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Appendix 1

Model description

The model is an enhanced version of the grassland model developed by May et al. (2009), which has been augmented by representing clonal plant types, which comprise about two thirds of plant species in grassland ecosystems (Klimeš et al. 1997). The model description follows the ODD protocol (overview, design concepts, detail) for describing individual-based models (Grimm et al. 2006, 2010).

Purpose

The model is designed to reproduce effects of grazing intensity and resource availability on small-scale community patterns observed at different hierarchical levels (diversity, biomass production and functional composition).

Entities, state variables and scales

The model includes the entities seeds, individual plants, and grid cells (Table A1). Seeds are described by the state variables grid position, age, and mass. Plant individuals, i.e. individual ramets in the case of clonal plant types or non-clonal individual plants, are characterized by state variables representing their grid position, the mass of three plant compartments (shoot, root and reproductive mass), the presence of growing spacers in case of clonal plant types, the duration of resource stress exposure, and 12 parameters related to traits defining the plant's functional type (Table A1). Plants have a 'zone-of-influence' (ZOI), i.e. a circular area around their stems' location (Schwinning and Weiner 1998, Weiner et al. 2001). On this area a plant acquires resources; if the ZOIs of neighbouring plants overlap, they compete for the resources on the overlapping area. We consider two independent ZOIs for a plant's shoot and root, representing above- and below-ground resource uptake and competition. The ZOIs' radii are determined from the biomass of the corresponding plant compartment, i.e. as plants grow, their interaction radius grows (Fig. A1).

In order to simplify spatial calculations of resource competition, ZOIs are projected onto a grid of discrete cells, each representing 1 cm^2. The state of a grid cell is defined by two constant resource availabilities, above and below ground. The size of the modelled area was 173×173 cm^2. To avoid edge effects, periodic boundary conditions were used, i.e. the grid essentially was a torus. A model's time step corresponds to one week; a vegetation period consisted of 30 weeks per year, and simulations were run for 100 years.

Process overview and scheduling

The scheduling of processes performed for each plant is depicted in Fig. A2. All processes are run every time step (week), except seed dispersal and seedling establishment which are limited to certain weeks of the year (Table A2). External seed input, if considered, takes place in week 20 only. Grazing events occur randomly with a certain probability which is constant for all time steps. Winter dieback of above-ground biomass is considered once a year, at the end of the vegetation period (Fig. A2). Seed mortality is considered a) at the end of the vegetation period, and b) prior to seed set in the next year to establish a transient seed bank. All processes depend on the plant's functional traits. All physical state variables such as mass or age are synchronously updated within the subroutines for growth, mortality, grazing and winter dieback, i.e. changes to state variables are updated only after all model entities have been processed (Grimm and Railsback 2005).

Design concepts

Basic principles

Our model is based in representing local competition via the zone-of-influence approach and the distinction between symmetric and asymmetric competition. Furthermore, intra-specific competition is assumed to be stronger than inter-specific competition (considering a PFT as a species in this context).

Emergence

All features observed at the community level, such as community composition and diversity, emerged from individual plant–plant interactions, grazing effects at the individual scale, and resource availabilities.

Adaptation

In the sub-model representing plant growth and above- and below-ground competition, plants adaptively allocate resources to shoot and root growth in order to balance the uptake of above- and below-ground resources (see below, Sub-models 'Plant growth and mortality').

Interactions

Competitive interactions between plant individuals were described using the ZOI approach.

Stochasticity

Seed dispersal and establishment, external seed input as well as mortality of seeds and plants are modelled stochastically to include demographic noise. Grazing events occur randomly during the vegetation period and the affected plants are chosen randomly, but the individual's probability of being grazed depends on plant traits (see Sub-model 'Grazing').

Observation

See section 'Design and analysis of simulation experiments' below.

Initialization

Initially, ten seedlings of each of the 86 plant function types (PFTs) (see section 'PFT definition' in article) with their respective seedling mass were randomly distributed over the grid. Their germination probability was set to 1.0 to assure equal initial population sizes of all PFTs. A spatially and temporally homogenous distribution for each of the above- and belowground resources was used in all simulation experiments.

Input

The model does not include any external input of driving environmental variables.

Sub-models

Competition

Following the ZOI approach, plants compete for resources in a circular area around their central location point. To relate plant mass to the area covered (A_{shoot}), we extended the allometric relation used by (Weiner et al. 2001)

$$A_{shoot} = c_{shoot} \times \left(f_{leaf} \times m_{shoot}\right)^{2/3} \tag{A1}$$

where c_{shoot} is a constant ratio between leaf mass and ZOI area and m_{shoot} is vegetative shoot mass (Table A1, A2). The factor f_{leaf} is introduced to describe different shoot geometries and is defined as the ratio between photosynthetically active (leaf) and inactive (stem) tissue. Only the former is considered for the calculation of the ZOI size. These circular areas are projected onto a grid of discrete cells. Grid cells thus contain the information by which plants they are covered, so that resource competition can be calculated cell by cell. The resources within a cell are shared among plants according to their relative competition coefficients (β_i). The resource uptake (Δres) of plant i from a cell with resource availability (Res_{cell}) covered by n plants is thus calculated as

$$\Delta res_i = \frac{\beta_i}{\sum_{j=1}^{n} \beta_j} \cdot Res_{cell} . \qquad \text{(A2)}$$

Calculating β_i in different ways allows including different modes of competition, i.e. symmetric or asymmetric (Weiner et al. 2001). We assume that the relative competitive ability of a plant is correlated with its maximum growth rate in the absence of resource competition. Therefore β_i is proportional to maximum resource utilization per unit area covered (ru_{max}, see Sub-model 'Plant growth and mortality' and Table A2). In the case of size-symmetric competition, β_i simply equals ru_{max}:

$$\beta_i = ru_{max} \qquad \text{(A3a)}$$

In the case of partially size-asymmetric competition β_i is a function of plant mass and shoot geometry:

$$\beta_i = ru_{max} \times m_{shoot} \times f_{leaf}^{-1} . \qquad \text{(A3b)}$$

The inverse of f_{leaf} is used, because plants with a lower fraction of leaf tissue are considered to be higher and thus show a higher competitive ability by overtopping other plants (Fig. A1). In this way, plants with equal ru_{max} receive equal amounts of resources from one unit of area irrespective of their mass or height in the case of size-symmetric competition, while larger and higher plants receive a higher share of resources in proportion to their shoot geometry in the case of partially asymmetric competition (Schwinning and Weiner 1998, Weiner et al. 2001). The resource uptake of a plant within one week can then be determined by summing the results of Eq. A2 over all cells covered by the plant.

To include differences between intra- and interspecific competition, individuals of the same PFT are considered as con-specifics and those of different PFTs as hetero-specifics. The relative competitive ability β_i of one plant is then determined as a decreasing function of the number of plants belonging to the same PFT (n_{PFT}) and covering the same cell:

$$\beta_i = ru_{max} \frac{1}{\sqrt{n_{PFT}}}. \qquad \text{(A3c)}$$

Equation A3c is used for size-symmetric competition instead of Eq. A3a. In the case of size asymmetry, plant mass and geometry are taken into consideration according to Eq. A3b. This approach represents a situation where intraspecific competition is increased relatively to interspecific competition and therefore implicitly includes niche differentiation of resource competition at the cell scale, which has been known as an important factor for species coexistence (Chesson 2000, Silvertown 2004).

Plant growth and mortality

Plant growth only depends on the resources (Δres) that the plant acquired during the current time step. In the absence of competition, plants show sigmoid growth. Therefore we adapted the growth equation used by Weiner et al. (2001) to the description of plant geometry used here:

$$\Delta m_{shoot} = g\left(\Delta res - c_{shoot}(f_{leaf})^{2/3} \times ru_{max} \frac{m_{shoot}^{2}}{m_{max}^{4/3}}\right), \qquad \text{(A4)}$$

where *g* is a constant conversion rate between resource units and plant biomass and m_{max} is the maximum mass of shoot or root, respectively. In addition, the maximum amount of resources that is allocated to growth each week is limited by a maximum resource utilization rate given by ru_{max} [resource units cm^{-2}] multiplied by ZOI area [cm^2]. If Eq. A4 yields a negative result, Δm is set to zero and thus negative growth is prohibited.

Growth of generative reproductive mass is restricted to the time between weeks 16–20. In this period, a constant fraction of the resources (AllocSeed, 5% for all PFTs) is allocated to growth of reproductive mass (Schippers et al. 2001), and reproductive mass is limited to 5% of shoot mass in total. The same resource conversion rate, *g*, is used for reproductive and vegetative biomass.

Equation A1–A4 are applied to shoot and root ZOIs independently, with the difference that for root growth the factors f_{leaf} and c_{root} are always one. We assume that the minimum uptake of above- and below-ground resources limits plant growth (Lehsten and Kleyer 2007) and introduced adaptive shoot-root allocation in a way that more resources are allocated to the growth of the plant compartment that harvests the limiting resource (Weiner 2004). For resource partitioning, we adopt the model of Johnson (1985) which assumes that the fraction of resources allocated to shoot growth is calculated as

$$\alpha_{shoot} = \frac{\Delta res_B}{\Delta res_B + \Delta res_A} \qquad \text{(A5)}$$

where Δres_A is above-ground and Δres_B is below-ground resource uptake.

Plants suffer resource stress if their resource uptake (in any layer) is below a fixed threshold fraction (thr_{res}) of their optimal uptake, which is calculated as maximum resource utilization times ZOI area. That means each week the condition

$$\Delta res < thr_{res} \cdot A_{shoot/root} \cdot ru_{max}$$

is evaluated and if it is true either for shoot or root the plant is considered as stress exposed during this week, and the state variable "duration of stress exposure", w_{stress} (Table A1), is incremented. Consecutive weeks of resource stress linearly increase the probability of death

$$p_{mort} = p_{base} + \frac{w_{stress}}{surv_{max}} \qquad \text{(A6)}$$

where $surv_{max}$ is the maximum number of weeks a plant can survive under stress exposure and

p_{min} is the stress independent background mortality of 0.7% per week corresponding to an annual mortality rate of 20% (Schippers et al. 2001).

Dead plants do not grow and reproduce anymore, but they still can shade others and are therefore still considered for above-ground competition. Each week the mass of all dead plants is reduced by 50 % (decrease Rate) and they are removed from the grid completely as soon as their total mass decreases below 10 mg.

Growth, dispersal and establishment of spacers of clonal plant types

For each individual (i.e. ramet) one spacer can grow at a time step. Analogously to generative reproduction, but in each week except for weeks of generative reproduction, 5% of resources acquired by the individual (Δres) are allocated to the growth of the spacer. First, the direction and distance of spacer growth is determined. The direction in which the spacer grows is chosen randomly from a uniform distribution. The distance of spacer growth is randomly chosen from a normal distribution, but the mean distance (SpacerL) is type-specific (Table A3). The actual distance a spacer grows per week is calculated following:

$$\Delta SpacerL = \Delta res \times 0.05 \times g / mSpacer \qquad \text{(A7)}$$

where *g* is a constant conversion rate between resource units and plant biomass and mSpacer is a type unspecific spacer mass of 70 mg per cm; this value was derived as mean of spacer masses of Phragmites australis (Granéli et al. 1992) and different sea grass species (Marbà et al. 2002). If the determined distance the spacer has to grow is reached and the respective cell is not the centre of another individual, spacer growth stops and the new ramet can establish with a fixed probability (p_{ram}) (see sub-model 'Seed production, dispersal, external seed input and establishment' below). If the reached cell is occupied by the centre of a different plant spacer growth continues randomly within a radius of two cells.

Resource sharing

Clonal plants of the integrator-type (sensu Oborny et al. 2000, see section Plant traits and PFT parameterization below) share resources throughout the whole genet. Thereby each ramet provides above- and below-ground resources that are not essential for its own survival. The minimum resources (Res_{min}) a ramet needs for survival are calculated as a fixed threshold fraction (thr_{res}) of the ramet´s optimal uptake analogously to the threshold fraction which determines resource stress (see above Plant growth and mortality).

$$Res_{min} = thr_{res} \cdot A_{shoot/root} \cdot ru_{max.}$$

Surplus resources are added for all ramets of the genet and hence equally shared among ramets. Ramets of non-integrator clonal plant types behave like non-clonal plant individuals in this respect, i.e. they do not share resources.

Seed production, dispersal, external seed input and establishment

All plants disperse their seeds in week 20 each year. Seed number is determined by dividing reproductive mass by the mass of one seed (Schippers et al. 2001, Lehsten and Kleyer 2007). For each seed, dispersal distance is drawn from a log-normal, and direction from a uniform distribution (Stoyan and Wagner 2001). Note that to avoid edge effects periodic boundary conditions are used.

External seed input, if considered, takes place in week 20, when all plants disperse their seeds. All PFTs of the regional PFT pool (containing 86 PFTs) are thereby considered as seed source. Seeds are set to the grid by randomly assigning coordinates. The number of seeds per PFT depends on the scenario chosen. For scenario 1 and 2 all PFTs get an equal mass of seeds for a given total number of seeds (860 respectively 8600). For scenarios 3 and 4 all PFTs get an equal number of seeds (10 respectively 100). To include stochasticity the assigned number of seed per PFT is randomly drawn from a Poisson distribution.

Germination and seedling establishment are limited to four weeks in autumn directly after dispersal and four weeks in spring of the next year for all PFTs (Table A2). In between, a winter mortality of 50% of seeds is assumed and all seeds which did not germinate in these two seasons are removed.

Seedling recruitment is separated in two consecutive processes: 1) seed germination and 2) seedling competition. Germination is only allowed in grid cells that are not covered by any plant or it's above-ground ZOI. In such cells, seeds germinate with a fixed probability (p_{germ}) and are converted to seedlings. In each cell only a single plant is allowed to establish. Seedling competition is modelled as a weighted lottery, using seed mass as a measure of competitive ability between seedlings (Chesson and Warner 1981, Schippers et al. 2001). The seedling that is chosen for establishment is converted into a plant with a shoot and root mass equal to seed mass. All other seedlings that germinated within the cell, die and are removed from the grid.

At the end of the vegetation period all growing spacers of clonal individuals establish with a fixed probability (p_{ram}) unless the cell they have reached by the time is occupied by the centre of a different individual already. If this is the case, the spacer is removed from the grid.

Grazing

Grazing is modelled as partial removal of an individual's above-ground biomass. The frequency of grazing is specified by a constant weekly probability (p_{graz}) of a grazing event. Grazing is a process that acts selectively towards trait attributes such as shoot size and tissue properties. Therefore, for each plant the susceptibility to grazing (s_{graz}) is calculated as a function of shoot size, geometry and PFT-specific palatability (palat).

$$s_{graz} = m_{shoot} \times f_{leaf}^{-1} \times palat \qquad \text{(A7)}$$

The probability for each plant to be grazed within one a grazing event is derived by dividing individual susceptibilities by the current maximum individual susceptibility of all plants. All plants are checked for grazing in random order. In case a plant is grazed, 50% of its shoot mass and its complete reproductive mass are removed. The random choice of plants is repeated for all other plants until 50% of the total (aboveground) biomass on the whole grid has been removed. When all plants have been checked for grazing once, but less than 50% of the total above-ground biomass has been removed, grazing probabilities for all individuals are calculated once more based on Eq. A7 and the whole procedure is repeated until 50% of aboveground biomass has been removed or until a residual biomass is reached which is considered ungrazable. This fraction is set to 15.3 g m^{-2} following (Schwinning and Parsons 1999). This allows a plant individual to be grazed never or several times during one week with a grazing event.

In addition to stochastic grazing, each year at the end of the vegetation period 50% of the above-ground mass of all plant individuals is removed to mimic vegetation dieback in winter.

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Table A1. State variables of the model's entities.

State variable	Unit	Description
Plants		
m_{shoot}	mg	vegetative shoot mass (leaves + stems)
m_{root}	mg	root mass
m_{repro}	mg	reproductive mass (seeds)
w_{stress}	weeks	duration of resource stress exposure
PFT ID	-	identification number for plant functional type
Spacer List	Ramets	list of growing spacers
12 trait parameters	(Table A3)	
Seeds		
m_{seed}	mg	seed mass
Age	years	time since release from mother plant
Grid cells		
Res_A	units cm^{-2}	above-ground resource availability
Res_B	units cm^{-2}	below-ground resource availability

Table A2. Parameters defining plant functional types (PFTs). Twelve of these 22 parameters can be different between plant individuals (marked via "**") and are therefore considered state variables characterizing a plant, whereas the remaining 10 parameters are the same for all plants and therefore considered general model parameters (Grimm et al. 2010).

Symbol	Description	Unit	Value
Vegetative traits			
f_{leaf}	ratio of leaf mass to total shoot mass	mg mg^{-1}	**
c_{shoot}	above-ground ZOI area per leaf mass	cm² mg^{-1}	**
c_{root}	below-ground ZOI area per root mass	cm² mg^{-1}	1.0
G	conversion rate resource units to biomass	mg resource unit^{-1}	0.25
ru_{max}	maximal resource utilization per time step and ZOI area (equal for shoot and root*)	resource units cm^{-2} week^{-1}	**
thr_{res}	threshold fraction of ru_{max} considered as resource stress	-	0.2
$surv_{max}$	maximal survival time under resource stress exposure	weeks	**
m_{max}	maximum plant mass (equal for shoot and root)	mg	**
Palat	palatability – susceptibility towards grazing	-	**
Clonal traits			
Resshare	integration of ramets within the genet	-	**
mSpacer	spacer mass	mg cm^{-1}	70
SpacerL	mean spacer length	cm	**
$std_{SpacerL}$	standard deviation of spacer length	cm	**
t_{ram}	time of ramet establishment	weeks of the year	1–30

p_{ram}	probability of ramet establishment	-	1
N_{ram}	number of growing spacers/ramet	-	1
Generative traits			
m_{seed}	mass of a single seed	mg	**
$mean_{disp}$	mean of dispersal distance	M	**
std_{disp}	standard deviation of dispersal distance	M	**
p_{germ}	germination probability	-	0.5
t_{disp}	time of seed dispersal	week of the year	20
t_{germ}	time of seed germination	week of the year	1–4 ; 21–25

**PFT specific values, see Table A3

Table A3. Trait syndromes and PFT specific trait parameter values

Trait / trait syndrome and attributes	Trait parameters			
Growth form[1]	f_{leaf}			
rosette	1.0			
intermediate	0.75			
erect	0.5			
Maximum plant size[1]	m_{max}	m_{seed}	$mean_{disp}$	std_{disp}
large	5000 mg	1 mg	0.1 m	0.1 m
medium	2000 mg	0.3 mg	0.3 m	0.3 m
small	1000 mg	0.1 mg	0.6 m	0.6 m
Resource response[1]	ru_{max}	$surv_{max}$		
competitor	60	2		
intermediate	40	4		
stress-tolerator	20	6		
Grazing response[1]	palat	c_{shoot}		
tolerator	1.0	1.0		
intermediate	0.5	0.75		
avoider	0.25	0.5		
Clonal integration[2]	Resshare			
integrator	1			
splitter	0			
Lateral spread[3]	SpacerL	$std_{SpacerL}$		
short	2.5 cm	2.5 cm		
long	17.5 cm	12.5 cm		

[1] May et al. 2009 [2]Oborny et al.2000 [3] Winkler et al. 2002

Figure A1. Illustration of the ‘zone-of-influence’ (ZOI) approach including above- and below-ground competition and different shoot geometries. Above- and below-ground ‘zones-of-influence’ are shown as green and brown circles, respectively. Stems and support tissue are represented as dark green cylinders. Plant individuals compete for resources in the areas of overlap only (arrows indicate the area of above-ground competition). The plant to the left has a lower ratio of leaf mass to shoot mass (fleaf) and thus a smaller above-ground ZOI. In return its competitive ability for above- ground resources (light) is higher as it is able to shade the plant to the right. The plant in the middle shows an established ramet built by the mother plant to the right. These clonal individuals belong to an integrator type PFT with an ongoing persistence of connective tissues between them.

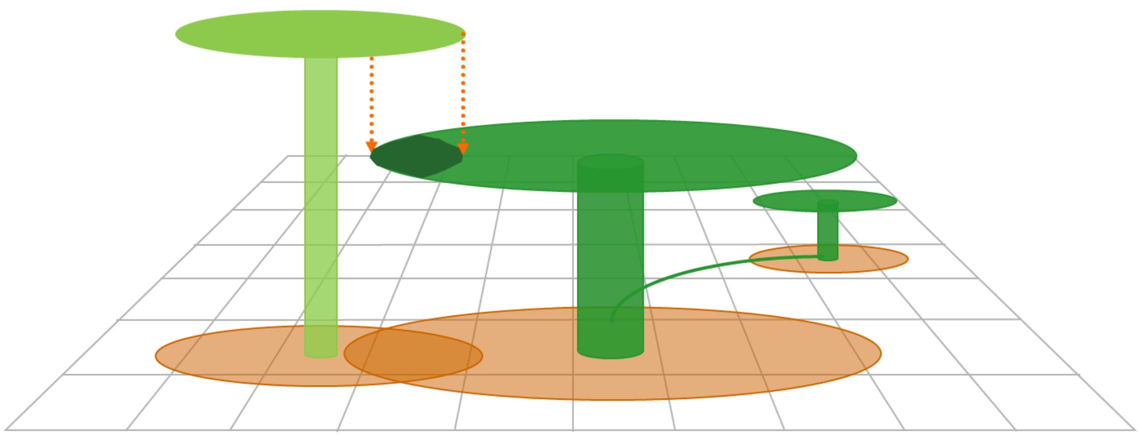
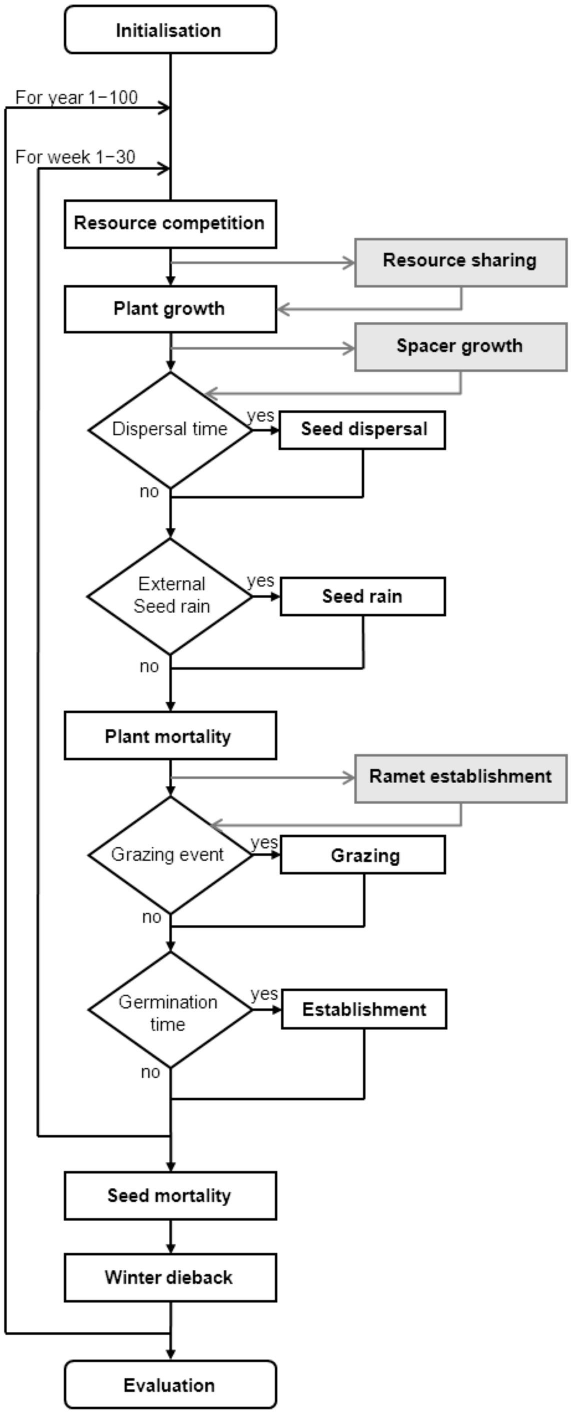


Figure A2. Flow chart of the model's processes, which are run for each individual plant. Processes related to clonal growth are marked by grey lines and boxes.



Appendix 2

Result figures and tables

Sensitivity analysis

Parameters were perturbed by 5 and 10 % downwards and upwards. Sensitivities were calculated as the difference between the model output at the modified parameter value and that at the standard parameter value, normalized by the model output at the standard parameter value (Reineking et al. 2006). Bold font indicates significant differences between standard and modified parameter settings (alpha = 5%, 50 repetitions, two-sided Wilcoxon rank sum test). Parameters were assumed to be strongly sensitive if the relative change in at least one output variable in at least one of the scenarios (grazing intensity, parameter change) was larger than the relative parameter change (Reineking et al. 2006), i.e. when statistically significant sensitivities were outside the interval [–0.05, 0.053] ([–0.1, 0.11]) for a 5% (10%) reduction of the parameter value, and outside [–0.48, 0.05] ([–0.09, 0.1]) for an 5% (10%) increase of the parameter value. While PFT richness showed a stronger sensitivity, in particular for high resource levels, Shannon diversity and aboveground biomass were highly robust.

Table A4. Results of sensitivity analysis for low resource scenarios.

Parameter	Standard value	Grazing intensity	Number of PFTs				Shannon diversity index				Aboveground_biomass			
			- 10%	-5 %	+ 5%	+ 10%	- 10%	-5 %	+ 5%	+ 10%	- 10%	-5 %	+ 5%	+ 10%
AllocSeed	0,05	extensive	0,01	0,00	**-0,05**	**-0,06**	0,00	0,00	-0,01	**-0,02**	0,00	0,01	0,01	0,02
		medium	0,01	0,01	0,01	**0,07**	0,01	0,01	0,01	**0,02**	0,01	0,02	0,01	-0,01
		intensiv	-0,04	-0,02	-0,03	-0,04	-0,01	0,00	0,00	0,00	0,00	0,00	-0,02	0,01
croot	1	extensive	0,01	**-0,03**	**0,03**	0,02	**-0,01**	-0,01	0,01	0,01	0,01	0,01	0,01	**0,06**
		medium	0,02	-0,04	-0,03	-0,04	**-0,02**	-0,01	0,01	0,01	**0,04**	0,02	0,01	0,00
		intensiv	0,03	0,00	0,02	0,00	-0,01	**-0,01**	0,01	0,01	**0,06**	0,02	-0,01	**-0,03**
decrease Rate	0,5	extensive	0,00	0,00	-0,01	0,03	0,01	0,01	0,00	0,00	0,02	0,00	0,02	0,00
		medium	-0,02	0,01	-0,02	-0,04	0,00	0,00	-0,01	-0,01	0,02	0,01	**0,03**	0,01
		intensiv	0,01	0,02	0,03	0,00	0,01	0,00	0,00	-0,01	0,01	0,00	0,00	0,00
mort_seeds	0,5	extensive	0,00	-0,01	-0,02	**-0,04**	0,00	0,00	-0,01	-0,01	-0,01	0,02	-0,02	-0,01
		medium	0,03	0,01	0,01	0,00	0,00	-0,01	0,00	-0,01	-0,03	**-0,04**	**-0,04**	-0,04
		intensiv	0,00	0,00	-0,01	0,01	0,00	**-0,01**	-0,01	0,00	0,00	-0,01	0,01	0,00
thrres	0,2	extensive	0,04	0,02	**-0,05**	**-0,13**	**0,02**	**0,01**	**-0,02**	**-0,04**	**-0,04**	0,01	0,00	0,02
		medium	**0,07**	**0,07**	-0,03	-0,03	**0,03**	0,01	0,01	**0,02**	**0,05**	**0,04**	-0,01	-0,03
		intensiv	**0,08**	0,03	-0,01	0,02	0,00	0,00	-0,01	**-0,02**	**0,07**	**0,03**	-0,02	**-0,05**
pgerm	0,5	extensive	0,00	-0,01	0,00	-0,02	0,01	0,00	0,00	0,00	**-0,03**	-0,01	-0,02	0,00
		medium	0,02	-0,02	0,00	-0,01	0,00	-0,01	0,00	0,00	**-0,03**	-0,02	-0,03	-0,02
		intensiv	-0,01	-0,01	-0,02	0,00	-0,01	-0,01	0,00	-0,01	-0,02	-0,02	0,00	-0,02
pmin	0,007	extensive	0,02	0,01	-0,02	-0,01	0,00	0,00	0,00	-0,01	0,01	0,00	0,00	-0,01
		medium	0,04	0,00	-0,04	-0,03	0,01	0,00	-0,01	**-0,02**	0,02	0,02	0,01	0,01
		intensiv	0,02	**0,06**	0,01	0,02	**0,02**	**0,02**	0,01	0,00	0,00	0,00	-0,02	-0,04
winterloss	0,5	extensive	-0,02	-0,01	-0,01	0,01	-0,01	0,00	0,00	0,00	-0,02	-0,01	-0,03	0,00
		medium	-0,02	-0,02	0,02	-0,01	-0,01	-0,01	0,00	-0,01	-0,02	-0,01	**-0,04**	**-0,04**
		intensiv	-0,02	-0,01	0,00	0,00	0,00	0,01	**0,01**	**0,02**	0,03	0,01	0,02	**0,03**
pram (clonality)	1	extensive	0,02	-0,01	x	x	0,01	0,00	x	x	0,00	0,01	x	x
		medium	-0,03	-0,01	x	x	-0,01	0,00	x	x	0,00	0,00	x	x
		intensiv	0,01	-0,01	x	x	0,00	0,00	x	x	-0,02	-0,01	x	x
mSpacer (clonality)	70	extensive	**-0,06**	-0,01	0,03	**0,05**	**-0,02**	0,00	0,01	0,01	**0,04**	0,02	0,01	0,03
		medium	0,01	-0,01	-0,03	0,01	0,01	0,00	0,00	0,01	-0,03	0,01	-0,02	-0,02
		intensiv	0,02	0,02	-0,02	0,01	0,01	0,00	0,00	0,00	0,02	0,03	0,01	0,01
bitsize (grazing)	0,5	extensive	-0,02	0,00	0,01	**0,04**	-0,01	0,00	0,00	0,01	0,01	0,01	0,01	0,02
		medium	0,03	0,02	-0,04	0,01	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,01
		intensiv	**0,05**	0,02	0,02	0,00	**-0,01**	-0,01	0,00	**0,01**	0,02	0,00	-0,01	-0,02
PropRemove (grazing)	0,5	extensive	-0,02	-0,01	0,00	-0,01	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,02
		medium	0,03	-0,01	-0,01	-0,01	0,00	-0,01	**-0,02**	-0,01	0,02	-0,01	0,00	0,01
		intensiv	0,01	0,00	0,01	-0,01	0,00	0,00	0,01	0,00	0,00	-0,01	0,01	0,01
ResidMass (grazing)	15,3	extensive	-0,01	-0,02	0,01	-0,02	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,00
		medium	-0,02	0,01	0,00	0,01	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,02
		intensiv	0,02	-0,02	-0,03	0,01	0,00	-0,01	0,00	0,00	-0,03	-0,02	**-0,02**	0,01

Table A5 Results of sensitivity analysis for high resource scenarios.

Parameter	Standard value	Grazing intensity	Number of PFTs				Shannon diversity index				Aboveground_biomass			
			- 10%	-5 %	+ 5%	+ 10%	- 10%	-5 %	+ 5%	+ 10%	- 10%	-5 %	+ 5%	+ 10%
AllocSeed	0,05	extensive	**0,05**	0,03	-0,01	**-0,09**	0,00	0,00	0,00	-0,01	0,02	0,01	-0,01	-0,01
		medium	-0,02	-0,02	0,02	0,00	**-0,06**	**-0,03**	**0,02**	**0,03**	**0,03**	0,00	-0,02	-0,02
		intensiv	-0,03	0,04	0,04	**0,10**	**-0,02**	0,00	0,01	**0,03**	-0,01	-0,01	0,00	0,00
croot	1	extensive	**-0,31**	**-0,14**	0,02	0,00	**-0,16**	**-0,06**	**0,02**	**0,02**	**0,05**	0,02	**-0,04**	**-0,08**
		medium	-0,04	0,01	**-0,08**	**-0,07**	0,01	0,01	**-0,02**	**-0,02**	0,00	0,01	0,01	0,00
		intensiv	**0,09**	0,05	0,02	**0,11**	**-0,03**	-0,02	**0,03**	**0,05**	**0,04**	0,00	-0,01	**-0,05**
decrease Rate	0,5	extensive	0,01	-0,02	-0,01	-0,01	**0,01**	**0,01**	0,00	-0,01	-0,01	-0,01	-0,01	-0,01
		medium	-0,01	-0,02	-0,01	0,02	0,01	0,01	0,00	0,00	**-0,04**	0,00	-0,01	-0,02
		intensiv	0,03	0,04	0,02	-0,03	0,01	0,01	0,00	-0,02	0,00	0,00	0,01	0,00
mort_seeds	0,5	extensive	0,01	0,01	-0,01	-0,03	0,01	0,01	0,00	-0,01	0,00	0,01	0,00	0,01
		medium	0,00	0,01	0,01	0,02	0,00	0,00	0,00	0,00	0,01	0,00	-0,01	-0,02
		intensiv	-0,02	0,00	-0,03	-0,02	0,01	0,01	-0,01	0,00	0,02	0,01	0,02	0,00
thrres	0,2	extensive	**-0,08**	-0,03	**-0,06**	**-0,13**	**-0,02**	0,00	**-0,01**	**-0,05**	0,01	0,00	**-0,03**	**-0,03**
		medium	**0,07**	0,03	**-0,04**	**-0,11**	**0,03**	0,01	-0,01	**-0,02**	**0,06**	0,03	-0,01	-0,02
		intensiv	**0,20**	**0,07**	0,00	-0,01	-0,01	-0,01	0,00	0,01	**0,06**	0,02	0,00	**-0,04**
pgerm	0,5	extensive	0,00	-0,02	0,00	0,02	0,00	-0,01	0,00	0,01	-0,01	0,00	0,00	-0,01
		medium	0,00	-0,03	-0,01	0,00	0,00	-0,01	-0,01	-0,01	-0,01	-0,02	-0,02	-0,01
		intensiv	0,00	0,00	-0,01	-0,01	-0,02	0,00	-0,01	0,00	-0,01	0,00	-0,01	0,01
pmin	0,007	extensive	-0,02	-0,02	-0,01	0,01	**-0,01**	-0,01	0,00	0,01	0,00	0,02	0,01	0,00
		medium	0,00	0,00	-0,01	**-0,04**	0,01	0,01	-0,01	**-0,03**	-0,02	0,01	0,01	0,02
		intensiv	**0,09**	**0,09**	0,03	0,01	**0,03**	**0,02**	0,00	-0,01	-0,01	0,00	-0,02	-0,02
winterloss	0,5	extensive	0,00	0,02	0,01	0,01	-0,01	0,01	0,00	0,01	0,00	-0,02	0,01	-0,02
		medium	-0,02	0,01	-0,01	-0,01	0,00	0,01	-0,01	-0,01	-0,01	0,01	0,01	0,01
		intensiv	-0,02	-0,02	0,00	-0,04	0,00	0,00	0,00	0,01	0,02	0,00	-0,01	0,00
pram (clonality)	1	extensive	**0,08**	**0,04**	x	x	**0,03**	**0,02**	x	x	0,00	-0,01	x	x
		medium	0,01	-0,02	x	x	-0,01	**-0,02**	x	x	0,00	-0,03	x	x
		intensiv	**-0,05**	-0,02	x	x	0,00	0,00	x	x	0,03	0,01	x	x
mSpacer (clonality)	70	extensive	**-0,09**	-0,03	**0,05**	0,02	**-0,02**	-0,01	0,00	-0,01	-0,02	-0,01	0,00	0,01
		medium	-0,03	-0,01	-0,03	**-0,04**	**0,04**	**0,03**	**-0,02**	**-0,05**	-0,01	-0,01	**0,05**	**0,05**
		intensiv	**0,09**	0,02	**-0,06**	**-0,08**	0,01	0,00	-0,01	**-0,02**	-0,02	0,00	0,00	-0,02
bitsize (grazing)	0,5	extensive	**0,04**	**0,04**	0,03	**0,04**	**0,02**	**0,02**	0,01	0,01	-0,01	0,02	0,00	-0,02
		medium	0,03	0,00	-0,01	**-0,05**	**0,02**	**0,01**	0,00	**-0,02**	-0,01	-0,01	0,00	-0,01
		intensiv	**0,12**	**0,08**	-0,01	-0,05	0,02	0,02	0,01	0,01	0,01	0,01	-0,01	**-0,03**
PropRemove (grazing)	0,5	extensive	**-0,04**	-0,02	**-0,05**	0,00	**-0,02**	-0,01	**-0,02**	-0,01	0,02	0,01	**0,03**	0,03
		medium	-0,03	0,01	0,00	0,00	0,01	**0,01**	0,00	0,01	0,02	0,01	0,01	0,00
		intensiv	-0,04	**-0,05**	**-0,07**	-0,01	-0,01	-0,01	**-0,03**	-0,01	0,00	0,02	-0,02	0,01
ResidMass (grazing)	15,3	extensive	0,00	0,02	0,01	0,02	0,01	0,01	0,00	0,00	0,00	-0,01	-0,01	-0,02
		medium	0,01	-0,01	0,00	-0,02	-0,01	0,00	-0,01	0,00	0,01	0,00	-0,01	0,00
		intensiv	-0,02	0,00	-0,02	0,02	-0,01	-0,01	-0,01	-0,24	-0,02	-0,01	-0,02	-0,02

Table A6. Low resource scenarios: Mean trait proportions and standard deviations for empirically observed communities, simulated communities (means from years 75–100), and initial trait distribution in the simulated communities (all proportions weighted by cover%).

		EMPIRICALLY OBSERVED COMMUNITIES						SIMULATED COMMUNITIES							
		Grazing intensity						Grazing intensity							
		extensive		intermediate		intensive		extensive		intermediate		intensive		initial distribution (year=1)	
TRAIT	Attribute	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Grazing response	Avoider	0.20	0.12	0.46	0.37	0.47	0.20	0.44	0.32	0.58	0.38	0.62	0.38	0.30	0.08
	Intermediate	0.11	0.10	0.13	0.16	0.03	0.05	0.38	0.26	0.35	0.31	0.36	0.28	0.35	0.10
	Tolerator	0.69	0.14	0.41	0.22	0.50	0.19	0.18	0.17	0.06	0.09	0.02	0.02	0.35	0.10
Plant mass	Small	0.32	0.15	0.41	0.26	0.33	0.13	0.48	0.39	0.77	0.54	0.73	0.44	0.31	0.08
	Medium	0.63	0.13	0.49	0.22	0.64	0.13	0.30	0.22	0.23	0.21	0.27	0.19	0.35	0.10
	Large	0.05	0.07	0.10	0.12	0.03	0.05	0.22	0.18	0.00	0.00	0.00	0.00	0.34	0.09
Growth form	Rosette	0.09	0.07	0.25	0.21	0.25	0.21	0.38	0.31	0.41	0.23	0.33	0.21	0.34	0.11
	Semi-erect	0.68	0.10	0.54	0.10	0.55	0.23	0.23	0.19	0.12	0.15	0.17	0.13	0.35	0.10
	Erect	0.23	0.12	0.21	0.14	0.20	0.24	0.39	0.23	0.47	0.10	0.51	0.10	0.31	0.08
Resource response	Competitor	0.38	0.29	0.46	0.25	0.53	0.18	0.20	0.16	0.00	0.00	0.00	0.00	0.32	0.08
	Intermediate	0.38	0.12	0.49	0.23	0.43	0.20	0.32	0.25	0.43	0.30	0.37	0.16	0.34	0.10
	Stress-tolerator	0.24	0.18	0.05	0.03	0.04	0.07	0.48	0.38	0.57	0.48	0.63	0.40	0.34	0.12
Lateral spread	No spread	0.20	0.10	0.06	0.03	0.10	0.08	0.28	0.24	0.29	0.23	0.31	0.17	0.29	0.05
	Short	0.37	0.24	0.41	0.09	0.39	0.23	0.39	0.36	0.37	0.33	0.34	0.27	0.41	0.11
	Long	0.43	0.14	0.53	0.11	0.51	0.25	0.33	0.22	0.34	0.23	0.35	0.18	0.30	0.06
Clonal integration	Integrator	0.80	0.17	0.67	0.08	0.54	0.20	0.59	0.48	0.60	0.47	0.62	0.39	0.56	0.16
	Splitter	0.20	0.17	0.33	0.08	0.46	0.20	0.41	0.34	0.40	0.30	0.38	0.20	0.44	0.08

Table A7. High resource scenarios: Mean trait proportions and standard deviations for empirically observed communities, simulated communities (means from years 75–100), and initial trait distribution in the simulated communities (all proportions weighted by cover%).

		EMPIRICALLY OBSERVED COMMUNITIES						SIMULATED COMMUNITIES							
		Grazing intensity						Grazing intensity							
		extensive		intermediate		intensive		extensive		intermediate		intensive		initial distribution (year=1)	
TRAIT	Attribute	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Grazing response	Avoider	0.26	0.18	0.34	0.14	0.51	0.28	0.20	0.12	0.70	0.48	0.93	0.68	0.27	0.09
	Intermediate	0.17	0.15	0.12	0.07	0.05	0.06	0.38	0.33	0.14	0.13	0.03	0.03	0.37	0.17
	Tolerator	0.57	0.21	0.54	0.12	0.44	0.26	0.42	0.36	0.16	0.17	0.04	0.09	0.36	0.15
Plant mass	Small	0.29	0.13	0.33	0.10	0.43	0.26	0.11	0.07	0.64	0.44	0.98	0.80	0.27	0.10
	Medium	0.69	0.11	0.64	0.08	0.53	0.25	0.17	0.12	0.09	0.10	0.02	0.02	0.35	0.15
	Large	0.02	0.03	0.03	0.05	0.04	0.03	0.71	0.07	0.28	0.17	0.00	0.00	0.38	0.19
Growth form	Rosette	0.14	0.12	0.09	0.05	0.17	0.11	0.09	0.08	0.73	0.50	0.56	0.31	0.33	0.17
	Semi-erect	0.71	0.07	0.67	0.09	0.64	0.22	0.46	0.40	0.26	0.23	0.13	0.17	0.37	0.16
	Erect	0.15	0.08	0.24	0.11	0.19	0.16	0.45	0.42	0.01	0.01	0.31	0.16	0.30	0.10
Resource response	Competitor	0.41	0.30	0.41	0.25	0.58	0.29	0.67	0.55	0.10	0.10	0.00	0.00	0.36	0.16
	Intermediate	0.46	0.20	0.39	0.08	0.40	0.28	0.33	0.22	0.33	0.30	0.40	0.34	0.34	0.15
	Stress-tolerator	0.13	0.24	0.20	0.24	0.02	0.02	0.00	0.00	0.57	0.20	0.60	0.43	0.30	0.12
Lateral spread	No spread	0.14	0.13	0.13	0.06	0.15	0.13	0.20	0.12	0.35	0.24	0.19	0.17	0.27	0.05
	Short	0.32	0.04	0.34	0.16	0.30	0.19	0.27	0.16	0.37	0.32	0.46	0.34	0.45	0.19
	Long	0.54	0.14	0.53	0.16	0.55	0.30	0.53	0.45	0.28	0.30	0.35	0.30	0.28	0.07
Clonal integration	Integrator	0.64	0.21	0.78	0.15	0.66	0.26	0.69	0.59	0.46	0.51	0.69	0.48	0.60	0.26
	Splitter	0.36	0.21	0.22	0.15	0.34	0.26	0.31	0.19	0.54	0.36	0.31	0.26	0.40	0.08

Figure A3. Response of community plant functional type richness (a) and Shannon diversity (b) for low (above panels) and high (bottom panels) resource availability under different levels of grazing intensity (x-axis) for seed rain scenarios 3 and 4 (equal seed input number scenarios with additional input of 10 resp. 100 seeds per PFT).

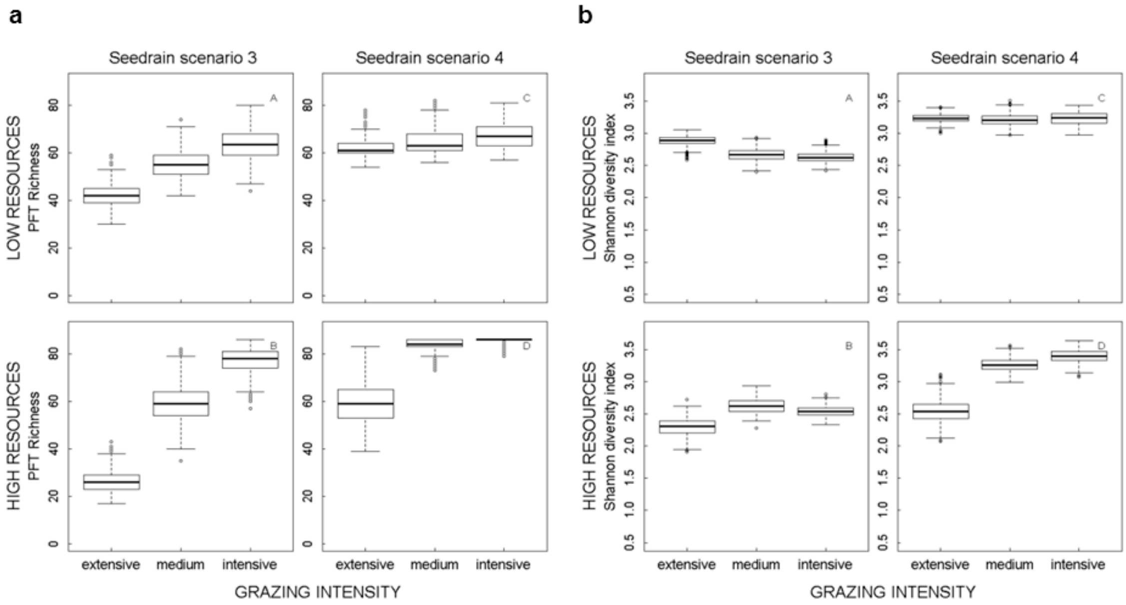


Figure A4.: Mean accordance of PFT identity between empirically observed and simulated communities in low (left) and high (right) resource scenarios.