Functional traits contribute in opposite directions to taxonomic turnover in northeastern US forests over time

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APPENDIX S4. Analyses including temperature and precipitation.

TEXT

Methods and results for models testing the relationship between differences in taxonomic similarity and differences in climate over time:

Climatic data: To assess climatic fluctuations along the study period, we obtained climatic variables through the PRISM Climate Group, Oregon State University (http://prism.oregonstate.edu) datasets at 4Km resolution. We used four biologically relevant variables: mean annual temperature (MAT), minimum annual temperature (MinAT), maximum annual temperature (MaxAT), and mean annual precipitation (MAP) from 2001 to 2014. Units of precipitation are given in millimeters and for temperature in degrees Celsius.

Analyses: Correlation between climatic variables– we tested the correlation between all pair of climatic variables using the Pearson method (all relationships were significant, Table S4.1).

Models–For our analyses, we used data from plots that had at least one census in 2001. These plots displayed a spatially patchy distribution with two main clusters depicting Northeast and Mid-Atlantic regions (Figure S4.1). To deal with this spatial segregation, we first checked if the residuals had a comparable variance in each cluster by modeling each cluster separately. These models tested the relationship between differences in taxonomic similarity and differences in climatic variables with plot and censuses were included as random effects. We found that the residual variance is comparable between the two observed clusters and, thus, we were able to combine both datasets for further analyses (Table S4.2). Furthermore, using the combined data from both clusters, we model taxonomic similarity between each pair of consecutive censuses (with year 2001 considered as the first census period) as a function of the difference in climatic variables during the study period (e.g., 2001-2014), cluster identity, and the interaction of both. We also included census as fixed effect since we found that taxonomic similarity is more similar for plots within a specific cluster and during the same census period. We included plot as random effect and used separate models for each climatic variable (i.e., mean annual precipitation (MAP), mean annual temperature (MAT), minimum annual temperature (MinAT), maximum annual temperature (MaxAT)). We evaluated model fit for each model using marginal and conditional coefficients of determination (R_m^2 and R_c^2 respectively) for linear mixed-effect models (Nakagawa & Schielzeth 2013). The R_m^2 represents the variance explained by fixed effects and the R_c^2 represents the variance explained by the full model that included both random and fixed effects. For all models, we used the *lmer* function from the *lme4* package (Bates et al. 2015) in R 3.4.0 (R Development Core Team 2017). We also performed variograms of the model

residuals using the function “variogram” from the *gstat* package in R (Pebesma & Graeler 2019), to check for spatial autocorrelation.

Results from the linear models show that overall climatic variables were no significantly related to differences in taxonomic similarity for all the studied indices (e.g. Sorensen, Horn, and Morisita-Horn,, Table S4.3). With the exception of one model that showed a significant negative effect of maximum annual temperature (MaxAT) on taxonomic similarity (based on Sørensen) (Figure S4.2). However, the variance explained by this model was small (3%). Finally, the variograms showed that the model residuals were not spatially autocorrelated (Figure S4.3).

References:

Bates, D., Mächler, M., Bolker, B.M., & Walker, S.C. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67: 1–48.

Nakagawa, S., & Schielzeth, H. 2013. A general and simple method for obtaining R2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution* 4: 133–142.

Pebesma, E., & Graeler, B. 2019. Package ‘gstat ’ Spatio-temporal geostatistical modelling, prediction and simulation. Version 2.0-2.

TABLES

Table S4.1. Person correlation between climatic variables. The values below the diagonal show the P values and the value above the diagonal show the r values. Mean annual precipitation (MAP), mean annual temperature (MAT), minimum annual temperature (MinAT), and maximum annual temperature (MaxAT).

	MAP	**MAT**	**MinAT**	**MaxAT**
MAP	NA	0.12	0.24	0.2
MAT	<0.001	NA	0.98	0.98
MinAT	<0.001	<0.001	NA	0.92
MaxAT	<0.001	<0.001	<0.001	NA

Table S4.2. Residual variance of models comparing differences in climatic variables and differences in species turnover based on Sørensen, Horn and Morisita-Horn indices. Climate was represented by mean annual precipitation (MAP), mean annual temperature (MAT), minimum annual temperature (MinAT), and maximum annual temperature (MaxAT). Cluster 1 and 2 represent the group of plots showed in **Figure A3.1.**

Metric	**Climatic variable**	**Cluster 1**	**Cluster 2**
Horn	MAP	0.01	0.01
Horn	MAT	0.01	0.01
Horn	MinAT	0.01	0.01
Horn	MaxAT	0.01	0.01
Morisita Horn	MAP	0.01	0.01
Morisita Horn	MAT	0.01	0.01
Morisita Horn	MinAT	0.01	0.01
Morisita Horn	MaxAT	0.01	0.01
Søresnsen	MAP	0.02	0.01
Søresnsen	MAT	0.02	0.01
Søresnsen	MinAT	0.02	0.01
Søresnsen	MaxAT	0.02	0.01

Table S4.3. Effects of climate on taxonomic turnover based on Sørensen, Horn and Morisita-Horn indices. Climate was represented by mean annual precipitation (MAP), mean annual temperature (MAT), minimum annual temperature (MinAT) and maximum annual temperature (MaxAT). Cluster represents the groups of plots showed in Figure A1.1.Bold numbers indicate significant effects (95% confidence intervals do not include 0).

Metric	Coefficient	Estimate	Std.Error	t-value
Morisita-Horn	**Intercept**	**-0.07**	**0.01**	**-6.51**
Morisita-Horn	MAP	0.00004	0.0001	0.41
Morisita-Horn	Cluster 1	0.02	0.01	1.78
Morisita-Horn	Census 1	**-0.01**	**0.00**	**-2.46**
Morisita-Horn	MAP:Cluster	0.00001	0.0001	0.17
Morisita-Horn	**Intercept**	**-0.07**	**0.01**	**-8.50**
Morisita-Horn	MAT	0.02	0.02	1.13
Morisita-Horn	Cluster 1	0.02	0.01	2.46
Morisita-Horn	**Census 1**	**-0.01**	**0.00**	**-2.23**
Morisita-Horn	MAT:Cluster	-0.01	0.02	-0.85
Morisita-Horn	**Intercept**	**-0.08**	**0.01**	**-8.21**
Morisita-Horn	MinAT	0.03	0.02	1.41
Morisita-Horn	Cluster 1	0.02	0.01	2.96
Morisita-Horn	**Census 1**	**-0.01**	**0.01**	**-2.58**
Morisita-Horn	MinAT:Cluster	-0.02	0.01	-1.16
Morisita-Horn	**Intercept**	**-0.06**	**0.01**	**-8.27**
Morisita-Horn	MaxAT	-0.002	0.02	-0.14
Morisita-Horn	Cluster 1	0.01	0.01	1.69
Morisita-Horn	Census 1	-0.004	0.002	-1.69
Morisita-Horn	MaxAT:Cluster	0.01	0.01	0.49
Horn	**Intercept**	**-0.06**	**0.01**	**-6.64**
Horn	MAP	0.00003	0.0001	0.32
Horn	Cluster 1	0.01	0.01	1.53
Horn	**Census 1**	**-0.01**	**0.003**	**-2.90**
Horn	MAP:Cluster	0.00002	0.0001	0.26
Horn	**Intercept**	**-0.06**	**0.01**	**-8.55**
Horn	MAT	0.02	0.02	0.78
Horn	Cluster 1	0.01	0.01	2.05
Horn	**Census 1**	**-0.01**	**0.00**	**-2.19**
Horn	MAT:Cluster	-0.01	0.01	-0.52

Table S4.3. (continuation)

Metric	Coefficient	Estimate	Std.Error	t-value
Horn	**Intercept**	**-0.07**	**0.01**	**-8.43**
Horn	MinAT	0.02	0.02	1.40
Horn	Cluster 1	0.02	0.01	2.75
Horn	**Census 1**	**-0.01**	**0.00**	**-2.90**
Horn	MinAT:Cluster	-0.01	0.01	-1.14
Horn	**Intercept**	**-0.06**	**0.01**	**-8.83**
Horn	MaxAT	-0.01	0.01	-0.97
Horn	Cluster 1	0.01	0.01	1.57
Horn	Census 1	-0.003	0.002	-1.76
Horn	MaxAT:Cluster	0.01	0.01	1.17
Sørensen	**Intercept**	**-0.09**	**0.01**	**-7.65**
Sørensen	MAP	0.0001	0.0001	0.88
Sørensen	Cluster 1	0.02	0.01	2.20
Sørensen	**Census 1**	**-0.01**	**0.00**	**-4.50**
Sørensen	MAP:Cluster	-0.00004	0.0001	-0.50
Sørensen	**Intercept**	**-0.08**	**0.01**	**-9.30**
Sørensen	MAT	0.01	0.02	0.28
Sørensen	Cluster 1	0.02	0.01	1.99
Sørensen	**Census 1**	**-0.01**	**0.01**	**-2.53**
Sørensen	MAT:Cluster	0.00	0.02	-0.13
Sørensen	**Intercept**	**-0.09**	**0.01**	**-9.28**
Sørensen	MinAT	0.03	0.02	1.47
Sørensen	Cluster 1	0.02	0.01	2.96
Sørensen	**Census 1**	**-0.02**	**0.01**	**-3.74**
Sørensen	MinAT:Cluster	-0.02	0.02	-1.25
Sørensen	**Intercept**	**-0.08**	**0.01**	**-10.60**
Sørensen	**MaxAT**	**-0.04**	**0.02**	**-2.04**
Sørensen	Cluster 1	0.01	0.01	2.09
Sørensen	**Census 1**	**-0.01**	**0.00**	**-2.93**
Sørensen	MaxAT:Cluster	0.02	0.01	1.96

FIGURES

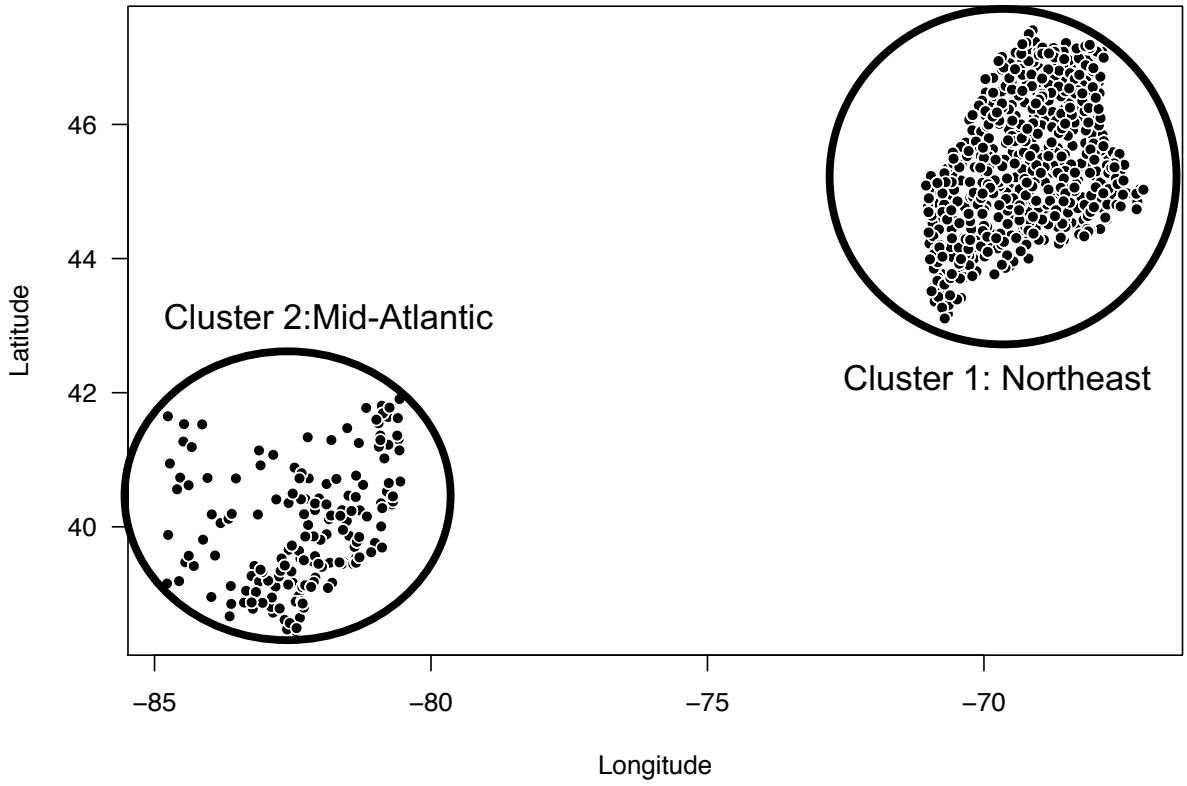

Figure S4.1. Distribution of plots used in the analyses.

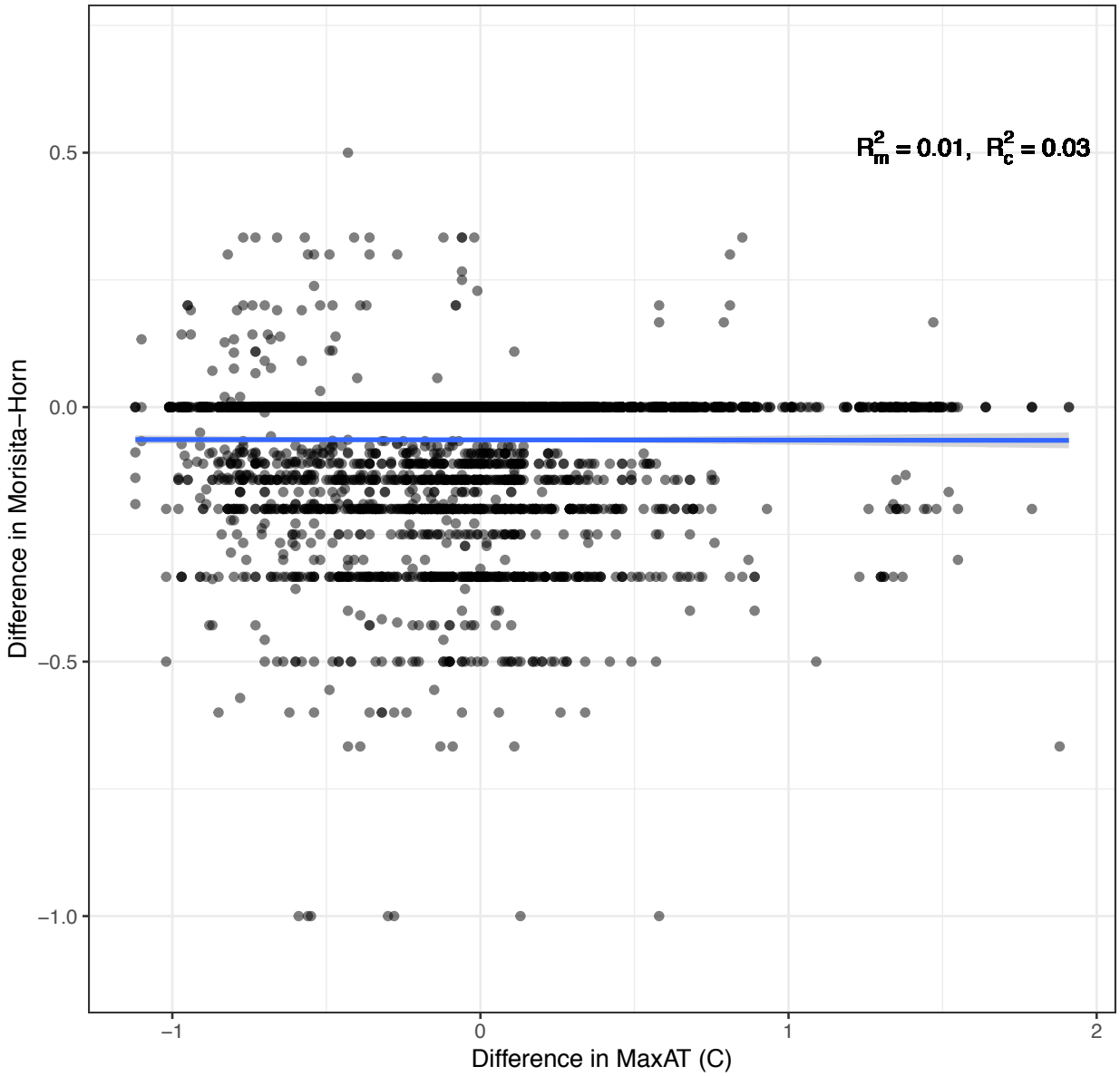

Figure S4.2. Differences in taxonomic similarity (based on Sørensen index) between consecutive censuses vs. differences in maximum annual temperature (MaxAT) between consecutive censuses for permanent plots located in northeastern USA. Information on model fit is provided by marginal and conditional R^2. See Table A1.2 for model results.

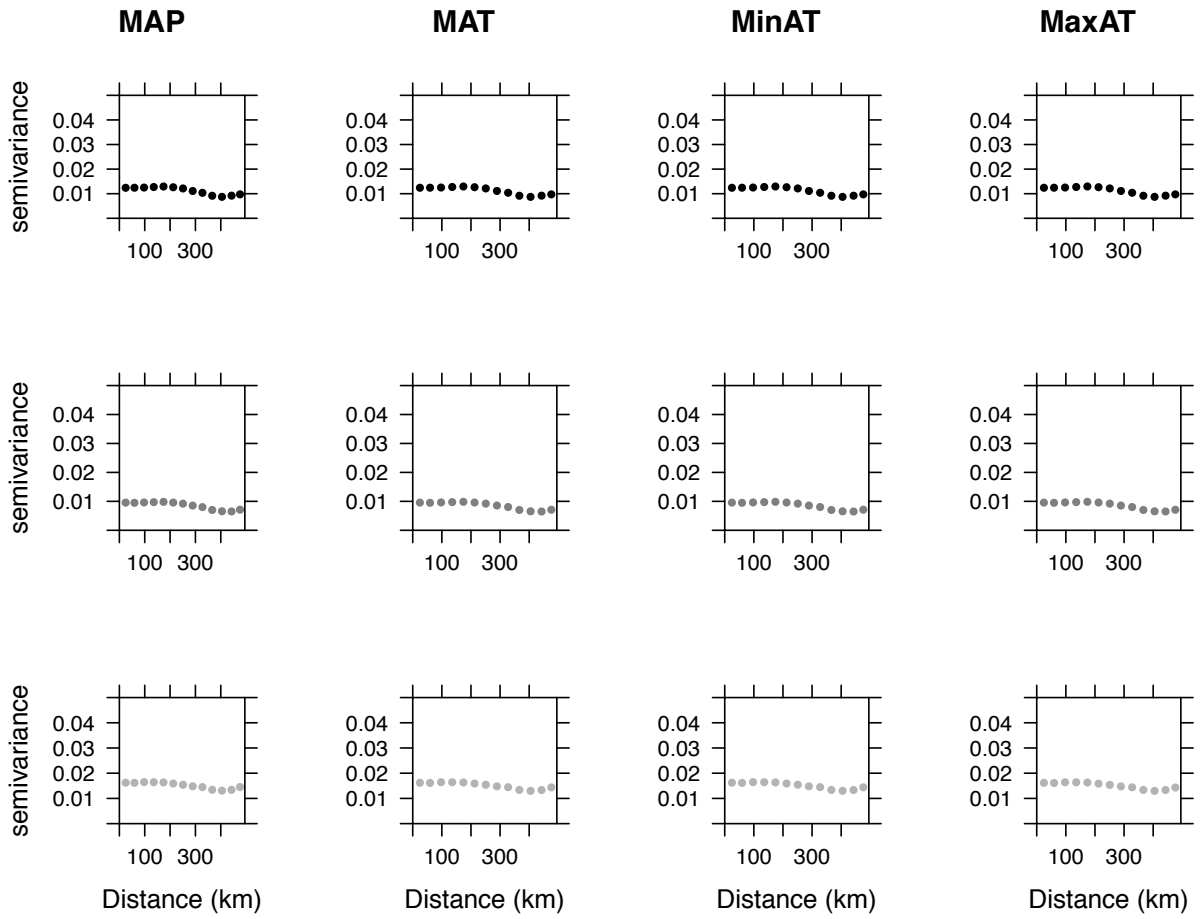

Figure S4.3. Variograms of the residuals of the models relating taxonomic dissimilarity and climate dissimilarity. The acronyms for climatic variables (columns) are: mean annual precipitation (MAP), mean annual temperature (MAT), minimum annual temperature (minAT) and maximum annual temperature (maxAT). The top row (black dots) represent the results based on the Morisita-Horn index. The middle row (dark gray dots) represent the results based on the Horn index. The bottom row (light gray dots) represent the results based on the Sørensen index. In the case of spatial autocorrelation, we expect the semivariance to increase from a low value at short distances towards an asymptotic value at large distance.