Linking Woody Cover Dynamics to Fire Events in European Landscapes

Ruben Butzer, Master Thesis

Abstract

Fire is an important ecosystem driver and disturbance agent for European landscapes. However, it remains unclear how woody cover dynamics in fire-affected areas differ across European biogeographic regions and land-use/land-cover (LULC) types, and how woody cover modulates fire risk across these categories. This study therefore aimed to assess (1) the role of biogeographical variation and (2) LULC mediation in shaping woody cover dynamics in fire affected areas, and (3) understand how woody cover influences fire risk across Europe. To address this, a comprehensive workflow was developed, combining wildE fractional woody cover data with MODIS burned area records. The analysis consisted of three core steps: First, descriptive statistics and seasonal distribution analyses were used to quantify general patterns of woody cover and fire dynamics across European biogeographical regions and LULC classes. Second, woody cover trajectory patterns were analysed to assess recovery pathways and the influence of repeated fire events. Finally, inside-outside comparisons were conducted to compare fire-affected areas with non-fire affected areas, using bootstrapped sampling and binomial logistic regression models with control pixels representing the general landscape. This methodology enabled the quantification of non-random associations between woody cover and fire occurrence, as well as temporal shifts in woody-fire relationships. Three core findings relating to the research questions emerged. First, woody cover dynamics exhibit strong biogeographical divergence across Europe in terms of post-fire losses and recovery pathways, with Mediterranean landscapes facing the most severe losses (up to 50%) and no full recovery within ten years post fire. Second, LULC mediation critically shapes fire distribution and post-fire recovery, as croplands exhibit minimal losses and positive recovery despite high fire frequency, while wetlands and forests experience pronounced declines. Third, there are significant associations between fractional woody cover and fire occurrence, with overall fire propensity highest at low to intermediate woody cover levels (20–60%) but varying markedly by region and LULC class. Logistic regression models identified significant temporal shifts in woody-fire relationships, with some regions transitioning from positive to negative correlations over time, reflecting evolving fire dynamics under climate change and land-use intensification. Overall, this study demonstrates that stratifying woody-fire dynamics by European biogeographical regions and LULC classes provides valuable insights into the regional patterns of European pyrogeography, with implications for fuel-fire management and conservation strategies in European regions.

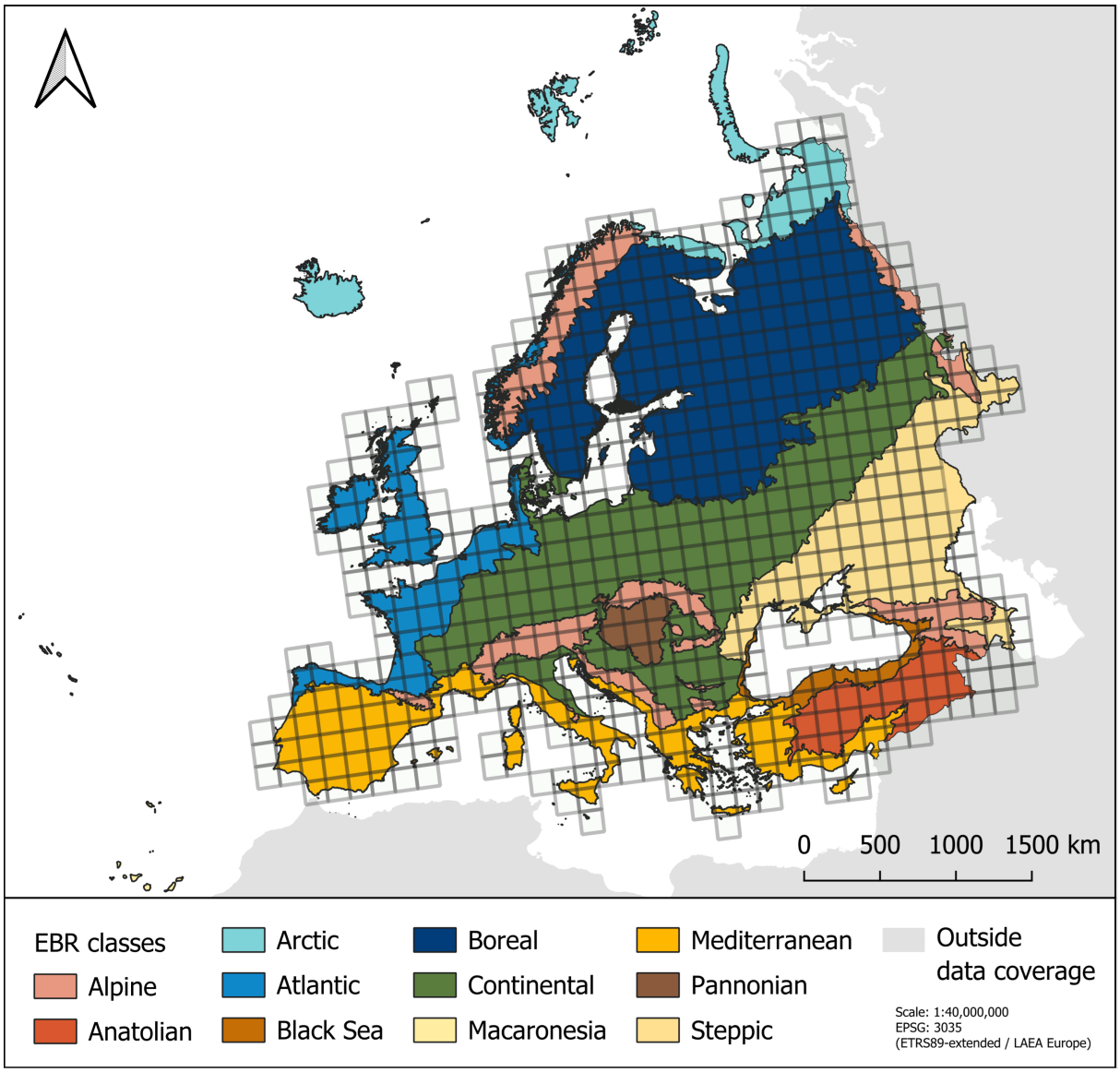


Figure 1| European biogeographical regions (EBR) (EEA, 2016) overlaid with the wildE woody cover processing grid. Regions not included in the analysis due to lack of woody cover data are Macaronesia, the Arctic Islands (Iceland, Faroe, Svalbard, Novaya Zemlya) and the Kazakh part of the Steppic ecoregion.

Table 1 | Overview of Data Products used in this Study. Includes Product Name and scientific reference as well as native spatial resolution and available time period.

Dataset	Product (Origin)	Resolution	Time Frame
Woody Cover	wildE Woody cover (Schneidereit et al., in preparation)	30 m	1985–2024
Burned Area	MCD64A1 (Giglio, Justice, et al., 2021)	500 m	2000–ongoing
LULC	MCD12Q1, IGBP Layer 1 (Friedl & Sulla-Menashe, 2022)	500 m	2000–2024
EBR	EEA Biogeographical Regions (EEA, 2016)	Vector	None

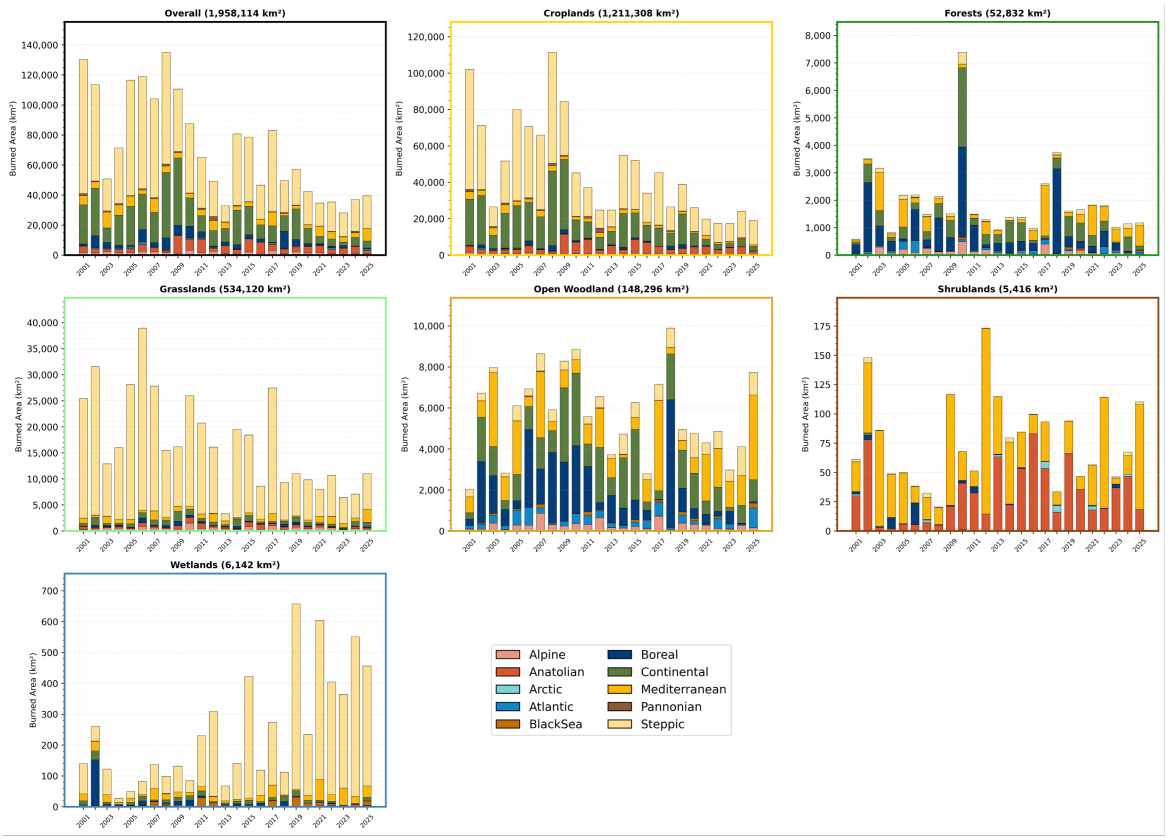


Figure 2 | Annual Burned Area per EBR stratified by LULC. This shows the impact of fire on EBRs by displaying the yearly absolute burned landcover area of each LULC.

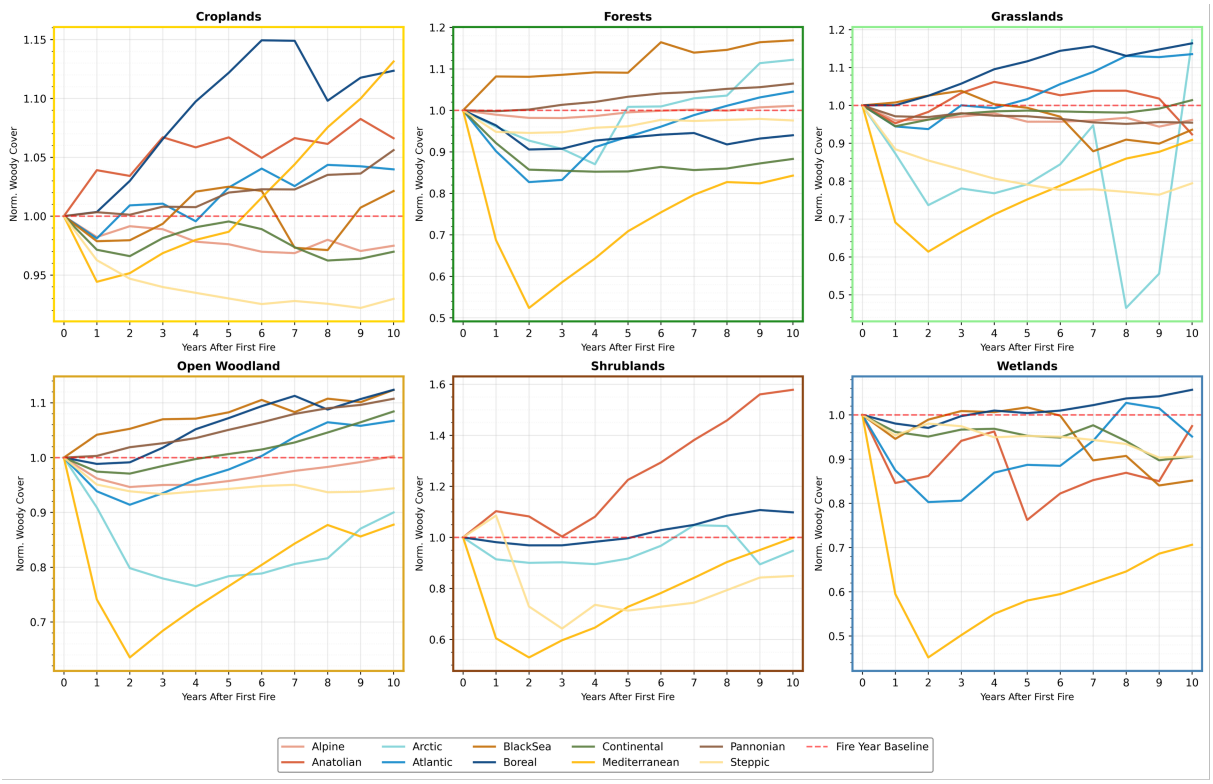


Figure 3| Normalised post-fire Woody Cover recovery trajectories of EBRs across LULC classes. Trajectories are based on areas which exhibited a single fire event during the study period. Horizontal red line indicates pre-fire baseline cover.

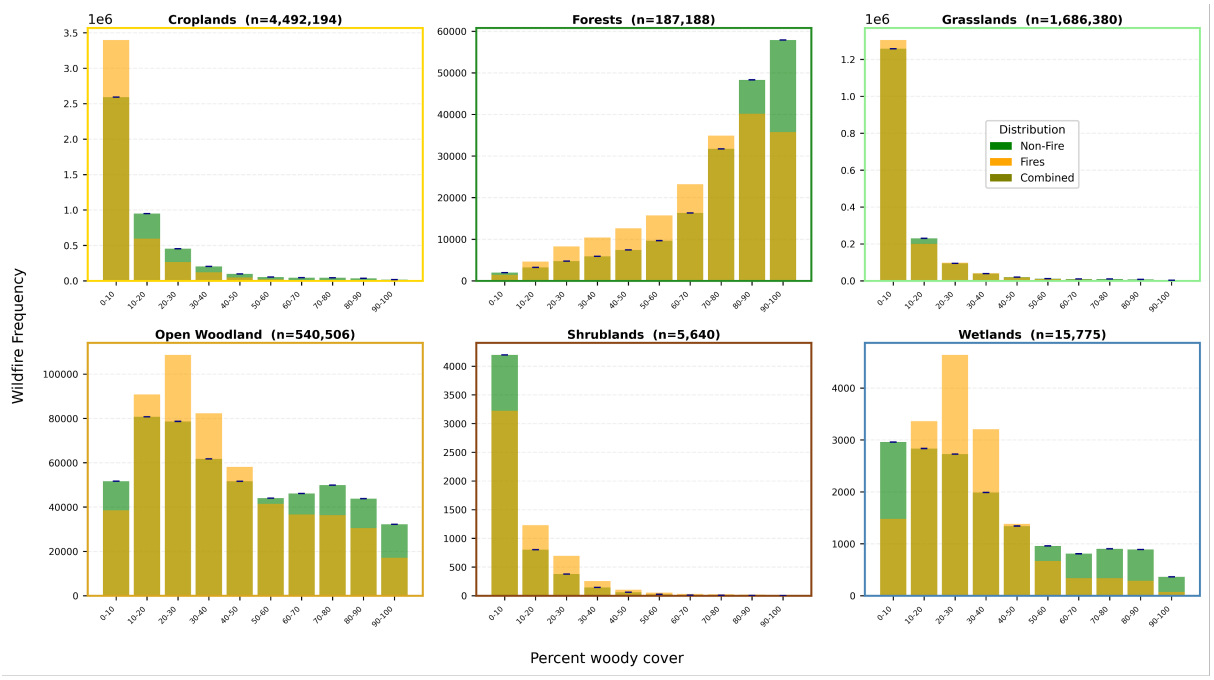


Figure 4| Fractional Woody Cover distribution by LULC in areas of Fire (yellow) compared to bootstrapped random sample representing the general landscape of the respective LULC (after Ivey et al., 2024). Relative fire propensity (FP) is indicated by the difference across both distributions. Error bars indicate the standard error of the 1000 null frequency distributions.

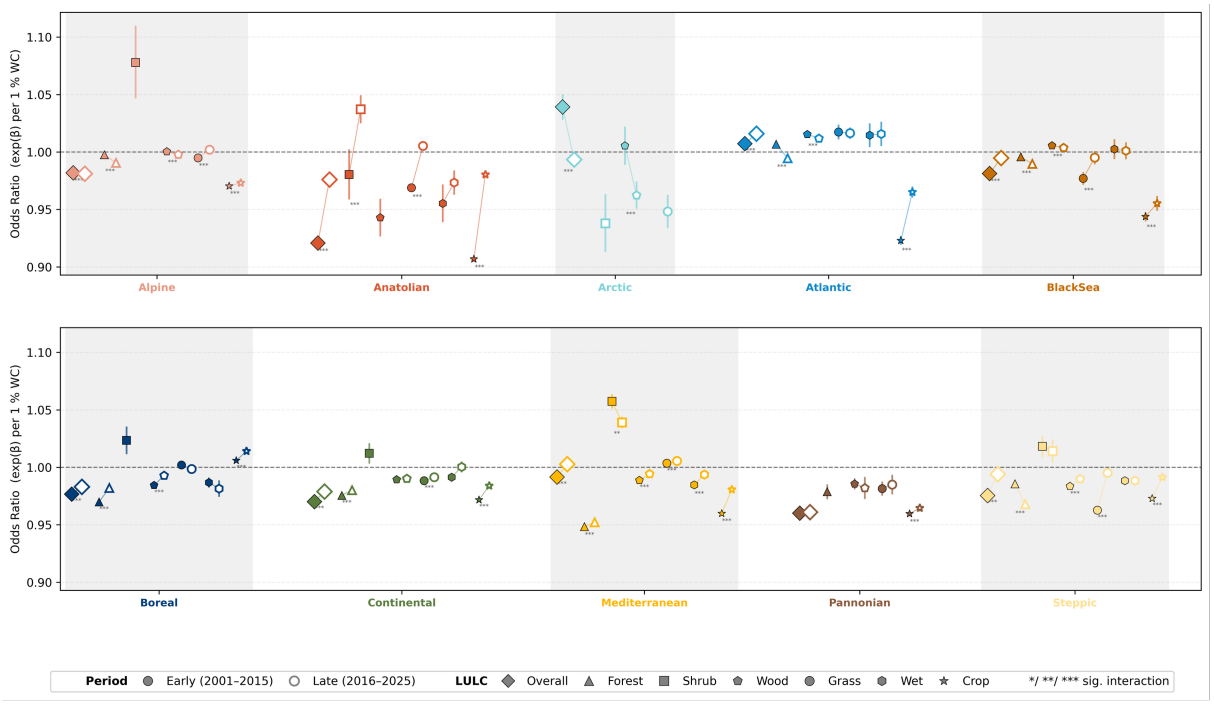


Figure 5 | Odds ratios (OR) from binomial logistic regressions showing the probability of fire occurrence as a function of pre-fire woody cover, stratified by EBR and LULC. Each point represents the exponentiated coefficient exp(β) for a 1 percentage-point increase in woody cover; values below 1.0 indicate that higher woody cover is associated with reduced fire likelihood. Filled markers denote the early period (2001–2015), open markers the late period (2016–2025). Connecting lines between paired early and late estimates highlight temporal shifts in the woody cover-fire relationship. Only strata with ≥ 30 fire events are shown. Asterisks indicate statistical significance of interaction ($p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).*