The following supplement accompanies the article

Modelling distribution of Mediterranean beech forests and soil carbon stock under climate change scenarios

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Supporting Material Text

Soil sampling, processing and chemical measurements

Soil was sampled with steel core samplers with diameter and length of 5 cm. The cores were placed on the ground after removing all the standing litter recognizable. In order to standardize and compare the results from the different locations, the cores were just considered as the first 5 cm of organic soil, with the level 0 cm beginning exactly when no more forest floor was recognizable. The cores have been weighted, sieved with a mesh size of 2 mm and then weighted again to assess the percentage of gravel within the sample. A subsample was oven dried at 75 °C in triplicate until constant weight to assess the moisture content.

The corresponding dry weight of the soil cores was used also to compute the bulk density, expressed as g of dry soil within the soil core volume, equivalent to cylinders of volume of $l\pi r^2$, with r (radius of the core sample) being 2.5 cm an l (length of the core), i.e. 5 cm.

As for chemical measurements, pH has been measured by shaking 10 g of soil in 25 ml distilled water for 10 min (Fioretto et al. 2000). After waiting 10 min, the supernatant was used to measure the pH with an electronic pH meter (HI 8424, HANNA Instruments, Sarmeola di Rubano, Italy). Total organic carbon was estimated by dividing the organic matter by a factor of 2 (Pribyl 2010). The estimate of soil organic carbon from organic matter has been proved as to be adequate, especially for soil highly rich in organic matter (Pereira et al. 2006, Pribyl 2010). This conversion factor proved to be adequate for our dataset by confronting the results with a subsample measured by a CNS elemental analyser (vario El III, Elementar Analysensysteme GmbH, Hanau, Germany) after the dried samples were finely ground (Song et al. 2012) and carbonates removed from the soil samples (Harris et al. 2001). All chemical measurements were done in duplicate for each of the six location samplings.

Organic matter was evaluated gravimetrically as the difference between the dry weight and the ashes after incineration in a muffle furnace at 375 °C for 16 h (Pribyl 2010). This combination of temperature and time allow incinerating all the organic matter present in the soil but avoid overestimation due to calcification of carbonates and/or loss of structural water from silicates or other minerals.

As for the conversion from the proportion to the amount of organic matter, we proceed as follows. In detail, soil cores, being circular and with a diameter of 5 cm, had a surface of 19.625 cm^2 and a volume of 98.174 cm^3. To pass from the surface of the soil cores to a surface of 1 ha, it is necessary to multiply for a factor of 5095541.4. Additionally, to pass from grams to Mg, it is necessary to divide by 10^6. Moreover, the actual amount can be computed once taking into account the bulk density. Bulk density has been measured once removing the volume occupied by gravel, which has been proved not to contain organic carbon (Henry et al. 2009). Organic matter concentration and bulk density have been shown to be highly correlated to organic matter (Throop et al. 2012) and we were able to estimate bulk density through a simple linear regression using organic matter concentration as independent variable (squared-R=0.414, $p<0.001$, N=74). Thus, the final amount of organic matter was computed as follows:

$$\text{Organic Matter Amount (Mg/ha)} = (\text{Organic Matter Proportion (g/g)} \times \text{Bulk Density (g/cm}^3) \times \text{Core Volume (cm}^3) \times 5095541.4) / 10^6$$

Finally, organic matter amount was converted to organic carbon by simply dividing the results by 2 (Pribyl 2010).

Variables selection procedure

Groups of intercorrelated variables were identified by considering a Spearman correlation coefficient |rho| >=0.7. The variables of each group underwent in turn a run of biomod2 and just the predictor with the highest AUC, averaged among all the modelling techniques, was retained from each group. Variables with averaged AUC <0.8 were dropped in any case, see also Tab. S4.

Supplementary Material References

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Supplementary Tables

Table S1: Geographical and lithological information about the sampled locations. pH, organic matter proportion, organic carbon proportion and organic carbon stock data are provided (values are means±s.e.m.)

Location ID	Italian Region	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Parent Material	Soil pH	Bulk Density (g/cm^3)	Organic Matter Proportion (g/g)	Organic Carbon Proportion (g/g)	Organic Carbon Stock (Mg/ha)
Pradaccio	Emilia Romagna	44.40	10.02	1355	Sandstone	3.64±0.08	0.39±0.07	0.42±0.08	0.21±0.04	42.15±10.96
Gran Sasso	Abruzzo	42.40	13.79	1596	Limestone	6.00±0.12	0.67±0.06	0.24±0.02	0.12±0.01	27.74±2.05
Umbra	Puglia	41.82	16.03	593	Limestone	5.87±0.12	0.61±0.05	0.23±0.02	0.12±0.01	17.03±2.05
Monte Meta	Molise	41.69	13.99	1440	Limestone	5.62±0.11	0.63±0.05	0.27±0.02	0.14±0.01	37.26±2.82
Camposauro	Campania	41.17	14.60	1376	Limestone	5.26±0.11	0.50±0.04	0.34±0.03	0.17±0.02	34.62±2.97
Partenio	Campania	40.98	14.71	1049	Limestone	5.91±0.12	0.95±0.12	0.16±0.02	0.08±0.01	22.90±2.34
Vulture	Basilicata	40.93	15.61	686	Foidolite	6.10±0.12	0.83±0.05	0.17±0.01	0.09±0.01	27.09±2.61
Laceno	Campania	40.80	15.10	1170	Limestone	5.48±0.11	0.67±0.11	0.24±0.04	0.12±0.02	48.62±12.05
Faito	Campania	40.66	14.50	1219	Limestone	5.93±0.12	0.47±0.08	0.36±0.06	0.18±0.03	22.19±2.95
Alburni	Campania	40.50	15.37	1161	Limestone	5.94±0.12	0.55±0.03	0.18±0.01	0.09±0.01	20.33±5.23
Cervati	Campania	40.29	15.50	1278	Limestone	5.92±0.11	0.59±0.06	0.30±0.03	0.15±0.02	38.99±4.61
Sirino	Basilicata	40.14	15.84	1558	Limestone	5.42±0.11	0.74±0.07	0.21±0.02	0.11±0.01	25.64±1.90
Novacco	Calabria	39.80	16.05	1328	Dolostone	5.49±0.11	0.49±0.05	0.40±0.04	0.20±0.02	35.14±3.09
Serre Calabre	Calabria	38.44	16.23	1134	Granite	4.90±0.09	0.59±0.02	0.25±0.01	0.13±0.01	27.28±0.78
Nebrodi	Sicilia	37.90	14.66	1474	Marl	5.50±0.11	0.85±0.09	0.19±0.02	0.10±0.01	36.28±3.63

Table S2: Estimates and significance levels of the coefficients of the GAM fitted between the model's residuals and the two covariates. (* $p\leq 0.05$; **: $p\leq0.01$; ***: $p\leq0.001$).

Relationship	Coefficient estimate	Estimated degrees of freedom	p-value
Residuals ~ Intercept +	-0.015		ns
smooth (Temperature Seasonality)		1	ns
Residuals ~ Intercept +	-0.015		ns
smooth (Elevation)		1.449	ns

Table S3: Overall organic carbon stocks for each scenario

Scenario	Italy Carbon Stock (Mg)
current_potential	106,613,633
2070_26	37,819,974
2070_45	22,790,759
2070_60	16,351,034
2070_85	1,321,102

Table S4: Results of the variable selection procedure implemented for the ENM

Evaluated variables	Included (AUC)	Excluded (AUC)
bio_1, bio_5, bio_6, bio_10, bio_11	bio_10 (0.945)	bio_1 (0.940), bio_5 (0.941), bio_6 (0.894), bio_11 (0.925)
bio_14, bio_15, bio_17, bio_18		bio_14 (0.749), bio_15 (0.750), bio_17 (0.754), bio_18 (0.780)
bio_12, bio_13, bio_16		bio_12 (0.718), bio_13 (0.732), bio_16 (0.717)
bio_2, bio_7	bio_2 (0.854)	bio_7 (0.734)
slope, roughness	roughness (0.838)	slope (0.823)
bio_2, bio_3	bio_3 (0.867)	bio_2 (0.853)
bio_10, elevation	bio_10 (0.944)	elevation (0.943)

List of WORLDCLIM variables:
bio_1 = Annual Mean Temperature
bio_2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
bio_3 = Isothermality (BIO2/BIO7) (* 100)
bio_4 = Temperature Seasonality (standard deviation *100)
bio_5 = Max Temperature of Warmest Month
bio_6 = Min Temperature of Coldest Month
bio_7 = Temperature Annual Range (BIO5-BIO6)
bio_8 = Mean Temperature of Wettest Quarter
bio_9 = Mean Temperature of Driest Quarter
bio_10 = Mean Temperature of Warmest Quarter
bio_11 = Mean Temperature of Coldest Quarter
bio_12 = Annual Precipitation
bio_13 = Precipitation of Wettest Month
bio_14 = Precipitation of Driest Month
bio_15 = Precipitation Seasonality (Coefficient of Variation)
bio_16 = Precipitation of Wettest Quarter
bio_17 = Precipitation of Driest Quarter
bio_18 = Precipitation of Warmest Quarter
bio_19 = Precipitation of Coldest Quarter

Supporting Material Figures

Fig. S1: Multivariate environmental similarity surface (MESS) values considering all the predictors included in the ENM. Legend: blue, positive; white, around zero; orange, negative; with more intense colours indicating more extreme values.

Fig. S2: Multivariate environmental similarity surface (MESS) values considering all the predictors included in the relationship with organic carbon. Legend: blue, positive; white, around zero; orange, negative; with more intense colours indicating more extreme values.

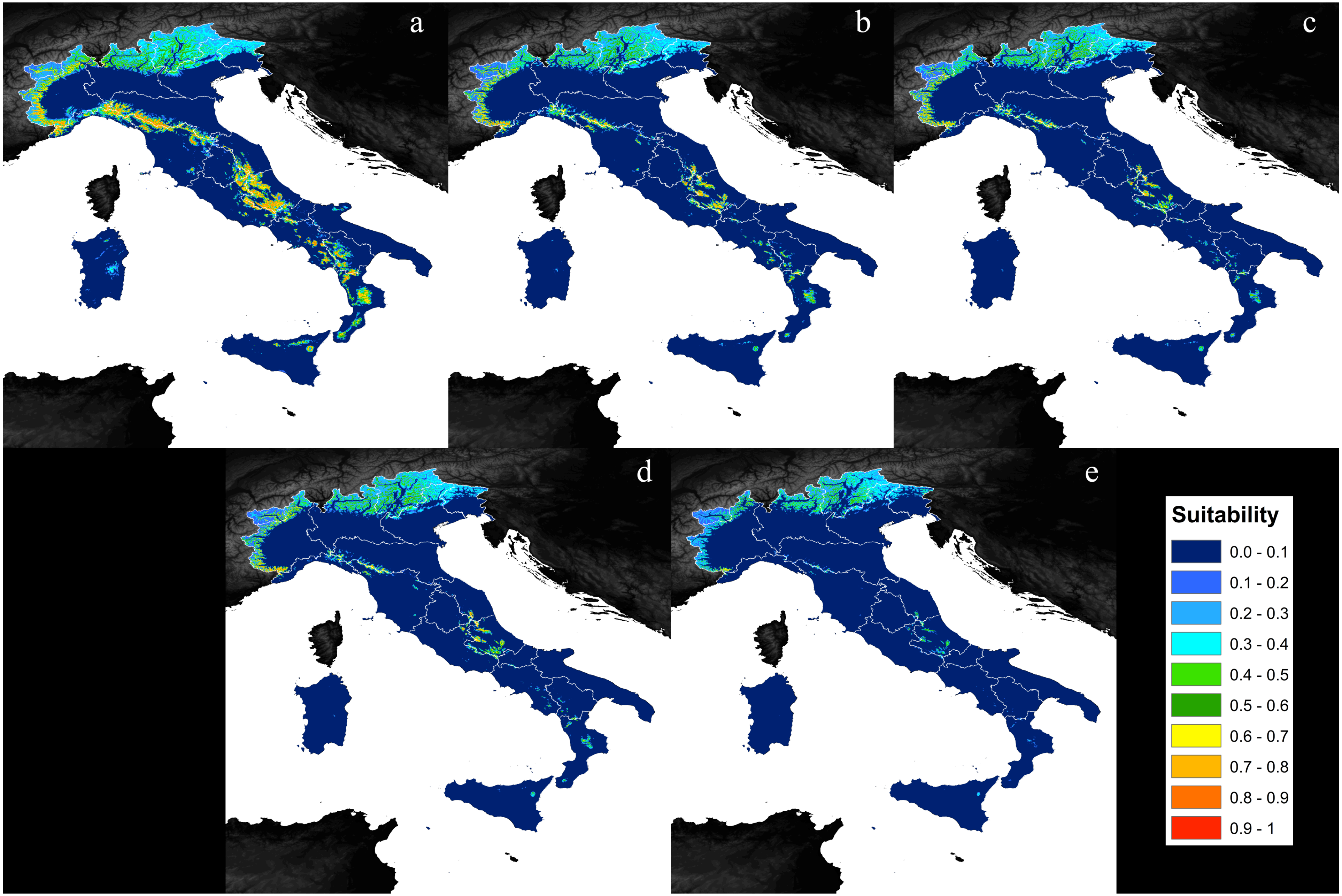

Fig. S3: Probability of occurrence, expressed from 0 (extreme likelihood of absence) to 1 (extreme likelihood of presence) for Beech into actual potential (a) and IPCC scenarios 2070_26 (b), 2070_45 (c), 2070_60 (d) and 2070_85 (e).

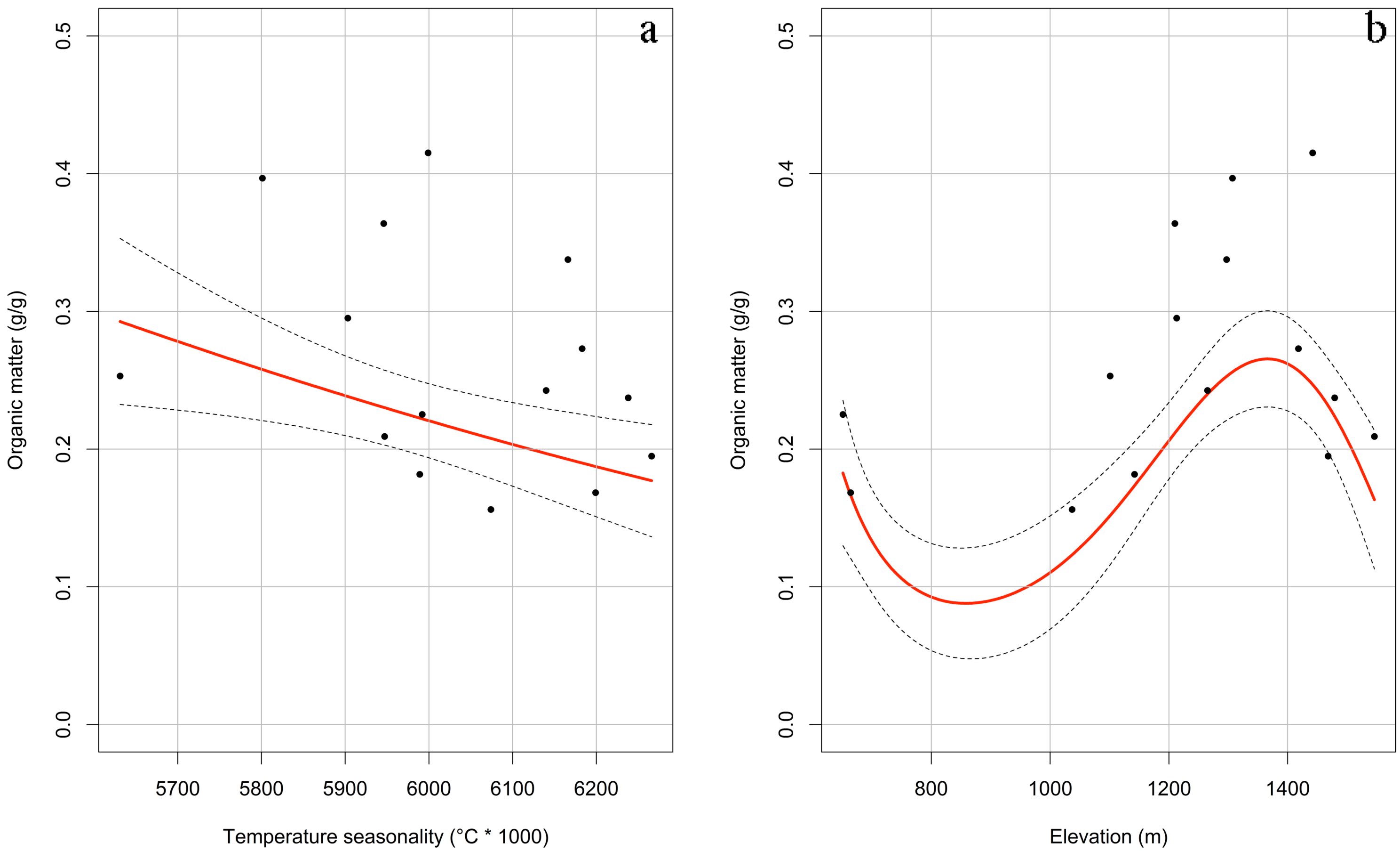

Fig. S4: Plot of the relationship between proportion of organic matter against temperature seasonality and elevation. Dashed lines represent 95% confidence interval.