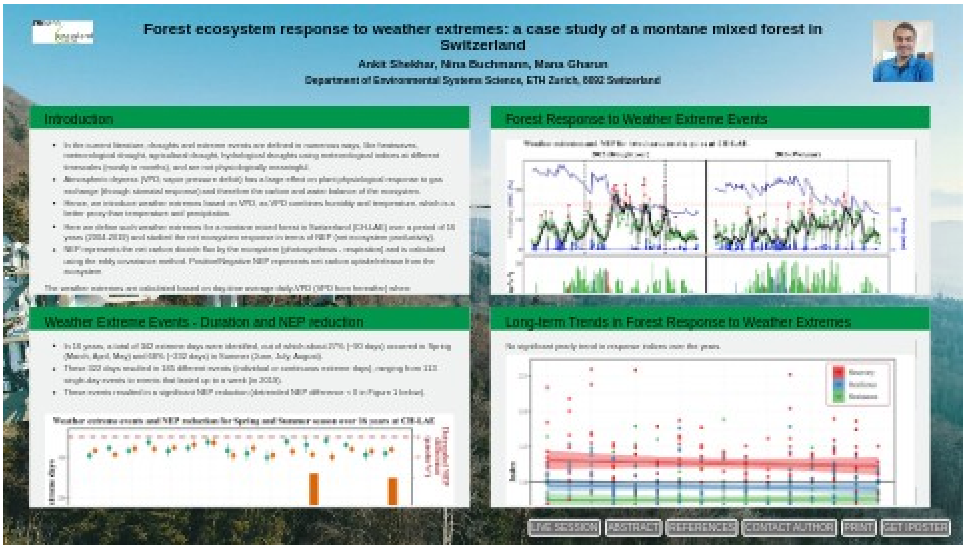
FOREST ECOSYSTEM RESPONSE TO WEATHER EXTREMES: A CASE STUDY OF A MONTANE MIXED FOREST IN SWITZERLAND



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INTRODUCTION

- In the current literature, droughts and extreme events are defined in numerous ways, like heatwaves, meteorological drought, agricultural drought, hydrological droughts using meteorological indices at different timescales (mostly in months), and are not physiologically meaningful.
- Atmospheric dryness (VPD; vapor pressure deficit) has a large effect on plant physiological response to gas exchange (through stomatal response) and therefore the carbon and water balance of the ecosystem.
- Hence, we introduce weather extremes based on VPD, as VPD combines humidity and temperature, which is a better proxy than temperature and precipitation.
- Here we define such weather extremes for a montane mixed forest in Switzerland (CH-LAE) over a period of 16 years (2004-2019) and studied the net ecosystem response in terms of NEP (net ecosystem productivity).

- NEP represents the net carbon dioxide flux by the ecosystem (photosynthesis - respiration) and is calculated using the eddy covariance method. Positive/Negative NEP represents net carbon uptake/release from the ecosystem

The weather extremes are calculated based on day-time average daily-VPD (VPD from hereafter) when:

1. The deviation of VPD from an expected value exceeded 95 percentile. The expected VPD value was calculated using a 10-days retrospective locally weighted smoothing (lowess) function (Dowd and Denny, 2020).

2. VPD is greater than 98 percentile of growing season VPD (i.e., 1.5 kPa).

WEATHER EXTREME EVENTS - DURATION AND NEP REDUCTION

- In 16 years, a total of 342 extreme days were identified, out of which about 27% (~90 days) occurred in Spring (March, April, May) and 68% (~232 days) in Summer (June, July, August).
- These 322 days resulted in 185 different events (individual or continuous extreme days), ranging from 113 single-day events to events that lasted up to a week (in 2019).
- These events resulted in a significant NEP reduction (detrended NEP difference < 0 in Figure 1 below).

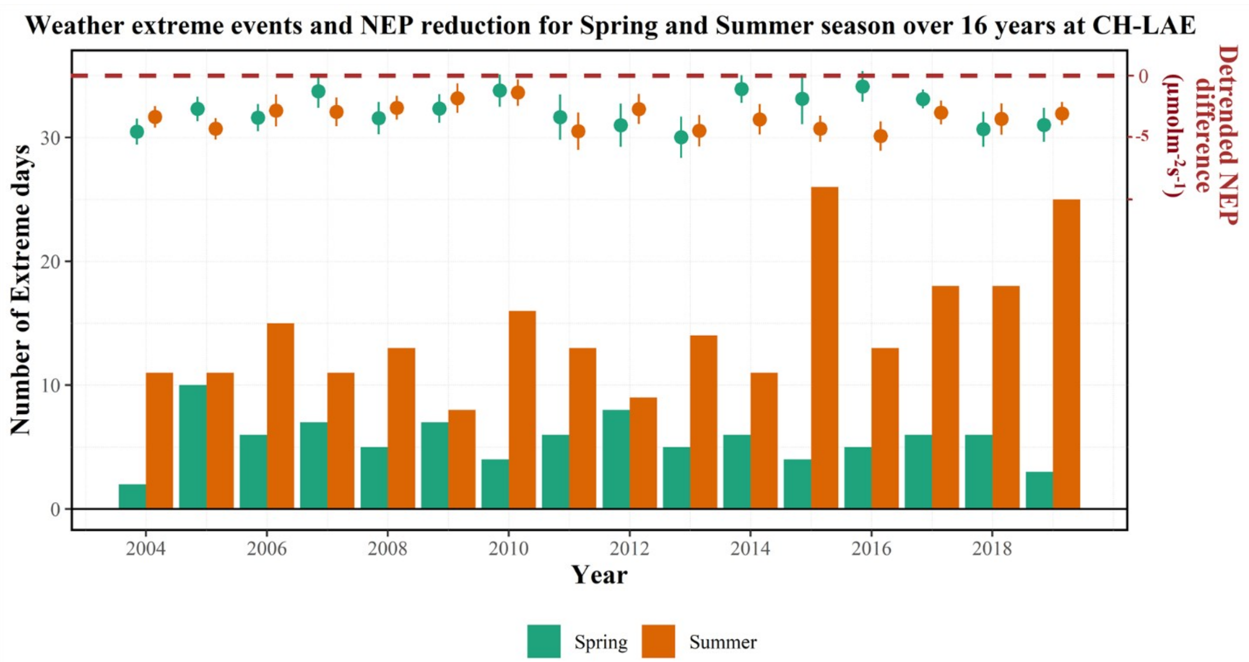

Figure 1. Weather extreme events and mean detrended NEP difference (NEP at VPD-extreme minus VPD-normal from Figure 2) during spring and summer season over 16 years at CH-LAE. VPD-normal is non-extreme VPD > 20th percentile (i.e. - 0.2 kPa).

FOREST RESPONSE TO WEATHER EXTREME EVENTS

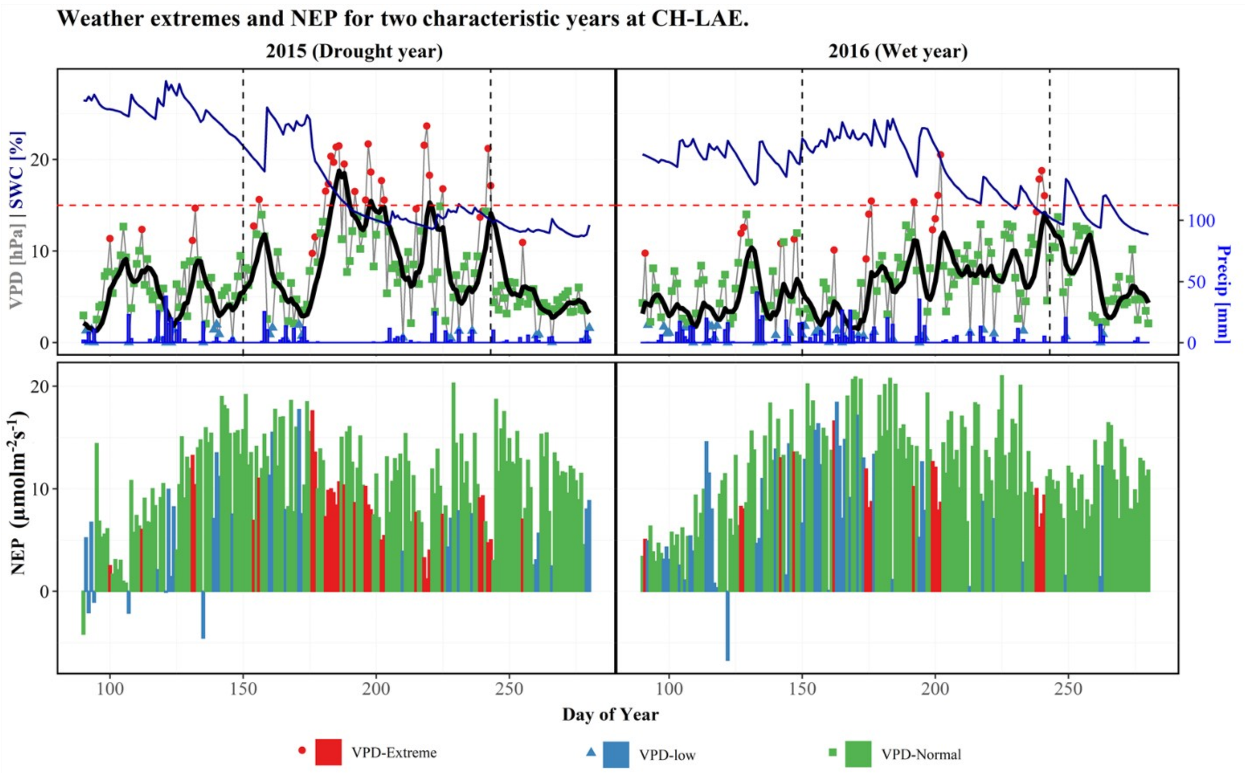

Figure 2. Weather extremes and corresponding NEP response for two characteristic years at CH-LAE. VPD-low represents VPD less than the 20th percentile (i.e., 0.2 kPa). The solid black line is the 10-day retrospective LOWESS smoothed VPD.

To quantify forest response to the weather extremes we calculated response indices based on Lloret et al., 2011.

$$Resistance = \frac{NEP_{Extreme}}{NEP_{Pre-Extreme}}; Recovery = \frac{NEP_{Post-Extreme}}{NEP_{Extreme}};$$

$$Resilience = \frac{NEP_{Post-Extreme}}{NEP_{Pre-Extreme}}; RelativeResilience = \frac{NEP_{Post-Extreme} - NEP_{Extreme}}{NEP_{Pre-Extreme}};$$

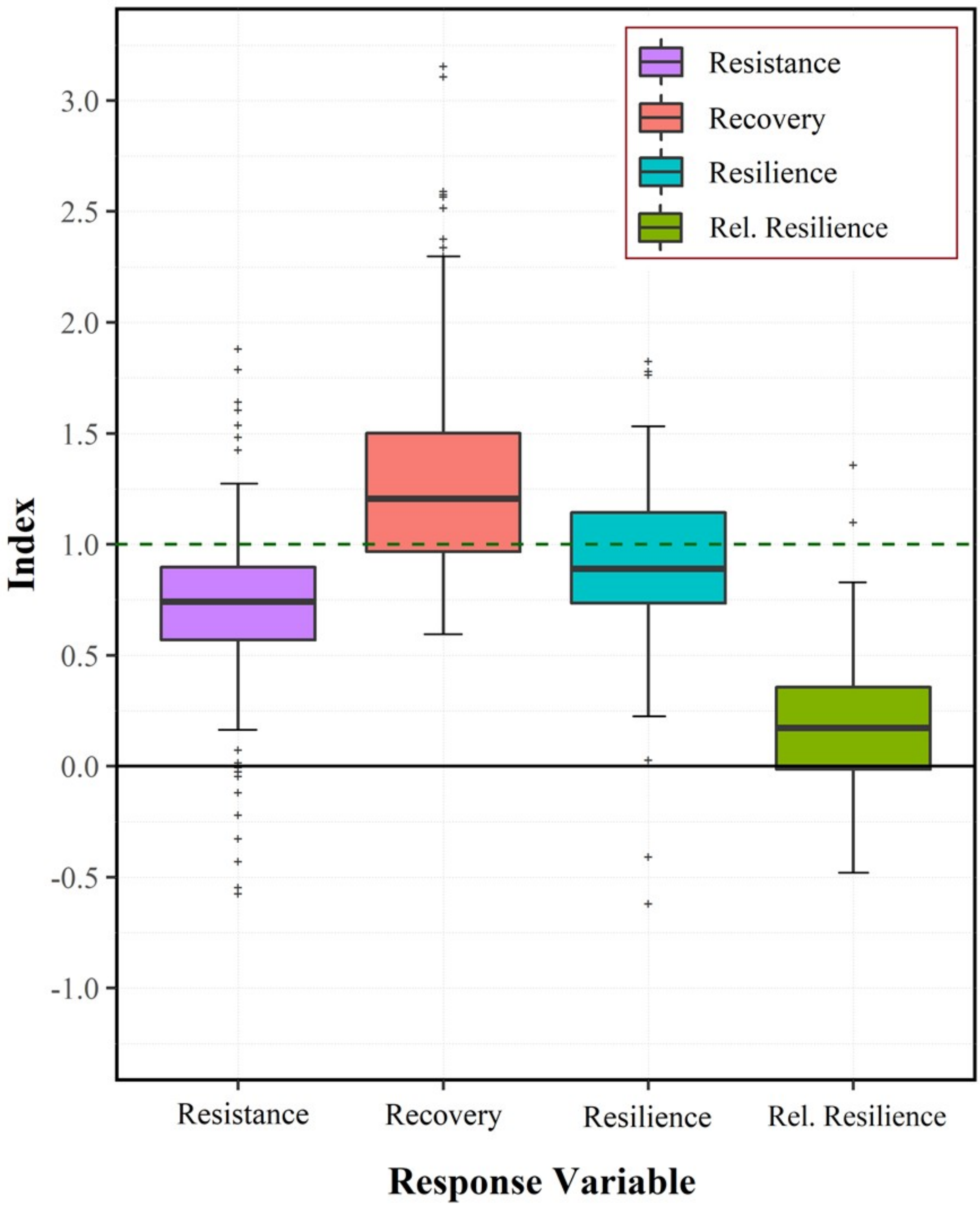

Figure 3. Overall response indices to weather extreme events at a CH-LAE in Switzerland.

- Median Resistance of 0.75; NEP decreased by 25% during weather extremes as compared to pre-extreme days.

- Median Recovery of 1.2; NEP increased by 20% after the weather extreme as compared to during extreme days.
- Median Resilience of 0.85; NEP decreased by 15% after the weather extreme as compared to before weather extreme.

LONG-TERM TRENDS IN FOREST RESPONSE TO WEATHER EXTREMES

No significant yearly trend in response indices over the years.

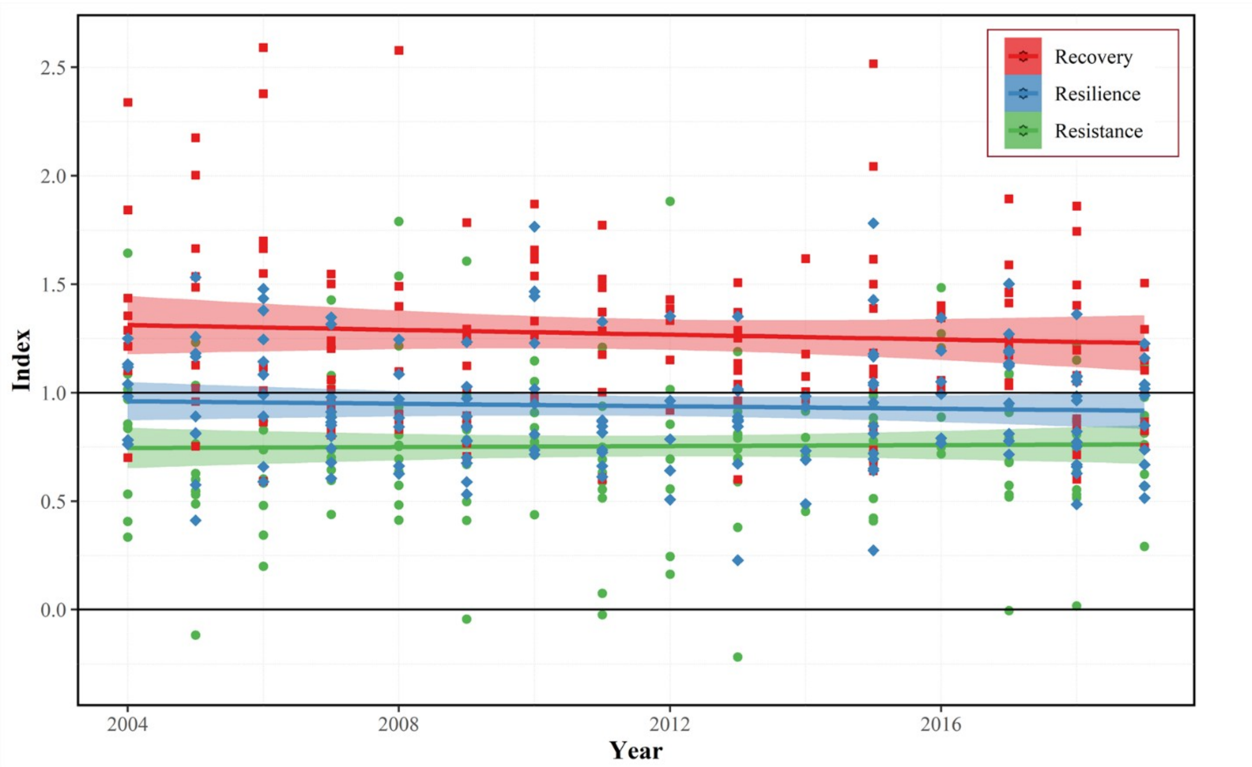

Figure 4. Long-term (16 years) trends in response indices to weather extreme events at CH-LAE in Switzerland.

CONCLUSIONS

- Significant increase in duration and frequency of weather extreme events at a mixed deciduous forest in Switzerland.
- These extreme events resulted in an average of 25% less net ecosystem productivity compared to before the extreme event.
- However, no significant yearly trend in the forest response index to these extreme events existed

ACKNOWLEDGMENT

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ABSTRACT

Extreme environmental events have become a major interest of ecologists. Commonly, extreme climatic events are identified based on “changes in the mean conditions” over a discrete period with respect to the longer-term climatology. In this study we aim to: 1) define a different type of extreme event, i.e. weather extreme events: an event with extreme deviation from an expected value (calculated based on past weather conditions) and 2) quantify ecosystem resistance, recovery, and resilience in response to these shock events based on changes in net ecosystem productivity (NEP) measured over 16 years (2004 – 2019), in a montane mixed forest in Switzerland (CH-LAE, Lägeren). In addition to the identification of the physiological extreme events, we test the hypothesis that extremes associated with continuously varying environmental conditions can modify the physiological functionality of a forest ecosystem.

We calculated weather extremes based on half-hourly measurements of atmospheric water demand (i.e. vapor pressure deficit, VPD) measured alongside eddy covariance flux measurements. Between 2004 and 2019, we found 185 such physiological extreme events (VPD-extreme), ranging from one to seven days, that occurred about 27 % in spring and 68 % in summer. On average NEP decreased by 25% during these VPD-extreme days compared to the normal-VPD day before, resulting in mean resistance ($NEP_{extreme}/NEP_{pre\text{-}extreme}$) of 0.75. Mean recovery ($NEP_{post\text{-}extreme}/NEE_{extreme}$) was about 0.85, indicating about a 15% decrease in NEP on days after the extreme events compared to before. There was no significant trend in resistance, recovery, and resilience over the 16 years. Finally, decreased functionality during these VPD-extreme days events confirms our hypothesis.

Our approach of looking at the forest response to extreme events is independent of “changes of mean conditions from long-term climatology” and focuses on the ability of the ecosystem to maintain functionality within the realm of “continuous environmental variability”. Identification of physiologically-relevant climatic extremes and testing the legacy effect from those events is a crucial requirement for understanding the future response of forests to climate change.

REFERENCES

Dowd, W. W., & Denny, M. W. (2020). A series of unfortunate events: characterizing the contingent nature of physiological extremes using long-term environmental records. Proceedings of the Royal Society B: Biological Sciences, 287(1918), 20192333. https://doi.org/10.1098/rspb.2019.2333

Lloret, F., Keeling, E. G., & Sala, A. (2011). Components of tree resilience: Effects of successive low-growth episodes in old ponderosa pine forests. Oikos, 120(12), 1909–1920. https://doi.org/10.1111/j.1600-0706.2011.19372.x