# Restoration of plant diversity in oak coppices transformed to high forests under global environmental threats

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## Abandoned coppicing and biodiversity

Coppicing is amongst the oldest forms of forest management continuously present across different European regions since neolithic era. However, the changes in socio-economic conditions during the second half of 20th century eventuated into vast transformation of coppiced woods to high forests particularly in the temperate Europe. Due to the short cutting cycles and low competitive pressure of trees, coppice systems are inhabited by many non-forest species demanding more open sites. Abandonment of coppicing have strong consequences for forest biodiversity and induced **significant decline of some species**, like ground flora or invertebrates. Plant communities directionally shifted to more mesic and nutrient demanding assemblages and exhibited clear **taxonomic homogenization** in time and space (Fig. 1).

## Major environmental threats for the restoration of vegetation diversity

The most important driver of biodiversity loss in former coppiced forests is the **land-use change**, i.e. abandonment of coppicing itself, but also the elimination of historical forms of forest use like grazing, hay making, litter raking or collecting of fine woody debris. However, also global environmental changes occurring during last decades, particularly **nitrogen (N) deposition** and **climate change**, triggered compositional shifts of species communities. Therefore, the crucial question for biodiversity conservation is, whether simple restoration of coppice systems recover former species assemblages under ongoing environmental changes. To address this, it is essential to understand how the drivers responsible for biodiversity loss interact and to disentangle their impact.

The current phenomenon – **eutrophication** of forest environment is the great example how above mentioned drivers interact and may disrupt the restoration of vegetation composition and diversity. The main source of eutrophication is the N deposition from air pollution or agriculture, however, also elimination of historical forest use resulted into increased level of nutrients due to the higher amount of biomass remaining in the forests. For example, litter of broadleaved temperate forests contains ca. 80 $kg.ha^{-1}.yr^{-1}$ of N (Pavlenda et al. 2011) while already 10–15 $kg.ha^{-1}.yr^{-1}$ is considered as critical load for temperate forests (Bobbink et al. 2010). Despite of that the observed changes in vegetation could be assigned to changes of stand structure accompanying the transformation of coppices to high forests rather than to N deposition (Verheyen et al. 2012, Kopecký et al. 2012). This suggest the process of the deceleration of litter decomposition and accumulation of nitrogen because of the denser canopies. However, the **accumulated N might rapidly release** and have very negative consequences for understorey vegetation **when canopies will open up again**. This so called **N time bomb** (Verheyen et al. 2012) has to be considered in the restoration of coppice systems.

**Opening of the canopy** involves also other threats for successful recovery of plant communities. Forest stand structure controls the microclimate and losing of microclimate buffering induce a process described as **thermophization**, i.e. increase in dominance of warm-adapted over cold-tolerant plants (De Frenne et al. 2013, Stevens et al. 2015). Moreover, the combination of microclimate warming with higher amount of light or even nitrogen trigger the largest community shifts (Fig. 2). Warming might also enhance the process of **biotic homogenization** (Savage, Vellend 2014) or promote **invasion of non-native species** (Bellard et al. 2013, Liu et al. 2017) which is amongst the greatest threats to biodiversity. Invasions of non-native plants to forest sites furthermore benefit from various **disturbances** accompanying forest harvest (Fig. 3). Concluding all these threats, the simple clear-cutting aiming to restore coppice systems and their biodiversity might totally fail.

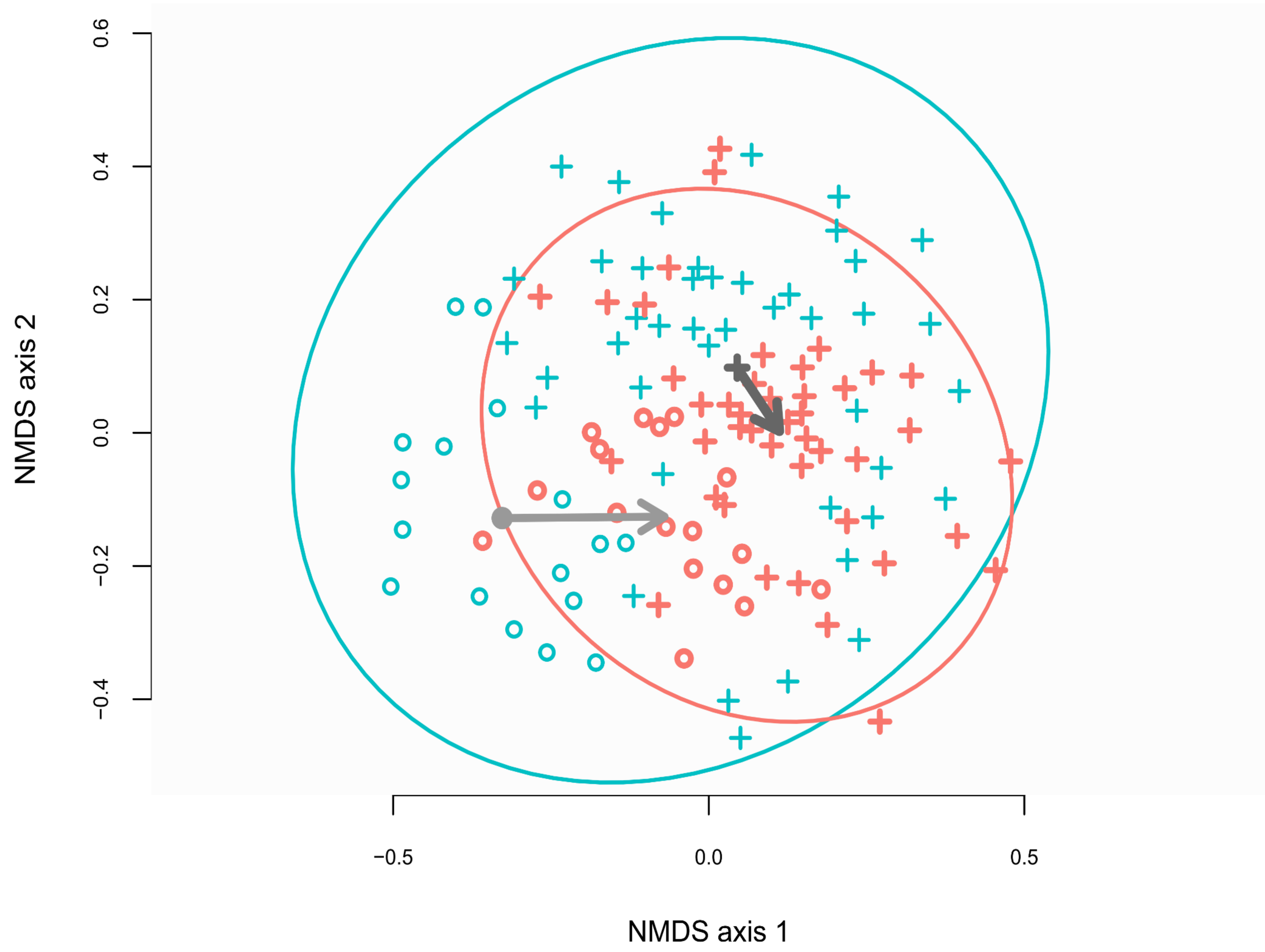


Figure 1 Abandonment of coppicing shifted plant assemblages to more moist and nutrient demanding. Moreover, the communities exhibited taxonomic homogenization in space. The figure shows example of temporal changes in oak (circles) and oak-hornbeam or beech forests (plus) in Slovak Karst (Slovakia, Central Europe) over 40 years (Máliš et al. *unpublished*). Blue indicate vegetation record on permanent plots in 1975 and red in 2015, arrows the direction and intensity of the change.

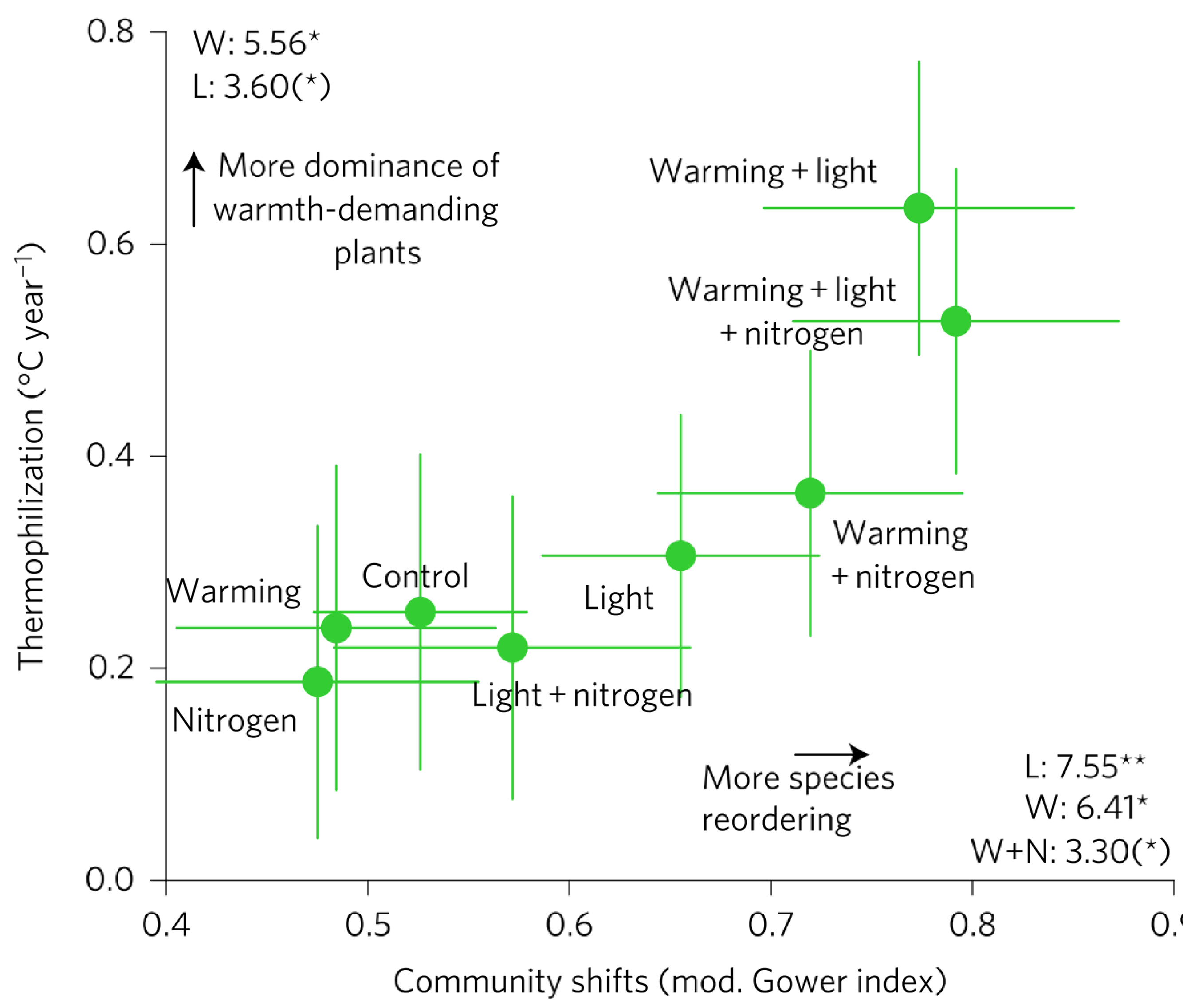


Figure 2 Recovery of former plant assemblages by simple forest stand cutting may fail due the considerable increase of global warming and nitrogen deposition impact on the understorey vegetation after opening of the stand canopy. The figure shows results of De Frenne et al. (2015) from the experimental testing of light impact on the thermophilization of plant communities under increased temperature and nitrogen loads.

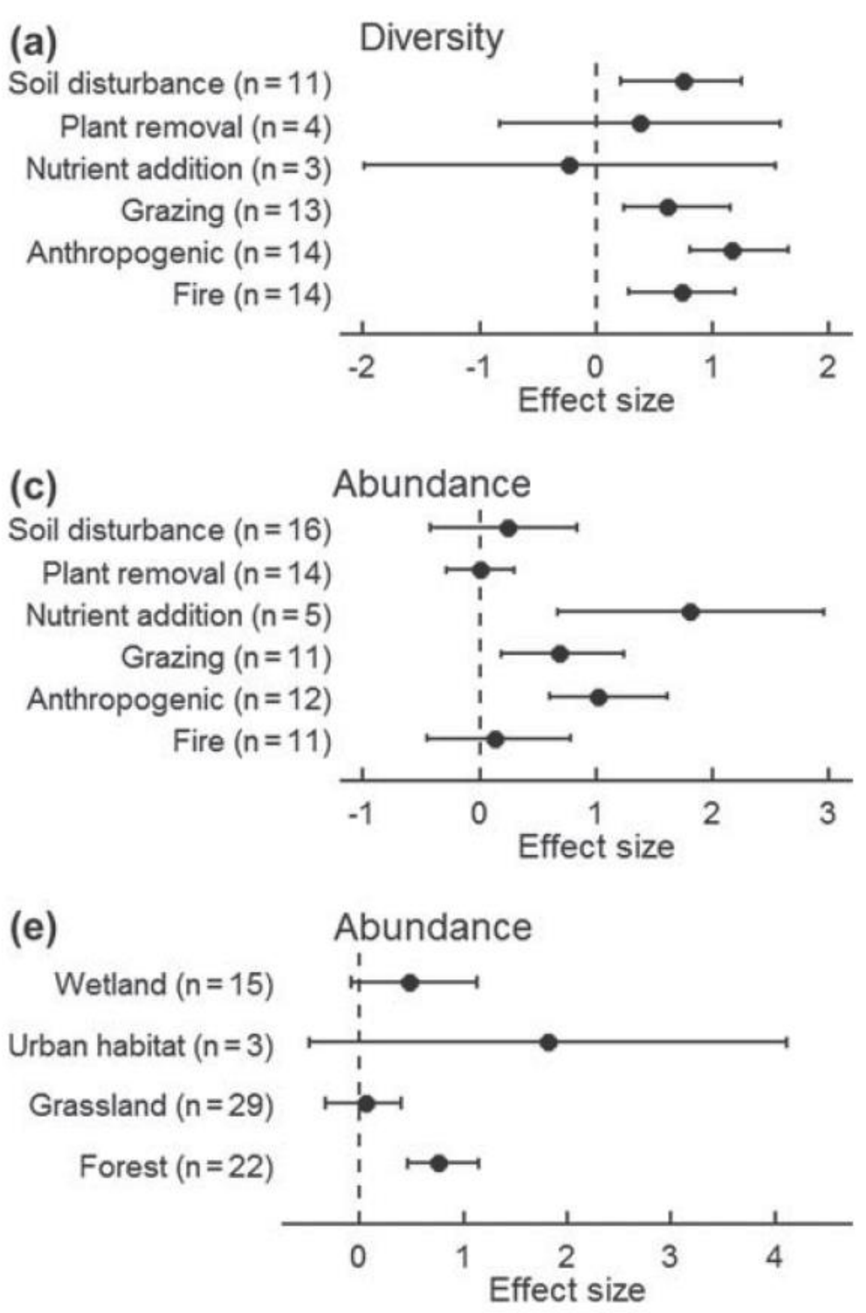


Figure 3 (left) Disturbances accompanying forest harvest support invasion of non-native plants into forest sites and might threat successful recovery of coppice systems vegetation. The figure shows the results of Jauni et al. (2015) meta-analysis. Positive effects sizes indicate that disturbed sites have on average greater plant diversity or abundance of non-native species than undisturbed sites.

## Way forward

The only way how to mitigate environmental threats to restoration of coppice systems biodiversity is to **develop appropriate silviculture techniques by well-designed field experiments** testing various approaches. Particularly employing of accumulated biomass removal or spatially small-scale cutting might be promising. There are already several ongoing experiments showing some positive effects (e.g. Vild et al. 2013, Hédl et al. 2017), however, their results can`t be generalized for all regions due to the **high spatial variability in land-use legacies, N deposition loads or other drivers** of temporal changes in vegetation (Bernhardt-Römermann et al. 2015, Perring et al. 2016). It is a matter of crucial importance to experimentally disentangle between confounding drivers and design regionally suitable restoration. Practically, we need more **experiments across variety of environmental conditions** and synthetize their results with studies investigating temporal changes in active coppice systems (e.g. Canullo et al. 2017, Šebesta et al. 2017) and those combining vegetation resurveys across different regions (Verheyen et al. 2017).

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