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Change in dominance determines herbivore effects on plant biodiversity

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Herbivores alter plant biodiversity (species richness) in many of the world's ecosystems, but the magnitude and the direction of herbivore effects on biodiversity vary widely within and among ecosystems. One current theory predicts that herbivores enhance plant biodiversity at high productivity but have the opposite effect at low productivity. Yet, empirical support for the importance of site productivity as a mediator of these herbivore impacts is equivocal. Here, we synthesize data from 252 large-herbivore exclusion studies, spanning a 20-fold range in site productivity, to test an alternative hypothesis—that herbivore-induced changes in the competitive environment determine the response of plant biodiversity to herbivory irrespective of productivity. Under this hypothesis, when herbivores reduce the abundance (biomass, cover) of dominant species (for example, because the dominant plant is palatable), additional resources become available to support new species, thereby increasing biodiversity. By contrast, if herbivores promote high dominance by increasing the abundance of herbivory-resistant, unpalatable species, then resource availability for other species decreases reducing biodiversity. We show that herbivore-induced change in dominance, independent of site productivity or precipitation (a proxy for productivity), is the best predictor of herbivore effects on biodiversity in grassland and savannah sites. Given that most herbaceous ecosystems are dominated by one or a few species, altering the competitive environment via herbivores or by other means may be an effective strategy for conserving biodiversity in grasslands and savannahs globally.

Consumers play a critical role in determining the structure and functioning of most ecosystems[1]. However, human activities have greatly altered top-down control by consumers with consequences for biodiversity and other ecosystem services not yet fully understood[1]. In part, this uncertainty arises because the effects of consumers on biodiversity are highly variable in both aquatic and terrestrial ecosystems[2–7]. One theory predicts that the effects of herbivores on biodiversity (species richness, the number of species) vary with ecosystem productivity[2,4,5,7–10]. In more productive systems, herbivory is expected to reduce the abundance of dominant species and increase biodiversity[7]. Dominant species often impact community structure[11], including species biodiversity, by monopolizing resources. Decreased dominance can be directly linked to increased availability of resources, including light, nutrients and water, leading to increased abundance of less common species, colonization by new species and/or a decrease in local species extinctions[7]. In

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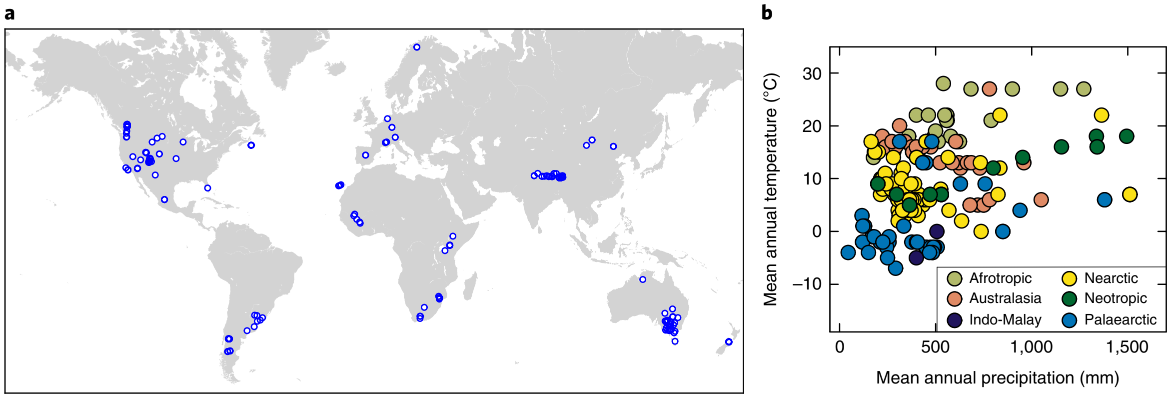

Fig. 1 | Location and climate of sites. a, Locations of the 252 grassland and savannah ecosystems where 1,212 grazed and ungrazed plots were located. All sites are represented by a single-sized open blue circle. Areas where symbols overlap appear to be darker blue. **b**, These study sites represent six biogeographic realms and encompass broad gradients of mean annual temperature and precipitation. Additional site details are provided in Supplementary Tables 1 and 2.

contrast, at low productivity, herbivores are predicted to decrease biodiversity by either (1) increasing dominance by grazing-tolerant species, which may reduce colonization rates or enhance extinctions of other species, or (2) not affecting dominance if species are unpalatable, but instead increasing extinctions of rare palatable species via consumption[7]. Collectively, these processes may result in a positive relationship between biodiversity and productivity with herbivory. However, deviations from this pattern are common, particularly in herbaceous plant communities (for example, see Olff and Ritchie[7], Koerner et al.[12], Milchunas and Lauenroth[13] and Eldridge et al.[14]). These discrepancies call into question the generality of productivity as a mediator of herbivore effects on biodiversity via the dominance mechanism. Indeed, high levels of plant community dominance are found in both high-[15] and low-productivity[16] systems, which suggests that changes in dominance may impact biodiversity directly and irrespective of productivity.

Here, we test how changes in dominance determine biodiversity responses to herbivory, and whether this dominance mechanism is mediated by site productivity. We synthesized data from 252 grassland and savannah sites (Fig. 1; Supplementary Table 1–3) that includes 1,212 plots sampled inside and outside of large-herbivore exclosures. These sites encompassed a broad range of environmental conditions across six biogeographic realms[17]. This data set included measures of plant community composition from all sites and aboveground net primary productivity (ANPP) from half the sites, as well as a number of herbivore community and site characteristics (see Methods). To quantify herbivore-induced changes in biodiversity, we calculated the log response ratio (ln(G/UG)) of plant species richness (average number of species per plot) outside (grazed, G) versus inside (ungrazed, UG) exclosures. We used two common dominance metrics—the Berger–Parker and Simpson's Dominance Indexes[18]—to evaluate changes in dominance with herbivory. Change of both metrics was calculated using log response ratios. We picked these two measures of dominance because both are robust to changes in richness at levels encompassed by our data sets (>5; refs.[18,19]) and thus can vary independently of richness. The Berger–Parker Dominance Index is a measure of the relative cover of the most abundant species regardless of species identity, while Simpson's Dominance Index is a measure of diversity that is highly sensitive to abundant species[20]. We chose to focus on the Berger–Parker Dominance Index metric because of its simplicity and its mathematical independence from richness. However, Simpson's Dominance Index, while more complicated, is a metric that can capture co-dominance by two or more species[18]. The inclusion of the Simpson's Dominance Index metric in our analyses (see Supplementary Information) allowed us to examine the robustness of the patterns observed with the Berger–Parker Dominance Index metric.

Results and discussion

Consistent with previous theory and several empirical studies[2,8,9,13], we found a positive relationship between changes in species richness in response to herbivores and ANPP, but the amount of variation explained was low (Fig. 2a). Contrary to theory, herbivory did not decrease species richness at low productivity. Instead, herbivory had, on average, either neutral or positive effects on richness across the entire 20-fold range in ANPP. Because not all studies in our data set measured ANPP, we used mean annual precipitation (MAP) as an ANPP proxy. This was possible due to the relationship between MAP and ANPP in our data set (linear regression: $R^2=0.21$, $P<0.001$, $F_{106}=27.63$) as well as in grasslands and savannahs globally[20,21]. Even with this expanded data set, richness responses were poorly related to MAP (Fig. 2b), consistent with the weak relationship observed for ANPP.

In contrast to the equivocal support for productivity influencing richness responses, we found a strong negative relationship between herbivore-induced changes in Berger–Parker dominance and the effect of herbivores on species richness (Fig. 2c). As predicted, when herbivores decreased dominance thereby reducing competition, species richness increased; however, when herbivores increased dominance, thereby increasing the strength of competition, richness declined. Negative relationships between species richness and dominance are common (for example, see McNaughton and Wolf[11], Koerner et al.[12] and Grime[22]), and this relationship was also evident in both grazed and ungrazed plots in our data set (Fig. 2d). These patterns were even stronger when using Simpson's dominance (Supplementary Fig. 2; $R^2=0.192$ for Berger–Parker dominance and $R^2=0.299$ for Simpson's dominance) suggesting that changes in co-dominance may be important in many of these grazing systems. Given this relationship and because we used measures of dominance that are mathematically independent of richness[18], this suggests that changes in dominance can be causally linked to biodiversity responses to herbivory. Changes in Berger–Parker dominance in response to grazing were not significantly related to either ANPP (Supplementary Fig. 1a) or precipitation (Supplementary Fig. 1b), suggesting this pattern is independent of site productivity. Similarly, changes in Simpson's dominance due to grazing were also not significantly related to ANPP or precipitation (Supplementary Fig. 3).

Although univariate approaches can be informative, both productivity and change in dominance could jointly influence the

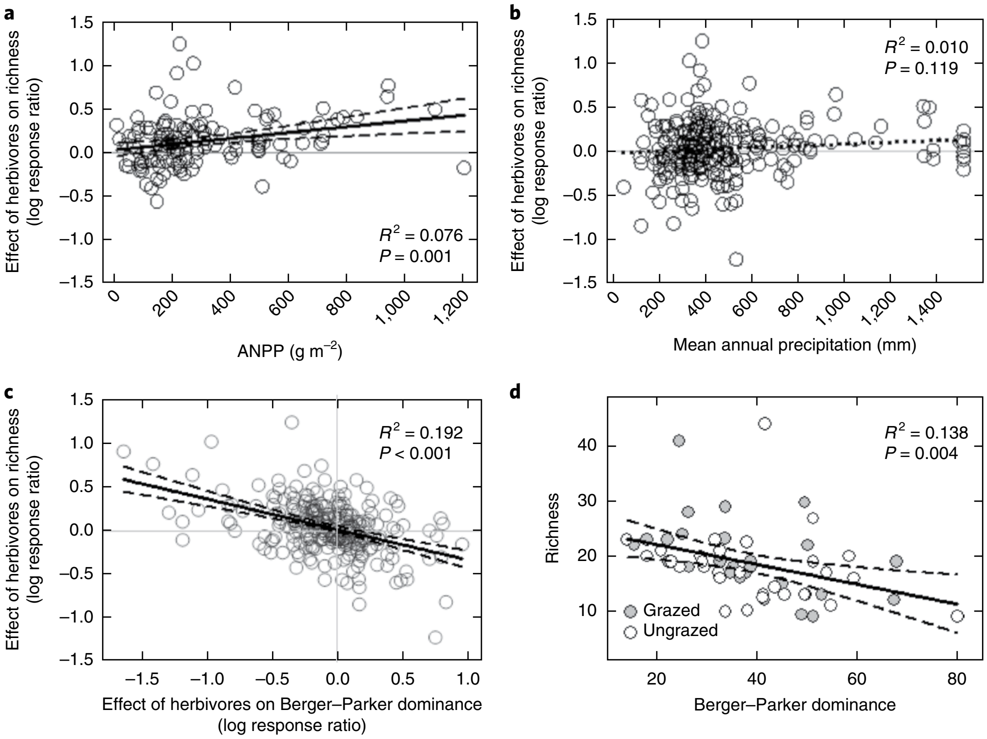

Fig. 2 | Herbivore effects on plant communities. **a**, Relationship between ANPP and the response of plant species richness to herbivory (ln(G/UG)), where G is the average plant species richness in grazed plots and UG is the same measurement in ungrazed plots (n = 132; Data Subset 1 in Supplementary Table 3). **b**, Relationship between MAP and the response of plant species richness to herbivory (n = 244; Data Subset 2 in Supplementary Table 3). **c**, Relationship between the change in dominance (Berger–Parker dominance) and the change in species richness as a function of herbivory (ln(G/UG)) (n = 252; all data). **d**, Relationship between dominance (Berger–Parker dominance) and species richness for grazed and ungrazed plots combined. This analysis is based only on studies with a common plot size of 25 m^2 (n = 58). The dashed lines represent 95% confidence intervals.

biodiversity response to herbivory. Therefore, we used path analysis[23] to assess whether productivity mediates the effect of change in dominance on the richness responses to herbivory. Our a priori model included additional non-mutually exclusive factors that could influence the relationship between herbivory and species richness[7], such as characteristics of the herbivore community (estimates of herbivore pressure; herbivore species richness; if herbivores were domesticated or not; and if browsers/mixed feeders were present in addition to grazers), the plant community (size of the species pool) and the duration of herbivore exclusion. See Methods for further details. These metrics allowed us to explicitly contrast the effects of site-level productivity versus change in dominance on the richness response to herbivory and include other factors that may affect both dominance and richness responses. We examined six alternative models (Fig. 3 and Supplementary Fig. 4) to explicitly contrast the effects of changes in ANPP versus dominance on the biodiversity response to grazing.

Our first model examined the widely hypothesized relationship between precipitation, site productivity and change in species richness (Fig. 3a, Model 1). This model also included characteristics of the herbivore and plant communities (site-level richness), as well as accounted for correlations between input variables (Supplementary Table 4). Because productivity was not available from all sites, this initial model was limited to data from the 122 sites where ANPP was measured directly (see Methods; Data Subset 1 in Supplementary Table 3). As expected, precipitation was strongly related to productivity in this data set (Fig. 3a, Model 1); consistent with our univariate analysis, we found a significant positive effect of site productivity on change in species richness. Grazing had neutral to mildly positive effects on richness at low productivity and a stronger positive effect at higher productivity. In addition, we found that grazing pressure negatively influenced the richness response, but to a lesser extent than productivity. Thus, at high grazing pressure, herbivores decreased richness irrespective of site productivity. Site-level species richness also affected how richness responded to herbivory. As site richness increased, herbivores had less of an effect on changes in species richness regardless of site productivity. Overall, this model explained 13% of variation in the richness response to herbivory.

In a second model (Fig. 3b, Model 2a) we added an estimate of site-level Berger–Parker dominance in the absence of grazing (averaged across all ungrazed plots at a site (U_{dom})), as well as the change in dominance in response to grazing ($\ln(G_{\mathrm{dom}}/U_{\mathrm{dom}})$) to assess the relative effects of productivity versus dominance on the richness response to herbivory. (The correlations between all input variables can be found in Supplementary Table 5.) While site productivity was weakly correlated with changes in richness (Fig. 3b, Model 2a), both site-level dominance and change in dominance were significantly and more strongly correlated with the richness response to grazing. That is, as site dominance increased, grazing had a stronger positive effect on species richness. Consistent with this relationship, the change in dominance due to herbivores was strongly related to changes in species richness. Thus, when grazing reduced dominance there was a strong increase in species richness. Similar to the previous model, grazing pressure remained significantly correlated with the change in species richness. In this model, other factors related to the herbivore community were also significant (that is, domestication and feeding guild), but their effects on change in richness were indirect via change in dominance. Also, site-level total species richness no longer directly or indirectly influenced change in species richness. Overall, inclusion of Berger–Parker dominance

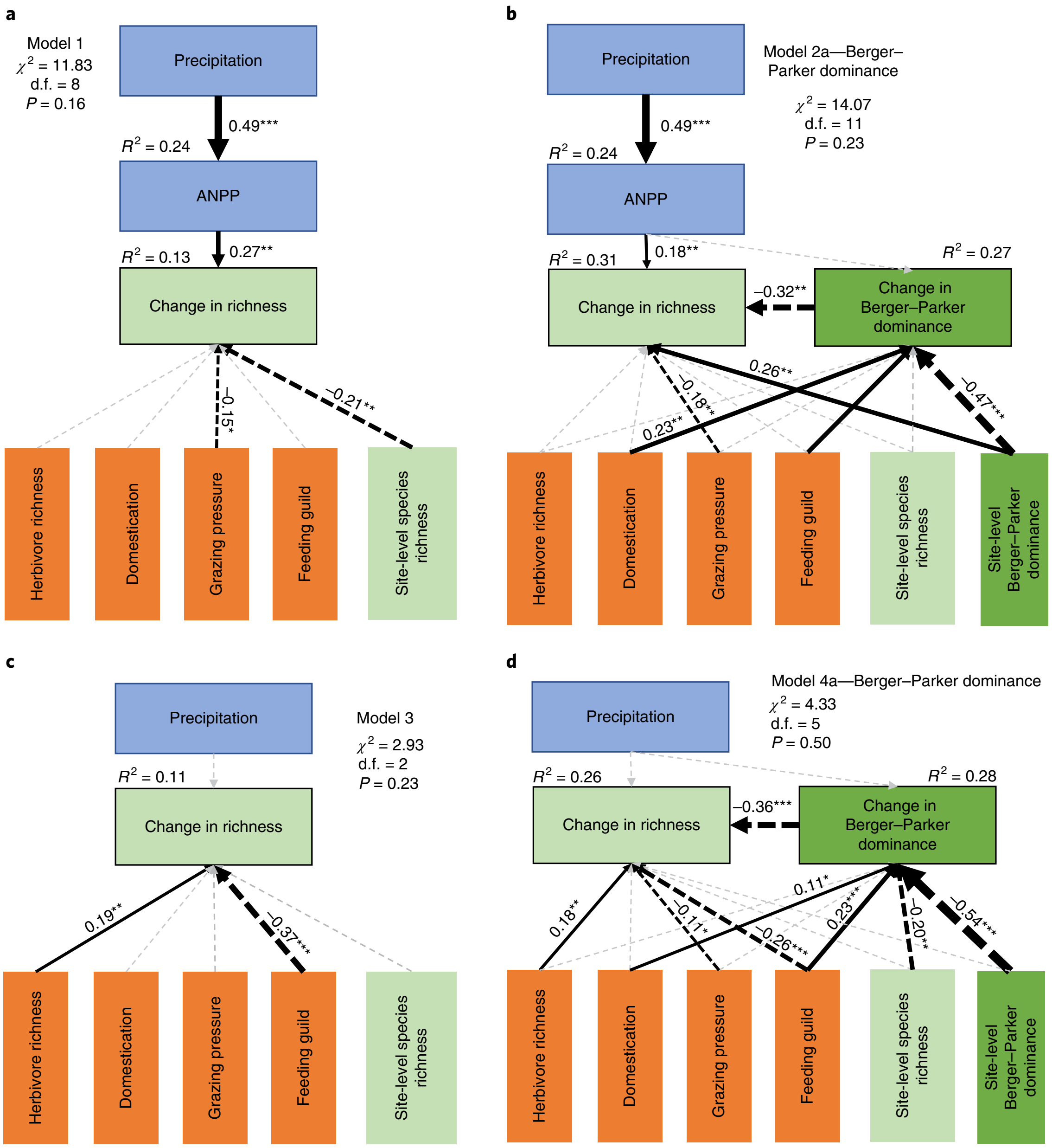

Fig. 3 | Drivers of plant richness response to herbivory. **a**,**b**, Path analyses testing the importance of ANPP (Model 1) and Berger–Parker dominance (Model 2a) on the change in species richness in response to herbivory. These models are restricted to sites where both ANPP and precipitation data were available ($n=122$; Data Subset 3 in Supplementary Table 3). See Supplementary Tables 4 and 5 for bivariate correlations between input variables that were included in these models to improve model fit. **c**,**d**, Path analyses testing the importance of productivity using precipitation as a proxy (Model 3) for productivity and Berger–Parker dominance (Model 4a) on the change in species richness in response to herbivory. These models use precipitation as a surrogate for ANPP allowing the use of more data ($n=244$; Data Subset 2 in Supplementary Table 3). See Supplementary Tables 7 and 8 for bivariate correlations between the input variables that were included in these models to improve model fit. All models also test for the effects of site and herbivore characteristics (see Methods). ***$P<0.001$, **$P<0.05$, *$P<0.10$. Non-significant relationships are shown in light grey dashed arrows; solid black arrows represent positive relationships and dashed black arrows represent negative relationships. The standardized effect sizes are shown, with arrow thickness proportional to the strength of the relationship. All models were a good fit to the data based on the chi-squared statistic ($P>0.05$ goodness of fit). See Supplementary Table 10 for additional model fit parameters for all four models.

doubled the explanatory power of the change in species richness when compared to the model that only included productivity ($R^2=0.31$ versus 0.13). When this second model included Simpson's instead of Berger–Parker dominance (Supplementary Fig. 4a, Model 2b; Supplementary Table 6), the explanatory power of the change in species richness increased ($R^2=0.39$), providing robust support for change in dominance as key to explaining changes in richness with herbivory. Additionally, ANPP no longer has a significant effect on change in richness from herbivory when Simpson's dominance was included in the model.

Models 1, 2a and 2b (Supplementary Information) were limited to the 122 sites that had productivity measurements. Because productivity is strongly correlated with MAP in our data set (Fig. 3a,b, Models 1 and 2a) as well as more broadly[20], we used precipitation as a proxy for productivity in Models 3, 4a and 4b (Supplementary Information). This allowed us to include 244 sites in the analysis

(Data Subset 3 in Supplementary Table 3). In Model 3, we examined the relationship between precipitation and change in species richness without dominance (similar to Model 1 but using a larger data set) as well as accounted for correlations between input variables (Supplementary Table 7). As with the ANPP data set, Model 3 could only explain 11% of the variation in change in richness, and there was no effect of precipitation in this model. When Berger–Parker dominance was included in the model (Model 4a; Supplementary Table 8), our explanatory power of change in richness more than doubled ($R^2 = 0.11$ versus 0.26); when Simpson's dominance was included (Supplementary Fig. 4b: Model 4b; Supplementary Table 9) our explanatory power of change in richness more than tripled ($R^2 = 0.11$ versus 0.36). Similar to Model 2, we again found that site-level Berger–Parker dominance and change in Berger–Parker dominance with herbivores were the main drivers of herbivory-induced changes in species richness ($R^2 = 0.26$). However, precipitation, as a surrogate for productivity, had no significant effect in the model. Importantly, incorporating the larger data set in Models 4a and 4b demonstrated that herbivore-driven changes in dominance exert stronger effects on richness change than site-level dominance per se (standardized partial effect sizes of −0.35 versus not significant, respectively). These models also identified a strong, negative relationship between site-level dominance and change in dominance (standardized partial effect size of −0.54 and −0.58). This occurred because change in dominance is expressed as a ratio of grazed to ungrazed dominance and indicates that grazers reduce dominance more in sites with higher dominance. With this more comprehensive data set, we identified additional factors with direct and indirect effects on richness response to herbivory. For example, grazers alone had a stronger impact on changes in species richness than when grazers and browsers were both present (standardized partial effect size for herbivore guild of −0.26 and −0.23). This pattern suggests that grazers target dominant grasses that then outcompete subordinate species when released from herbivory. However, grazers and browsers may have less of a net effect on species richness due to compensatory feeding, supporting the theory[7] and patterns from previous studies[12,24,25]. Overall, the more data-rich models confirm the role of dominance in controlling the richness response to herbivory rather than productivity.

To further explore the relationship between community dominance and herbivory, we focused on the palatability of the dominant species. Palatability strongly influences how a plant species responds to herbivory. Previous research has shown that herbivores reduce the dominance of palatable tall grasses in the productive mesic grasslands of North America, resulting in increased biodiversity[12,26]. Alternatively, large herbivores in a mesic South African savannah dominated by an unpalatable grass had only minor impacts on dominance and diversity[12]. Dominant species can also be palatable but grazing-tolerant so that dominance increases with herbivory. This is the case in East African mesic grasslands where large herbivores generate extensive grazing lawns in which a few grazing-tolerant grasses withstand high densities of large herbivores and high rates of consumption[27,28]. Such grazing lawns exhibit both high dominance and low biodiversity[27]. Finally, high dominance and low biodiversity also could occur if there is another species in the community capable of compensating for reduced abundance of the dominant species. Thus, including traits that confer palatability of dominant species into analyses may be key to a more detailed mechanistic understanding of herbivore effects on biodiversity.

Assessing the role of palatability in determining dominance responses to herbivory was not possible with our empirical analysis due to a lack of trait data for the whole suite of plant species. However, we incorporated palatability into a stochastic community assembly model to simulate the effect of herbivory on Berger–Parker dominance and richness independent of productivity. This model considered community assembly, as well as dominance and richness responses following grazing, as random processes (see Methods for details). Change in dominance was calculated using the relative cover of the dominant species. In the model, changes in dominance and species richness can occur via competitor release, local extinction and new species arrivals. We assessed three scenarios with the model: (1) all dominant species are palatable, that is, grazed (Fig. 4a); (2) all dominant species are unpalatable (Fig. 4b); and (3) communities have a random chance of being dominated by either a palatable or unpalatable species (Fig. 4c). We found that when all simulated communities were dominated by palatable species (Fig. 4a) or when communities were dominated by either a palatable or unpalatable species (Fig. 4c), the resulting ensembles of 1,000 simulations generated richness and dominance responses to herbivory that were remarkably similar to empirical observations (Fig. 2c). In contrast, if the dominant species was unpalatable (leaving only less common species to be grazed), there were few instances where richness increased while dominance decreased (that is, few points in the upper left-hand quadrant of Fig. 4b). These simulations are consistent with the biodiversity response to herbivory depending primarily on the palatability and subsequent response of the dominant species, irrespective of productivity.

Conclusion

Our findings extend theory[2,5,7,22,29] by identifying change in community dominance, and thus the competitive landscape, as the primary and generalizable mechanism underlying biodiversity response to herbivory. Change in dominance explains herbivore impacts on biodiversity—both positive and negative—globally across grasslands and savannahs with 20-fold differences in productivity and vastly different biogeographic and evolutionary histories. This dominance mechanism is consistent with the light availability mechanism identified by Borer et al.[5] because increases in dominance can increase light limitation[30]. But dominance also changes with herbivory in sites where light is not limiting[27]. Thus, the dominance mechanism applies to a wider range of ecosystems, reflecting competitive interactions for the availability of either above- or below-ground resources[7]. This dominance mechanism is also consistent with the evolutionary history mechanism identified by Milchunas and colleagues[13,31] as dominance and the traits of the dominant species, particularly those related to palatability, are determined by a site's evolutionary history. Strong community dominance by just a few species is a nearly universal feature of ecosystems[15,22,29], and dominant species are known to control most ecosystem processes[22,32]. As a consequence, our results point to 'dominance management' as an effective strategy for conserving species biodiversity and ecosystem functioning in grasslands and savannahs globally.

Methods

Data. We compiled a database, the Grazing Exclosure Database, consisting of plant community composition data from 252 large vertebrate herbivore exclosure sites (Supplementary Tables 1 and 2). To be included in the Grazing Exclosure Database, sites had to meet five criteria: (1) exclosures had to be located in herbaceous-dominated communities—sites ranged from tallgrass prairie to alpine meadows to desert, but all are dominated or co-dominated by herbaceous species; (2) large vertebrate herbivores (adult body mass > 45 kg) had to be excluded from plots using fencing with adjacent plots exposed to herbivores; herbivore type and number varies among the sites, including domesticated cattle, sheep, goats, burros and horses, as well as native wildlife such as caribou, kangaroo and the full complement of large African herbivores, and the inside of the exclosure could not be manipulated or managed other than the removal of herbivores (that is, no mowing or burning that did not also occur outside the exclosure); (3) data had to be collected after at least three years of exclusion of large herbivores; this was to ensure sufficient time for the plant community to respond to the absence of herbivores; (4) paired plots inside and outside the exclosure had to be sampled at the same time and sampling intensity; (5) community data had to be available at the species level; data types include cover, line intercept, biomass and pin hits (but not frequency or density), all of which were converted to relative abundance values.

Explanatory variables. Several covariates were used in the analyses that described plant, experiment and herbivore community characteristics. Site

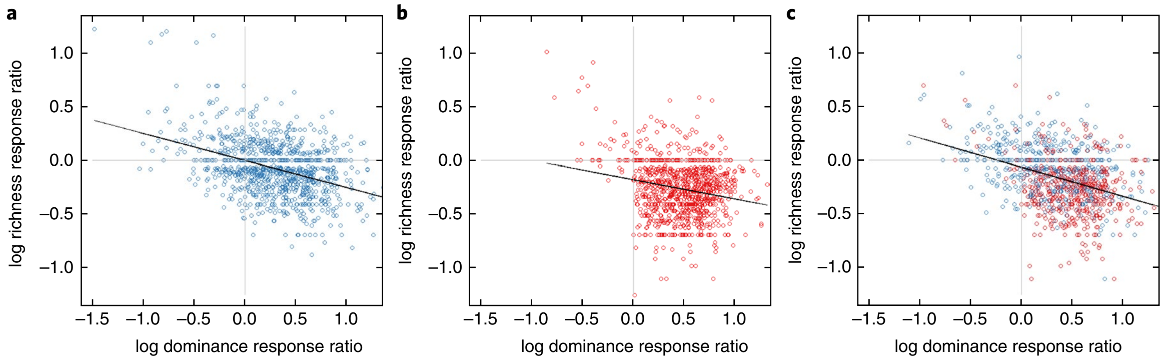

Fig. 4 | Simulation of plant community assembly in response to herbivory with three scenarios of palatability of the dominant species. **a**, In the first scenario, each assembled community has a dominant species that is grazed (blue) and all subordinate species have a 50% probability of being a grazed species. **b**, In the second scenario, each assembled community has a dominant species that is not grazed (red) and all subordinate species have a 50% probability of being a grazed species. **c**, In the third scenario, in each assembled community all plant species have a 50% probability of being a grazed species including the dominant species. The blue dots represent communities that have a dominant species that is grazed. The red dots represent assembled communities in which the dominant species was ungrazed. All scenarios treat community assembly and dominance, and richness responses following grazing, as random processes (see details in Methods).

primary productivity was based on ungrazed vegetation, as reported by individual investigators for a subset of the sites ($n=132$). Individual investigators supplied precipitation data, while mean annual temperature was based on WorldClim[33]. Site-level richness and dominance were calculated using the species composition data. Site richness was calculated as the total number of plant species found across all plots. Site dominance was calculated as the mean dominance across all ungrazed plots using the Berger–Parker Dominance Index, which is the relative abundance of the most abundant species in the plot. Four variables were used to describe the herbivore community. Investigators provided an assessment of herbivory pressure (low, moderate, high) and species of large herbivores excluded. We converted herbivore species information into three variables: herbivore richness; feeding guild; and domestication. Herbivore richness is the number of large-herbivore species excluded by the fences. Predominantly, these exclosures excluded grazers (feeding guild = 0); when browsers or mixed feeders were present either in combination with grazers or alone (feeding guild = 1), we hypothesized this would have different effects on the herbaceous community. Domestication refers to human involvement with herbivore species presence and abundance. Native herbivores (wildlife) were coded as domestication = 0, while domesticated herbivores (for example, cattle) or the combination of the two were coded as domestication = 1 since they were hypothesized to have different effects than native herbivores alone. Experiment length was the number of years post exclosure construction; this variable was included in many exploratory analyses but was never significant and often led to poor model fit to the data. Exclosure age was not significantly correlated with either change in richness or change in dominance. Therefore, exclosure age was dropped from all path analyses.

Although many sites provided multiple years of data, here we present only the most recent year of data collected from each site. For analyses involving ANPP, a subset of sites was used ($n=132$; Data Subset 1 in Supplementary Table 3), while nearly all sites were included in analyses using only precipitation ($n=244$; 8 sites were strategically placed in topographic locations that were either wetter or drier than expected based on precipitation and were, therefore, only used in the ANPP analysis but not the precipitation analyses; Data Subset 2 in Supplementary Table 3). Likewise, when models included both ANPP and precipitation, a subset was used ($n=122$; Data Subset 3 in Supplementary Table 3). When models did not include either ANPP or precipitation as predictors, we used all sites in the database ($n=252$).

Response variables. The majority of sites had a single exclosure ($n=132$). When more than one exclosure was built in the same year, each exclosure and corresponding paired plot was considered a block. When multiple subplots were sampled within each exclosure or paired plot, species abundance was summed for each species across the subplots to obtain species data at the plot level (that is, one plot per block). Plant community richness and dominance were calculated at the plot level for inside and outside the exclosure. Plant community richness was calculated as the number of species in the plot in that year. Dominance was quantified in two ways. The Berger–Parker Dominance Index was calculated as the maximum relative abundance of the most abundant species in each plot. The Simpson's Dominance Index was calculated as

$$D_{\mathrm{Simp}} = \sum_{s=1}^{S} p_s^2$$

where S is the number of species in the sample and p_s is the proportional abundance of the sth species. To quantify herbivore-induced changes in biodiversity, we calculated the log response ratio (ln(G/UG)) of plant species richness outside (grazed, G) versus inside (ungrazed, UG) each exclosure. Change in community dominance with herbivory (both Berger–Parker and Simpson's) was also estimated by using this log response ratio. The log response ratios were then averaged across blocks to obtain a single value for each site.

Analyses. We developed linear models using R version 3.1 (R Foundation for Statistical Computing). We used the lm() R function to analyse the relationships between the effect of herbivores on richness (log response ratio) and ANPP (Fig. 2a), MAP (Fig. 2b), and the effect of herbivores on dominance (log response ratio; Fig. 2c), and for the relationship between dominance and richness (Fig. 2d).

To determine the relative importance of various proposed explanatory variables on the richness response to herbivory (log response ratio), we used path analysis conducted in AMOS version 7 (SPSS). We contrasted the effects of site-level productivity versus dominance on species richness response to herbivory using two alternative models. All models also included hypothesized influential covariates, such as the characteristics of the herbivore community, the plant community and experimental duration. Data were screened for distributional properties and nonlinear relations. Site-level plant richness and herbivore richness were log-transformed as a result of these evaluations. While site-level dominance and richness theoretically could be driven by precipitation, the correlations between site-level richness and precipitation (Pearson's correlation coefficient = 0.357; linear regression $R^2=0.126$) and between site-level Berger–Parker dominance and precipitation (Pearson's correlation coefficient = −0.246; linear regression $R^2=0.06$) within our data set were low. Therefore, these relationships were dropped from the path analysis due to replication constraints. Model 1 examined the widely hypothesized relationship between precipitation, ANPP and change in species richness (Fig. 3a). Because ANPP was not available from all sites, this model used data from 122 of the 252 sites where ANPP was measured and precipitation was a good proxy for ANPP. Model 2a (Fig. 3b) used the same data as Model 1 but included an estimate of site-level Berger–Parker dominance in the absence of grazing (U_{dom}), as well as the change in Berger–Parker dominance in response to grazing ($\ln(G_{\mathrm{dom}}/U_{\mathrm{dom}})$) to assess the relative effects of ANPP versus Berger–Parker dominance on richness response to herbivory. Model 2b—Simpson's dominance (Supplementary Fig. 4a)—was the same as Model 2a but included an estimate of site-level Simpson's dominance in the absence of grazing (U_{SimpDom}), as well as the change in Simpson's dominance in response to grazing ($\ln(G_{\mathrm{SimpDom}}/U_{\mathrm{SimpDom}})$) to assess the relative effects of ANPP versus Simpson's dominance on richness response to herbivory. Because ANPP is strongly correlated with MAP, in our data set (Fig. 3a,b) and more broadly[20], we used precipitation as a proxy for ANPP, allowing us to run similar models again but including 244 sites in the analysis (Model 3 and Models 4a and 4b). Several input variables were correlated (based on AMOS recommendations for correlated variables that improve model fit); therefore, they were included as such in the models (Supplementary Tables 4–9). All models were a good fit to the data, according the chi-squared statistic with $P > 0.05$ as well as other measures of goodness of fit (see Supplementary Table 10).

Null model simulation. To explore possible mechanisms for observed herbaceous community responses to herbivory, we created a simple community assembly and grazing response model in which idealized plant communities first assemble stochastically, with each new species assigned a canopy cover drawn from a negative binomial distribution (mean cover, $\mu = 15\%$; dispersion $= 1.0$) until the collective canopy cover $= 100\%$ of available space, after which time no further species can be added. The grazing process is then simulated with (1) species in the community assigned as 'palatable' or 'unpalatable' using a random binomial process ($P = 0.5$), and (2) reduction in cover of palatable species simulated as a random uniform process where ~50% of palatable species are excluded by grazing (that is, cover is reduced to 0%), and the cover of the remaining palatable species is reduced by 50–99% of their original extent. The community response to the resources made available through grazing-induced loss in plant cover is then simulated via the effect of two mechanisms: (1) competitive release of ungrazed species ('growth response'); and (2) establishment of novel species (that is, species assumed to have been absent in the ungrazed community, but available in the regional species pool; 'immigration response'). The growth and immigration responses are simulated alternately until the resulting community again occupies all available space, with each ungrazed species increasing its cover in proportion to the grazing-induced loss in total cover in the plot, and new immigrants arriving via the negative binomial stochastic process used in the original community assembly.

Reporting summary. Further information on experimental research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

While not all raw species abundances are publicly available because of lack of permission from data owners (contact individual data set owners listed in Supplementary Table 1), all data generated and analysed during the current study (site-level richness response to herbivory, site-level Berger–Parker and Simpson's dominance response to herbivory, site ANPP, and site MAP) are provided in Supplementary Table 2.

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Author contributions

S.E.K. managed the project including conceptualizing the questions, collecting and analysing the data, developing the figures and writing the manuscript. M.D.S. conceptualized the questions and wrote the manuscript. D.E.B. conceptualized the questions, collected the data and wrote the manuscript. N.P.H. performed simulations and wrote the manuscript. M.L.A. and N.P.L. executed the path analyses and developed the figures. S.L.C. and A.K.K. wrote the manuscript. S.E., E.J.F. and D.I.T. contributed to data collection and management. S.E.K., M.D.S., D.E.B., N.P.H., M.L.A., S.L.C., A.K.K., N.P.L., E.J.F., S.E. and D.I.T. attended multiple working groups to complete this manuscript while all other co-authors contributed data to the synthesis; all authors (both members of the working group and not) edited the manuscript. See the author contribution table (Supplementary Table 11) for a complete list of contributions.

Competing interests

The authors declare no competing interests.

Additional information

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Change in dominance determines herbivore effects on plant biodiversity

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Supplementary Table 1. Site locations and contact researcher. Sites are organized first by Biogeographic Realm and then by site mean annual precipitation (MAP; low to high); additionally, Site # and organization are consistent between SupplementaryTables 1-3.

Site #	Site Name	Country	Lat	Long	Contact
Afrotropics					
1	Tierberg_Karoo_Research_Centre	South Africa	-33.2	22.4	Sue Milton
2	KarooNP_Sandrivier	South Africa	-32.3	22.3	TinekeKraaij
3	KarooNP_Lammertjiesleegte	South Africa	-32.3	22.6	TinekeKraaij
4	Pniel	South Africa	-28.6	24.4	David Ward
5	Kruger_Letaba	South Africa	-23.8	31.4	Frances Siebert
6	Mali_Korokodjo	Mali	15.3	-9.5	Niall Hanan, Moussa Karembe, FadialaDembele
7	Kruger_Nwan	South Africa	-24.5	31.9	Sally Koerner, Melinda Smith
8	Kenya_North	Kenya	0.5	36.9	Jacob R. Goheen, Todd M. Palmer, Robert M. Pringle
9	Ethiopia	Ethiopia	4.8	38.4	Ayana Angassa
10	Mpala	Kenya	0.3	36.9	David Augustine
11	Kruger_Buff	South Africa	-24.4	31.8	Stephanie Eby, Melinda Smith
12	Kruger_Marheya	South Africa	-24.5	31.8	Sally Koerner, Melinda Smith
13	Kruger_Satara	South Africa	-24.4	31.7	Sally Koerner, Melinda Smith
14	Kruger_Nkuhlu	South Africa	-25	31.8	Frances Siebert
15	Mali_Lakamane	Mali	14.6	-9.9	Niall Hanan, Moussa Karembe, FadialaDembele
16	Kenya_Central	Kenya	0.4	36.9	Jacob R. Goheen, Todd M. Palmer, Robert M. Pringle
17	KLEE_cattle (O vs. C)	Kenya	0.3	36.8	Corinna Riginos, Kari E. Veblen, Truman Young
18	KLEE_wildlife (O vs. MW)	Kenya	0.3	36.8	Corinna Riginos, Kari E. Veblen, Truman Young
19	Kenya_South	Kenya	0.3	36.9	Jacob R. Goheen, Todd M. Palmer, Robert M. Pringle
20	Serengeti_Nutnet	Tanzania	-2.3	34.5	Mike Anderson
21	Mali_Neguela	Mali	12.9	-8.5	Niall Hanan, Moussa Karembe, FadialaDembele
22	Mali_Tiorola	Mali	11.6	-7.1	Niall Hanan, Moussa Karembe, FadialaDembele
23	Mali_Tiendaga	Mali	11	-6.8	Niall Hanan, Moussa Karembe, FadialaDembele
24	Mananga_High	South Africa	-24.4	31.7	Deron Burkepile
25	Mananga_Low	South Africa	-24.4	31.9	Deron Burkepile
26	SataraNorth_High	South Africa	-24.4	31.9	Deron Burkepile
27	SataraNorth_Low	South Africa	-24.4	31.7	Deron Burkepile
28	SataraSouth_High	South Africa	-24.5	31.9	Deron Burkepile
29	SataraSouth_Low	South Africa	-24.4	31.7	Deron Burkepile
30	Shibotawna_High	South Africa	-24.4	31.7	Deron Burkepile
31	Shibotawna_Low	South Africa	-24.4	31.9	Deron Burkepile
Australasia					
32	AUS_FowlersGap	Australia	-31.1	141.7	David Eldridge
33	AUS_Mallee	Australia	-34.2	142.5	David Eldridge
34	AUS_Arumpo	Australia	-33.9	143	David Eldridge
35	AUS_Kimberley	Australia	-32.5	145.6	David Eldridge
36	AUS_Ag_Biod	Australia	-34.1	142.5	David Eldridge
37	AUS_Buronga	Australia	-34.2	142.2	James Val
38	AUS_Murray	Australia	-34.3	141.8	John Morgan, Nick Schultz
39	AUS_Hattah	Australia	-34.7	142.3	John Morgan, Nick Schultz
40	AUS_Wapweelah	Australia	-29.3	145.5	David Eldridge
41	AUS_Yathong_large	Australia	-32.6	145.6	David Eldridge
42	AUS_Yathong_small	Australia	-32.5	145.6	David Eldridge
43	AUS_Werrai	Australia	-35.4	144.6	David Eldridge
44	AUS_OBriens	Australia	-36.2	144.4	John Morgan, Nick Schultz
45	AUS_Pinegrove	Australia	-36.2	144.4	John Morgan, Nick Schultz
46	AUS_Paradise	Australia	-34.8	144.8	David Eldridge
47	AUS_Kinypanial	Australia	-36.3	143.8	John Morgan, Nick Schultz
48	AUS_CYP	Australia	-35	146.5	David Eldridge
49	AUS_Savernake	Australia	-35.8	146	David Eldridge
50	AUS_Inverleigh	Australia	-38.1	144.1	John Morgan, Nick Schultz

51	AUS_Warrambeen	Australia	-37.9	143.9	John Morgan, Nick Schultz
52	AUS_Berry	Australia	-32.9	148.1	David Eldridge
53	AUS_Darlington	Australia	-37.9	143	Claire Moxham, Josh Dorrough
54	AUS_Grampians	Australia	-37.1	142.4	John Morgan, Nick Schultz
55	AUS_Craigieburn	Australia	-37.6	144.9	John Morgan, Nick Schultz
56	Molesworth_ST	New Zealand	-42.2	172.8	Sean Husheer
57	Molesworth_SW	New Zealand	-42.1	172.9	Sean Husheer
58	AUS_Hamilton	Australia	-37.8	142.1	Claire Moxham, Josh Dorrough
59	Molesworth_CC	New Zealand	-42.2	172.9	Sean Husheer
60	AUS_Birregurra	Australia	-38.3	146.7	Claire Moxham, Josh Dorrough
61	Molesworth_HG	New Zealand	-42.1	172.9	Sean Husheer
62	Molesworth_SD	New Zealand	-42.2	172.9	Sean Husheer
63	VictoriaRiverResearchStation	Australia	-16.1	131	Gary Bastin
64	Molesworth_PT	New Zealand	-42.3	173	Sean Husheer
65	AUS_WilsonsPromontory	Australia	-38.9	146.2	John Morgan, Nick Schultz
Indo-malay					
66	India_Kibber	India	32.3	78	SumantaBagchi
67	India_Nutnet	India	32.3	78	Mahesh Sankaran, V. T. Yadugiri
Nearctic					
68	MNP_14mileTank	USA	35.4	-115.4	Erik Beever
69	MNP_TenmileTank	USA	35.3	-115.4	Erik Beever
70	MNK_16mileTank	USA	35.3	-115.5	Erik Beever
71	MNP_30	USA	35.2	-115.5	Erik Beever
72	Park Pasture	USA	38	-109.7	Kyle Nehring, Kari E. Veblen, Jane Zelikova
73	Cisco Wash 1	USA	39	-109.4	Kyle Nehring, Kari E. Veblen, Jane Zelikova
74	Cisco Wash 2	USA	39	-109.4	Kyle Nehring, Kari E. Veblen, Jane Zelikova
75	Cisco Mesa	USA	39.1	-109.4	Kyle Nehring, Kari E. Veblen, Jane Zelikova
76	Sand Flat	USA	38	-109.9	Kyle Nehring, Kari E. Veblen, Jane Zelikova
77	N_Clan	USA	39.8	-117.7	Lauren Baur, Kate Schoenecker
78	Hotel Mesa	USA	38.8	-109.2	Kyle Nehring, Kari E. Veblen, Jane Zelikova
79	Westwater	USA	39.2	-109.2	Kyle Nehring, Kari E. Veblen, Jane Zelikova
80	Horse Pasture	USA	39.1	-109.6	Kyle Nehring, Kari E. Veblen, Jane Zelikova
81	Buckhorn	USA	38.9	-109.2	Kyle Nehring, Kari E. Veblen, Jane Zelikova
82	Jornada	USA	32.6	-106.7	John Anderson
83	Neponset	USA	38	-109.6	Kyle Nehring, Kari E. Veblen
84	Dry Valley	USA	38.2	-109.4	Kyle Nehring, Kari E. Veblen, Jane Zelikova
85	Canada_Currie	Canada	50.7	-120.5	Lauchlan Fraser
86	Canada_LGS.6	Canada	50.7	-120.4	Lauchlan Fraser
87	DeseretLow	USA	41.4	-111.4	Elisabeth Bakker, Mark Ritchie
88	DeseretSage	USA	41.2	-111.1	Elisabeth Bakker, Mark Ritchie
89	Kate Hollow	USA	41.3	-111.2	Kyle Nehring, Kari E. Veblen
90	Canada_Dewdrop.2	Canada	50.8	-120.6	Lauchlan Fraser
91	Canada_lls1	Canada	50.8	-120.4	Lauchlan Fraser
92	Salt Creek Mesa	USA	38.9	-109.2	Kyle Nehring, Kari E. Veblen, Jane Zelikova
93	Short Grass Steppe	USA	40.8	-104.8	Elisabeth Bakker, Daniel Milchunas
94	Stanley Park	USA	38.8	-109.1	Kyle Nehring, Kari E. Veblen, Jane Zelikova
95	Canada_hav	Canada	50.1	-120.5	Lauchlan Fraser
96	Canada_hbb	Canada	50.1	-120.5	Lauchlan Fraser
97	Canada_MG1.LDB	Canada	50.8	-120.4	Lauchlan Fraser
98	Canada_MG2.LDB	Canada	50.8	-120.4	Lauchlan Fraser
99	House Park	USA	38	-109.9	Kyle Nehring, Kari E. Veblen, Jane Zelikova
100	Canada_hkb	Canada	50.1	-120.5	Lauchlan Fraser
101	Canada_MG3.LDB	Canada	50.7	-120.4	Lauchlan Fraser
102	Canada_Goose.Lake	Canada	50.1	-120.4	Lauchlan Fraser
103	Canada_Lundbom.Lake	Canada	50.1	-120.6	Lauchlan Fraser
104	N_Sulphur	USA	38.6	-113.9	Lauren Baur, Kate Schoenecker
105	North Cottonwood	USA	38.2	-109.7	Kyle Nehring, Kari E. Veblen, Jane Zelikova
106	Canada_gooselake2	Canada	50.1	-120.4	Lauchlan Fraser

107	Canada_Mara.1	Canada	50.7	-120.5	Lauchlan Fraser
108	Harts Point	USA	38	-109.5	Kyle Nehring, Kari E. Veblen, Jane Zelikova
109	Texas Flat	USA	41.3	-111.2	Kyle Nehring, Kari E. Veblen, Jane Zelikova
110	FortKeogh	USA	46.4	-105.9	Lance Vermeire, Dustin Strong
111	CPER	USA	40.8	-104.7	David Augustine, Dan Milchunas
112	Steamboat Mesa	USA	37.6	-109.8	Kyle Nehring, Kari E. Veblen, Jane Zelikova
113	Wild Cow Point	USA	37.9	-110	Kyle Nehring, Kari E. Veblen, Jane Zelikova
114	N_Pryor	USA	45.1	-108.3	Lauren Baur, Kate Schoenecker
115	Canada_Dewdrop.1	Canada	50.8	-120.7	Lauchlan Fraser
116	Canada_llrs	Canada	50.8	-120.4	Lauchlan Fraser
117	Canada_LG5.LDB	Canada	50.7	-120.4	Lauchlan Fraser
118	Canada_Summit.North	Canada	50.1	-120.4	Lauchlan Fraser
119	Canada_LG4.LDB	Canada	50.7	-120.4	Lauchlan Fraser
120	Canada_Repeter	Canada	50.1	-120.4	Lauchlan Fraser
121	Canada_LGS.4	Canada	50.7	-120.4	Lauchlan Fraser
122	Canada_UG2.LDB	Canada			Lauchlan Fraser
123	Harts Draw	USA	38	-109.5	Kyle Nehring, Kari E. Veblen, Jane Zelikova
124	Canada_LG2.LDB	Canada	50.7	-120.4	Lauchlan Fraser
125	Canada_Powerline	Canada	50.1	-120.4	Lauchlan Fraser
126	Canada_hsr	Canada	50.1	-120.5	Lauchlan Fraser
127	Canada_MGBR.1	Canada	50.8	-120.4	Lauchlan Fraser
128	Canada_LG1.LDB	Canada	50.7	-120.4	Lauchlan Fraser
129	Canada_MGBR.2	Canada	50.8	-120.4	Lauchlan Fraser
130	Canada_LGS.5	Canada	50.7	-120.4	Lauchlan Fraser
131	Canada_UG3.LDB	Canada			Lauchlan Fraser
132	Canada_LG3.LDB	Canada	50.7	-120.4	Lauchlan Fraser
133	Canada_Redhil	Canada	50.8	-120.4	Lauchlan Fraser
134	Canada_Frolek	Canada	50.8	-120.4	Lauchlan Fraser
135	Canada_Long.lake.6	Canada	50.8	-120.4	Lauchlan Fraser
136	N_Theodore	USA	47	-103.4	Lauren Baur, Kate Schoenecker
137	The Dip	USA	37.7	-110	Kyle Nehring, Kari E. Veblen
138	Canada_LGS.1	Canada	50.7	-120.4	Lauchlan Fraser
139	Canada_Summit.South	Canada	50.1	-120.4	Lauchlan Fraser
140	California_Sedgwick_Airstrip	USA	34.7	-120	Carla Dantonio, Claudia Tyler, Barbara Fernandex-Going
141	California_Sedgwick_Lisque	USA	34.7	-120	Carla Dantonio, Claudia Tyler, Barbara Fernandex-Going
142	California_Sedgwick_Mesa	USA	34.7	-120	Carla Dantonio, Claudia Tyler, Barbara Fernandex-Going
143	Lost Park	USA	41.4	-111.1	Kyle Nehring, Kari E. Veblen, Jane Zelikova
144	Canada_LGS.2	Canada	50.7	-120.4	Lauchlan Fraser
145	Canada_TMV	Canada	50.8	-120.4	Lauchlan Fraser
146	N_Spring	USA	38	-108.6	Lauren Baur, Kate Schoenecker
147	Canada_Drum	Canada	50.1	-120.7	Lauchlan Fraser
148	Canada_llw	Canada	50.8	-120.4	Lauchlan Fraser
149	Canada_FLHT.2	Canada	50.7	-120.4	Lauchlan Fraser
150	Canada_Long.lake.5	Canada	50.8	-120.4	Lauchlan Fraser
151	Canada_fht1	Canada	50.7	-120.4	Lauchlan Fraser
152	Canada_Long.lake.4	Canada	50.8	-120.4	Lauchlan Fraser
153	Mexico_LaColorada	Mexico	22	-102.3	Gerardo Armando Aguado Santacruz
154	Mexico_LaMesa	Mexico	22	-102.3	Gerardo Armando Aguado Santacruz
155	Mexico_LaPresa	Mexico	22	-102.3	Gerardo Armando Aguado Santacruz
156	Mexico_Vaquerias	Mexico	22	-102.3	Gerardo Armando Aguado Santacruz
157	Canada_LGS.3	Canada	50.7	-120.4	Lauchlan Fraser
158	Canada_UG1.LDB	Canada			Lauchlan Fraser
159	Washington_OakCreek	USA	46.7	-120.8	Andrew Kulmatiski
160	Washington_Wenas	USA	46.8	-120.7	Andrew Kulmatiski
161	California_Sedgwick	USA	34.7	-120	Carla Dantonio, Karen Stahlheber
162	Washington_LTMurray	USA	48	-120.8	Andrew Kulmatiski
163	DeseretHigh	USA	41.4	-111.4	Elisabeth Bakker, Mark Ritchie
164	California_RanchoMarino	USA	35.5	-121.1	Carla Dantonio, Barbara Fernandex-Going, Don Canestro

165	Washington_Sinlahekin	USA	48.7	-120.7	Andrew Kulmatiski
166	CedarCreek	USA	45.1	-93.2	Elisabeth Bakker, Jean Knops
167	Konza	USA	39.1	-96.6	Sally Koerner, Melinda Smith
168	KonzaPrairie	USA	39.1	-96.6	Elisabeth Bakker, Jean Knops
169	MAERC	USA	27.1	-81.2	Elizabeth Boughton, Patrick Bohlen
170	NS_East Light BIO	Canada	44	-59.8	Bill Freedman
171	NS_Main Station Dry Heath	Canada	43.9	-60	Bill Freedman
172	NS_Main Station Grassland	Canada	43.9	-60	Bill Freedman
173	NS_Main Station Mesic Heath	Canada	43.9	-60	Bill Freedman
174	NS_West Light	Canada	43.9	-60	Bill Freedman
175	NS_Wind Turbine (a)	Canada	43.9	-60	Bill Freedman
176	NS_Wind Turbine (b)	Canada	43.9	-60	Bill Freedman
Neotropic					
177	Argentina_RMcI84	Argentina	-45.4	-70.3	CesaAriela
178	Argentina_S18	Argentina	-45.4	-70.3	CesaAriela
179	Argentina_S19	Argentina	-45.4	-70.3	CesaAriela
180	Argentina_S20	Argentina	-45.4	-70.3	CesaAriela
181	Argentina_S12	Argentina	-41.1	-70.6	CesaAriela
182	Argentina_S13	Argentina	-41.1	-70.6	CesaAriela
183	Argentina_S14	Argentina	-41.1	-70.6	CesaAriela
184	Argentina_S15	Argentina	-41.1	-70.6	CesaAriela
185	Argentina_S16	Argentina	-41.1	-70.6	CesaAriela
186	Argentina_S17	Argentina	-41.1	-70.6	CesaAriela
187	Argentina_ML	Argentina	-45.6	-71.4	CesaAriela
188	Argentina_S21	Argentina	-45.6	-71.4	CesaAriela
189	Argentina_S22	Argentina	-45.6	-71.4	CesaAriela
190	Argentina_S1	Argentina	-41.1	-70.9	CesaAriela
191	Argentina_S2	Argentina	-41.1	-70.9	CesaAriela
192	Argentina_S3	Argentina	-41.1	-70.9	CesaAriela
193	Argentina_S10	Argentina	-41.1	-71	CesaAriela
194	Argentina_S11	Argentina	-41.1	-71	CesaAriela
195	Argentina_S4	Argentina	-41.1	-71.1	CesaAriela
196	Argentina_S5	Argentina	-41.1	-71.1	CesaAriela
197	Argentina_S6	Argentina	-41.1	-71.1	CesaAriela
198	Argentina_S7	Argentina	-41.1	-71.1	CesaAriela
199	Argentina_S8	Argentina	-41.1	-71	CesaAriela
200	Argentina_S9	Argentina	-41.1	-71.1	CesaAriela
201	Argentina_Sierra	Argentina	-38.1	-62	Alejandro Loydi
202	LasChilcas	Argentina	-36.5	-58.5	Enrique Chaneton
203	Uruguay_Relincho	Uruguay	-34.3	-57	Felipe Lezama
204	Argentina_ElPalmar	Argentina	-31.9	-58.3	Felipe Lezama
205	Uruguay_Quebrada	Uruguay	-32.9	-54.5	Felipe Lezama
206	Uruguay_SUL	Uruguay	-33.9	-55.6	Felipe Lezama
207	Uruguay_Glencoe	Uruguay	-32	-57.2	Felipe Lezama
Palerarctic					
208	Tibet_Site25_Rutog_Rusong	China	33.3	79.7	Jianshuang Wu
209	Mongolia_BGgrassland	Mongolia	43.9	103.5	Takehiro Sasaki
210	Tibet_Site10_Gegyai_Xiongbar	China	32.1	81.8	Jianshuang Wu
211	Tibet_Site24_Gegyai_Xiongbar2	China	32.1	81.8	Jianshuang Wu
212	Mongolia_Mgshrubland	Mongolia	45.8	106.2	Takehiro Sasaki
213	Mongolia_Mgairport	Mongolia	45.8	106.3	Takehiro Sasaki
214	Tibet_Site23_Gegyai_Wenbudangsang	China	32.1	82.9	Jianshuang Wu
215	Tibet_Site22_Gerze_Gerze	China	32.3	84.1	Jianshuang Wu
216	Tibet_Site21_Gerze_Dongcuo	China	32.3	84.4	Jianshuang Wu
217	Tibet_Site20_Gerze_DongcuoTemple	China	32	85.1	Jianshuang Wu
218	Tibet_Site19_Nyima_Zhongcang2	China	32	85.4	Jianshuang Wu
219	Tibet_Site9_Nyima_Zhongcang	China	32	85.1	Jianshuang Wu
220	Tibet_Site18_Nyima_Erjiu2	China	32.3	86.7	Jianshuang Wu

221	Tibet_Site6_Shuanghu_Beicuo	China	33.2	87.7	Jianshuang Wu
222	Tibet_Site7_Nyima_Erjiu	China	31.9	86.9	Jianshuang Wu
223	Tibet_Site8_Nyima_Arsuo	China	31.9	86.6	Jianshuang Wu
224	Tibet_Site17_Shuanghu_Shuanghu	China	33.2	88.8	Jianshuang Wu
225	CanaryIsland_Valle	Canary Islands	28.1	-17.3	Silvia Fernandez-Lugo
226	China_LC	China	43.6	116.7	Qiang Yu
227	China_SG	China	43.5	116.6	Qiang Yu
228	Tibet_Site5_Bangoin_Marqian	China	31.8	89.9	Jianshuang Wu
229	Tibet_Site16_Bangoin_Pubao2	China	31.4	90.3	Jianshuang Wu
230	Tibet_Site4_Bangoin_Pubao	China	31.4	90.3	Jianshuang Wu
231	Spain_ChapineriaHP	Spain	40.4	-4.2	Marta Rueda
232	Spain_ChapineriaLP	Spain	40.4	-4.2	Marta Rueda
233	Tibet_Site3_Bangoin_Pengcuo_South	China	31.4	91	Jianshuang Wu
234	CanaryIsland_Teno	Canary Islands	28.3	-16.8	Silvia Fernandez-Lugo
235	Tibet_Site15_Bangoin_Beilar	China	31.4	91	Jianshuang Wu
236	Tibet_Site2_Amdo_Cuomar	China	32.3	91.5	Jianshuang Wu
237	Tibet_Site14_Nagqu_Namarqie	China	31.6	91.5	Jianshuang Wu
238	CanaryIsland_Anaga	Canary Islands	28.5	-16.2	Silvia Fernandez-Lugo
239	Tibet_Site1_Amdo_Bangai	China	32.3	91.9	Jianshuang Wu
240	Tibet_Site12_Amdo_Marluo	China	32.3	91.9	Jianshuang Wu
241	Lapland_Jehkas	Finland	69.1	20.8	Minna-MaaritKytöviita
242	Lapland_Saana	Finland	69.1	20.8	Minna-MaaritKytöviita
243	Tibet_Site11_Amdo_Guozur	China	31.7	91.8	Jianshuang Wu
244	Tibet_Site13_Nagqu_Nagqu	China	31.7	92	Jianshuang Wu
245	Germany1	Germany	49.9	8.7	Angelika Schwabe, Christian Storm
246	Germany2	Germany	49.9	8.7	Angelika Schwabe, Christian Storm
247	JunnerKoeland	Netherlands	52.5	6.5	Elisabeth Bakker, Han Olff
248	SwissNP_Short	Switzerland	46.7	10.3	Anita Risch, Martin Schuetz, MartijnVandegehuchte
249	SwissNP_Tall	Switzerland	46.7	10.3	Anita Risch, Martin Schuetz, MartijnVandegehuchte
250	France_Heath	France	45.1	6.1	Claire Deleglise, Gregory Loucougaray
251	France_Mesic	France	44.9	5.5	Claire Deleglise, Gregory Loucougaray
252	France_Xeric	France	44.9	5.5	Claire Deleglise, Gregory Loucougaray

Supplementary Table 2. Site characteristics. Sites are organized first by Biogeographic Realm and then by site mean annual precipitation (MAP; low to high); additionally, Site # and organization are consistent between SupplementaryTables 1-3.

Site #	Site Name	MAP (mm)	MAT (°C)	ANPP (g/m^2)	Excl. Age	Site Richness	Site BP Dom	Site Simp Dom	Richness Response	BP-Dom Response	Simp Dom Response
	Afrotropics										
1	Tierberg_Karoo_Research_Centre	176	14		28	16	36.9	0.25	-0.15	0.12	0.16
2	KarooNP_Sandrivier	196	17		11	54	26.5	0.16	0.02	0.11	0.01
3	KarooNP_Lammertjiesleegte	282	15		11	64	35.7	0.21	-0.17	0.17	0.22
4	Pniel	360	18		5	8	68.2	0.52	-0.14	-0.05	-0.03
5	Kruger_Letaba	400	22	118	12	75	53.0	0.30	0.00	-0.11	-0.21
6	Mali_Korokodjo	427	28	243	4	48	15.8	0.08	-0.25	-0.31	0.00
7	Kruger_Nwan	463	22	500	9	36	42.1	0.28	0.11	0.13	0.14
8	Kenya_North	493	18	512	6	33	31.5	0.17	-0.39	0.30	0.48
9	Ethiopia	500	19		30	31	30.4	0.16	-0.07	0.08	0.30
10	Mpala	514	17		4	45	35.2	0.19	-0.11	-0.14	-0.09
11	Kruger_Buff	547	22	487	7	46	64.6	0.53	0.49	-0.19	-0.29
12	Kruger_Marheya	557	21	560	7	32	76.8	0.64	0.28	-0.27	-0.35
13	Kruger_Satara	559	22	609	9	24	78.3	0.68	-0.10	0.01	0.01
14	Kruger_Nkuhlu	560	21	372	10	179	13.2	0.04	0.23	-0.73	-0.38
15	Mali_Lakamane	577	27	228	4	54	12.6	0.07	0.11	0.19	0.01
16	Kenya_Central	578	18	1204	6	32	40.3	0.23	-0.17	-0.21	-0.16
17	KLEE_cattle (O vs. C)	613	17		18	29	37.6	0.22	-0.03	-0.12	-0.08
18	KLEE_wildlife (O vs. MW)	613	17		18	36	37.6	0.22	0.06	-0.08	-0.11
19	Kenya_South	625	17	722	6	35	59.6	0.43	0.20	-0.48	-0.58
20	Serengeti_Nutnet	789	21	166	5	23	34.9	0.20	0.14	-0.12	-0.05
21	Mali_Neguela	868	27	421	2	56	18.5	0.08	0.12	-0.34	-0.15
22	Mali_Tiorola	1043	27	718	4	61	15.9	0.07	0.13	-0.24	-0.09
23	Mali_Tiendaga	1132	27	573	4	72	14.1	0.07	0.10	-0.20	-0.21
24	Mananga_High		22	311	7	44	41.5	0.26	0.16	-0.03	0.07
25	Mananga_Low		22	93	7	31	45.6	0.29	-0.13	-0.02	0.01
26	SataraNorth_High		22	769	7	21	73.3	0.60	0.39	-0.34	-0.40
27	SataraNorth_Low		22	504	5	26	60.6	0.43	0.14	-0.44	-0.42
28	SataraSouth_High		22	790	7	21	71.2	0.55	0.41	-0.23	-0.42
29	SataraSouth_Low		22	553	7	26	49.8	0.32	0.45	-0.17	-0.24
30	Shibotawna_High		22	517	7	31	35.3	0.24	0.12	0.23	0.22
31	Shibotawna_Low		22	135	7	16	52.6	0.42	-0.09	-0.22	-0.32
	Australasia										
32	AUS_FowlersGap	223	18		12	53	34.7	0.20	0.10	-0.33	-0.33
33	AUS_Mallee	240	16	73	17	15	71.3	0.52	0.18	0.06	0.13
34	AUS_Arumpo	245	17		28	30	36.7	0.22	-0.24	0.14	0.09
35	AUS_Kimberley	245	17		12	78	16.1	0.06	-0.06	-0.34	-0.19
36	AUS_Ag_Biod	246	17		5	58	29.6	0.15	-0.17	0.05	0.10
37	AUS_Buronga	260	17		13	35	25.1	0.13	-0.82	0.82	1.00
38	AUS_Murray	272	17	172	15	12	87.8	0.78	0.32	0.01	0.01
39	AUS_Hattah	293	16	171	9	26	39.2	0.25	0.21	-1.30	-1.33
40	AUS_Wapweelah	312	20		19	31	28.0	0.19	0.00	0.70	0.66
41	AUS_Yathong_large	340	17		10	34	52.0	0.35	-0.61	0.15	0.52
42	AUS_Yathong_small	340	17		31	77	37.2	0.22	-0.27	0.36	0.53
43	AUS_Werrai	375	16	54	5	21	37.3	0.20	-0.16	-0.35	-0.23
44	AUS_OBriens	381	15	407	4	26	26.4	0.14	-0.05	-0.04	-0.13
45	AUS_Pinegrove	381	15	162	10	22	19.5	0.10	-0.33	0.70	0.70
46	AUS_Paradise	400	16		65	24	37.7	0.19	0.41	-0.07	-0.06
47	AUS_Kinypanial	409	15	208	12	34	18.6	0.08	0.00	0.15	0.01

48	AUS_CYP	432	16	73	10	54	33.6	0.19	0.06	-0.40	-0.56
49	AUS_Savernake	475	16		7	67	37.3	0.23	0.00	0.00	0.01
50	AUS_Inverleigh	523	13	306	11	18	93.8	0.88	0.24	-1.07	-1.69
51	AUS_Warrambeen	587	13	944	12	30	91.2	0.83	0.77	-1.42	-2.27
52	AUS_Berry	605	17		7	79	16.7	0.08	0.30	-0.50	-0.36
53	AUS_Darlington	620	13	500	3	29	40.5	0.28	0.05	-0.43	-0.73
54	AUS_Grampians	629	12	44	6	35	20.8	0.09	-0.15	-0.61	-0.40
55	AUS_Craigieburn	665	13	350	8	29	18.5	0.11	0.08	0.80	0.69
56	Molesworth_ST	680	5		19	66	19.8	0.10	0.06	0.19	0.14
57	Molesworth_SW	680	5		13	17	24.5	0.18	-0.09	0.19	0.16
58	AUS_Hamilton	686	13	242	3	22	39.8	0.27	0.33	-0.58	-0.73
59	Molesworth_CC	720	5		19	28	26.3	0.12	-0.27	0.08	0.24
60	AUS_Birregurra	730	12	712	3	23	33.4	0.26	0.10	0.23	-0.07
61	Molesworth_HG	750	5		19	48	16.2	0.08	-0.35	0.16	0.26
62	Molesworth_SD	750	5		19	25	24.5	0.16	-0.20	0.14	0.14
63	VictoriaRiverResearchStation	780	27	108	29	20	62.4	0.44	-0.11	0.20	0.30
64	Molesworth_PT	780	6		14	21	46.2	0.25	0.06	-0.46	-0.31
65	AUS_WilsonsPromontory	960	13	941	16	23	75.9	0.60	0.65	-1.12	-1.73
Indo-malay											
66	India_Kibber	400	-5	55	5	34	39.4	0.27	0.19	-0.07	-0.13
67	India_Nutnet	507	0	55	4	15	46.9	0.32	-0.08	0.07	0.17
Nearctic											
68	MNP_14mileTank	164	17		22	13	45.3	0.32	0.53	-0.61	-0.62
69	MNP_TenmileTank	181	15		22	14	35.4	0.24	-0.08	0.14	0.02
70	MNK_16mileTank	184	15		22	7	52.4	0.37	0.22	-0.20	-0.33
71	MNP_30	203	15		22	21	42.0	0.31	-0.32	0.41	0.42
72	Park Pasture	213	7		56	27	28.9	0.18	-0.05	-0.25	-0.19
73	Cisco Wash 1	215	10		51	16	41.4	0.27	-0.08	0.01	0.15
74	Cisco Wash 2	215	10		51	24	58.5	0.37	-0.11	-0.50	-0.46
75	Cisco Mesa	223	10		53	21	32.8	0.23	-0.06	0.32	0.22
76	Sand Flat	225	8		51	28	51.4	0.30	0.10	-0.45	-0.46
77	N_Clan	229	8		23	22	41.3	0.26	-0.29	0.18	0.29
78	Hotel Mesa	237	11		51	32	21.0	0.12	0.29	0.23	0.19
79	Westwater	242	9		51	20	33.8	0.25	0.59	0.14	-0.18
80	Horse Pature	270	8		48	23	54.0	0.35	0.11	-0.33	-0.25
81	Buckhorn	272	9		51	29	32.5	0.20	0.34	-0.25	-0.29
82	Jornada	280	14		23	43	63.3	0.51	-0.09	0.05	0.11
83	Neponset	286	7		20	26	14.2	0.07	0.00	0.45	0.30
84	Dry Valley	293	9		35	18	59.5	0.39	-0.21	-0.18	-0.14
85	Canada_Currie	304	6	155	73	12	76.1	0.59	0.11	-1.19	-1.27
86	Canada_LGS.6	304	6	187	10	16	73.4	0.56	0.07	-0.18	-0.32
87	DeseretLow	305	2	125	7	18	52.5	0.36	0.24	-0.20	-0.15
88	DeseretSage	305	4	47	7	27	32.8	0.19	0.09	-0.15	-0.08
89	Kate Hollow	310	3		20	23	24.7	0.10	0.20	-0.45	-0.34
90	Canada_Dewdrop.2	320	6	164	37	13	70.0	0.51	0.09	-0.83	-0.84
91	Canada_lls1	320	6	198	13	16	47.3	0.40	0.59	-0.11	-0.42
92	Salt Creek Mesa	320	11		43	23	32.8	0.16	-0.10	0.00	0.25
93	Short Grass Steppe	322	8	91	7	48	56.3	0.39	-0.21	0.09	0.07
94	Stanley Park	322	10		54	24	45.6	0.34	0.38	0.40	0.34
95	Canada_hav	327	4	202	13	20	32.9	0.18	0.11	-0.10	-0.21
96	Canada_hbb	327	4	248	13	14	54.8	0.37	0.18	-0.24	-0.25
97	Canada_MG1.LDB	327	6	231	30	16	55.0	0.36	-0.21	0.00	0.02
98	Canada_MG2.LDB	327	6	215	30	20	45.6	0.26	0.18	0.11	0.12
99	House Park	327	8		55	35	31.8	0.16	0.23	0.06	-0.02
100	Canada_hkb	328	4	276	13	11	88.9	0.80	1.03	-0.97	-1.29
101	Canada_MG3.LDB	328	6	250	30	21	73.4	0.55	-0.06	-0.57	-0.87
102	Canada_Goose.Lake	329	4	284	78	24	71.3	0.52	-0.11	-1.19	-1.29
103	Canada_Lundbom.Lake	329	4	191	26	9	58.5	0.38	0.32	0.04	0.07

104	N_Sulphur	332	7		82	20	38.2	0.26	-0.07	0.27	0.31
105	North Cottonwood	332	12		55	25	36.7	0.23	0.06	-0.32	-0.24
106	Canada_gooselake2	334	4	252	5	18	22.3	0.16	0.06	0.50	0.27
107	Canada_Mara.1	334	6	158	73	16	57.2	0.37	-0.15	0.30	0.49
108	Harts Point	338	7		53	15	49.6	0.34	0.00	0.07	0.20
109	Texas Flat	338	3		55	25	23.0	0.14	0.15	0.78	0.71
110	FortKeogh	339	7	124	20	48	49.0	0.35	0.00	0.05	0.08
111	CPER	340	8	70	72	78	46.3	0.31	0.08	0.23	0.25
112	Steamboat Mesa	345	9		45	20	29.6	0.21	-0.06	0.16	0.01
113	Wild Cow Point	349	8		55	25	29.2	0.21	0.05	0.11	-0.15
114	N_Pryor	352	6		22	66	38.1	0.24	0.07	-0.10	-0.17
115	Canada_Dewdrop.1	353	6	84	37	9	51.7	0.38	0.41	0.00	-0.05
116	Canada_llrs	353	6	312	30	16	51.9	0.33	0.24	-0.34	-0.60
117	Canada_LG5.LDB	362	6	219	30	12	88.8	0.79	0.32	-0.14	-0.26
118	Canada_Summit.North	362	4	340	41	17	44.0	0.26	0.29	-0.84	-0.81
119	Canada_LG4.LDB	364	6	147	30	17	58.5	0.40	0.69	-0.26	-0.44
120	Canada_Repeter	364	4	319	39	12	39.1	0.31	0.49	-0.45	-0.71
121	Canada_LGS.4	365	6	127	10	12	72.2	0.55	0.29	-0.19	-0.28
122	Canada_UG2.LDB	365		179	30	13	43.1	0.32	0.37	-0.42	-0.72
123	Harts Draw	372	9		56	18	54.8	0.37	0.44	-0.37	-0.24
124	Canada_LG2.LDB	373		189	30	12	72.2	0.56	0.11	0.07	0.10
125	Canada_Powerline	373	4	219	13	15	79.6	0.65	0.92	-1.65	-1.70
126	Canada_hsr	375	4	211	13	20	52.1	0.30	-0.18	-0.19	-0.11
127	Canada_MGBR.1	375	6	288	30	20	57.8	0.38	0.00	-0.18	-0.33
128	Canada_LG1.LDB	376	6	115	30	9	78.6	0.63	0.29	-0.63	-0.80
129	Canada_MGBR.2	376	6	271	30	21	30.3	0.20	-0.19	-0.08	-0.07
130	Canada_LGS.5	383	6	173	10	12	71.6	0.56	-0.25	-0.52	-0.60
131	Canada_UG3.LDB	383		229	26	15	98.2	0.97	1.25	-0.36	-0.67
132	Canada_LG3.LDB	384	6	153	30	13	57.6	0.38	-0.10	-0.11	-0.15
133	Canada_Redhil	384	6	314	50	16	45.8	0.27	0.06	0.08	0.09
134	Canada_Frolek	388	6	294	51	18	56.0	0.35	0.31	-0.82	-0.89
135	Canada_Long.lake.6	388	6	230	30	22	47.9	0.27	-0.10	-0.06	-0.12
136	N_Theodore	389	6		68	111	41.7	0.24	-0.07	-0.48	-0.47
137	The Dip	390	9		20	25	18.2	0.08	0.14	0.00	0.03
138	Canada_LGS.1	391	6	88	10	16	68.2	0.49	0.24	-0.16	-0.24
139	Canada_Summit.South	391	4	418	41	14	60.5	0.40	0.75	-0.13	-0.23
140	California_Sedgwick_Airstrip	401	14	271	13	30	65.4	0.55	0.34	-0.22	-0.33
141	California_Sedgwick_Lisque	401	14	271	16	56	43.3	0.26	0.19	-0.08	-0.14
142	California_Sedgwick_Mesa	401	14	271	16	54	61.5	0.42	0.47	-0.89	-1.00
143	Lost Park	409	3		55	15	80.0	0.65	0.29	-0.17	-0.27
144	Canada_LGS.2	412	6	163	10	10	43.7	0.27	0.18	0.07	0.22
145	Canada_TMV	412	6	221	19	17	30.7	0.16	-0.13	0.03	0.03
146	N_Spring	413	7		12	46	43.7	0.27	0.10	-0.17	-0.14
147	Canada_Drum	434	5	99	15	13	46.7	0.34	-0.10	0.31	0.24
148	Canada_llw	434	6	206	30	13	25.4	0.17	-0.09	0.17	0.08
149	Canada_FLHT.2	441	6	188	10	14	57.8	0.42	0.20	0.25	0.30
150	Canada_Long.lake.5	441	6	208	30	17	49.1	0.29	0.12	-0.22	-0.27
151	Canada_fht1	448	6	247	10	18	67.1	0.48	0.27	-0.21	-0.35
152	Canada_Long.lake.4	448	6	198	30	15	32.5	0.18	0.07	0.30	0.38
153	Mexico_LaColorada	450	17	114	6	34	37.9	0.19	-0.37	-0.20	-0.23
154	Mexico_LaMesa	450	17	100	5	13	53.9	0.33	-0.20	-0.20	-0.07
155	Mexico_LaPresa	450	17	132	7	37	41.6	0.24	-0.41	-0.10	-0.16
156	Mexico_Vaquerias	450	17	88	6	31	27.2	0.19	0.29	0.00	-0.22
157	Canada_LGS.3	469	6	176	10	20	43.9	0.31	0.35	0.26	0.17
158	Canada_UG1.LDB	469		255	30	12	85.0	0.73	0.26	-0.23	-0.45
159	Washington_OakCreek	526	7	200	51	45	10.0	0.06	0.14	-0.07	-0.04
160	Washington_Wenas	526	8	13	31	27	25.3	0.16	0.32	-0.35	-0.41
161	California_Sedgwick	565	14	287	16	37	44.6	0.30	0.04	-0.13	-0.25

162	Washington_LTMurray	569	4	22	31	29	23.0	0.15	0.16	-0.03	-0.19
163	DeseretHigh	635	2	203	7	33	30.8	0.19	0.10	-0.26	-0.30
164	California_RanchoMarino	733	13	422	7	42	50.1	0.33	0.03	-0.18	-0.24
165	Washington_Sinlahekin	737	0	97	51	64	22.1	0.14	-0.16	0.06	0.02
166	CedarCreek	825	7	222	7	84	22.9	0.13	0.03	0.42	0.39
167	Konza	835	12	525	8	95	53.7	0.36	0.39	-0.48	-0.61
168	KonzaPrairie	835	22	302	7	56	28.0	0.17	0.33	-0.02	-0.24
169	MAERC	1364	22	1105	13	25	63.6	0.51	0.50	0.22	0.23
170	NS_East Light BIO	1511	7		20	19	48.8	0.30	0.00	-0.79	-0.70
171	NS_Main Station Dry Heath	1511	7		20	26	27.4	0.17	-0.10	0.04	0.08
172	NS_Main Station Grassland	1511	7		20	19	36.6	0.21	0.13	0.06	0.10
173	NS_Main Station Mesic Heath	1511	7		20	26	25.6	0.11	0.09	-0.18	0.11
174	NS_West Light	1511	7		10	19	58.6	0.37	-0.21	-0.57	-0.67
175	NS_Wind Turbine (a)	1511	7		4	21	32.1	0.18	-0.06	0.03	0.26
176	NS_Wind Turbine (b)	1511	7		4	25	35.7	0.19	0.23	-0.18	-0.13
Neotropic											
177	Argentina_RMcI84	199	9		15	31	28.0	0.16	-0.11	0.17	0.23
178	Argentina_S18	199	9		47	18	35.2	0.23	-0.22	0.24	0.20
179	Argentina_S19	199	9		27	19	25.4	0.17	-0.57	0.48	0.62
180	Argentina_S20	199	9		15	15	32.2	0.22	-0.34	0.04	0.10
181	Argentina_S12	297	7		59	9	62.7	0.48	-0.56	0.16	0.28
182	Argentina_S13	297	7		59	11	53.1	0.39	-0.16	0.15	0.08
183	Argentina_S14	297	7		59	11	64.5	0.46	-0.42	-0.32	-0.26
184	Argentina_S15	297	7		59	17	36.1	0.20	-0.31	0.07	0.26
185	Argentina_S16	297	7		59	14	61.3	0.44	-0.01	-0.33	-0.31
186	Argentina_S17	297	7		59	16	61.6	0.44	-0.13	-0.29	-0.35
187	Argentina_ML	365	5		14	35	54.3	0.33	-0.10	-0.24	-0.35
188	Argentina_S21	365	5		14	25	61.4	0.40	-0.02	-0.30	-0.46
189	Argentina_S22	365	5		14	21	39.6	0.25	-0.19	0.42	0.44
190	Argentina_S1	472	7		59	25	27.5	0.16	-0.40	0.37	0.55
191	Argentina_S2	472	7		59	20	48.5	0.35	0.08	0.16	0.07
192	Argentina_S3	472	7		59	18	73.2	0.56	-0.60	0.07	0.14
193	Argentina_S10	530	7		59	15	44.0	0.27	-1.23	0.74	1.16
194	Argentina_S11	530	7		59	18	45.9	0.34	-0.20	-0.25	-0.26
195	Argentina_S4	530	7		59	18	69.0	0.53	-0.11	0.06	0.07
196	Argentina_S5	530	7		59	22	62.5	0.44	-0.57	0.03	0.10
197	Argentina_S6	530	7		59	17	77.1	0.60	-0.57	-0.11	-0.14
198	Argentina_S7	530	7		59	20	42.5	0.26	-0.37	-0.03	0.07
199	Argentina_S8	530	7		59	13	48.1	0.32	-0.33	-0.22	-0.06
200	Argentina_S9	530	7		59	17	40.0	0.27	-0.20	0.25	0.19
201	Argentina_Sierra	800	12	500	16	61	26.6	0.13	0.07	0.10	0.21
202	LasChilcas	953	14	530	21	54	21.5	0.13	0.42	0.05	-0.10
203	Uruguay_Relincho	1155	16	655	11	91	24.7	0.12	0.29	-0.09	-0.24
204	Argentina_ElPalmar	1338	18	720	30	90	36.7	0.22	0.51	-0.32	-0.36
205	Uruguay_Quebrada	1341	16	585	6	92	24.2	0.10	-0.05	-0.10	-0.07
206	Uruguay_SUL	1341	16	707	13	59	25.6	0.12	0.34	0.44	0.45
207	Uruguay_Glencoe	1495	18	650	18	94	33.3	0.14	0.11	-0.84	-0.78
Palerarctic											
208	Tibet_Site25_Rutog_Rusong	45	-4		4	3	60.9	0.45	-0.41	0.15	0.27
209	Mongolia_BGgrassland	116	3		9	23	61.9	0.46	-0.07	-0.05	-0.03
210	Tibet_Site10_Gegyai_Xiongbar	120	-2		3	8	68.4	0.52	-0.85	0.16	0.25
211	Tibet_Site24_Gegyai_Xiongbar2	120	-2		4	8	67.6	0.48	-0.13	0.06	0.11
212	Mongolia_Mgshrubland	121	1		9	28	62.1	0.45	0.58	-0.46	-0.62
213	Mongolia_Mgairport	130	1		35	18	44.9	0.29	0.10	0.16	0.31
214	Tibet_Site23_Gegyai_Wenbudangsang	150	-4		4	7	81.3	0.69	0.41	-0.50	-0.57
215	Tibet_Site22_Gerze_Gerze	170	-1		4	9	37.3	0.23	-0.47	0.52	0.70
216	Tibet_Site21_Gerze_Dongcuo	180	-1		4	8	34.5	0.28	0.29	0.46	0.16
217	Tibet_Site20_Gerze_DongcuoTemple	212	-2		4	14	56.6	0.36	0.29	-0.12	-0.20

218	Tibet_Site19_Nyima_Zhongcang2	220	-2		4	11	66.8	0.48	-0.25	-0.43	-0.42
219	Tibet_Site9_Nyima_Zhongcang	225	-2		3	9	76.6	0.61	0.29	0.02	0.02
220	Tibet_Site18_Nyima_Erjiu2	245	-3		4	5	86.5	0.76	0.00	-0.12	-0.19
221	Tibet_Site6_Shuanghu_Beicuo	250	-5		3	9	65.8	0.46	0.00	-0.07	-0.07
222	Tibet_Site7_Nyima_Erjiu	258	-1		3	6	64.3	0.47	0.18	0.09	0.10
223	Tibet_Site8_Nyima_Arsuo	258	-2		3	8	48.1	0.30	-0.47	0.11	0.23
224	Tibet_Site17_Shuanghu_Shuanghu	292	-7		4	9	76.1	0.59	-0.12	-0.51	-0.78
225	CanaryIsland_Valle	313	17	174	4	92	40.7	0.23	0.00	0.07	-0.04
226	China_LC	334	1	150	29	30	27.6	0.16	-0.56	0.53	0.63
227	China_SG	334	1	150	28	28	34.3	0.20	-0.30	0.79	1.08
228	Tibet_Site5_Bangoin_Marqian	376	-2		3	16	50.5	0.34	0.08	-0.34	-0.22
229	Tibet_Site16_Bangoin_Pubao2	400	-2		4	16	39.7	0.29	0.15	-0.07	-0.18
230	Tibet_Site4_Bangoin_Pubao	405	-2		3	22	37.1	0.21	0.22	-0.31	-0.43
231	Spain_ChapineriaHP	433	13	837	6	56	28.2	0.17	0.42	-0.25	-0.39
232	Spain_ChapineriaLP	433	13	230	6	42	22.2	0.12	-0.16	0.95	1.04
233	Tibet_Site3_Bangoin_Pengcuo_South	448	-3		3	19	34.0	0.18	-0.27	0.18	0.28
234	CanaryIsland_Teno	450	13		6	136	24.8	0.11	-0.03	-0.05	0.07
235	Tibet_Site15_Bangoin_Beilar	450	-3		4	27	21.4	0.11	-0.05	0.75	0.83
236	Tibet_Site2_Amdo_Cuomar	468	-4		3	29	32.2	0.18	0.51	0.02	-0.23
237	Tibet_Site14_Nagqu_Namarqie	475	-3		4	11	57.8	0.38	0.00	-0.24	-0.30
238	CanaryIsland_Anaga	480	17	256	4	114	25.7	0.10	-0.09	0.31	0.34
239	Tibet_Site1_Amdo_Bangai	484	-4		3	29	61.2	0.39	-0.29	-0.30	-0.50
240	Tibet_Site12_Amdo_Marluo	484	-4		4	33	38.5	0.18	0.24	-0.19	-0.24
241	Lapland_Jehkas	489	-3	185	11	32	76.1	0.59	0.11	-0.11	-0.20
242	Lapland_Saana	489	-3	185	11	33	76.2	0.59	-0.10	-0.01	-0.02
243	Tibet_Site11_Amdo_Guozur	494	-3		4	23	37.6	0.21	-0.10	-0.12	-0.19
244	Tibet_Site13_Nagqu_Nagqu	508	-3		4	21	40.2	0.24	-0.60	0.44	0.58
245	Germany1	629	9		11	105	19.6	0.09	0.18	0.36	0.26
246	Germany2	629	9		14	55	51.3	0.35	0.13	-0.08	-0.14
247	JunnerKoeland	758	9	463	7	42	52.0	0.38	0.21	0.01	0.04
248	SwissNP_Short	850	0	401	5	113	21.8	0.11	0.00	0.01	-0.06
249	SwissNP_Tall	850	0	500	5	117	25.5	0.12	0.02	0.06	0.07
250	France_Heath	940	4	320	30	80	30.6	0.15	0.11	-0.23	-0.28
251	France_Mesic	1380	6	220	30	75	25.7	0.11	0.01	0.08	0.05
252	France_Xeric	1380	6	130	30	64	16.1	0.08	-0.09	0.25	0.25

Supplementary Table 3. Data Subsets. In this manuscript, different subsets of data were used depending on if the analysis required a site level estimate of ANPP (Subset 1), a site level estimate of MAP (used as a proxy for ANPP; Subset 2), or both ANPP and MAP estimates (Subset 3). Sites are organized first by Biogeographic Realm and then by site mean annual precipitation (MAP; low to high); additionally, Site # and organization are consistent between Supplementary Tables 1-3.

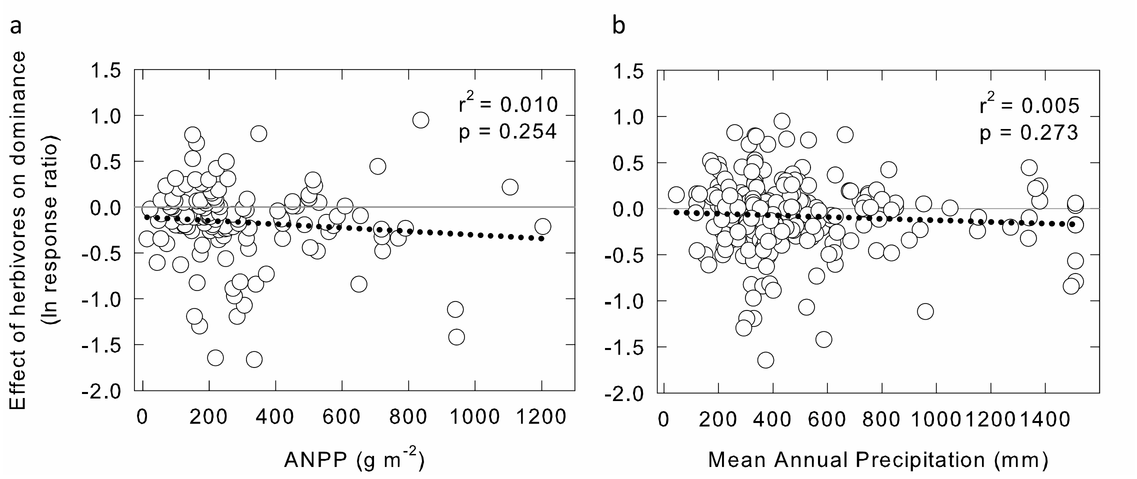
Site #	Site Name	Data Subset 1 [Used in analyses which required site level ANPP estimate]	Data Subset 2 [Used in analyses which required site level MAP]	Data Subset 3 [Used in analyseswhich required both site level ANPP & MAP]
	Afrotropics			
1	Tierberg_Karoo_Research_Centre	No	Yes	No
2	KarooNP_Sandrivier	No	Yes	No
3	KarooNP_Lammertjiesleegte	No	Yes	No
4	Pniel	No	Yes	No
5	Kruger_Letaba	Yes	Yes	Yes
6	Mali_Korokodjo	Yes	Yes	Yes
7	Kruger_Nwan	Yes	Yes	Yes
8	Kenya_North	Yes	Yes	Yes
9	Ethiopia	No	Yes	No
10	Mpala	No	Yes	No
11	Kruger_Buff	Yes	Yes	Yes
12	Kruger_Marheya	Yes	Yes	Yes
13	Kruger_Satara	Yes	Yes	Yes
14	Kruger_Nkuhlu	Yes	Yes	Yes
15	Mali_Lakamane	Yes	Yes	Yes
16	Kenya_Central	Yes	Yes	Yes
17	KLEE_cattle (O vs. C)	No	Yes	No
18	KLEE_wildlife (O vs. MW)	No	Yes	No
19	Kenya_South	Yes	Yes	Yes
20	Serengeti_Nutnet	Yes	Yes	Yes
21	Mali_Neguela	Yes	Yes	Yes
22	Mali_Tiorola	Yes	Yes	Yes
23	Mali_Tiendaga	Yes	Yes	Yes
24	Mananga_High	Yes	No	No
25	Mananga_Low	Yes	No	No
26	SataraNorth_High	Yes	No	No
27	SataraNorth_Low	Yes	No	No
28	SataraSouth_High	Yes	No	No
29	SataraSouth_Low	Yes	No	No
30	Shibotawna_High	Yes	No	No
31	Shibotawna_Low	Yes	No	No
	Australasia			
32	AUS_FowlersGap	No	Yes	No
33	AUS_Mallee	Yes	Yes	Yes
34	AUS_Arumpo	No	Yes	No
35	AUS_Kimberley	No	Yes	No
36	AUS_Ag_Biod	No	Yes	No
37	AUS_Buronga	No	Yes	No
38	AUS_Murray	Yes	Yes	Yes
39	AUS_Hattah	Yes	Yes	Yes
40	AUS_Wapweelah	No	Yes	No
41	AUS_Yathong_large	No	Yes	No
42	AUS_Yathong_small	No	Yes	No
43	AUS_Werrai	Yes	Yes	Yes

44	AUS_OBriens	Yes	Yes	Yes
45	AUS_Pinegrove	Yes	Yes	Yes
46	AUS_Paradise	No	Yes	No
47	AUS_Kinypanial	Yes	Yes	Yes
48	AUS_CYP	Yes	Yes	Yes
49	AUS_Savernake	No	Yes	No
50	AUS_Inverleigh	Yes	Yes	Yes
51	AUS_Warrambeen	Yes	Yes	Yes
52	AUS_Berry	No	Yes	No
53	AUS_Darlington	Yes	Yes	Yes
54	AUS_Grampians	Yes	Yes	Yes
55	AUS_Craigieburn	Yes	Yes	Yes
56	Molesworth_ST	No	Yes	No
57	Molesworth_SW	No	Yes	No
58	AUS_Hamilton	Yes	Yes	Yes
59	Molesworth_CC	No	Yes	No
60	AUS_Birregurra	Yes	Yes	Yes
61	Molesworth_HG	No	Yes	No
62	Molesworth_SD	No	Yes	No
63	VictoriaRiverResearchStation	Yes	Yes	Yes
64	Molesworth_PT	No	Yes	No
65	AUS_WilsonsPromontory	Yes	Yes	Yes
Indo-malay				
66	India_Kibber	Yes	Yes	Yes
67	India_Nutnet	Yes	Yes	Yes
Nearctic				
68	MNP_14mileTank	No	Yes	No
69	MNP_TenmileTank	No	Yes	No
70	MNK_16mileTank	No	Yes	No
71	MNP_30	No	Yes	No
72	Park Pasture	No	Yes	No
73	Cisco Wash 1	No	Yes	No
74	Cisco Wash 2	No	Yes	No
75	Cisco Mesa	No	Yes	No
76	Sand Flat	No	Yes	No
77	N_Clan	No	Yes	No
78	Hotel Mesa	No	Yes	No
79	Westwater	No	Yes	No
80	Horse Pature	No	Yes	No
81	Buckhorn	No	Yes	No
82	Jornada	No	Yes	No
83	Neponset	No	Yes	No
84	Dry Valley	No	Yes	No
85	Canada_Currie	Yes	Yes	Yes
86	Canada_LGS.6	Yes	Yes	Yes
87	DeseretLow	Yes	Yes	Yes
88	DeseretSage	Yes	Yes	Yes
89	Kate Hollow	No	Yes	No
90	Canada_Dewdrop.2	Yes	Yes	Yes
91	Canada_lls1	Yes	Yes	Yes
92	Salt Creek Mesa	No	Yes	No
93	Short Grass Steppe	Yes	Yes	Yes
94	Stanley Park	No	Yes	No
95	Canada_hav	Yes	Yes	Yes
96	Canada_hbb	Yes	Yes	Yes
97	Canada_MG1.LDB	Yes	Yes	Yes
98	Canada_MG2.LDB	Yes	Yes	Yes
99	House Park	No	Yes	No

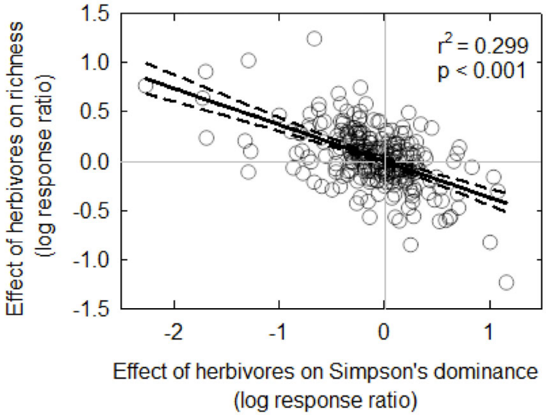
100	Canada_hkb	Yes	Yes	Yes
101	Canada_MG3.LDB	Yes	Yes	Yes
102	Canada_Goose.Lake	Yes	Yes	Yes
103	Canada_Lundbom.Lake	Yes	Yes	Yes
104	N_Sulphur	No	Yes	No
105	North Cottonwood	No	Yes	No
106	Canada_gooselake2	Yes	Yes	Yes
107	Canada_Mara.1	Yes	Yes	Yes
108	Harts Point	No	Yes	No
109	Texas Flat	No	Yes	No
110	FortKeogh	Yes	Yes	Yes
111	CPER	Yes	Yes	Yes
112	Steamboat Mesa	No	Yes	No
113	Wild Cow Point	No	Yes	No
114	N_Pryor	No	Yes	No
115	Canada_Dewdrop.1	Yes	Yes	Yes
116	Canada_llrs	Yes	Yes	Yes
117	Canada_LG5.LDB	Yes	Yes	Yes
118	Canada_Summit.North	Yes	Yes	Yes
119	Canada_LG4.LDB	Yes	Yes	Yes
120	Canada_Repeter	Yes	Yes	Yes
121	Canada_LGS.4	Yes	Yes	Yes
122	Canada_UG2.LDB	Yes	Yes	Yes
123	Harts Draw	No	Yes	No
124	Canada_LG2.LDB	Yes	Yes	Yes
125	Canada_Powerline	Yes	Yes	Yes
126	Canada_hsr	Yes	Yes	Yes
127	Canada_MGBR.1	Yes	Yes	Yes
128	Canada_LG1.LDB	Yes	Yes	Yes
129	Canada_MGBR.2	Yes	Yes	Yes
130	Canada_LGS.5	Yes	Yes	Yes
131	Canada_UG3.LDB	Yes	Yes	Yes
132	Canada_LG3.LDB	Yes	Yes	Yes
133	Canada_Redhil	Yes	Yes	Yes
134	Canada_Frolek	Yes	Yes	Yes
135	Canada_Long.lake.6	Yes	Yes	Yes
136	N_Theodore	No	Yes	No
137	The Dip	No	Yes	No
138	Canada_LGS.1	Yes	Yes	Yes
139	Canada_Summit.South	Yes	Yes	Yes
140	California_Sedgwick_Airstrip	Yes	Yes	Yes
141	California_Sedgwick_Lisque	Yes	Yes	Yes
142	California_Sedgwick_Mesa	Yes	Yes	Yes
143	Lost Park	No	Yes	No
144	Canada_LGS.2	Yes	Yes	Yes
145	Canada_TMV	Yes	Yes	Yes
146	N_Spring	No	Yes	No
147	Canada_Drum	Yes	Yes	Yes
148	Canada_llw	Yes	Yes	Yes
149	Canada_FLHT.2	Yes	Yes	Yes
150	Canada_Long.lake.5	Yes	Yes	Yes
151	Canada_fht1	Yes	Yes	Yes
152	Canada_Long.lake.4	Yes	Yes	Yes
153	Mexico_LaColorada	Yes	Yes	Yes
154	Mexico_LaMesa	Yes	Yes	Yes
155	Mexico_LaPresa	Yes	Yes	Yes
156	Mexico_Vaquerias	Yes	Yes	Yes
157	Canada_LGS.3	Yes	Yes	Yes

158	Canada_UG1.LDB	Yes	Yes	Yes
159	Washington_OakCreek	Yes	Yes	Yes
160	Washington_Wenas	Yes	Yes	Yes
161	California_Sedgwick	Yes	Yes	Yes
162	Washington_LTMurray	Yes	Yes	Yes
163	DeseretHigh	Yes	Yes	Yes
164	California_RanchoMarino	Yes	Yes	Yes
165	Washington_Sinlahekin	Yes	Yes	Yes
166	CedarCreek	Yes	Yes	Yes
167	Konza	Yes	Yes	Yes
168	KonzaPrairie	Yes	Yes	Yes
169	MAERC	Yes	Yes	Yes
170	NS_East Light BIO	No	Yes	No
171	NS_Main Station Dry Heath	No	Yes	No
172	NS_Main Station Grassland	No	Yes	No
173	NS_Main Station Mesic Heath	No	Yes	No
174	NS_West Light	No	Yes	No
175	NS_Wind Turbine (a)	No	Yes	No
176	NS_Wind Turbine (b)	No	Yes	No
Neotropic				
177	Argentina_RMcI84	No	Yes	No
178	Argentina_S18	No	Yes	No
179	Argentina_S19	No	Yes	No
180	Argentina_S20	No	Yes	No
181	Argentina_S12	No	Yes	No
182	Argentina_S13	No	Yes	No
183	Argentina_S14	No	Yes	No
184	Argentina_S15	No	Yes	No
185	Argentina_S16	No	Yes	No
186	Argentina_S17	No	Yes	No
187	Argentina_ML	No	Yes	No
188	Argentina_S21	No	Yes	No
189	Argentina_S22	No	Yes	No
190	Argentina_S1	No	Yes	No
191	Argentina_S2	No	Yes	No
192	Argentina_S3	No	Yes	No
193	Argentina_S10	No	Yes	No
194	Argentina_S11	No	Yes	No
195	Argentina_S4	No	Yes	No
196	Argentina_S5	No	Yes	No
197	Argentina_S6	No	Yes	No
198	Argentina_S7	No	Yes	No
199	Argentina_S8	No	Yes	No
200	Argentina_S9	No	Yes	No
201	Argentina_Sierra	Yes	Yes	Yes
202	LasChilcas	Yes	Yes	Yes
203	Uruguay_Relincho	Yes	Yes	Yes
204	Argentina_ElPalmar	Yes	Yes	Yes
205	Uruguay_Quebrada	Yes	Yes	Yes
206	Uruguay_SUL	Yes	Yes	Yes
207	Uruguay_Glencoe	Yes	Yes	Yes
Palerarctic				
208	Tibet_Site25_Rutog_Rusong	No	Yes	No
209	Mongolia_BGgrassland	No	Yes	No
210	Tibet_Site10_Gegyai_Xiongbar	No	Yes	No
211	Tibet_Site24_Gegyai_Xiongbar2	No	Yes	No
212	Mongolia_Mgshrubland	No	Yes	No
213	Mongolia_Mgairport	No	Yes	No

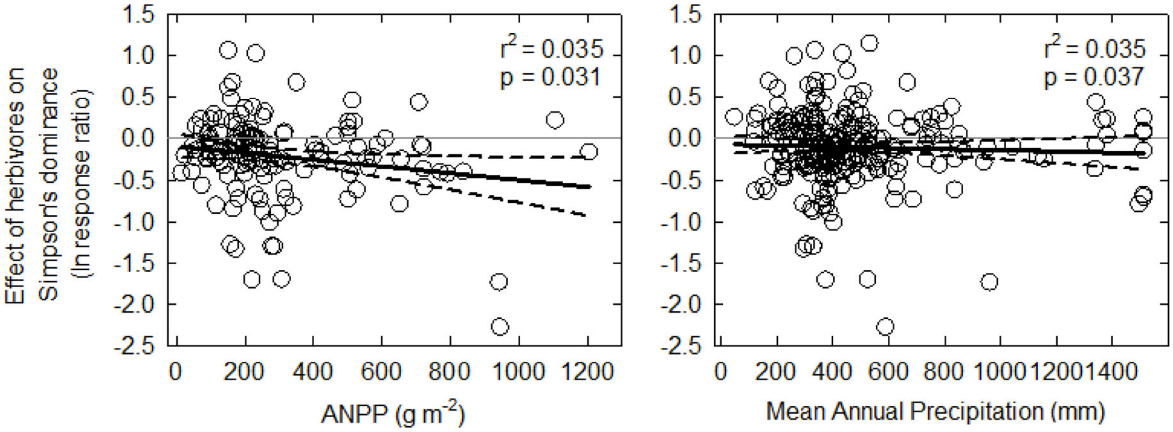
214	Tibet_Site23_Gegyai_Wenbudangsang	No	Yes	No
215	Tibet_Site22_Gerze_Gerze	No	Yes	No
216	Tibet_Site21_Gerze_Dongcuo	No	Yes	No
217	Tibet_Site20_Gerze_DongcuoTemple	No	Yes	No
218	Tibet_Site19_Nyima_Zhongcang2	No	Yes	No
219	Tibet_Site9_Nyima_Zhongcang	No	Yes	No
220	Tibet_Site18_Nyima_Erjiu2	No	Yes	No
221	Tibet_Site6_Shuanghu_Beicuo	No	Yes	No
222	Tibet_Site7_Nyima_Erjiu	No	Yes	No
223	Tibet_Site8_Nyima_Arsuo	No	Yes	No
224	Tibet_Site17_Shuanghu_Shuanghu	No	Yes	No
225	CanaryIsland_Valle	Yes	Yes	Yes
226	China_LC	Yes	Yes	Yes
227	China_SG	Yes	Yes	Yes
228	Tibet_Site5_Bangoin_Marqian	No	Yes	No
229	Tibet_Site16_Bangoin_Pubao2	No	Yes	No
230	Tibet_Site4_Bangoin_Pubao	No	Yes	No
231	Spain_ChapineriaHP	Yes	Yes	Yes
232	Spain_ChapineriaLP	Yes	Yes	Yes
233	Tibet_Site3_Bangoin_Pengcuo_South	No	Yes	No
234	CanaryIsland_Teno	No	Yes	No
235	Tibet_Site15_Bangoin_Beilar	No	Yes	No
236	Tibet_Site2_Amdo_Cuomar	No	Yes	No
237	Tibet_Site14_Nagqu_Namarqie	No	Yes	No
238	CanaryIsland_Anaga	Yes	Yes	Yes
239	Tibet_Site1_Amdo_Bangai	No	Yes	No
240	Tibet_Site12_Amdo_Marluo	No	Yes	No
241	Lapland_Jehkas	Yes	Yes	Yes
242	Lapland_Saana	Yes	Yes	Yes
243	Tibet_Site11_Amdo_Guozur	No	Yes	No
244	Tibet_Site13_Nagqu_Nagqu	No	Yes	No
245	Germany1	No	Yes	No
246	Germany2	No	Yes	No
247	JunnerKoeland	Yes	Yes	Yes
248	SwissNP_Short	Yes	Yes	Yes
249	SwissNP_Tall	Yes	Yes	Yes
250	France_Heath	Yes	Yes	Yes
251	France_Mesic	Yes	Yes	Yes
252	France_Xeric	Yes	Yes	Yes



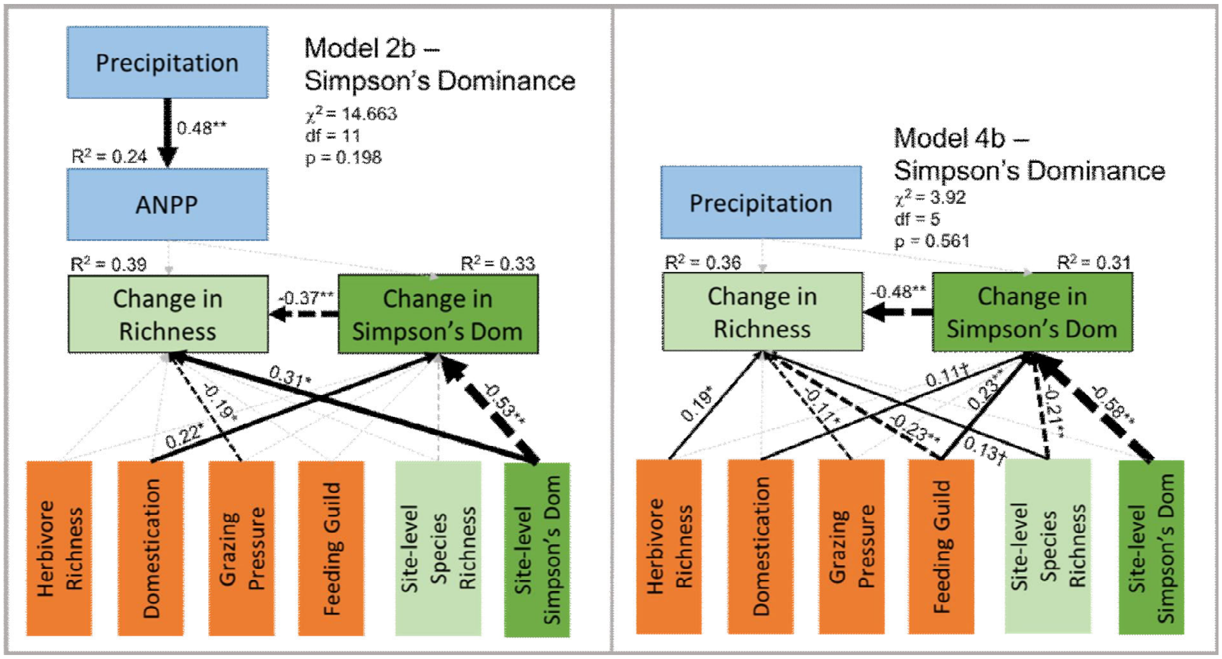
Supplementary Figure 1. Effects of ANPP and mean annual precipitation on Berger-Parker dominance response to herbivory.**a**, The relationship between aboveground net primary production (ANPP) and the response of plant-species dominance (Berger-Parker) to herbivory (ln(G/UG)), where G is the average plant species dominance in grazed plots and UG is the same measurement in ungrazed plots (n=132; Data Subset 1 in Supplementary Table 3). **b**, The relationship between mean annual precipitation and the response of plant species dominance (Berger-Parker) to herbivory (n=246; Data Subset 2 in Supplementary Table 3).



Supplementary Figure 2. Relationship between the change in Simpson's dominance and the change in species richness as a function of herbivory (ln(G/UG)) (*n*=252; all data).



Supplementary Figure 3. Effects of ANPP and mean annual precipitation on Simpson's dominance response to herbivory.**a**, The relationship between aboveground net primary production (ANPP) and the response of plant-species dominance (Simpson's) to herbivory (ln(G/UG)), where G is the average plant species dominance in grazed plots and UG is the same measurement in ungrazed plots (n=132; Data Subset 1 in Supplementary Table 3). **b**, The relationship between mean annual precipitation and the response of plant species dominance (Simpson's) to herbivory (n=246; Data Subset 2 in Supplementary Table 3).



Supplementary Figure 4. Drivers of plant richness response to herbivores.**a** Path analyses testing the importance of aboveground net primary productivity (ANPP) and Simpson's dominance (Model 2b - Simpson's) on the change in species richness in response to herbivory. These models are restricted to sites where both ANPP and precipitation data were available (n=122; Data Subset 3 in Supplementary Table 3). **b** Path analyses testing the importance of productivity using precipitation as a proxy for productivity and dominance (Model 4b - Simpson's) on the change in species richness in response to herbivory (n=244; Data Subset 2 in Supplementary Table 3). See Supplementary Table 6& 9 for bivariate correlations between input variables which were included in these models to improve model fit. All models also test for the effects of site and herbivore characteristics (see Methods). $^{**}p<0.001$, $^{*}p<0.05$, $^{\dagger}p<0.10$. Non-significant relationships are shown in light gray dashed arrows, solid black arrows represent positive relationships and dashed black arrows represent negative relationships. Shown are standardized effect sizes, with arrow thickness proportional to the strength of the relationship. All models were a good fit to the data based on the x^2 statistic (p>0.05 is good). See Supplementary Table 10 for additional model fit parameters for all four models.

Supplementary Table 4. Correlated variables included in Model 1 that improve model fit between exogenous and endogenous variables in the path analysis. Included correlations are denoted by estimates present.

	Precipitation	Herbivore richness	Domestication	Grazing pressure	Feeding guild	Species richness	Error of ANPP
Precipitation						0.549	
Herbivore richness			-0.519	-0.013	-0.519	0.175	0.135
Domestication				-0.113	-0.499	-0.236	
Grazing pressure					-0.036		
Feeding guild						0.245	-0.165
Species richness							0.025
Error of ANPP							

Supplementary Table 5. Correlated variables included in Model 2a that improve model fit between exogenous and endogenous variables in the path analysis. Included correlations are denoted by estimates present.

	Precipitation	Herbivore richness	Domestication	Grazing pressure	Feeding guild	Species richness	Plant BP dominance	Error of ANPP
Precipitation						0.550	-0.326	
Herbivore richness			-0.519	-0.021	0.590	0.174	0.031	0.135
Domestication				-0.103	-0.499	-0.234		
Grazing pressure					-0.036			
Feeding guild						0.243	-0.162	-0.165
Species richness							-0.536	0.025
Plant BP dominance								0.208
Error of ANPP								

Supplementary Table 6. Correlated variables included in Model 2b - Simpson's that improve model fit between exogenous and endogenous variables in the path analysis. Included correlations are denoted by estimates present.

	Precipitation	Herbivore richness	Domestication	Grazing pressure	Feeding guild	Species richness	Plant Simpson's dominance	Error of ANPP
Precipitation						0.548	-0.304	
Herbivore richness			-0.519	-0.021	0.590	0.179	0.015	0.135
Domestication				-0.100	-0.501	-0.244		
Grazing pressure					-0.038			
Feeding guild						0.249	-0.144	-0.165
Species richness							-0.530	0.025
Plant Simpson's dominance								0.231
Error of ANPP								

Supplementary Table 7. Correlated variables included in Model 3 that improve model fit between exogenous and endogenous variables in the path analysis. Included correlations are denoted by estimates present.

	Precipitation	Herbivore richness	Domestication	Grazing pressure	Feeding guild	Species richness
Precipitation		-0.185		-0.125	-0.207	0.388
Herbivore richness			-0.407	0.027	0.569	0.092
Domestication				-0.116	-0.274	-0.250
Grazing pressure					0.025	
Feeding guild						0.050
Species richness						

Supplementary Table 8. Correlated variables included in Model 4a that improve model fit between exogenous and endogenous variables in the path analysis. Included correlations are denoted by estimates present.

	Precipitation	Herbivore richness	Domestication	Grazing pressure	Feeding guild	Species richness	Plant BP dominance
Precipitation		-0.190		-0.127	-0.224	0.397	-0.275
Herbivore richness			-0.406	0.031	0.569	0.076	
Domestication				-0.121	-0.274	-0.235	
Grazing pressure					0.036		0.129
Feeding guild						0.011	
Species richness							-0.536
Plant BP dominance							

Supplementary Table 9. Correlated variables included in Model 4b -Simpson's that improve model fit between exogenous and endogenous variables in the path analysis. Included correlations are denoted by estimates present.

	Precipitation	Herbivore richness	Domestication	Grazing pressure	Feeding guild	Species richness	Plant Simpson's dominance
Precipitation		-0.191		-0.127	-0.223	0.395	-0.275
Herbivore richness			-0.407	0.030	0.569	0.079	
Domestication				-0.117	-0.275	-0.246	
Grazing pressure					0.034		0.121
Feeding guild						0.017	
Species richness							-0.538
Plant Simpson's dominance							

Supplementary Table 10. Goodness of fit metrics suggest all path analysis models are a good fit to the data – Normalized Fit Index = 0.971 (>0.95 is considered a good fit); Tucker Lewis Index = 0.991 (>0.95 is considered a good fit); Root-Mean Square Error of Approximation = 0.040 (<0.05 is considered a good fit) with a PCLOSE = 0.588 (PCLOSE is the probability that RMESA = 0.05, if PCLOSE > 0.05, the model is considered a good fit).

	Model 1	Model 2a	Model 2b	Model 3	Model 4a	Model 4b
NFI	0.951	0.962	0.963	0.988	0.991	0.992
TLI	0.938	0.961	0.957	0.957	1.011	1.016
RMSEA (PCLOSE)	0.062 (0.339)	0.048 (0.467)	0.052 (0.428)	0.044 (0.419)	0.00 (0.771)	0.000 (0.808)