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Appendix 1

Model assumptions

Model timescale

In the presence of herbivores, the regrowth model should only be used when equilibrium can be reached relatively quickly, such as in one to two growing seasons, as it assumes an inexhaustible potential to regrow aboveground biomass. Over longer timeframes, persistent herbivory may diminish these stores leading to variable growth rates and additional outcomes, such as patterns of species coexistence, beyond those predicted by the regrowth model (Owen-Smith 2008). However, our model is still applicable as relatively brief changes in the intensity or occurrence of herbivory are common in natural systems as in the case of population cycles (Turchin and Batzli 2001) or heterogeneous foraging (McNaughton 1985, Jacob and Brown 2000, Nickel et al. 2003) that can strongly affect plant diversity.

Given the above assumption, we assume that equilibria in our model are achieved without seasonal fluctuations capable of annually resetting the system. While assuming aseasonality in a temperate system is an oversimplification, it is not entirely unreasonable to expect that some plant communities, with their associated herbivores, may achieve, or at least approach, equilibrium within a growing season from initial conditions established by prior seasons' dynamics. For example, many perennial, grassland species possess belowground stores that permit rapid growth and response to changes in the environment (Golley 1960, del-Val and Crawley 2004, Erb 2012, Hock 2014). Small-bodied herbivores with high recruitment, such as many rodents, may similarly be able to rapidly respond to changes in the plant community (Golley 1960, Holling 1961, Taitt and Krebs 1981). Moreover, our model reaches equilibrium relatively quickly (<200 days in Fig. 3) suggesting the absence of seasonality is a reasonable assumption. Therefore, a plant–herbivore community may approach an equilibrium as modeled here such that these conclusions are reasonable approximations of actual outcomes.

Parameter limitations

As we seek to compare conditions in which herbivores increase plant diversity to conditions where they decrease diversity, we limit our analyses to scenarios in which herbivores may potentially have either effect. Therefore, we limit our analyses and discussions for all tradeoffs to conditions that allow the plant species to stably coexist in the absence of herbivory, as described by inequality 3, so that all equilibria presented here are stable. Outside of these bounds, coexistence is not possible in the absence of herbivory so that herbivores could only increase or have no effect on diversity.

We selected baseline parameters from values reported for these or closely related organisms that allowed coexistence in the presence and absence of herbivores (Table 1, Supplementary material Appendix 3). Consequently, our application of the model approximates but does not necessarily apply exactly to any single, real system. To establish conditions in which both plant species are identical for every parameter, we necessarily set competition coefficients and carrying capacities outside of observed ranges. However, the observed ranges for each parameter still allow some insight into the extent that these variables might differ in modeling growth–defense or competition–defense tradeoffs.

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Appendix 2

Solving for equilibria

The zero net growth isocline (ZNGI) for the herbivore can be solved from the initial herbivore equation (Eq. 6):

$$N_2^* = AN_1^* - D \tag{A1}$$

where

$$D = \frac{m}{a_2(mb-c)} \tag{A2}$$

$$A = -\frac{a_1}{a_2} \tag{A3}$$

While the ZNGI equation is attractive, the remaining equilibria are far less so. In terms of N_1, the equilibrium for the herbivore population is:

$$H^* = \frac{R_1\left(1-\frac{N_1^*+(AN_1^*-D)\beta_{1,2}}{k_1}\right)\left(1+b(N_1^*a_1+(AN_1^*-D)a_2)\right)}{N_1^*a_1} \tag{A4}$$

Derivations of this and other equilibria are available below. The equilibrium for the remaining plant population (N_1) explodes into:

$$N_1^* = \frac{\left(\begin{array}{c}(-2AD\beta_{2,1}-Ak_1P-Ak_1-DG-D)- \\ \sqrt{\begin{array}{l}A^2{k_1}^2P^2+2A^2{k_1}^2P+A^2{k_1}^2+4A^2Dk_1P\beta_{1,2}+2ADGk_1P+2ADk_1P \\ -2ADk_1+D^2G^2+2D^2G+D^2-2ADGk_1-4DGk_1\beta_{1,2}-4D^2G\beta_{1,2}\beta_{2,1}\end{array}}\end{array}\right)}{\left(2(-A^2\beta_{2,1}-A-AG-G\beta_{2,1})\right)} \tag{A5}$$

where

$$P = \frac{R_2}{R_1}, \tag{A6}$$

$$G = \frac{APk_1}{k_2}. \tag{A7}$$