

Ecography

ECOG-05269

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Supplementary material

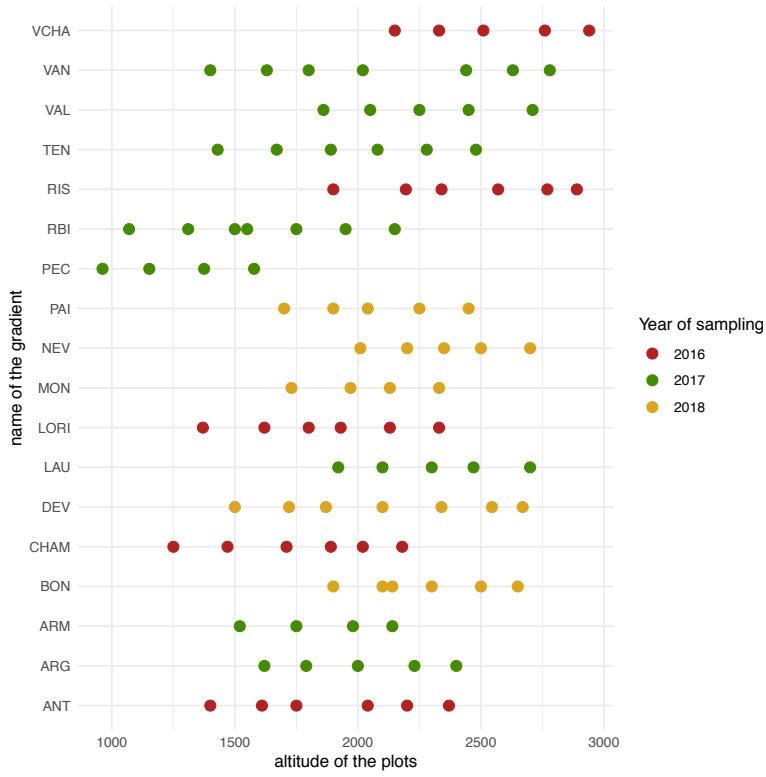
Supplementary material Appendix 1

ORCHAMP: Spatio-temporal observatory of biodiversity and ecosystem functioning of mountains' socio-ecosystems

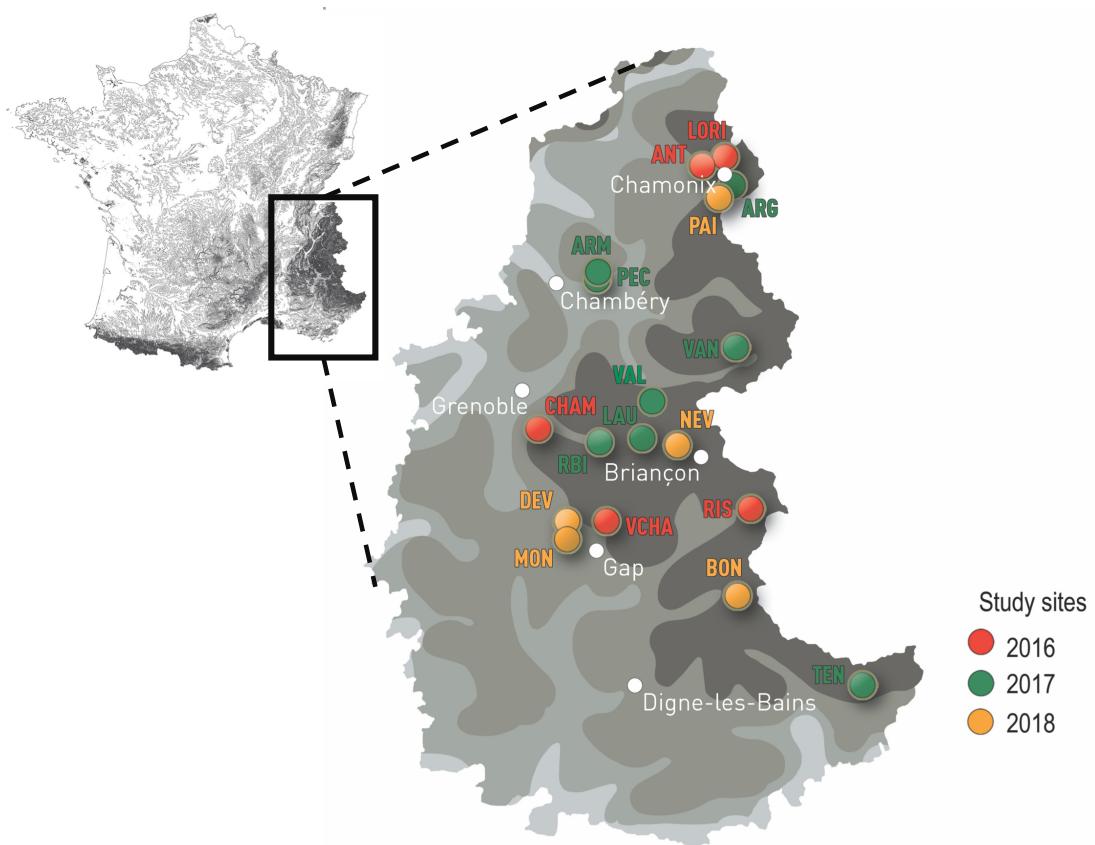
1. Brief description

ORCHAMP is a long-term observatory of mountain ecosystems aiming to observe, understand and model biodiversity and ecosystem functioning over space and time. It relies on the active involvement of local actors, managers and researchers with the objective to better safeguard the contribution of biodiversity to human society.

ORCHAMP is built around multiple elevational gradients representative of the pedo-climatic environmental space of the French Alps (Fig. 1, Fig. A1). In this article we used 18 gradients (Fig. A1). Each gradient consists of 4 to 8 permanent plots distributed regularly each 200 m of altitude, from down the valley to the top (Fig A1, A). They are resampled on average every 5 years using a rotating sampling scheme. In this article no resampling data were used. Measures include physical properties (soil temperature, physicochemical, and pedology), biodiversity estimates (botanical surveys, multi-trophic biodiversity using soil environmental DNA, tree growth, deadwood in forests), ecosystem functions (productivity, enzymatic activities, soil organic matter) and human uses (Fig. A2). Data are open-access and synthetized following GEOBON recommendations on Essential Biodiversity Variables. Specific data used in this paper are described in the main text.



A.



B.

Figure A1: Overview of the 18 gradients of ORCHAMP used in this study: Repartition of the elevations per gradient (A), location of gradients (B), names and year of sampling (A, B).

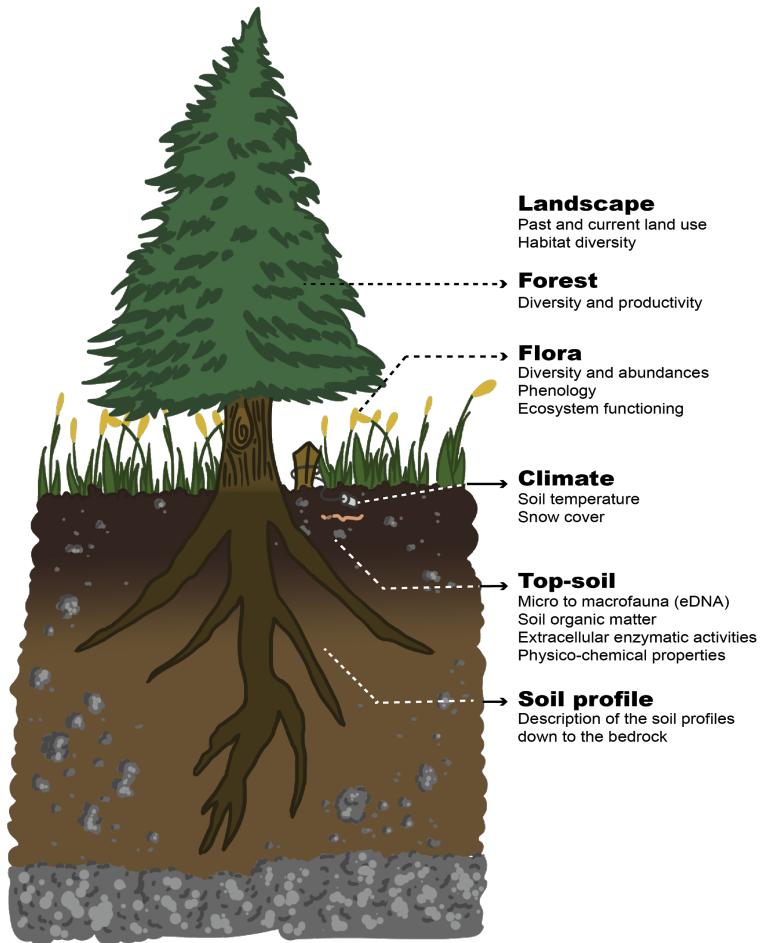


Figure A2: Overview of all measures of landscape, pedo-climatic environment and biodiversity taken on each plot of ORCHAMP

2. Institutions involved in ORCHAMP

ORCHAMP is a consortium gathering a large range of actors: national and regional park managers, botanical conservatory experts, natural area conservatory managers, association, researchers from universities and research institutions. Most of the actors involved in ORCHAMP are also members of the LTSER Zone Atelier Alpes. The project is led by the LECA (Laboratoire d'Écologie Alpine - <https://leca.osug.fr/>), located in Grenoble.

For additional information please visit our website: <https://orchamp.osug.fr/home> or contact us: orchamp@univ-grenoble-alpes.fr

- **LECA** - Laboratoire d'Écologie Alpine; Univ. Grenoble Alpes, CNRS, Univ. Savoie Mont Blanc, Laboratoire d'Ecologie Alpine, Grenoble, France
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- **CBN Alpin** - Conservatoire Botanique National Alpin
<http://www.cbn-alpin.fr/>
- **CBN Med** - Conservatoire Botanique National Méditerranéen de Porquerolles

<http://www.cbnmed.fr/src/prez.php>

- **PN des Ecrins** - Parc National des Ecrins & **RI du Lauvitel** - Réserve intégrale du Lauvitel
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- **CREA** - Centre de Recherches sur les Écosystèmes d'Altitude
<https://creamontblanc.org/fr>
- **Natura 2000 Clarée**
<https://inpn.mnhn.fr/site/natura2000/FR9301499>
- **Natura 2000 Dévoluy-Durbon-Charance-Champsaur**
<http://hautes-alpes.n2000.fr/devoluy>
- **SMIGIBA** - Syndicat Mixte de Gestion Intercommunautaire du Buëch et de ses affluents
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- **Grenoble-Alpes Métropole**
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- **Grenoble-Alpes Métropole:** *Alexandre Mignotte, Pierre-Eymard Biron*

4. ORCHAMP Funding

Each institution involved in the consortium is co-funding the project either through in-kind funding or participation to specific projects.

ANR - Agence Nationale de la Recherche: GlobNets (ANR-16- CE02-0009), Origin-Alps (ANR-16-CE93-004)

ANR ‘Investissement d’Avenir’: Trajectories (ANR-15-IDEX-02), Montane: (OSUG@2020: ANR-10-LAB-56)

AFB - Agence Française pour la Biodiversité: Sentinelles des Alpes

AURA - Région Auvergne-Rhône-Alpes: CBNA regional convention

LTSER ZAA - Zone Atelier Alpes (CNRS, IRSTEA)

Interreg Alcotra FEDER: PITEM Biodiv'ALP

Other local fundings: Parc National des Ecrins (PNE), Réserve intégrale du Lauvitel, Parc National du Mercantour (PNM), Grenoble Alpes Métropole, Agence de l'eau Rhône-Méditerranée Corse (AERMC), Electricité de France (EDF), Mairie du Dévoluy, Institut de Radioastronomie Millimétrique (IRAM), Communauté de communes de la vallée de Chamonix Mont-Blanc

Supplementary material Appendix 2

Table A1: Overview of modelled species, their full names, their average trait values and the total number of occurrences in the 99 plots. *Species abbr.* correspond to the abbreviations used in the paper. *Taxref* corresponds to the French National taxonomic repository (<https://inpn.mnhn.fr/programme/referentiel-taxonomique-taxref>). Traits were retrieved from our own trait database, and averaged at the species level. On average 10 individuals were sampled over different environmental conditions typical for the French Alps following standard protocols. For some species we had to adapt this strategy: We approximated *Cerastium arvense* subsp. *strictum* leaf carbon and nitrogen contents with leaf carbon and nitrogen from *Cerastium arvense* subsp. *suffruticosum*. We retrieved LDMC and SLA for *Melampyrum sylvaticum* and for *Potentilla crantzii* from TRY (www.try-db.org).

Species full names	Species abbr.	Taxref	Leaf Dry Matter Content (mg.g ⁻¹)	Plant Height (cm)	Specific Leaf Area (m.kg ⁻¹)	Leaf C/N	Nb of occurrences
<i>Antennaria dioica</i> (L.) Gaertn.	A. dio	82796	277.44	14	14.3	34.52	28
<i>Anthoxanthum odoratum</i> L.	A. odo	82922	282.05	27.5	29.42	19.89	63
<i>Arnica montana</i> L.	A. mon	83874	162.53	30	20.28	24.67	26
<i>Avenella flexuosa</i> (L.) Drejer	A. fle	85418	307.82	45	3.63	16.63	48
<i>Bistorta vivipara</i> (L.) Delarbre	B. viv	86082	244.67	18.75	15.34	17.49	30
<i>Botrychium lunaria</i> (L.) Sw.	B. lun	86183	193.64	15.67	23.12	9.86	30
<i>Campanula rhomboidalis</i> L.	C. rho	87716	226.31	45	28.74	17.1	21
<i>Chaerophyllum villarsii</i> W. D. J. Koch	C. vil	90359	163.55	75	48.83	11.55	23
<i>Euphrasia minima</i> DC.	E. min	97772	187.84	4	15.75	31.8	30
<i>Festuca laevigata</i> Gaudin	F. lae	98319	314.07	40	8.14	33.91	33
<i>Festuca nigrescens</i> Lam.	F. nig	98404	302.97	45	8.27	31.07	23
<i>Festuca violacea</i> Gaudin	F. vio	98607	356.11	30	6.47	21.8	28
<i>Galium pumilum</i> Murray	G. pum	99511	185.24	25	18.9	19.18	31
<i>Gentiana acaulis</i> L.	G. aca	99854	221.69	9.5	17.53	19.93	23
<i>Geranium sylvaticum</i> L.	G. syl	100160	251.09	50	20.52	21.3	22
<i>Geum montanum</i> L.	G. mon	100208	282.83	10	13.03	33.15	36

<i>Helianthemum nummularium</i> (L.) Mill.	H. num	100956	239.81	16.25	17.32	14.26	24
<i>Homogyne alpina</i> (L.) Cass.	H. alp	102925	235.71	15	11.97	24.46	41
<i>Leontodon hispidus</i> L.	L. his	105502	152.42	27.5	25.93	20.99	29
<i>Melampyrum sylvaticum</i> L.	M. syl	107800	156.15	20	41.4	28.71	23
<i>Myosotis alpestris</i> F. W. Schmidt	M. alp	108987	167.51	11.75	42.5	14.1	26
<i>Nardus stricta</i> L.	N. str	109366	370.62	18.5	5.56	23.75	43
<i>Phleum rhaeticum</i> (Humphries) Rauschert	P. rha	113224	261.81	30	31.74	18.59	23
<i>Phyteuma betonicifolium</i> Vill.	P. bet	113361	218.44	50	30.03	12.03	20
<i>Picea abies</i> (L.) H. Karst.	P. abi	113432	534.81	2500	2.71	39.52	25
<i>Plantago alpina</i> L.	Pl. alp	113806	199.62	7	12.83	22.2	37
<i>Poa alpina</i> L.	P. alp	114105	286.4	23.33	18.98	26.92	39
<i>Potentilla aurea</i> L.	P. aur	115414	283.6	15	20.56	17.01	36
<i>Potentilla crantzii</i> (Crantz) Fritsch	P. cra	115449	327.26	13.33	15.22	17.96	21
<i>Potentilla grandiflora</i> L.	P. gra	115498	327.21	22.5	14.53	19.33	33
<i>Sesleria caerulea</i> (L.) Ard.	S. cae	123071	325.89	27.5	19.37	27.53	23
<i>Soldanella alpina</i> L.	S. alp	124139	242.22	9	12.22	25.71	23
<i>Thymus pulegioides</i> L.	T. pul	126566	314.33	11.83	14.67	20.99	23
<i>Trifolium alpinum</i> L.	T. alp	127219	294.34	11.25	22.22	15.87	24
<i>Trifolium pratense</i> L.	T. pra	127439	230.78	25.67	28.62	13.52	21
<i>Vaccinium myrtillus</i> L.	V. myr	128345	312.1	27.5	19.96	28.87	53
<i>Vaccinium vitis-idaea</i> L.	V. vit	128355	374.12	12	9.91	55.9	22
<i>Viola calcarata</i> L.	V. cal	129527	185.19	9.25	22.54	19.99	37
<i>Campanula scheuchzeri</i> Vill.	C. sch	132522	269.26	20	16.15	20.1	54
<i>Carex sempervirens</i> Vill.	C. sem	132810	347.93	30	13.6	30.53	51
<i>Cerastium arvense</i> L.	C. arv	133087	212.58	10	22.06	22.39	39
<i>Juniperus communis</i> L.	J. com	136974	500.95	40	1.96	51.02	25
<i>Lotus corniculatus</i> L.	L. cor	137438	202.18	5	17.83	10.11	37
<i>Scorzonera pyrenaica</i> (Gouan) Holub	S. pyr	612627	174.32	12	22.14	23.8	23

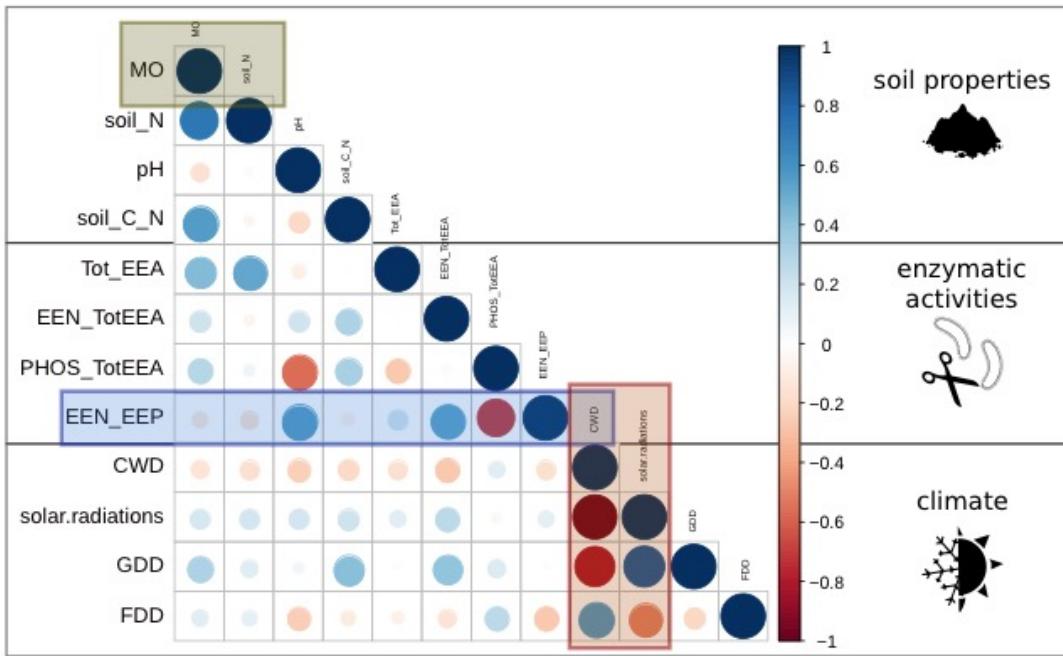


Figure A3: Pairwise correlations between environmental variables. We used the `findCorrelation` function of the package `caret` in R to identify which variables to remove to reduce pairwise correlations below 0.6 (Kuhn 2008). The selection was in line with ecological arguments for the variable importance for plant distributions, given the data and the literature. Indeed, one variable characterizing soil properties, soil organic matter (MO, highlighted by the kaki box), one variable characterizing enzymatic activities, the ratio of enzymatic activities targeting nitrogen and phosphorous (EEN/EEP, highlighted by the blue box) and two variables characterizing climate, climatic water deficit and solar radiations (respectively CWD & solar.radiations, highlighted by the red box) were removed, which conserved the balance between the three categories of predictors. Moreover, among variables characterizing soil properties, MO was only a weak predictor of alpine plant distributions in the literature (Vonlanthen et al. 2006, Dubuis et al. 2013, Buri et al. 2017, 2020). Among the variables characterizing enzymatic activities, we expected EEN/EEP to be associated with plant distributions through an indirect mechanism (see Introduction). Among the variables characterizing climate, although solar radiation was theoretically crucial for plant growth (Körner 2003), it was rarely reported as a significant driver of their distributions (Vonlanthen et al. 2006, Choler 2018). Besides, although water availability is crucial for plant distributions, we approximated it in this paper through CWD, which we calculated from air

temperature and which we could not measure in situ. Therefore, it seems reasonable to drop solar radiation and CWD in favor to simpler climatic variables as GDD and FDD as advised by Choler (2018).

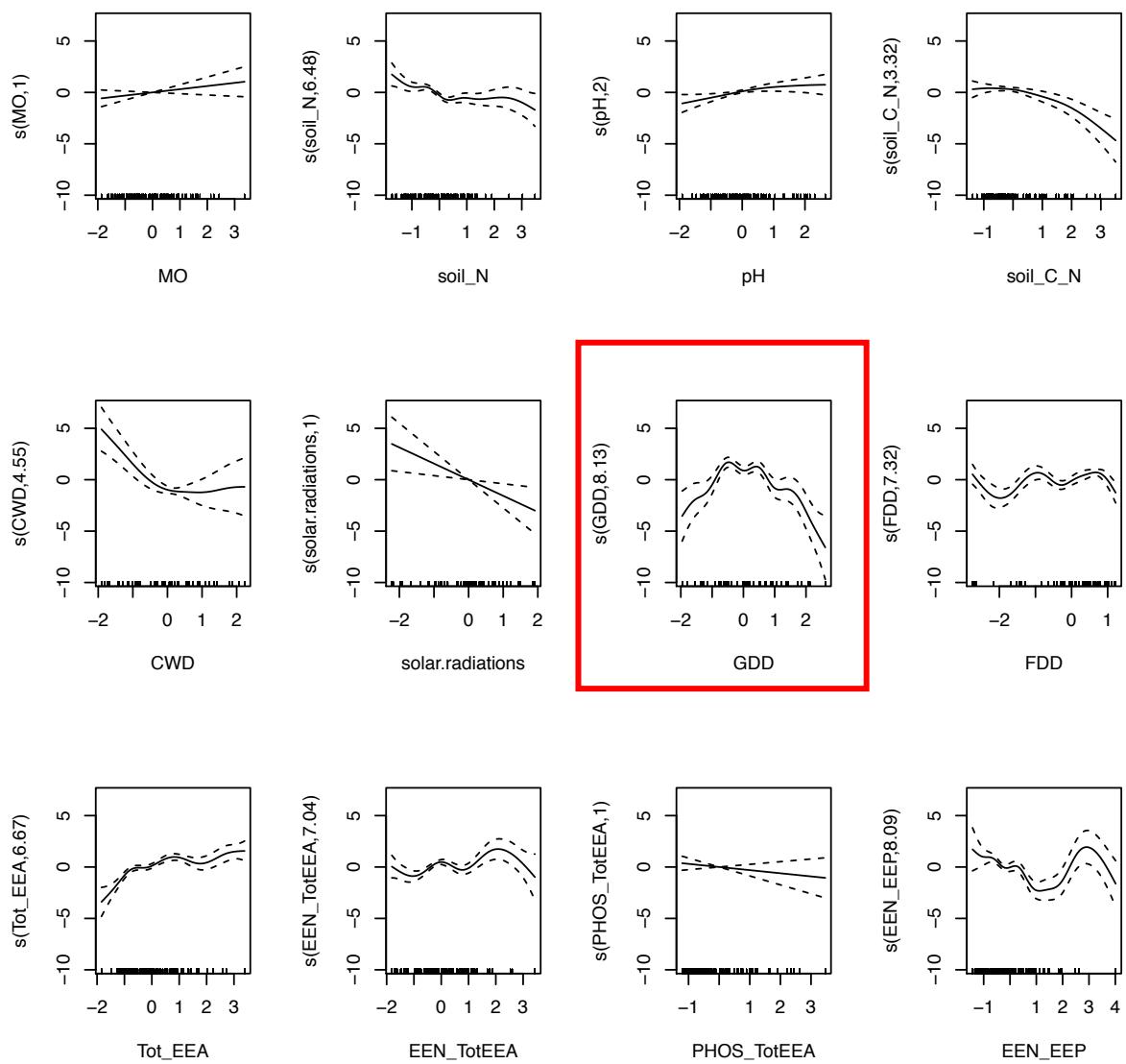


Figure A4: Partial response curves of the selected 44 species to all environmental variables from a generalized additive mixed-effect model. From this, we visually determined that only GDD needed to be modelled with a quadratic term, which is highlighted with a red frame.

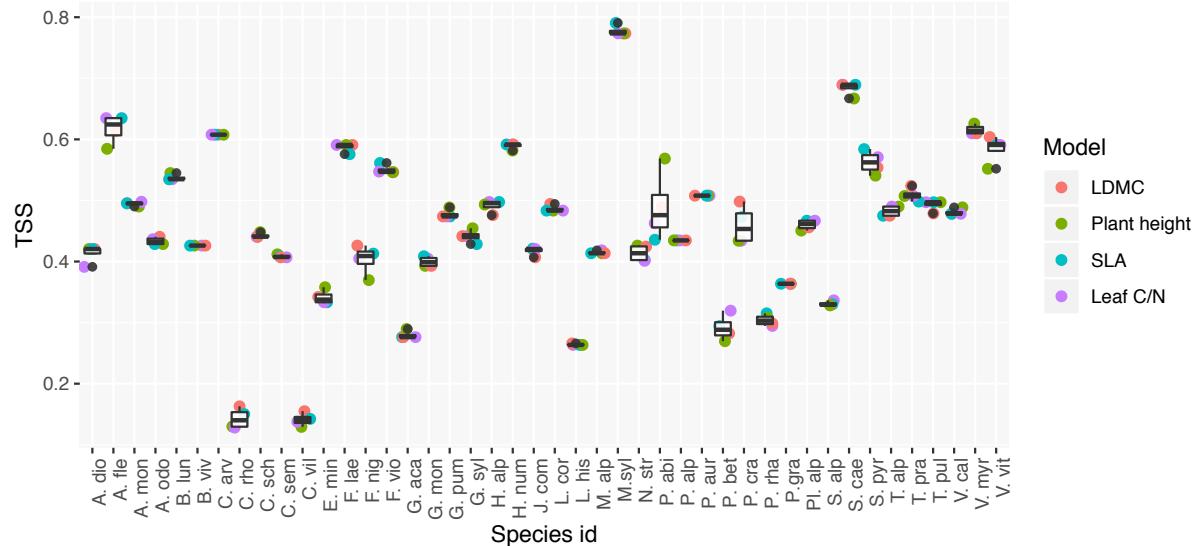
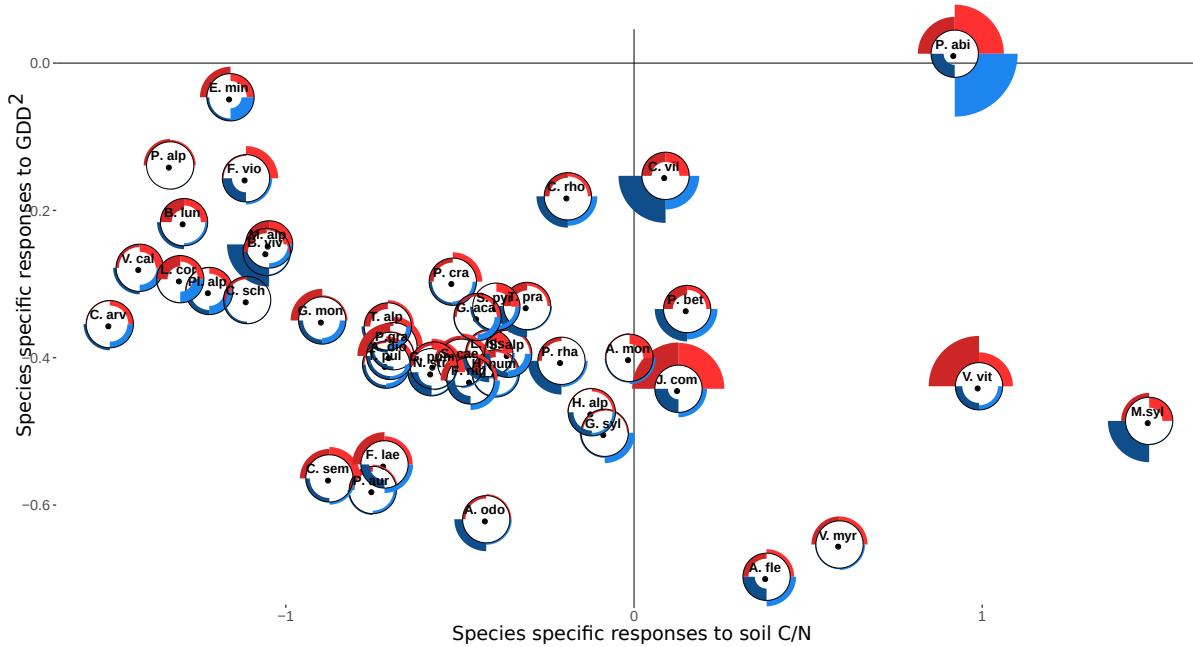


Figure A5: Predictive ability of the hierarchical trait-based species distribution models (independently done for the four traits) as measured by the true skill statistics (TSS). The box corresponds to the median and quartiles across the four models and each colored point corresponds to the TSS value for each trait-specific model.

A.



B.

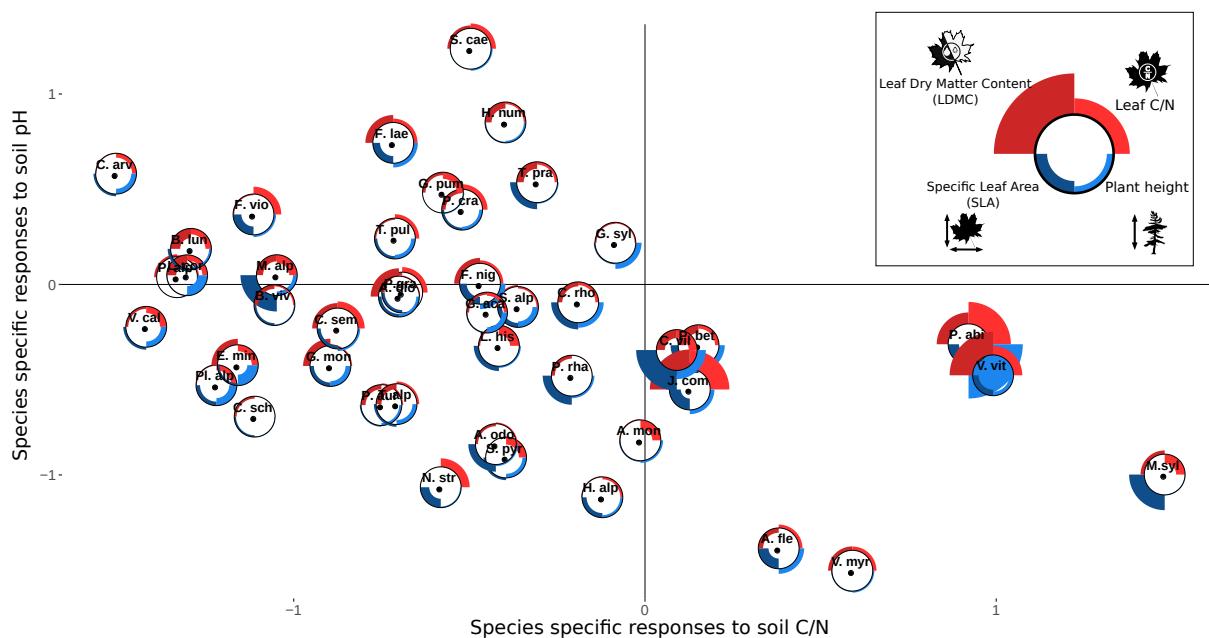


Figure A6: Species-specific partial responses to pairs of environmental gradients, represented by a dot per species. A. GDD² plotted against soil C/N. B. pH plotted against soil C/N. Each functional trait of each species is represented by a quarter of a pie-chart centered on the species dot (SLA: dark blue; plant height: light blue; leaf dry matter content: dark red; leaf C/N: light red, as represented with the example of *Vaccinium vitis-idaea* on the right-up box). For each trait, the dark circle of the pie-charts represents the average of the trait in the dataset.

For a given species and a given trait, the colored quarter being within or outside the circle means that this trait value of the species is respectively below or above the dataset average for this trait. Full species names are given in Supplementary material Appendix 2 Table A1.

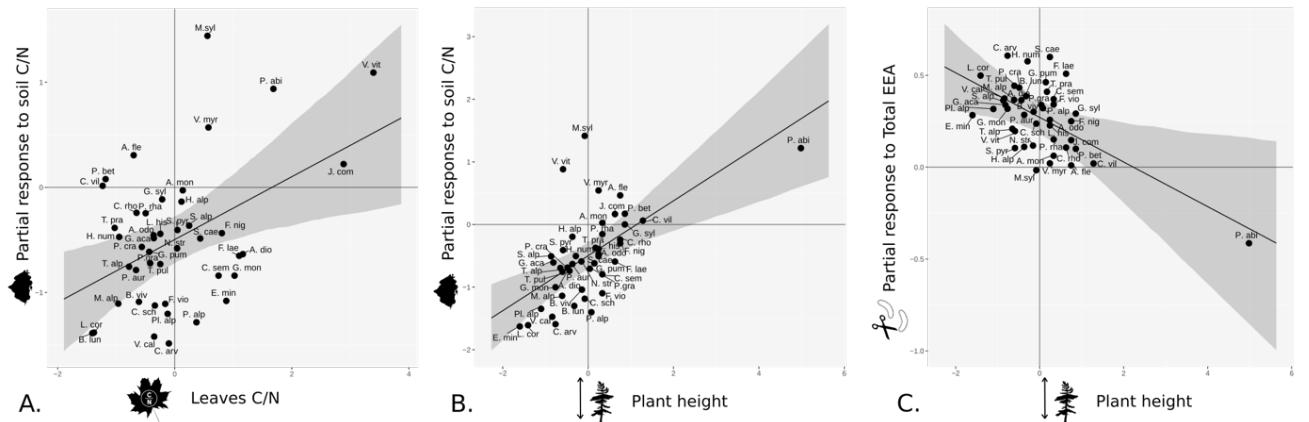


Figure A7: Species partial responses to environmental variables as a function of their functional traits. A. Soil C/N plotted against leaf C/N (model 4); B. Soil C/N plotted against plant height (model 2), C. Total enzymatic activity plotted against plant height (model 3).