Development of Mortality Rates in Carpathian Temperate Forests

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Introduction

This study investigates mortality dynamics of five common temperate forest tree species across Western Carpathian forest. The aim of a study is to reveal temporal trends and potential differences in mortality patterns of tree species.

Methodology

We used a dataset from 130 ICP Forests Level I plots, focusing on mortality caused by factors other than planned forestry interventions (e.g., thinning, planned utilization) to capture natural dynamics. In total, we analyzed **1161** observed individual mortality events: **257** Fagus sylvatica (Fsy), **45** Abies alba (Aal), **604** Picea abies (Pab), and **125** Pinus sylvestris (Psy), **130** Quercus petraea (Qpe). We calculated the mortality ratio as the number of observed deaths relative to the number of evaluated trees each year for each species.

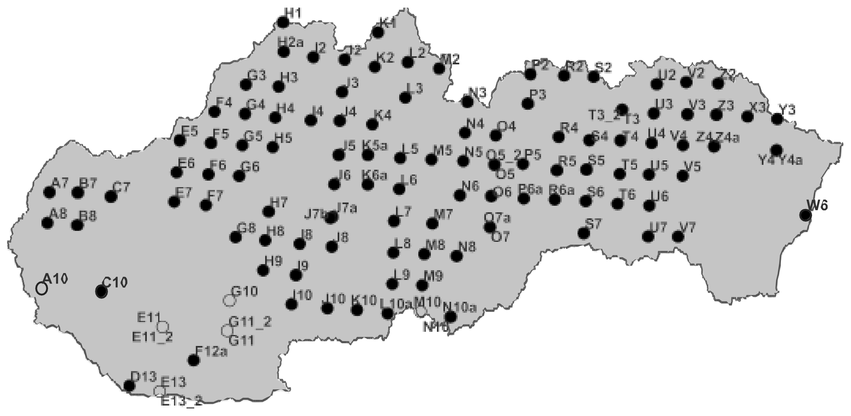

Figure1 Map of active ICP Forests Level I plots and plots included into the analysis. Black color indicates plots with the occurrence of the investigated species included into the analysis; every plot is marked by an ID that consists of transect and serial number (A7). Plots that were relocated to areas with similar conditions nearby the original ones due to various reasons are denoted by lowercase letters (a, b, etc.), while plots that were reestablished in the exact same location are marked with '_2'.

Results

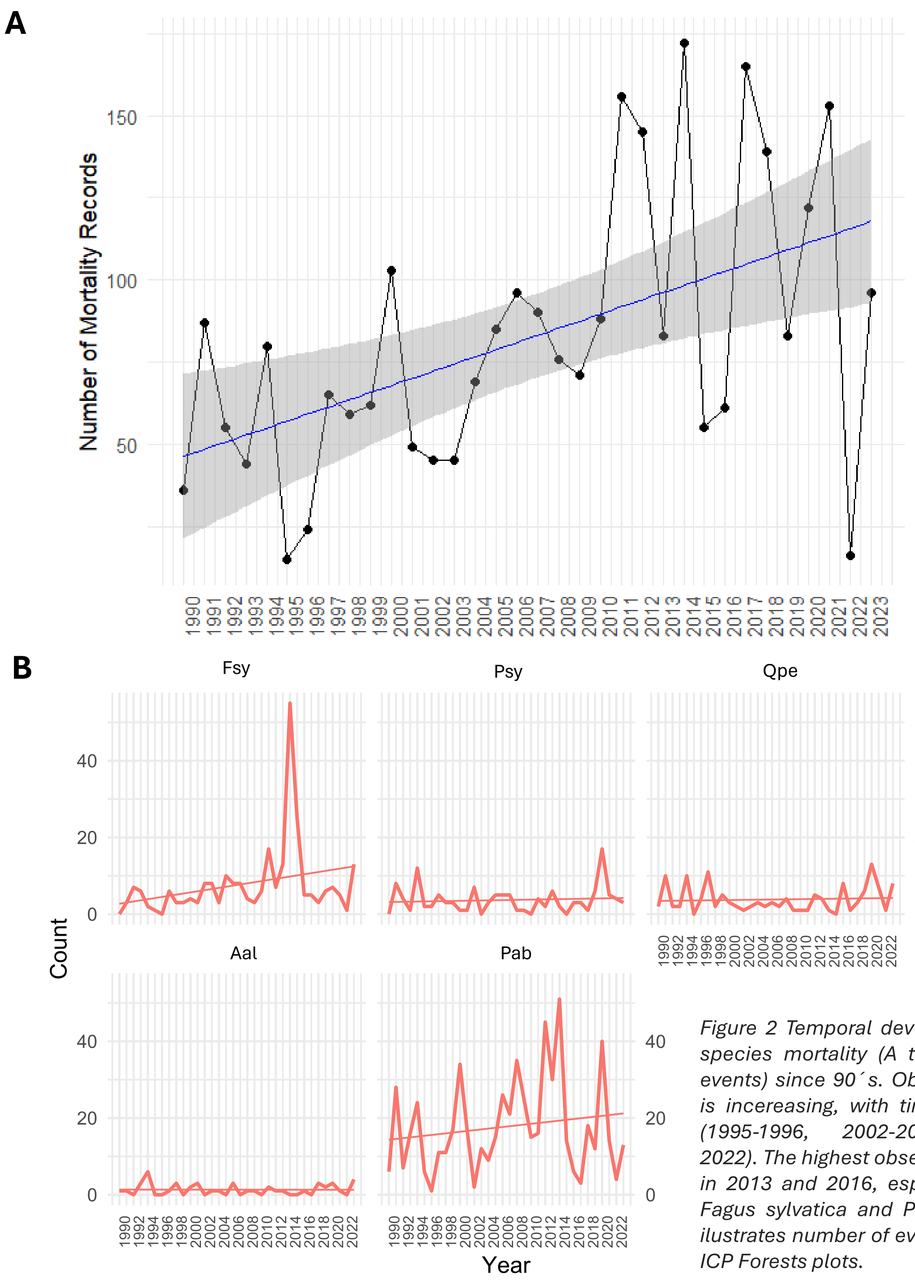

Figure 2 Temporal development of examined species mortality (A total number recorded events) since 90´s. Observed temporal trend is increasing, with time to time decreases (1995-1996, 2002-2004, 2010, 2017 and 2022). The highest observed mortality occured in 2013 and 2016, especially in the case of Fagus sylvatica and Picea abies (B). Plot C ilustrates number of evaluated trees on level I ICP Forests plots.

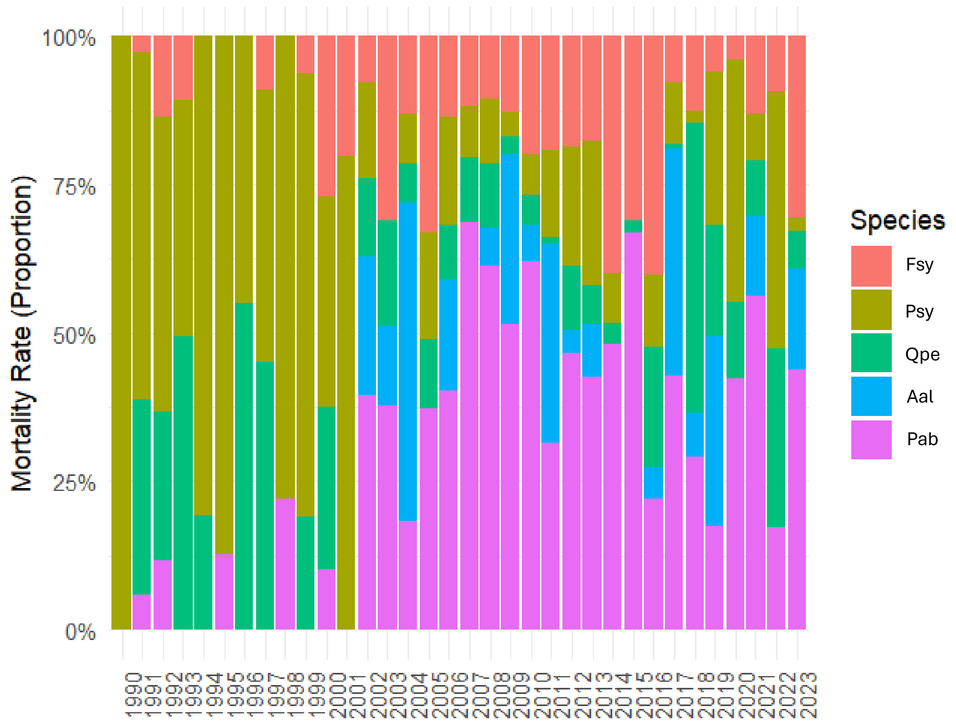

Figure 3 Mortality rate proportion at the total observed mortality events per each species. Mortality rates are showing incereasing trends in case of Picea abies and Fagus sylvatica, Quercus sp. and Abies alba are showing neutral mortality patterns. In case of Pinus silvetris, mortality rates are decreasing compared to 90´s (except for 2022)

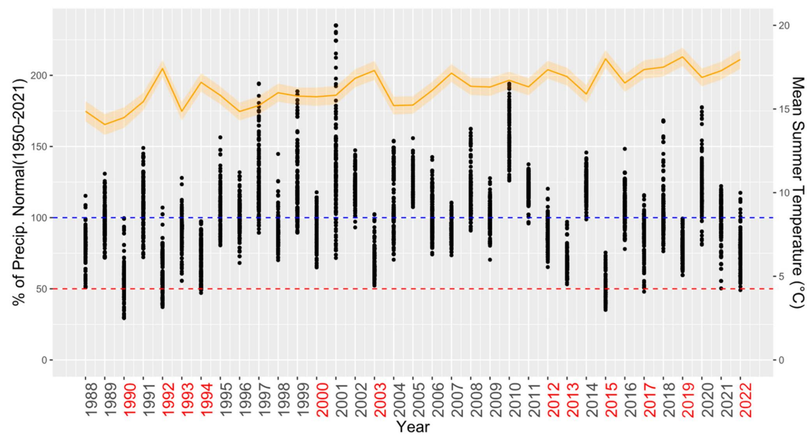

Figure 4 Selected dry years (red) based on summer precipitation compared to normal precipitation levels (1950–2021- EOBS). Dots represents annual values for each plot. Blue dashed line indicates 100%, and red dashed line indicates 50% of long-term normal precipitation. Orange line represents mean summer temperatures with 95% confidence intervals (orange shaded area) for the means derived from all ICP Forests Level I plots.

Discussion

Our findings reveal that the frequency of mortality events shows temporal trends, often consistent with the overall growth decline of the species. Species-specific responses to climatic extremes were observed:

- **Fagus sylvatica** demonstrated increasing mortality after an extreme drought in 2000, with the highest values reached in 2013, following the long dry period since 2012.
- **Picea abies** showed a consistently negative trend with significant dieback during the period 2011-2014.
- **Abies alba** showed a neutral trend in mortality rates.
- **Quercus petraea** demonstrated a neutral trend in mortality rates.
- **Pinus sylvestris** showed a neutral trend, with higher mortality in the extremely dry year of 2022.
- Aside from management-caused mortality, significant increases were observed **after long dry periods (2012-2013)** or with a one-year lag after extremely dry and hot years **(2015, 2022)**.

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