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Global trait–environment relationships of plant communities

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Supplementary Information

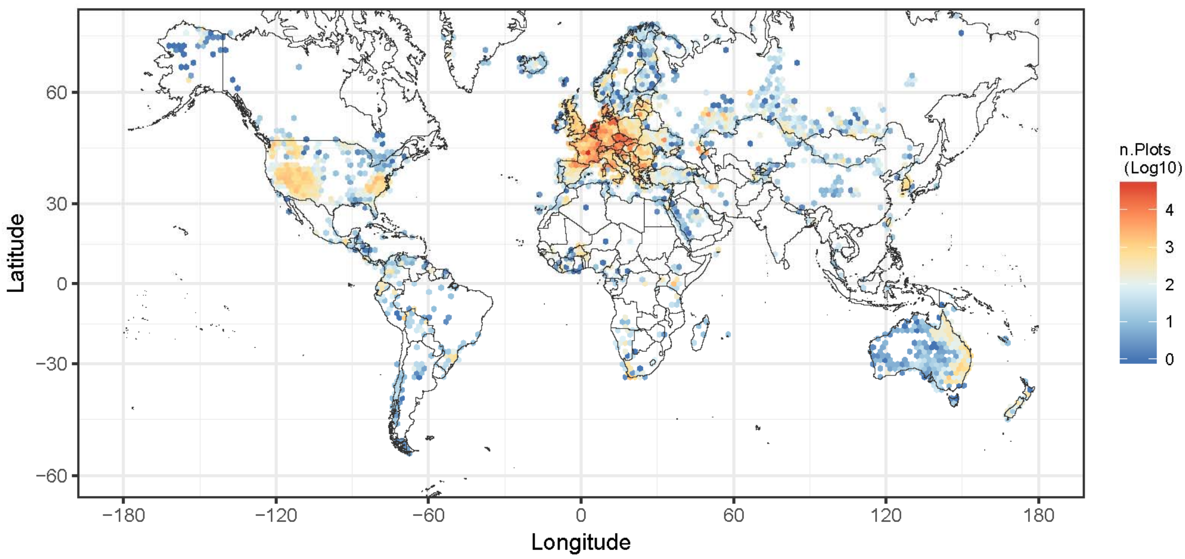
Supplementary Table 1: Per cent coverage of the sPlot 2.1 database with original trait values, with respect to species for which original trait values were measured in TRY (of a total of 58,065 species in sPlot 2.1), to species × plot observations for which original trait values were available (of a total of 21,050,514 observations) and to plots (of a total of 1,104,219 plots for which coordinates and environmental information was available). For a comparison with gap-filled trait values, per cent coverage across all species is 45.87%, per cent coverage of all species × plot occurrences is 88.7%, and per cent coverage of plots is 100%.

Trait	Abbreviation	Coverage of species %	Coverage of occurrences %	Coverage of plots %
Leaf area	LA	37.38	87.11	99.65
Specific leaf area	SLA	34.66	89.16	100.00
Leaf fresh mass	Leaf.fresh.mass	7.04	47.89	88.79
Leaf dry matter content	LDMC	15.89	81.94	97.78
Leaf C	LeafC	15.14	65.60	95.97
Leaf N	LeafN	28.27	77.57	99.16
Leaf P	LeafP	18.53	60.99	96.54
Leaf N per area	LeafN.per.area	18.51	60.78	94.98
Leaf N:P ratio	Leaf.N:P.ratio	12.53	45.32	93.58
Leaf $\delta^{15}N$	Leaf.delta15N	7.14	11.10	72.28
Seed mass	Seed.mass	59.64	91.18	99.65
Seed length	Seed.length	9.35	75.01	93.82
Seed number per reproductive unit	Seed.num.rep.unit	7.22	72.82	92.71
Dispersal unit length	Disp.unit.length	11.40	81.36	93.82
Plant height	Plant.height	58.03	96.58	99.90
Stem specific density	SSD	22.35	29.26	86.75
Stem conduit density	Stem.cond.dens	15.24	10.88	53.15
Conduit element length	Cond.elem.length	13.18	7.62	48.20

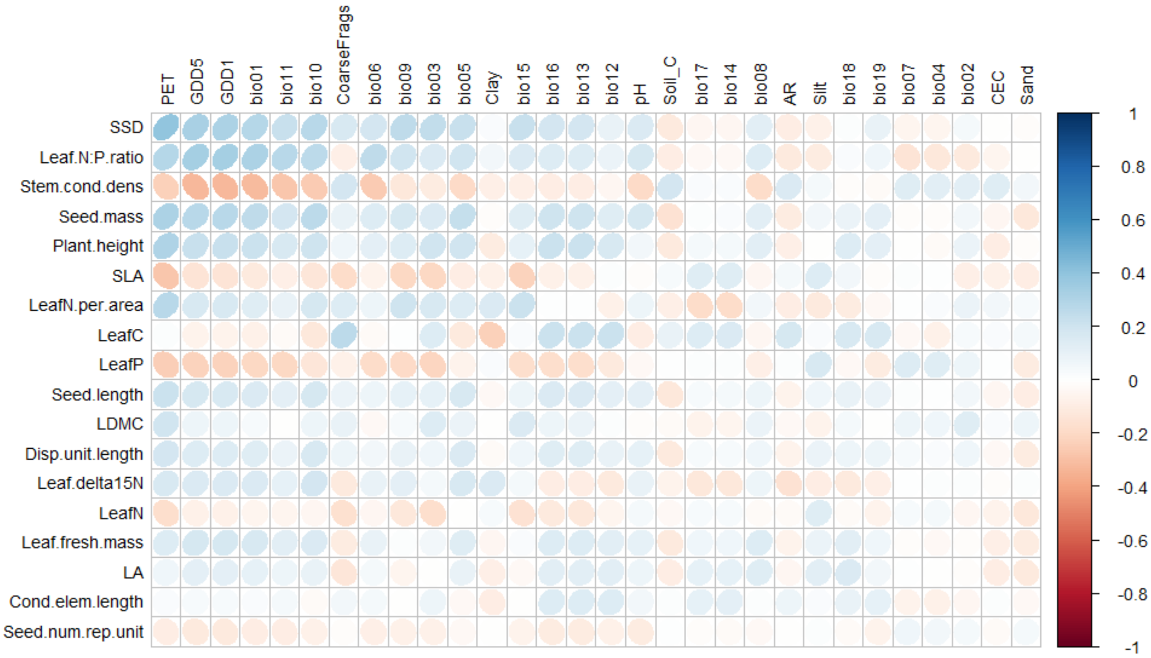
Supplementary Table 2: Environmental variables used as predictors. Climate data were obtained from CHELSA[38,39] (www.chelsa-climate.org), GDD1 and GDD5 were calculated from CHELSA data, based on monthly temperature and precipitation values for the years 1979–2013[40-41]. The index of aridity (AR) and potential evapotranspiration (PET) were extracted from the CGIAR-CSI website (www.cgiar-csi.org). Soil variables were obtained from the SOILGRIDS project (https://soilgrids.org/) and reflect mean values expected at 0.15 m depth.

Variable	Abbreviation	Unit	Data source
Annual Mean Temperature	Bio01	°C*10	CHELSA
Mean Diurnal Range (Mean of monthly (maximum temperature - minimum temperature))	Bio02	°C	CHELSA
Isothermality (bio2/bio7) (* 100)	Bio03	-	CHELSA
Temperature Seasonality (standard deviation of monthly temperature averages)	Bio04	°C*100	CHELSA
Max Temperature of Warmest Month	Bio05	°C*10	CHELSA
Min Temperature of Coldest Month	Bio06	°C*10	CHELSA
Temperature Annual Range (bio5-bio6)	Bio07	°C*10	CHELSA
Mean Temperature of Wettest Quarter	Bio08	°C*10	CHELSA
Mean Temperature of Driest Quarter	Bio09	°C*10	CHELSA
Mean Temperature of Warmest Quarter	bio10	°C*10	CHELSA
Mean Temperature of Coldest Quarter	bio11	°C*10	CHELSA
Annual Precipitation	bio12	mm/year	CHELSA
Precipitation of Wettest Month	bio13	mm/month	CHELSA
Precipitation of Driest Month	bio14	mm/month	CHELSA
Precipitation Seasonality	bio15	coefficient of variation	CHELSA
Precipitation of Wettest Quarter	bio16	mm/quarter	CHELSA
Precipitation of Driest Quarter	bio17	mm/quarter	CHELSA
Precipitation of Warmest Quarter	bio18	mm/quarter	CHELSA
Precipitation of Coldest Quarter	bio19	mm/quarter	CHELSA
Growing degree days above 1°C	GDD1	°C days	calculated
Growing degree days above 5°C	GDD5	°C days	calculated
Index of aridity	AR	(*10,000)	CGIAR-CSI

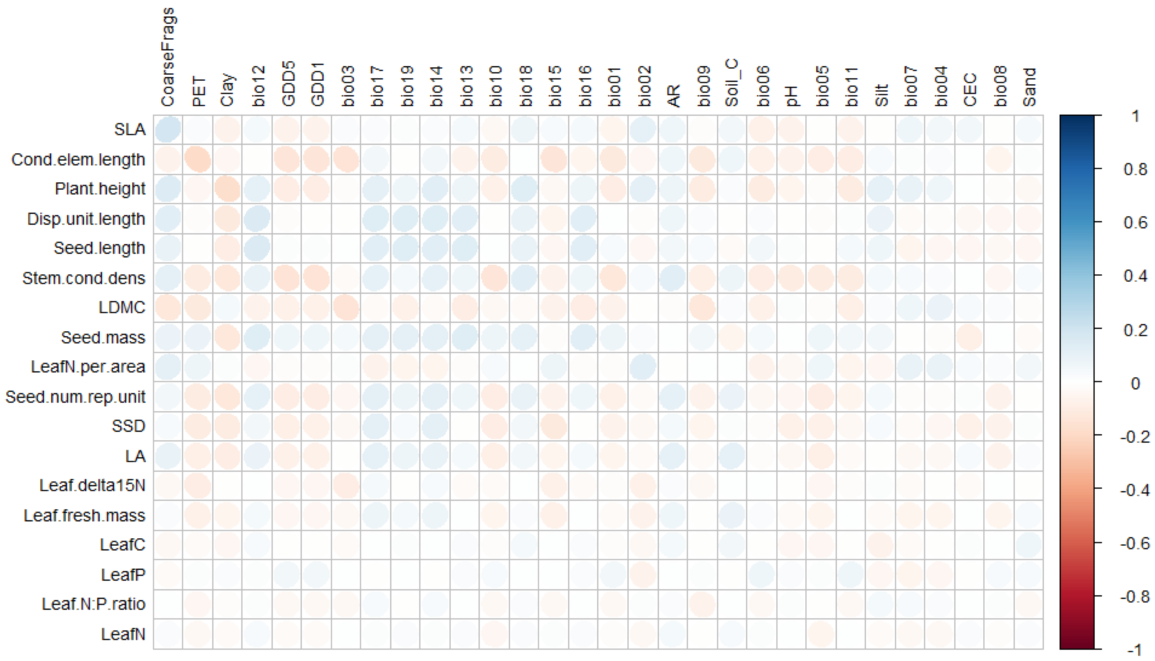
Potential evapotranspiration	PET	mm/year	CGIAR-CSI
Cation exchange capacity of soil	CEC	$cmol_c\ kg^{-1}$	SOILGRIDS
Soil pH	pH	(*10)	SOILGRIDS
Coarse fragment volume	CoarseFrags	vol. %	SOILGRIDS
Soil organic carbon content in the fine earth fraction	Soil_C	$g\ kg^{-1}$	SOILGRIDS
Clay content (0–2 µm)	Clay	mass fraction %	SOILGRIDS
Silt content (2–50 µm)	Silt	mass fraction %	SOILGRIDS
Sand content (50–2000 µm)	Sand	mass fraction %	SOILGRIDS



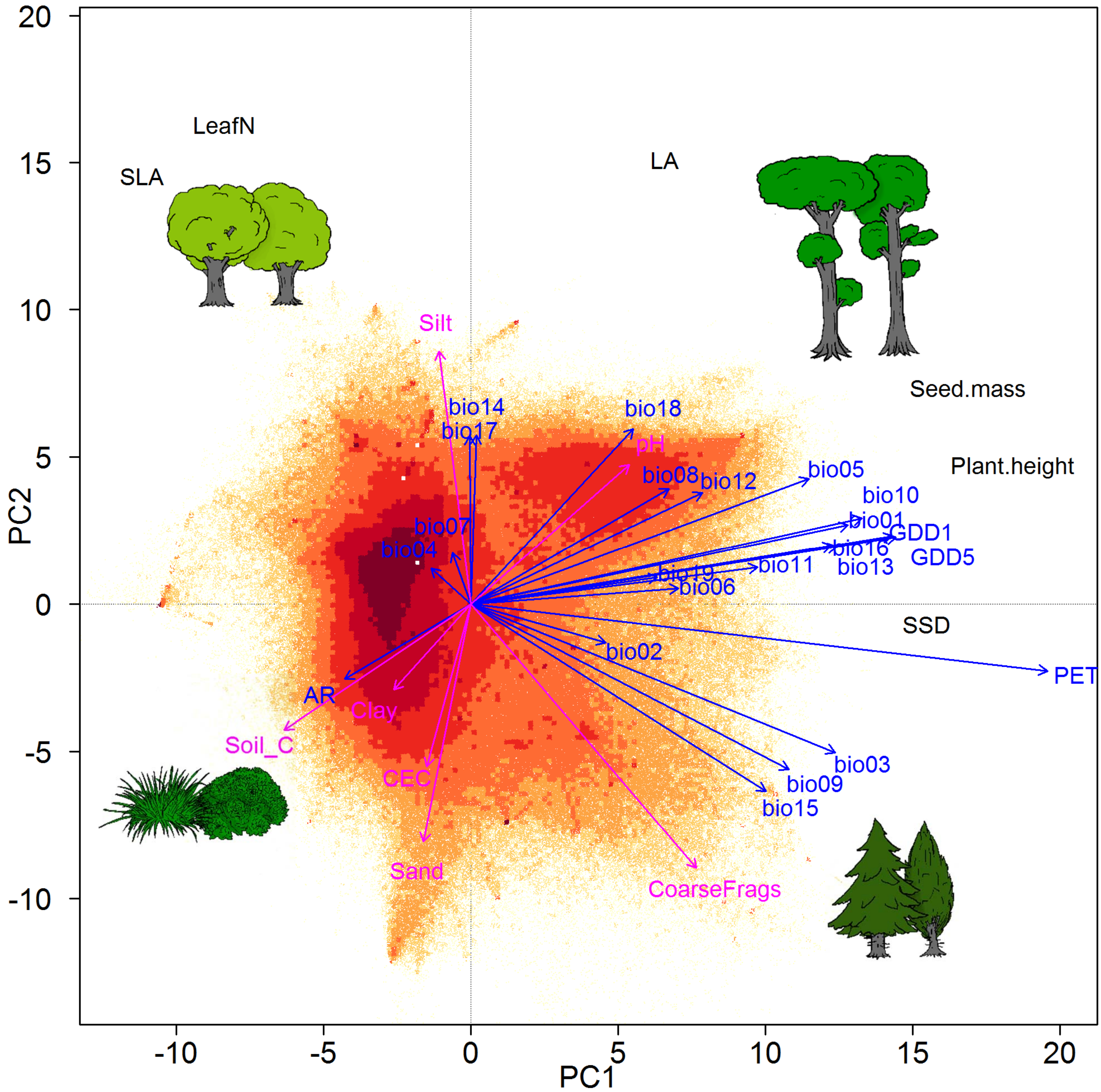
Supplementary Fig. 1: Distribution of plots in sPlot 2.1. The map shows plot density in a Mercator projection with a hexagonal grid with a radius of 120.14 km, corresponding to 5000 km^2 per grid cell at the equator. Hexagons at 60° latitude have a size of 1250 km^2.



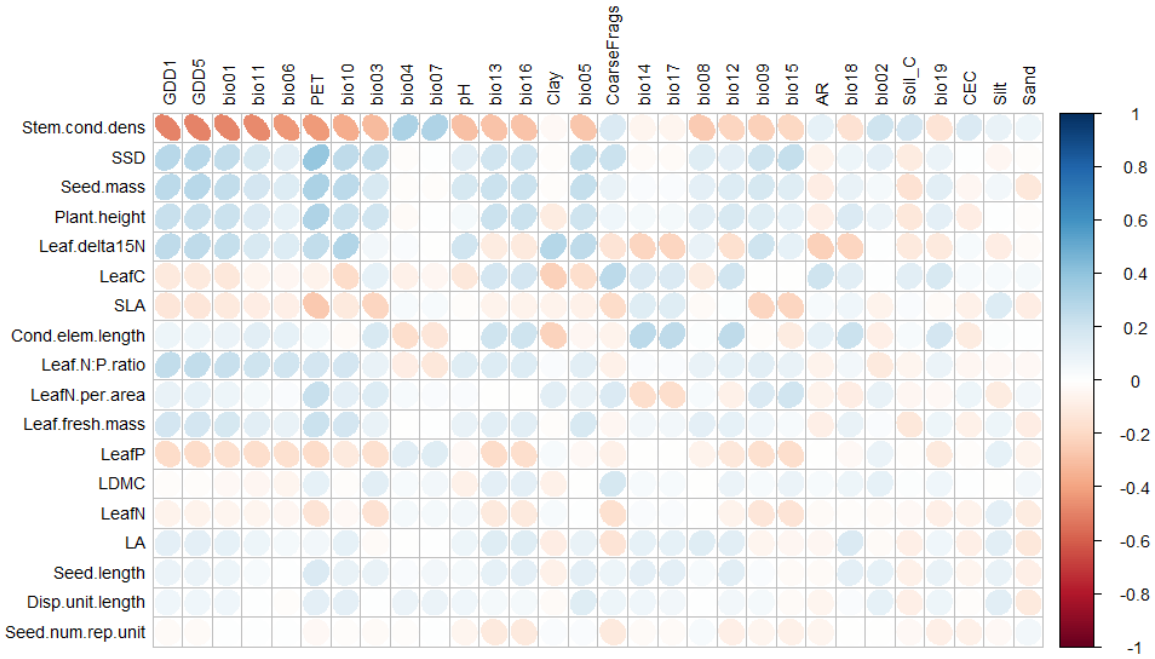
Supplementary Fig. 2: Visualisation of the Pearson correlation matrix of plot-level trait means (community-weighted means, CWMs) of all 18 traits (rows) in the entire dataset (n = 1,114,304) with all 30 environmental predictors (columns). Positive correlations are shown in blue, negative ones in red colour, with increasing colour intensity as the correlation value moves away from 0. The eccentricity of the ellipses is scaled to the absolute value of the correlation[51]. Rows and columns are arranged from top to bottom and from left to right according to decreasing absolute correlation values. The highest correlation coefficient (between stem specific density and PET) was 0.395 (r^2=0.156). The best predictors for the plant height and seed mass trade-off were potential evapotranspiration (PET) and growing degree days above 5°C (GDD5), with r^2=0.093 and 0.052 for plant height and r^2=0.099 and 0.074 for seed mass, respectively. The best predictors for traits of the leaf economics spectrum were PET and the seasonality in precipitation (bio15), with r^2=0.078 and 0.051 for specific leaf area (SLA) and r^2=0.039 and 0.024 for leaf dry matter content (LDMC), respectively. See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



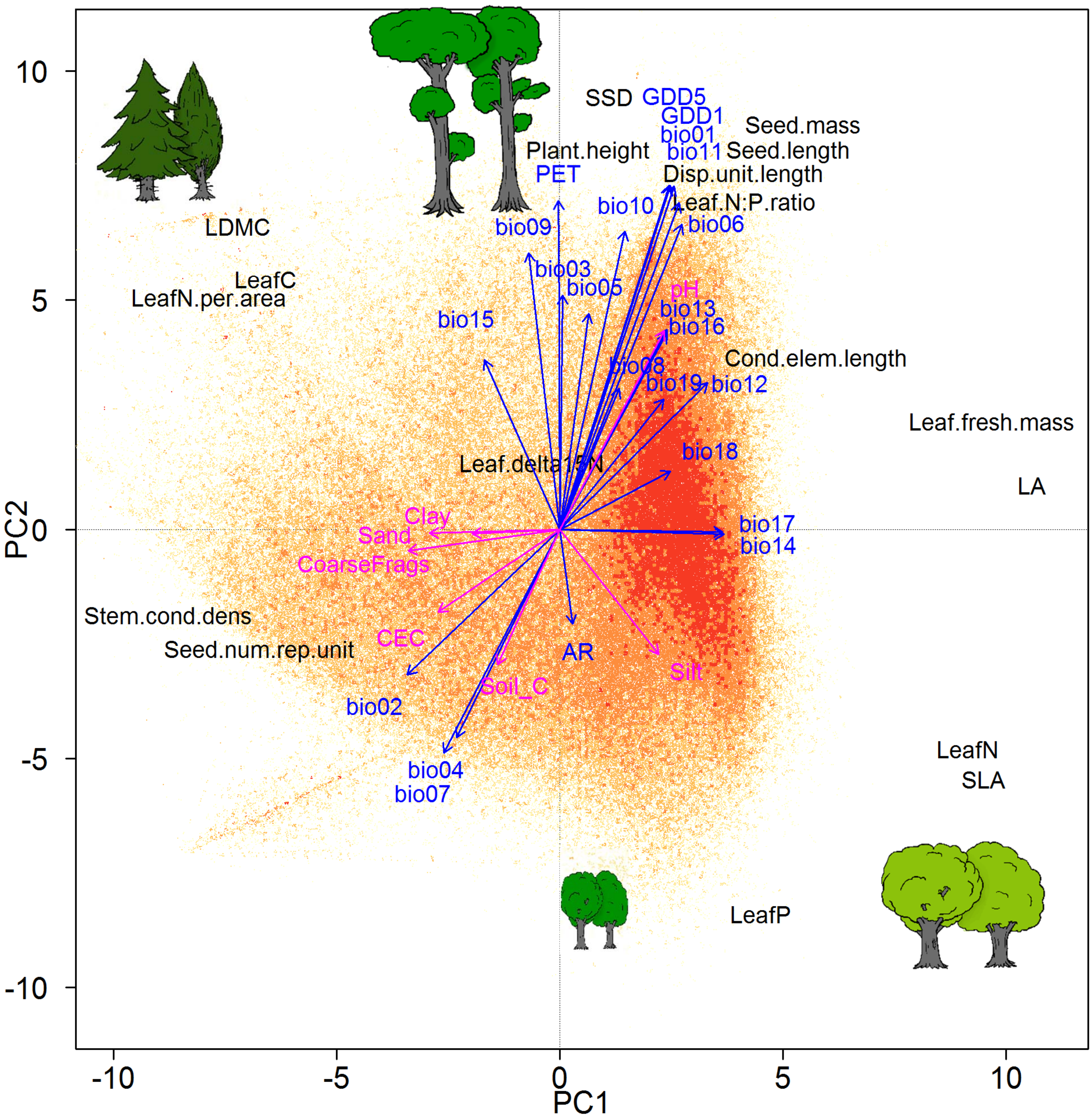
Supplementary Fig. 3: Visualisation of the Pearson correlation matrix of within-plot trait variances (community-weighted variances, CWVs) of all 18 traits (rows) in the entire dataset (n = 1,098,015) with all environmental predictors (columns). Positive correlations are shown in blue, negative ones in red colour, with increasing colour intensity as the correlation value moves away from 0. The eccentricity of the ellipses is scaled to the absolute value of the correlation[51]. Rows and columns are arranged from top to bottom and from left to right according to decreasing absolute correlation values. The highest correlation coefficient was encountered between specific leaf area (SLA) and the volumetric content of coarse fragments in the soil CoarseFrags, r^2=0.036), followed by the correlation of PET to CWV of conduit element length (r^2=0.035). See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



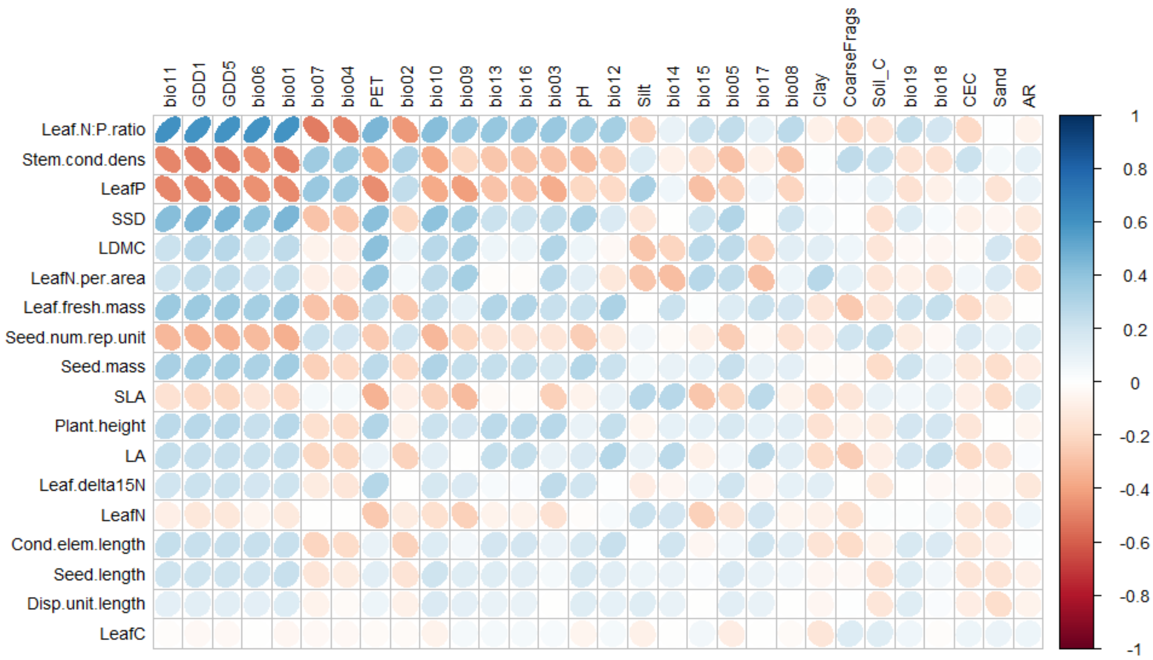
Supplementary Fig. 4: Principal Component Analysis of global plot-level trait means (community-weighted means, CWMs), based on the original trait values measured for the species from the TRY database for the six traits used by Díaz et al.[1] (leaf area, specific leaf area, leaf N, seed mass, plant height and stem specific density). The plots (n = 954,459) are shown by coloured dots, with shading indicating plot density on a logarithmic scale, ranging from yellow with 1–8 plots at the same position to dark red with 501–1626 plots. Post-hoc correlations of PCA axes with climate and soil variables are shown in blue and magenta, respectively. Arrows are enlarged in scale to fit the size of the graph; thus, their lengths show only differences in variance explained relative to each other. Variance in CWM explained by the first and second axis was 43.5% and 30.9%, respectively. The vegetation sketches schematically illustrate the size continuum (short *vs.* tall) and the leaf economics continuum (low *vs.* high SLA and leaf N content per dry mass in dark and light green colours, respectively). See Table 1, 2 and Supplementary Tables 2 for the description of traits and environmental variables and compare with Fig. 2 for the same analyses with 18 traits based on gap-filled trait-data.



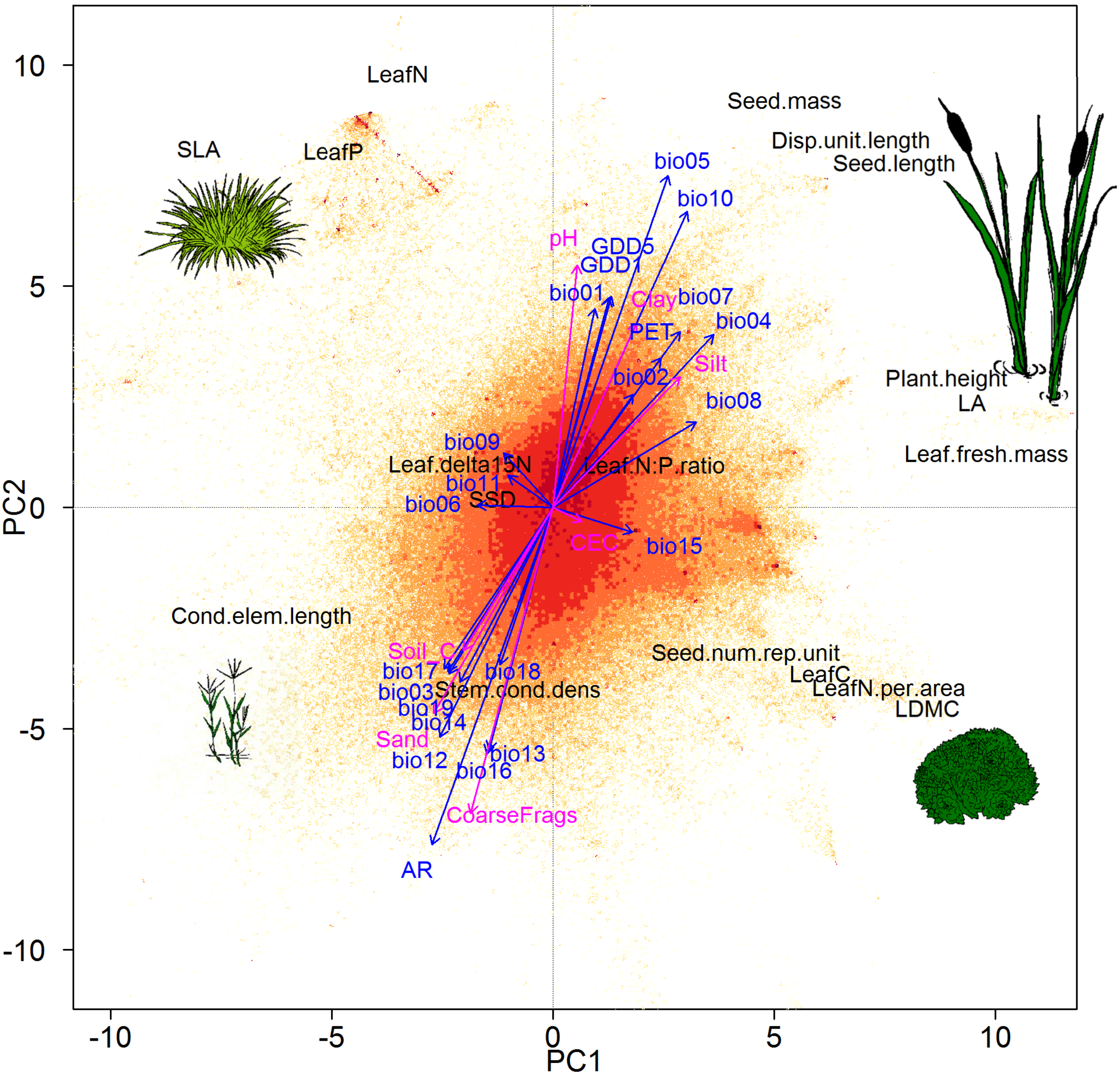
Supplementary Fig. 5: Visualisation of the Pearson correlation matrix of plot-level trait means (community-weighted means, CWMs) of all 18 traits (rows) based on the original trait values measured for the species from the TRY database in the entire dataset (n = 1,104,219) with all 30 environmental predictors (columns). Positive correlations are shown in blue, negative ones in red colour, with increasing colour intensity as the correlation value moves away from 0. The eccentricity of the ellipses is scaled to the absolute value of the correlation[51]. Rows and columns are arranged from top to bottom and from left to right according to decreasing absolute correlation values. The highest correlation coefficient was encountered for Stem conduit density and growing degree days above 1°C (GDD1, r^2=0.242), with similarly high coefficients of determination for growing degree days above 5°C (GDD5), mean annual temperature (bio1) and mean temperature of the coldest quarter (bio 11). There was also a high correlation of stem specific density and PET (r^2=0.152). The best predictors for the plant height and seed mass trade-off were potential evapotranspiration (PET) and growing degree days above 5°C (GDD5), with r^2=0.093 and 0.051 for plant height and r^2=0.099 and 0.074 for seed mass, respectively. The best predictors for traits of the leaf economics spectrum were PET and the seasonality in precipitation (bio15), with r^2=0.068 and 0.047 for specific leaf area (SLA), respectively. See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



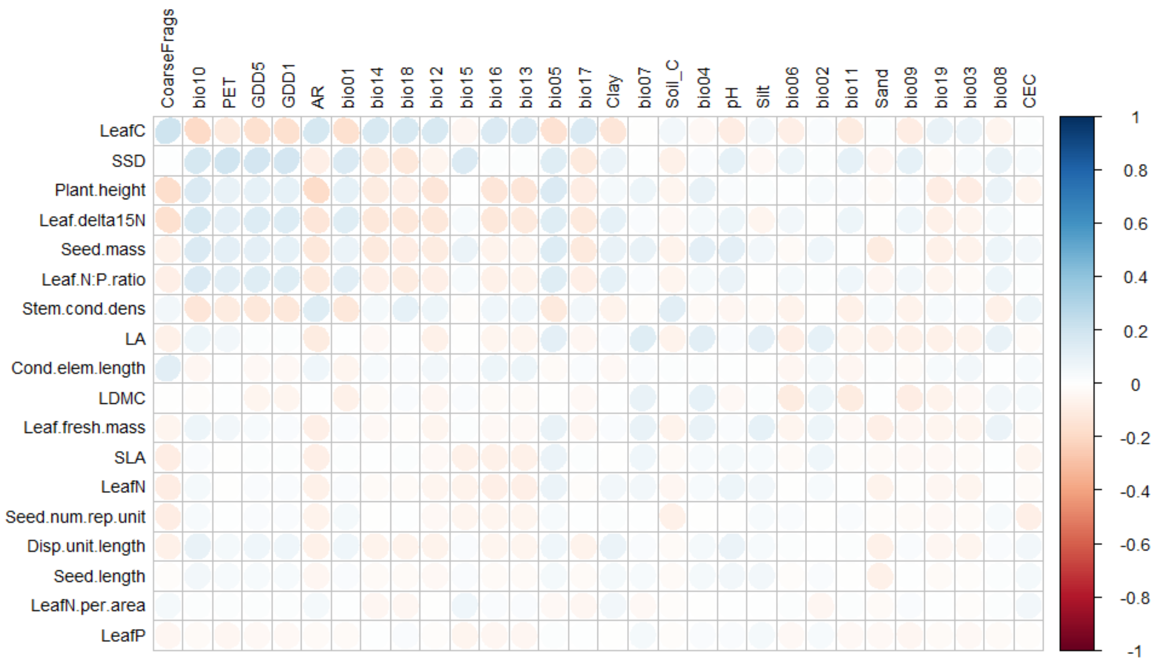
Supplementary Fig. 6: Principal Component Analysis of plot-level trait means (community-weighted means, CWM) of forest communities only in the dataset. The plots (n = 330,873) are shown by coloured dots, with shading indicating plot density on a logarithmic scale, ranging from yellow with 1–4 plots at the same position to dark orange with 32–453 plots. Post-hoc correlations of PCA axes with climate and soil variables are shown in blue and magenta, respectively. Arrows are enlarged in scale to fit the size of the graph; thus, their lengths show only differences in variance explained relative to each other. Variance in CWM explained by the first and second axis was 32.9% and 27.6%, respectively. The vegetation sketches schematically illustrate low and high variation in the plant size and leaf economics continua. See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



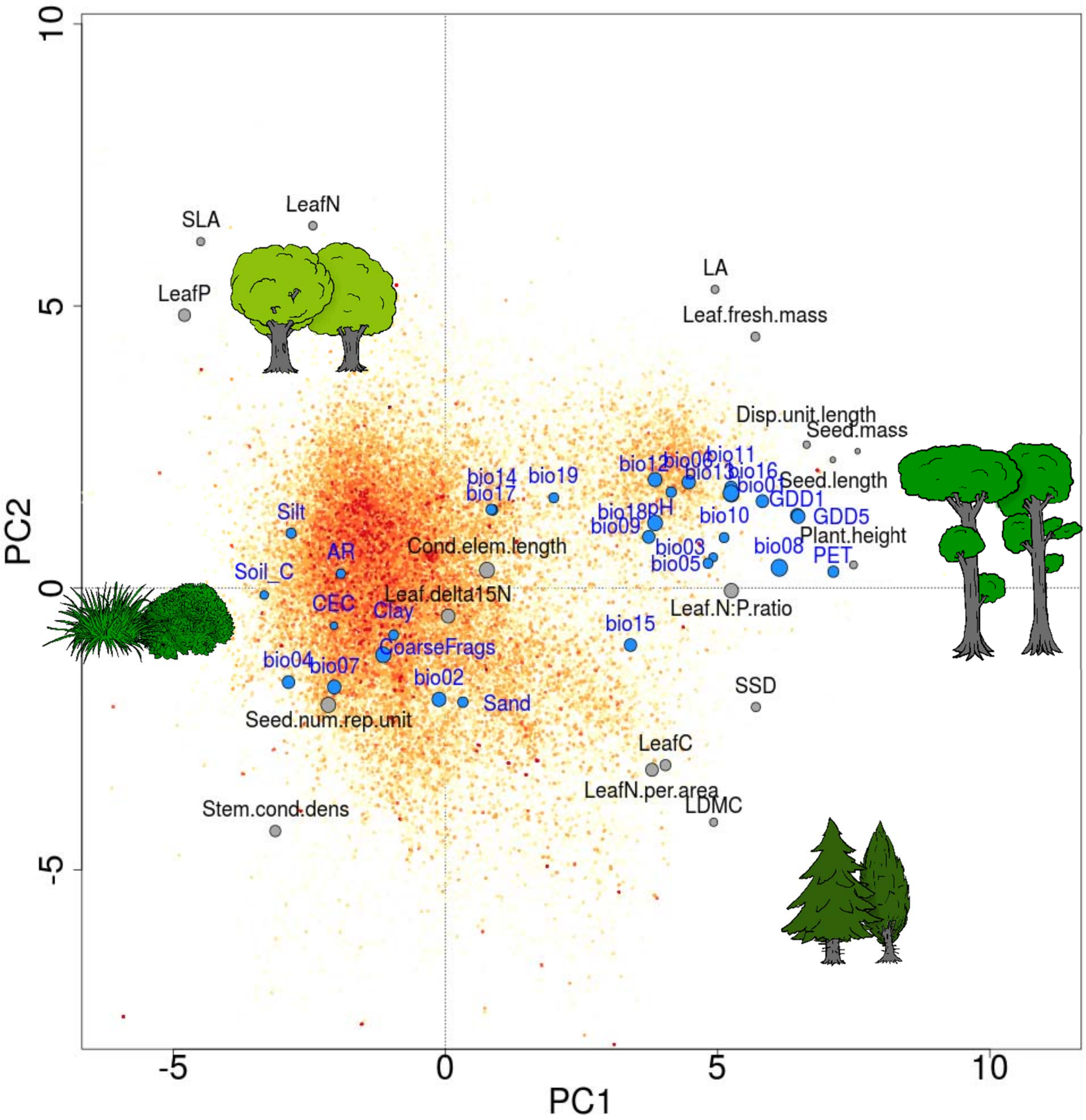
Supplementary Fig. 7: Visualisation of the Pearson correlation matrix of plot-level trait means (community-weighted means, CWMs) of all 18 traits (rows) of forest communities only in the dataset (n = 330,873) with all environmental predictors (columns). Positive correlations are shown in blue, negative ones in red colour, with increasing colour intensity as the correlation value moves away from 0. The eccentricity of the ellipses is scaled to the absolute value of the correlation[51]. Rows and columns are arranged from top to bottom and from left to right according to decreasing absolute correlation values. The highest correlation coefficient (between leaf N:P ratio and the mean temperature of coldest quarter (bio11)) was 0.607 (r^2=0.369). See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



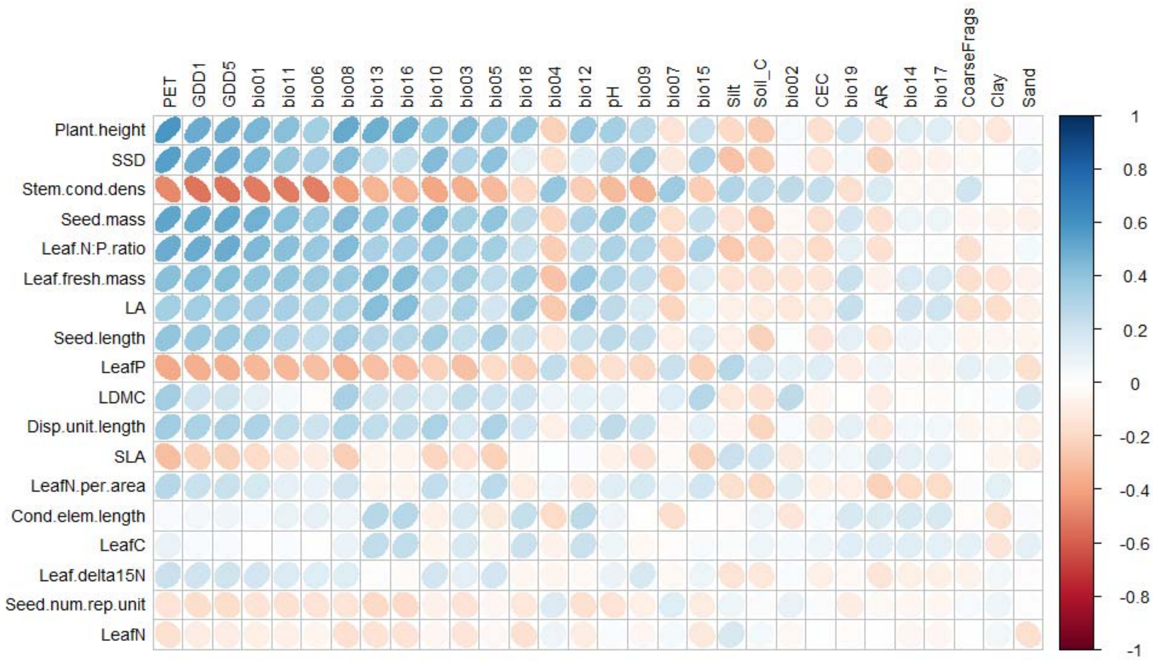
Supplementary Fig. 8: Principal Component Analysis of plot-level trait means (community-weighted means, CWMs) of non-forest communities only in the dataset. The plots (n = 513,035) are shown by coloured dots, with shading indicating plot density on a logarithmic scale, ranging from yellow with 1–4 plots at the same position to dark red with 251–1111 plots. Post-hoc correlations of PCA axes with climate and soil variables are shown in blue and magenta, respectively. Arrows are enlarged in scale to fit the size of the graph; thus, their lengths show only differences in variance explained relative to each other. Variance in CWM explained by the first and second axis was 24.3% and 17.5%, respectively. The vegetation sketches schematically illustrate low and high variation in the plant size and leaf economics continua. See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



Supplementary Fig. 9: Visualisation of the Pearson correlation matrix of plot-level trait means (community-weighted means, CWMs) of all 18 traits (rows) of non-forest communities only in the dataset (n = 513,035) with all environmental predictors (columns). Positive correlations are shown in blue, negative ones in red colour, with increasing colour intensity as the correlation value moves away from 0. The eccentricity of the ellipses is scaled to the absolute value of the correlation[51]. Rows and columns are arranged from top to bottom and from left to right according to decreasing absolute correlation values. The highest correlation coefficient (between leaf C content per dry mass and the volumetric content of coarse fragments in the soil (CoarseFrags)) was 0.204 (r^2=0.042). See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



Supplementary Fig. 10: Summary of Principal Components Analyses applied to 100 resampled subsets of plot-level trait means (community-weighted means, CWMs) from the entire dataset for all 18 traits in the sPlot dataset. Each subset was resampled from the global environmental space (see Methods) and comprised between 99,342 and 99,400 (mean 99,380) plots. The coloured dots show the plots of one random example of these 100 subsets, with shading indicating plot density on a logarithmic scale, ranging from yellow with 1–3 plots at the same position to red with 10–81 plots in the subset. The loadings of each of the traits are displayed by a grey circle, its radius scaled to the range of loadings on PC1 and PC2 of all 100 runs. Post-hoc regressions of PCA axes with each of the environmental variables are illustrated by blue circles, its radius scaled to the range of correlations with PC1 and PC2. The circles are rather small, indicating that both the loadings and the post-hoc correlations with the environment had very similar values in the different runs. The mean variance in CWM explained by the first and second axis across the 100 runs was 33.4% ± 0.04 sd and 17.5% ± 0.03 sd, respectively. The vegetation sketches schematically illustrate low and high variation in the plant size and leaf economics continua. See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.



Supplementary Fig. 11: Visualisation of the mean Pearson correlation coefficients of plot-level trait means (community-weighted means, CWMs) of all 18 traits (rows) with all environmental predictors (columns) of the 100 resampled subsets. Each subset was resampled from the global environmental space (see Methods) and comprised between 99,342 and 99,400 (mean 99,379.5) plots. Positive correlations are shown in blue, negative ones in red colour, with increasing colour intensity as the correlation value moves away from 0. The eccentricity of the ellipses is scaled to the absolute value of the correlation[51]. Rows and columns are arranged from top to bottom and from left to right according to decreasing absolute mean correlation values. The highest mean correlation coefficient (between plant height and potential evapotranspiration (PET) was 0.585 (r^2=0.342). See Table 2 and Supplementary Table 2 for the description of traits and environmental variables.

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