Appendix A: Full description of the dynamic grassland model DynaGraM

Online Supplementary Material to the article:
Thibault Moulin, Antoine Perasso, Pierluigi Calanca, François Gillet. *DynaGraM*: a process-based model to simulate multi-species plant community dynamics of managed grasslands. *Ecological Modelling.*

In *DynaGraM*, the grassland vegetation is represented by n herbaceous species, species groups or plant functional types as described by n state variables. The subscript i refers to state variables and parameters that are species-specific. Below stands a comprehensive description of the model. Differential equations are written with the only dependence on state and forcing variables, whereas functions contain explicitly the dependence on time. The time unit is the day.
All state variables, forcing variables and parameters are listed in Table B1 (Online Supplementary Material, Appendix B).

Plant biomass dynamics

For a given species or species group i, green biomass dynamics is described by equation (1). Like in *ModVege* (Jouven et al., 2006), biomass (kg DM ha^{-1}) is computed daily as the difference between gain (the actual growth rate gr_i) and loss due to leaf senescence $\mu_i\, SEN(T)$ and defoliations (mowing and grazing). We define the potential growth rate Gr_i as the one obtained in optimum conditions. Actual growth rate gr_i is computed by taking into account environmental limitations related to soil and climate conditions, as well as management and seasonal patterns. For clarity reason, only the dependence on state and forcing variables is indicated:

$$\frac{dB_i}{dt} = gr_i - \mu_i\, SEN(T) - mow_i(B_i) - graz_i(B_i) \tag{1}$$

$$gr_i = Gr_i(B_i, PAR)\, SEA(T)\, Rred(PAR)\, Nred_i(Nm)\, Tred_i(T)\, Wred_i(WR, PET)\, Ared_i \tag{2}$$

According to equation (2), the actual growth rate gr_i of a given species i is equal to the potential growth rate Gr_i multiplied by reducers and enhancer terms; Gr_i expresses potential growth as a function of standing biomass B_i and photosynthetically active radiation PAR; SEA, a function of the sum of temperatures, is an empirical representation of the seasonal pattern of shoot growth; $Rred$, $Nred_i$, $Tred_i$, $Wred_i$ and $Ared_i$ correspond to daily growth reducers associated with solar radiation, soil mineral N availability, temperature, soil water status and trampling by livestock, respectively; $\mu_i\, SEN(T)$ is the seasonal sink, depending on the sum of temperatures, associated with senescence, and mow_i and $graz_i$ are the biomass removal rates due to mowing and grazing.

Potential growth

As formulated in *LINGRA* (Schapendonk et al., 1998) and used later in *ModVege* (Jouven et al., 2006), potential growth is described by an Ivlev function of the total leaf area index of the canopy (LAI_{tot}). The radiation absorbed by the canopy is then distributed within the community according to the relative contribution of each species or PFT to the total leaf area index, following a light interception term LAI_i/LAI_{tot} (Thornley and Johnson, 1990). This potential growth Gr_i corresponds to the maximal growth obtained in optimum conditions regarding resources (nutrients, water), temperature and in absence of disturbances (trampling). It describes the efficiency of use of solar radiation by the canopy for photosynthesis processes.

One should notice that this Gr_i function is of particular importance, as it is the only term of equation (2) depending on biomass B_i itself. We set:

$$\begin{aligned} LAI_i(B_i(t)) &= SLA_i \, \frac{B_i(t)}{10} \, LAM \\ LAI_{tot}(B_i(t)) &= \sum_{i=1}^{n} LAI_i\left(B_i(t)\right) \end{aligned} \tag{3}$$

$$gr_i(B_i(t), PAR(t)) = 10 \; PAR(t) \, RUE_{\max} \left(1 - e^{-\alpha \, LAI_{tot}\,(B_i(t))}\right) \frac{LAI_i\left(B_i(t)\right)}{LAI_{tot}\left(B_i(t)\right)} \tag{4}$$

where RUE_{max} is the maximum radiation use efficiency of the whole canopy, α the extinction coefficient (assumed to be the same for all species), SLA_i the specific leaf area of species i, and LAM the percentage of laminae present in the green biomass. The factor 10 simply accounts for unit consistency.

Plant growth reducers

Then, five reducers decrease biomass production. First, $Rred$ depicts a decrease in radiation use efficiency at light intensity higher than 5 MJ m^{-2}, see equation (5). This term acts at the community level and is common to all the n species or species groups.

$$Rred(PAR(t)) = \min\left(1, 1 - \gamma_1(PAR(t) - \gamma_2)\right) \tag{5}$$

where γ_1 and γ_2 parameters were given by Schapendonk et al. (1998).
Second, growth limitation according to mineral N availability is modelled in equation (6) by a Holling type III functional response to Nm. This function is adapted from Tilman (1982). The half-saturation term k_i corresponds to the amount of mineral N resource for which the plant growth rate is reaching half its maximum (assuming that other resources are not limiting). This parameter k_i traduces the species requirement in nutrients for growth.

$$Nred_i(Nm(t)) = \frac{Nm(t)^2}{k_i^2 + Nm(t)^2} \tag{6}$$

Then, the temperature reducer is defined in equation (7) with a linear piecewise function and describes the photosynthesis activation (above a threshold T_0) and stimulation by mean daily temperature until an optimum temperature range $[T_{1,i}, T_2]$. The species-specific lower optimum temperature $T_{1,i}$ accounts for the plant phenology, i.e. its precocity of development. Values of constant parameters T_0, T_2 and T_3 are estimated from Schapendonk et al. (1998).

$$Tred_i(T(t)) = \begin{cases} 0 & \text{if} \quad T(t) \leq T_0 \\ \dfrac{T(t) - T_0}{T_{1,i} - T_0} & \text{if} \quad T_0 \leq T(t) \leq T_{1,i} \\ 1 & \text{if} \quad T_{1,i} \leq T(t) \leq T_2 \\ \dfrac{T_3 - T(t)}{T_3 - T_2} & \text{if} \quad T_2 \leq T(t) \leq T_3 \\ 0 & \text{if} \quad T(t) \geq T_3 \end{cases} \tag{7}$$

Soil water content also reduces plant growth, as a function of the soil water stress W – a ratio of water available for plant growth, see equation 9 – and of the potential evapotranspiration PET. Indeed, the threshold of soil water content for which plant growth rate starts to be impacted directly depends on PET (Johns and Smith, 1975). One novelty is the replacement of three piecewise functions accounting for water growth limitation (McCall and Bishop-Hurley, 2003) by a ratio of Ivlev functions involving a convex combination of PET. Parameters β_1, β_2 and $PET_{\max}$ are introduced to fit each piecewise function. It results with a continuous reducer without threshold values in PET to avoid the jump between curves. We add an exponent η_i as an amplification term, specific of each species i. Thus we get equation (8):

$$Wred_i(WR(t), PET(t)) = \left(\frac{1 - e^{-(\frac{PET(t)}{PET_{\max}}\beta_2 + (1 - \frac{PET(t)}{PET_{\max}})\beta_1)\, W(WR(t))}}{1 - e^{-(\frac{PET(t)}{PET_{\max}}\beta_2 + (1 - \frac{PET(t)}{PET_{\max}})\beta_1)}} \right)^{\eta_i} \tag{8}$$

$$W(WR(t)) = \frac{WR(t) - PWP}{WHC - PWP} \tag{9}$$

where PWP is the permanent wilting point and WHC is the water holding capacity, both expressed in mm. The fifth growth reducer $Ared_i$, defined in equation 10, represents a decrease in plant growth due to trampling. This function of the cattle stock density SD is modelled following *GraS* (Siehoff et al., 2011) and is based on indicator values of species tolerance to trampling ($\sigma_i \in [1, 9]$) and on the grazing intensity (with $SD_{\max}$, the maximal bovine livestock density). The exponent T_{tol} adjusts the order of magnitude of the trampling effect to the four other plant growth reducers. In presence of cattle, we get:

$$Ared_i(t) = \left((1 - \frac{\sigma_i}{9})(1 - \frac{SD(t)}{SD_{\max}}) + \frac{\sigma_i}{9} \right)^{T_{tol}} \tag{10}$$

Fig. 1 represents the four species-specific reducers of plant growth, $Nred$, $Wred$, $Tred$ and $Ared$, plotted as functions of Nm, WR, T and SD, respectively. It shows, for the seven representative species selected in this study, the impact of species-specific parameters on the reduction of the growth rate of each species (see Table 3 of the article). Curves are slightly shifted for species with identical parameter values. $Wred$ is plotted here for different values of PET; the thick magenta curve illustrates the limit case obtained for $PET = 0$ and the thick red curve for a maximal value $PET = 8$; in-between are curves obtained for three intermediate values of PET (1, 4 and 6).

Seasonal effect

The seasonal effect is an empirical function of the sum of temperatures ST (accumulated degree days) and acts as a reducer or an enhancer of biomass growth rate according to the season. This function accounts for variations in storage and mobilization of reserves by herbaceous species (Jouven et al., 2006). This SEA term follows a constant basic level ($SEA_{\min} < 1$) during autumn and winter. In spring, before the period of reproductive growth, it increases to reach a peak ($SEA_{\max} > 1$) and linearly decreases in summer, as defined in equation (11).

$$SEA(T(t)) = \begin{cases} SEA_{\min} & \text{if}\, ST(T(t)) \leq 200 \\ SEA_{\min} + (SEA_{\max} - SEA_{\min})\dfrac{ST(T(t)) - 200}{ST_1 - 400} & \text{if}\, 200 \leq ST(T(t)) \leq ST_1 - 200 \\ SEA_{\min} & \text{if}\, ST_1 - 200 \leq ST(T(t)) \leq ST_1 - 100 \\ SEA_{\min} + (SEA_{\min} - SEA_{\max})\dfrac{ST(T(t)) - ST_2}{ST_2 - (ST_1 - 100)} & \text{if}\, ST_1 - 100 \leq ST(T(t)) \leq ST_2 \\ SEA_{\min} & \text{if}\, ST(T(t)) \geq ST_2 \end{cases} \tag{11}$$

The temperature sum ST is the sum of positive daily temperatures of a given year, from January 1 to December 31:

$$ST(T(t)) = \sum_{i=1\,(\mathrm{mod}\,365)}^{t\,(\mathrm{mod}\,365)} \max(T(i), 0) \tag{12}$$

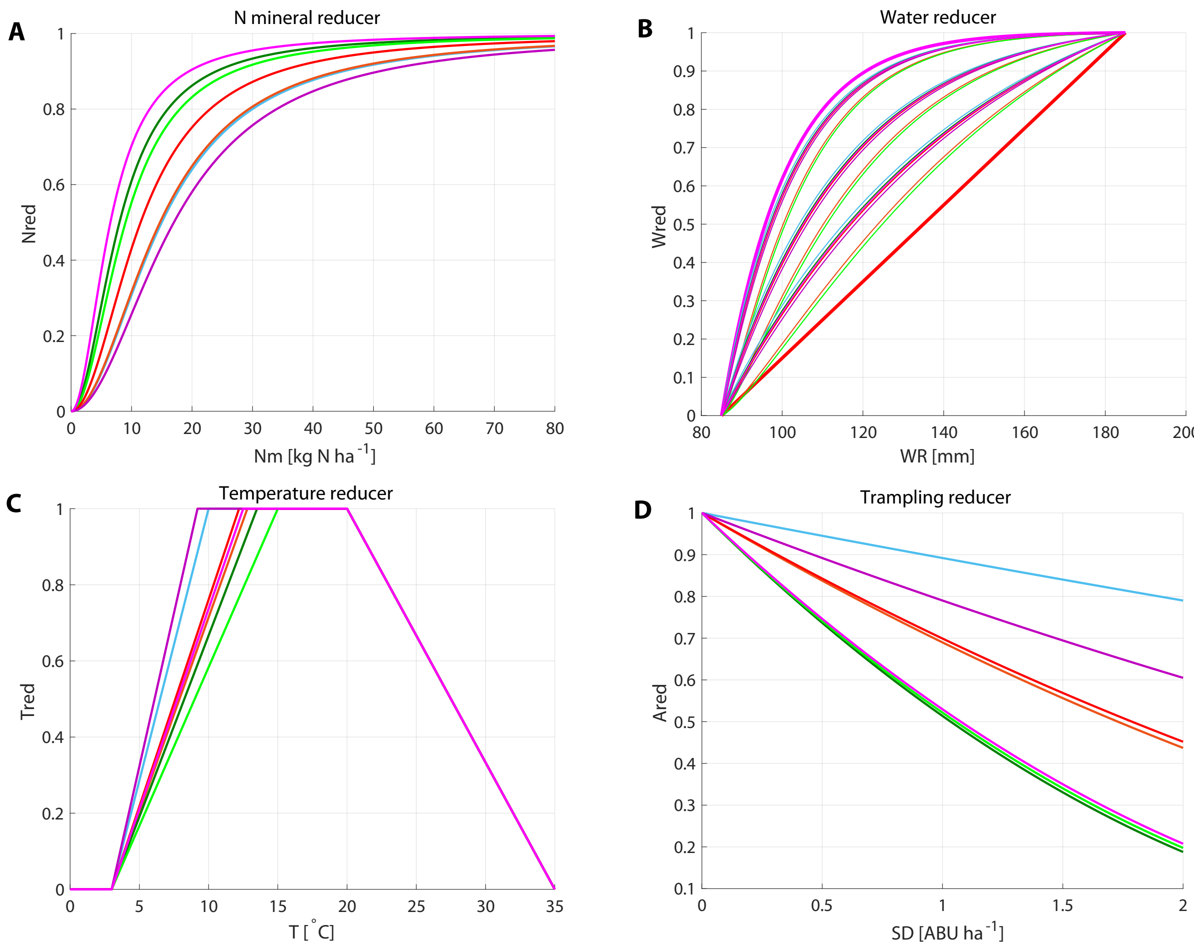

Figure 1: Response curves of the species-specific plant growth reducers: (A) nutrient reducer $Nred$ as a function of the soil mineral nitrogen Nm, (B) water reducer $Wred$ as a function of the soil water reserve WR, (C) temperature reducer $Tred$ as a function of the average daily air temperature T, and (D) trampling reducer $Ared$ as a function of the cattle stock density SD.

Leaf senescence

Green biomass loss is partly due to the senescence of leaves, computed as a basic senescence rate μ_i associated with a seasonal sink SEN, a threshold function of the temperature sum ST built as a simplification of ageing processes introduced in *ModVege*, see equation 13. When ST exceeds a threshold Ψ_1, then senescence linearly increases from its minimum until its maximum after exceeding a second threshold Ψ_2.

$$SEN(T(t)) = \begin{cases} SEN_{\min} & \text{if} \quad ST(T(t)) \leq \Psi_1 \\ SEN_{\min} + (SEN_{\max} - SEN_{\min}) \dfrac{ST(T(t)) - \Psi_1}{\Psi_2 - \Psi_1} & \text{if} \quad \Psi_1 \leq ST(T(t)) \leq \Psi_2 \\ SEN_{\max} & \text{if} \quad ST(T(t)) \geq \Psi_2 \end{cases} \tag{13}$$

Agricultural defoliations

The last two terms on the right-hand side of equation (1) correspond to defoliation rates due to mowing and grazing events. Both are modelled as pulse-wise functions, following a predefined schedule, repeated each year. Removal of aboveground biomass by mowing is assumed to be proportional to the standing biomass of each species, whereby the proportionality factor λ_i also depends on the species to account for differences in the vertical distribution of biomass, following equation (14).

$$mow_i(B_i(t)) = \lambda_i \, B_i(t) \tag{14}$$

The approach adopted to model removal of aboveground biomass by grazing is based on the assumption that each livestock unit consumes daily a required amount of biomass. This loss is distributed among all species or PFTs in such a way that it depends on cattle's appetence ρ_i and on the relative biomass of the species or PFT i. It translates a balance between a very attractive species with a low abundance and a poorly attractive species with a high abundance. Denoting by SD the stocking density (ABU ha^{-1}) and by κ the daily consumption of an adult bovine unit (kg DM ABU^{-1} d^{-1}) and assuming a Holling type III functional response we get equation (15):

$$graz_i(B_i(t)) = \kappa \, SD(t) \, \frac{\rho_i B_i^2(t)}{1 + \sum\limits_{j=1}^{n} \rho_j B_j^2(t)} \tag{15}$$

Soil variable dynamics

Following previous works (Schwinning and Parsons, 1999), the dynamics of soil nutrients is restricted to nitrogen, this element being divided in two pools: No for organic N stored in the soil organic matter and Nm for mineral N available in the soil solution (mostly as nitrate NO_3^-) or adsorbed on the clay-humic complexes (as ammonium NH_4^+). WR is the soil water reserve.

Organic nitrogen

The organic N compartment is fed by three sources: (i) after leaf senescence, a fraction c_o of the leaf nitrogen content δ_i is released to the No compartment, accounting for some loss; (ii) by cattle restitution (dungs), proportional to the cattle density SD at a constant rate N_d; (iii) by organic fertilization (solid manure), with an inflow Φ_o at each event. Following other modelling approaches (Lazzarotto et al., 2009; Schwinning and Parsons, 1999), we assume that the only outflow of this compartment corresponds to the mineralization of No into Nm, computed as the product of a maximal rate θ reached in optimum conditions, adjusted by two reducers linked to soil temperature $Tred_{soil}$ and soil moisture $Wred_{soil}$. Hence, we get equation (16):

$$\frac{d}{dt} No = \sum_{i=1}^{n} (\delta_i \, c_o \, \mu_i \, SEN(T) B_i) \; + N_d \, SD + \Phi_o \; - \theta \, Tred_{soil}(T) \, Wred_{soil}(WR) \, No \tag{16}$$

First, the temperature reducer of mineralization $Tred_{soil}$ is formulated as an exponentially increasing function of temperature (Kirschbaum, 2000), see equation (17). Tm_1 corresponds to the critical temperature that leads to a maximal mineralization rate. g_T and Tm_2 are two empirical parameters introduced for adjustments.

$$Tred_{soil}(T(t)) = e^{g_T \frac{T(t)-Tm_1}{T(t)+Tm_2}} \tag{17}$$

Second, soil water content acts on mineralization as an increasing sigmoid function of WR. Soil water stress W has been introduced above in equation (9). g_{W1}, g_{W2} and g_{W3} are shape parameters taken from Paul et al. (2003).

$$Wred_{soil}(WR(t)) = \left(g_{W1} + g_{W2}\, e^{g_{W3}\, W(WR(t))}\right)^{-1} \tag{18}$$

Mineral nitrogen

The mineral N pool increases (i) by mineralization of organic N, (ii) by cattle restitution (urine), proportional to the cattle density SD at a constant rate N_u, and by (iii) mineral fertilization, with an inflow Φ_m at each event. This compartment is depleted by two outflows: lixiviation and plant consumption. First, when the amount of mineral N exceeds a soil holding capacity $Nm_{\max}$, the excess mineral N is removed through leaching, at a rate Λ defined in equation (19). The coefficient 1/2 roughly describes a delay in the removal of exceeding mineral N.

$$\Lambda(Nm(t)) = \frac{1}{2}\, \max(Nm(t) - Nm_{\max},\, 0) \tag{19}$$

Second, mineral N is consumed by plant uptake: the production of each unit of biomass (corresponding to the positive term in equation (1)), requires the consumption of a fixed amount δ_i of Nm. A coefficient c_m accounts for a decrease in the amount of mineral N consumed by plants with maturity. Hence, the mineral N dynamics is described in equation (20).

$$\begin{aligned}\frac{d}{dt}Nm = {}& \theta\, Tred_{soil}(T)\, Wred_{soil}(WR)\, No \;+ N_u\, SD \;+ \Phi_m \;- \Lambda(Nm)\\ & - \sum_{i=1}^{n} \delta_i\, c_m\, gr_i(B_i, PAR)\; Rred(PAR)\; Nred_i(Nm)\; Tred_i(T)\; Wred_i(WR, PET)\; Ared_i\; SEA(T)\end{aligned} \tag{20}$$

Water reserve

Dynamics of the soil water reserve (mm) is described in equation (21), following the formulation of *ModVege* [Jouven2006a]. This level varies between 0 and the water holding capacity WHC, Nevertheless, only the water above the permanent wilting point PWP is available for plants.

$$\frac{d}{dt}WR = P \;- AET(B_i,\, WR,\, PET) \;- \Delta(B_i,\, WR,\, PET,\, P) \tag{21}$$

Precipitation P fills the reserve. The second term corresponds to the loss of water by actual evapotranspiration (AET), which is the sum of plant transpiration ATr and evaporation AEv. AET follows the *PROGRASS* formulation [Lazzarotto2009], used in recent developments of *ModVege* [Calanca2016]. Thus, with W the water stress defined in equation (9), AET is defined by equation (22):

$$AET(t) = \min\left(WR(t)\,;\; ATr(t) \,+\, AEv(t)\right) \tag{22}$$

$$\begin{aligned}ATr(t) &= PET(t)\, \min\left(1\,;\, \frac{LAI_{tot}(t)}{3}\right) \left(\frac{1 - e^{-\left(\frac{PET(t)}{PET_{\max}}\beta_2 + \left(1-\frac{PET(t)}{PET_{\max}}\right)\beta_1\right) W(WR(t))}}{1 - e^{-\left(\frac{PET(t)}{PET_{\max}}\beta_2 + \left(1-\frac{PET(t)}{PET_{\max}}\right)\beta_1\right)}}\right)\\ AEv(t) &= \frac{WR(t)}{WHC}\, PET(t)\, \left(1 - \min\left(1\,;\, \frac{LAI_{tot}(t)}{3}\right)\right)\end{aligned} \tag{23}$$

The last term in equation 21 corresponds to the loss of water by drainage, which is the loss by infiltration or runoff of the water overflow that exceeds the water holding capacity WHC, see equation (24).

$$\Delta(t) = \max\left(WR(t) + P(t) - AET(t) - WHC\,;\,0\right) \tag{24}$$

Synthesis of the *DynaGraM* model

Finally, the *DynaGraM* model is entirely described by the equation system (25) by $n+3$ ordinary differential equations. The intermediate variables introduced to describe the model are summarized in Table 1.

$$\begin{cases} \dfrac{d}{dt}B_i(t) = gr_i(B_i, PAR)\, Rred(PAR)\, Nred_i(Nm)\, Tred_i(T)\, Wred_i(WR, PET)\, Ared_i\, SEA(T) \\ \quad - \mu_i\, SEN(T) - mow_i(B_i) - graz_i(B_i), \qquad i \in [1,\, n], \\ \dfrac{d}{dt}No(t) = \displaystyle\sum_{i=1}^{n} \delta_i\, c_o\, \mu_i\, SEN(T) B_i\ + N_d\, SD + \Phi_o\ - \theta\, Tred_{soil}(T)\, Wred_{soil}(WR)\, No, \\ \dfrac{d}{dt}Nm(t) = \theta\, Tred_{soil}(T)\, Wred_{soil}(WR)\, No\ + N_u\, SD\ + \Phi_m\ - \Lambda(Nm(t)) \\ \quad - \displaystyle\sum_{i=1}^{n} \delta_i\, c_m\, gr_i(B_i, PAR)\, Rred(PAR)\, Nred_i(Nm)\, Tred_i(T)\, Wred_i(WR, PET)\, Ared_i\, SEA(T), \\ \dfrac{d}{dt}WR(t) = P\ - AET(B_i,\, WR,\, PET)\ - \Delta(B_i,\, WR,\, PET,\, P) \end{cases} \tag{25}$$

Table 1: Summary of intermediate variables introduced to describe *DynaGraM*.

Symbol	Definition	Equation
gr_i	Actual growth of green biomass	(2)
LAI_i	Leaf area index	(3)
Gr_i	Potential growth of green biomass	(4)
$Rred$	Radiation reducer accounting for radiation use efficiency	(5)
$Nred_i$	Nutrient reducer of vegetative growth	(6)
$Tred_i$	Temperature reducer of vegetative growth	(7)
$Wred_i$	Water reducer of vegetative growth	(8)
W	Water stress	(9)
$Ared_i$	Trampling reducer of vegetative growth	(10)
SEA	Seasonal pattern of vegetation growth	(11)
SEN	Seasonal pattern of leaf senescence	(13)
mow_i	Biomass removal by mowing	(14)
$graz_i$	Biomass removal by grazing	(15)
$Tred_{soil}$	Effect of temperature on mineralization rate	(17)
$Wred_{soil}$	Effect of soil water on mineralization rate	(18)
Λ	Lixiviation of exceeding mineral N	(19)
AET	Actual evapotranspiration	(22)
Δ	Drainage by infiltration of exceeding soil water	(24)

Estimation of values for the species-specific parameters

In *DynaGraM*, the grassland vegetation is described by n species or species groups, associated with nine species-specific parameters describing biological characteristics of each species. A list of the seven representative species considered in this study, with values of species-specific parameters, is provided in Table 3 of the manuscript. The method used for the estimation of each parameter value is specified in the following paragraphs.

In addition, a fine tuning of some species-specific parameters was required to get simulation results close to observed vegetation patterns. We adjusted the values around the estimates of the three most uncertain parameters, namely k, μ and T_1, to get a coherent overall dynamics at the community level. No changes have been made for the values of the six other species-specific parameters. The considered values for the nine species-specific parameters are listed in the Table 3 of the manuscript, and kept constant for all simulations.

SLA, Specific Leaf Area [m^2 g^{-1}] Median values of the Specific Leaf Area of each representative species has been extracted from the TRY database and converted to the appropriate unit (Kattge et al., 2011).

λ, proportion of biomass removed at each mowing event [-] λ_i accounts for the proportion of standing biomass of each species removed by a mowing event. For the sake of simplicity, this proportion λ_i is assumed to be fixed and independent of the actual vegetative height of the species before the mowing event. This ratio has been estimated in equation (26) from the maximum canopy height of each species, H_i [m] (Perronne et al., 2014), considering that one mowing event removes all standing biomass taller than 0.05 m.

$$\lambda_i = \frac{H_i - 0.05}{H_i} \tag{26}$$

ρ and σ, forage value and trampling tolerance [-] ρ_i, forage value, and σ_i, trampling tolerance, were defined by Briemle et al. (2002) and species-specific values were extracted from the Biolflor database (Kühn et al., 2004). These two ordinal parameters correspond to utilization indicator values ranging from 1 to 9. A high value of ρ_i denotes a high forage value of the living plant species i for cattle. The higher is σ_i, the higher is the tolerance to trampling of the given species i.

δ, leaf nitrogen content [kg N (kg DM)$^{-1}$] Values of δ_i, the leaf nitrogen content, have been extracted from LNC measures published by Soussana et al. (2012), and converted to the appropriate unit.

k, half-saturation constant of the nitrogen resource [kg N ha^{-1}] k_i, the half-saturation constant of the nitrogen resource, describes the tolerance of each herbaceous species to a stress on the mineral N resource. Values has been estimated from indicator values (ranging from 1 to 9) describing nutrient requirements of plant species (Julve, 2019). A value of 1 describes a high tolerance of the plant to a nutrient stress, when a value of 9 accounts for important requirements of soil N for plant growth. To adjust the order of magnitude of k_i to Nm, a factor 2 has been applied.

μ, senescence rate [d^{-1}] μ_i represents the basic senescence rate of leaves. Values have been computed from the multiplicative reverse of the leaf life span, the latter being estimated from a linear regression defined by equation (27). Ryser and Urbas (2000) reported measures of leaf life span in days for 32 grasses, including 4 of the 7 representative species considered in this study. Beside, we found an acceptable correlation between on one hand values of the SLA and the LDMC (Leaf Dry Matter Content), values from (Perronne et al., 2014), and on the other hand this leaf life span μ_i. A multiple linear regression has been performed on the 32 grasses studied by Ryser and Urbas (2000) to estimate the linear coefficients provided in equation (27). We considered this regression significant with $P = 5.562\,10^{-5}$, an adjusted $R^2 = 0.521$ and with a residual standard error of 0.00508 on 24 degrees of freedom.

$$\mu_i = (0.023 + 0.382\, SLA_i - 0.0000629\, LDMC_i)^{-1}. \tag{27}$$

T_1, lowest limit of optimal growth temperature [°C] $T_{1,i}$ describes the lower limit of optimal growth temperature. For a set of 32 species, a measure of the mean onset of flowering date is available, expressed as Julian day (Al Haj Khaled, 2005). Grass species have been classified in seven categories of precocity (Al Haj Khaled et al., 2005). We associated this onset of flowering date to the beginning of the optimal temperature range for plant growth. To convert days in Celsius degrees, we performed a sinusoidal regression of the temperature data of the specific year 2004 considered in our study. From the smoothed curve of temperature data obtained, we matched the first flowering day to the corresponding estimated temperature $T_{1,i}$. For species not taken into account by this study, we computed a mean value from species belonging to the same PFT. Nevertheless, the reference provided no information for legumes: we arbitrary set the following temperature for legumes $T_{1,i} = 12.5$ °C.

η, Tolerance to water stress [-] η_i accounts for the water requirement of each species and corresponds in equation (8) of the water reducer function W_{red} to an exponent $\in$ [0.5, 2], which adjusts the impact of water stress on the plant growth rate. Julve (2019) provides an index *HE* that describes the optimal soil moisture for a maximal growth rate for a wide set of species, including all species considered here. This index corresponds to indicator values belonging to the interval [1, 12]. A value of 1 corresponds to a very high tolerance of the xerophilous species to water stress, whereas a value higher than 9 applies to aquatic species. For the 7 species considered in this study, values of *HE* were equal to 5 or 7. We arbitrary associated:

- a value of 5 translates a medium tolerance to water stress, leading to $\eta_i = 1$.
- a value of 7 translates a lower tolerance to water stress, leading to $\eta_i = 1.3$.

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