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 deciduos 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.

Stand Name	**Data source**	**Substrate**	**Number of Plots**	**Annual Mean T °C**	**Annual rainfall mm**	**Elevation**	**Aspect °**	**Slope °**	**Latitude**	**Longitude**
Auberive	FR_YP	Limestone	22	9	800-900	455	229	5	47.749	5.068
Ballons-Comtois	FR_YP	Granit	14	6.9	1300-1400	1043	189	16	47.818	6.798
Bauges	FR_ALPS	Limestone	29	7.2	1350-1850	1107	266	22	45.701	6.167
Bois du Parc	FR_YP	Limestone	9	10.9	650-750	195	222	4	47.583	3.649
Cajada forest	IT_NE	Dolomite/Limestone	9	7.2	1300-1500	1255	141	11	46.235	12.237
Chartreuse	FR_ALPS	Limestone	31	6.8	1300-1900	1136	245	19	45.339	5.791
Chizé	FR_YP	Limestone	18	12	800-900	89	207	2	46.146	-0.386
Cilento N	IT_FAGUS	Limestone	24	10.1	718-1250	1272	177	17	40.465	15.339
Cilento S	IT_CILENTO	Limestone/ Flysch	12	11.2	700	1246	175	17	40.257	15.344
Citeaux	FR_YP	Alluvial deposits	10	10.9	700-800	231	205	2	47.09	5.05
Combe Lavaux	FR_YP	Limestone	8	9.1	800-900	572	197	12	47.226	4.939
Fontainebleau	FR_YP	Acidic sands	25	10.5	600-700	138	172	3	48.421	2.66
Gran Sasso	IT_FAGUS	Limestone	19	9.1	1062-1097	1354	263	17	42.508	13.514
Haut Tuileau	FR_YP	Alluvial deposits	12	10	650-750	175	170	2	48.104	4.188
Haute-Chaine du Jura	FR_YP	Limestone	6	7.5	1300-1400	1101	109	25	46.299	5.986
Lure	FR_YP	Limestone	7	8	1000-1100	1448	109	31	44.123	5.82
Orseg	HU	gravel/loess	25	9.2	700-800	308	134	5	46.892	16.308
Rambouillet	FR_YP	Acidic sands	16	10	600-700	164	180	2	48.671	1.763
Val Tovanella	IT_NE	Dolomite/Limestone	11	7.2	1300-1500	1236	306	19	46.309	12.302

Stand Name	Data source	Substrate	Number of Plots	Annual Mean T °C	Annual rainfall mm	Elevation	Aspect °	Slope °	Latitude	Longitude
Ventoux	FR_YP	Limestone	9	7.9	1000-1100	1356	187	25	44.181	5.261
Ventron	FR_YP	Limestone	3	8.9	1200-1300	956	266	22	47.939	6.931
Vercors	FR_ALPS	Limestone	18	7	1200-1500	1232	189	15	45.145	5.506
Verrières	FR_YP	Acidic sands marls	7	9.6	600-700	177	203	2	48.757	2.25

Table S1: Caption for this example table. {#tbl:TableS1}

References