

Manuscript Title

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Abstract

Policies to mitigate climate change and biodiversity loss often assume that protecting carbon-rich forests provides co-benefits in terms of biodiversity, due to the spatial congruence of carbon stocks and biodiversity at biogeographic scales. However, it remains unclear whether this holds at the scales relevant for management, with particularly large knowledge gaps for temperate forests and for taxa other than trees. We built a comprehensive dataset of Central European temperate forest structure and multi-taxonomic diversity (beetles, birds, bryophytes, fungi, lichens, and plants) across 352 plots. We used Boosted Regression Trees to assess the relationship between above-ground live carbon stocks and (a) taxon-specific richness, (b) a unified multidiversity index. We used Threshold Indicator Taxa ANalysis to explore individual species' responses to changing above-ground carbon stocks and to detect change-points in species composition along the carbon-stock gradient. Our results reveal an overall weak and highly variable relationship between richness and carbon stock at the stand scale, both for individual taxonomic groups and for multidiversity. Similarly, the proportion of win-win and trade-off species (i.e. species favored or disadvantaged by increasing carbon stock, respectively) varied substantially across taxa. Win-win species gradually replaced trade-off species with increasing carbon, without clear thresholds along the above-ground carbon gradient, suggesting that community-level surrogates (e.g. richness) might fail to detect critical changes in biodiversity. Collectively, our analyses highlight that leveraging co-benefits between carbon and biodiversity in temperate forest may require stand-scale management that prioritizes either biodiversity or carbon in order to maximize co-benefits at broader scales. Importantly, this contrasts with tropical forests, where climate and biodiversity objectives can be integrated at the stand-scale, thus highlighting the need for context-specificity when managing for multiple objectives. Accounting for critical change-points of target taxa can help to deliver this specificity, by defining a safe operating space to manipulate carbon while avoiding biodiversity losses.

Introduction

Forests play a critical role in mitigating climate change, in addition to providing many ecosystem services fundamental to human society (FAO, 2015; MEA, 2005). The estimated amount of carbon stored in forests globally is almost 900 Pg (=10¹⁵ g), with a net global carbon sink of 1.1 Pg C per year (Pan et al., 2011). Forests also provide habitat for over half of all known terrestrial plant and animal species (MEA, 2005), albeit covering only 27% of the Earth's land area (FAO, 2015). Conserving forests and managing them sustainably is therefore fundamental for facing two of the most pressing societal challenges of our times: biodiversity loss and climate change (MEA, 2005).

Materials and methods

Study sites

Our study area included a network of 352 plots in 22 temperate forest sites (ranging from 200 to 400 km²), sampled in six different projects (Burrascano et al., 2018), and covering a wide latitudinal and longitudinal range across Europe (Figure 1, Table S1). The sites covered deciduous forest types that are common in temperate Europe, including acidophilous oak and oak-birch forests (20 plots), mesophytic deciduous forests (84 plots), European beech (*Fagus sylvatica*) and montane beech forests (232 plots in total), as well as thermophilous deciduous forests (16 plots). Forest type nomenclature follows EEA (2006). Although our dataset cannot be considered representative of the overall variability of these forest types, it covers a wide range of structural types (one-, two- and multi-layered stands), ages, management histories, and management regimes, including coppice, shelterwood, group selection and unmanaged stands, comprising late-successional phases of the forest succession gradient. Stands in the Hungarian dataset represent a gradient in tree species composition, from oak- to beech-dominated forest, but all sharing similar age (mature, between 70-120 yr), and mesic

conditions. The datasets in the Italian and French Alps contrast pairs of managed and unmanaged stands in similar growing conditions, as well as ancient and recent forests (i.e. resulting from afforestation of previous pastures and meadows). Forest stands in the Cilento National Park were selected as a representative subset of the most common forest types in the park area, while those in the Gran Sasso National Parks spanned across a range of structural types but all belonged to beech-dominated forest types prioritised for conservation. We report summary statistics of the main structural characteristics for each forest site in Table S2 and show the distribution of silvicultural systems across sites in Figure S1.

References
