soslivestock model

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ODD protocol

1. Model description and purpose

The purpose of this model is to analyze how different management strategies affect the wellbeing, sustainability and resilience of an extensive livestock system under scenarios of climate change and landscape configurations. For this purpose, it simulates one cattle farming system, in which agents (cattle) move through the space using resources (grass). Three farmer profiles are considered: 1) a subsistence farmer that emphasizes self-sufficiency and low costs with limited attention to herd management practices, 2) a commercial farmer focused on profit maximization through efficient production methods, and 3) an environmental farmer that prioritizes conservation of natural resources and animal welfare over profit maximization. These three farmer profiles share the same management strategies to adapt to climate and resource conditions (Table 1), but differ in their goals and decision-making criteria for when, how, and whether to implement those strategies (Table 2). This model is based on the *SequiaBasalto* model (Dieguez Cameroni et al. 2012, 2014, Bommel et al. 2014 and Morales et al. 2015), replicated in NetLogo by Soler-Navarro et al. (2023).

Table 1. *Summary of management strategies used to adapt to climate and resource conditions.*

Management strategy			Definition
Resource	Spatial resource use	Free grazing	Livestock graze freely throughout the entire pasture
		Rotational grazing	The pasture is divided into four paddocks. Livestock move from one paddock to another according to different criteria
Livestock	Stocking rate	Ordinary sales	In the fall, the regular livestock sale takes place
		Extraordinary sales	When the effects of a drought are severe, the "unwanted sale" of livestock (a sale that would not be made under other circumstances) takes place
	Breeding	Uncontrolled	Breeding takes place at any time of the year
		Controlled	Breeding takes place in summer
	Weaning	Natural	Weaning takes place at the age of 8

|			months
		Early	Weaning occurs between 1 and 7 months of age, depending on the mother's body condition
	Feed supplementation	No	Livestock completely dependent on naturally growing pasture
		Yes	The farmer supplements feed for animals below a minimum weight

Table 2. *Summary of management strategies in use by each farmer profile.*

Management strategy	Subsistence	Commercial	Environmental
Spatial resource use	Free grazing or Rotational grazing (animals are moved to another paddock at the end of the season)	Free grazing or Rotational grazing (based on the live weight of livestock)	Free grazing or Rotational grazing (based on the carrying capacity of the paddock)
Ordinary sales: Sell non-replacement males	Yes	Yes	Yes
Ordinary sales: Sell of old cows and non-replacement females	No	Yes	Yes
Extraordinary sales	No	Yes (when the body condition of livestock deteriorates)	Yes (when the carrying capacity of the rangeland is compromised)
Breeding	Uncontrolled	Controlled	Controlled
Weaning	Natural or Early if the mother dies prematurely	Natural or Early if the mother dies prematurely or if the mother's body condition falls below a certain threshold	Natural or Early if the mother dies prematurely
Feed supplementation	No	Yes	Yes

2. Entities, state variables, and scales

The entities of the model are cows moving and grazing in a rangeland. One healthy herd of

cows is assumed, without predators, with a 2% natural annual mortality and the possibility of exceptional deaths due to forage crisis when animal *Live Weight (LW)* falls below a critical survival value (i.e., *Minimum Weight*). In this study system, an *Animal Unit (AU)* is defined as a cow with a *LW* of 380 kg. Cows follow a lifecycle of seven age groups, i.e., born calf (male or female), weaned calf (male or female), heifer, steer, bull, cow, and cow with calf (Figure 1).
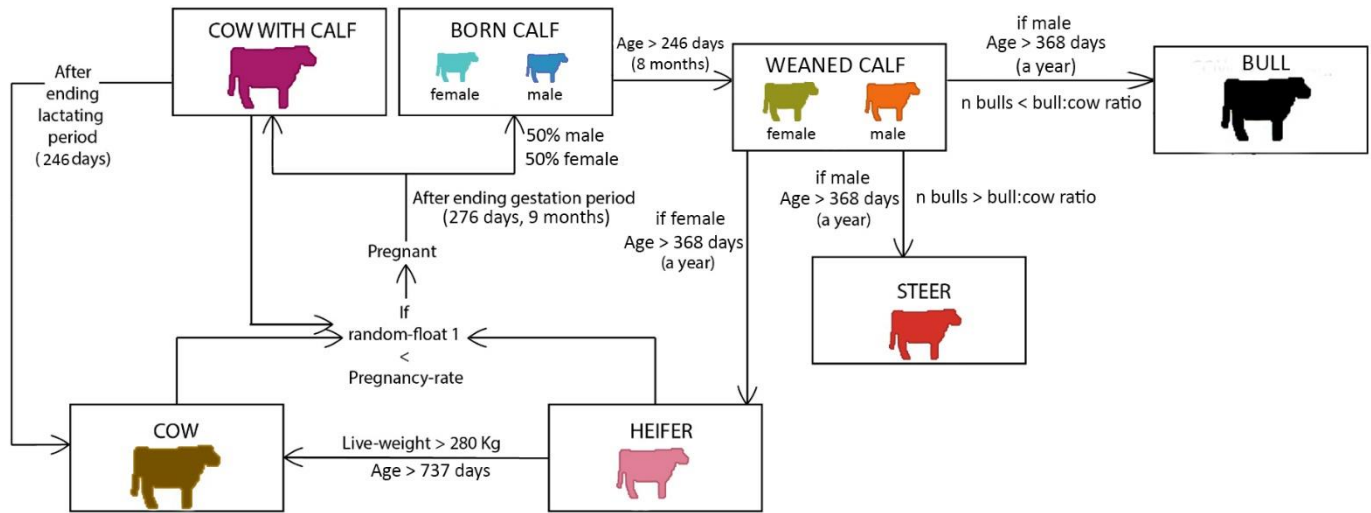
Figure 1. *Diagram of age classes*

The world represents one "wrapped" rangeland composed of interconnected patches of one hectare each. Patches have an amount of resource (grass height) which grows by the logistic growth function. Each patch has a soil quality level that affects the grass growth. In addition, quality and quantity of the grass varies according to the amount of grass eaten by cows, the season and the climatic conditions.

Cows move through the pasture depending on the quality and quantity of the grass and the spatial management strategy (Table 1). Herd management varies depending on the farmer profile (Table 2). Each farmer employs a set of management strategies that adhere to a daily and seasonal schedule, triggered by resource availability and livestock condition.

The time step of the model is one day.

The values of the variables and parameters used in this model are shown in Table 3.

Table 3. *List and description of the main variables and parameters.*

Variable	Description	Value	Unit
Age	Age of each animal	0 - 5520	days
Age-sell-old-cow/bull	Age at which an animal is considered old	10	years
Bull:cow-ratio	Number of breeding males per breeding female (animals in "heifer" and "cow" age classes)	30	cows

Cattle-prices	Market prices for cattle per season (winter/spring/summer/fall) in a normal year	Born-calves = 0.940/1/0.970/0.961 Weaned-calves = 0.980/1.020/1/0.982 Steers/bulls = 0.856/0.917/0.881/0.873 Heifers = 0.701/0.733/0.727/0.696 Cows/pregnant-cows = 0.561/0.611/0.573/0.581 Pregnant-cows = 0.561/0.611/0.573/0.581 Cow-with-calf = 0.610/0.664/0.665/0.617	USD/kg
Climacoef	Coefficient that affects the grass growth	0.05 – 1.5	Dmnl
Commercial-farmer-ES-min-weight	Average minimum weight of the herd at which the **commercial farmer** starts the extraordinary sale of animals	225	kg
Cow-age-max	Life expectancy of cattle (when the animal reaches 5520 days, it dies)	5520	days
Cow-age-min	This variable, together with a minimum weight of 280 kg, determines the beginning of the "cow" stage for heifers (when the animal reaches 737 days of age AND 280 kg, it enters the "cow" age class)	737	days
Current-season	Season of the year. The initial season is defined at the start of simulation	0 = winter 1 = spring 2 = summer 3 = fall	Dmnl
Daily-DM-consumed-by-cattle (DailyDDMC)	Amount of dry matter an animal can consume in a day (assumption used by the **environmental farmer** to estimate the carrying capacity)	8.5	kg/head
DM-cm-ha	Quantity of dry matter contained in one centimeter per hectare	180	kg/cm/ha
Early-weaning-threshold	Minimum weight at which a cow is separated from her calf (early weaning)	230	kg
Effort-time	Time required by the farmer to implement the different management strategies of the livestock system	Breeding-effort = 15 minutes Rotational-effort = 30 minutes Sales-effort = 5 minutes/animal Supplement-effort = 2 minutes/animal Weaning-effort = 5 minutes/animal	Minutes and minutes/animal
Feed-sup-conversion-ratio	Ratio of kilograms of dry matter to kilograms of live weight (kilograms of feed the animal must consume to gain one kilogram of live weight)	7	-

Grass-energy (GE)	Grass metabolizable energy content in one kilogram of dry matter	1.8	Mcal/kg
Grass-height (GH)	Primary production (biomass), expressed in centimeters	1 – 22.2	cm
Heifer/steer-age-min	Beginning of the "heifer" (for female calves) or "steer" (for male calves) stage of the livestock life cycle (when the "weaned-calf" reaches 369 days of age, it enters the "heifer" or "steer" age class)	369	days
Keep-MAX-n-breeding-cows	Maximum number of breeding cows (animals in the "Cow" and "Cow-with-calf" age classes) desired by the farmer. "Cows" and "Cow-with-calf" animals above this number are considered non-replacement cows and then sold during ordinary or extraordinary sales	100	animals
Keep-MIN-n-breeding-cows	Minimum number of breeding cows (animals in the "Cow" and "Cow-with-calf" age classes) desired by the farmer. "Cows" and "Cow-with-calf" animals below this number are not sold during ordinary or extraordinary sales	2	animals
Kmax (K)	Maximum grass height achieved according to the season of the year	Winter = 7.4 Spring = 22.2 Summer = 15.6 Fall = 11.1	cm
Lactating-time	Duration of the lactating period of cows with calves	246	days
Live-weight (LW)	State of the animals in terms of live weight. The initial live-weight is defined at the start of simulation	40 – 1000	kg
Live-weight-gain-max	Maximum kilograms of live weight a cow can gain in a day	0.6	kg/day
MaxLWbull	Maximum live weight for bulls and steers	1000	kg

MaxLWcow	Maximum live weight for cows	650	kg
MaxLWG (μ)	Maximum live weight that cattle can gain according to the season of the year	Winter = 40 Spring = 60 Summer = 40 Fall = 40	kg
Min-weight-for-feed-sup	Minimum weight at which the farmer begins feeding supplements to animals	Bull/cow/cow-with-calf = 240 Heifer/steer = 220 Weaned-calf = 150	kg
Ni (v)	Parameter that affects the live weight gain of cattle	0.24	cm^{-1}
Perception	Affects the movement of animals: probability to move to the nearest patch with the highest grass height or to a random neighboring patch	0.5	-
Pregnancy-time	Duration of the gestation period of pregnant cows	276	days
r	Maximum growth rate of grass	0.02	$days^{-1}$
RG-commercial-farmer-live-weight-threshold	Average minimum weight of the herd at which the **commercial farmer** moves animals from one paddock to another (only when rotational grazing is in effect)	245	kg
Seasoncoef	Seasonal coefficient that affects the live weight gain in relation with the grass quantity (determined by the season of the year)	Winter = 1 Spring = 1.15 Summer = 1.05 Fall = 1	-
Season-length	Length of the season	92	days
Soil-quality (SQ)	Coefficient that affects the maximum grass height that can be achieved in a patch.	0 - 1	-
Supplement-prices	Market prices for food supplements per season (winter/spring/summer/fall) in a normal year	0.113/0.121/0.123/0.115	USD/kg
Weaned-calf-age-min	Beginning of the "weaned-calf" stage of the livestock life cycle (when an animal within the "born-calf" age class reaches 246 days of age, it enters the "weaned-calf" age class)	246	days

Weight-gain-lactation	Live weight gain of lactating animals ("born-calf" age class)	0.61	kg
Xi (ξ)	Parameter that affects the live weight gain of cattle	132	kg
%-DM-available-for-cattle (%DM)	Percentage of dry matter available for livestock, as determined by the **environmental farmer**, in relation to the estimated carrying capacity	30	%

3. Process overview and scheduling

Each step begins with the growth of grass as a function of climate and season. This is followed by updating the live weight of animals according to the grass height of their patch, and grass consumption, which is determined based on the updated live weight. Animals can be supplemented by the farmer in case of severe drought. After consumption, cows grow and reproduce, and a new grass height is calculated. This updated grass height value becomes the starting grass height for the next day. Cows then move to the next area with the highest grass height. After that, cattle prices are updated and cattle sales are held on the first day of fall. In the event of a severe drought, special sales are held. Finally, at the end of the day, the farm balance and the farmer's effort are calculated.

3.1. Grass grows

The grass grows following a logistic regression, thus *Grass Height (GH)* is:

(Eq. 1) $GH = GH_{to} + GH_{to} \times r \times \left(1 - \frac{GH_{to}}{K \; x \; SQ \; x \; Climacoef}\right)$ - *GH-consumed*

Where *K* is the maximum grass height (*GH*), *SQ* is a coefficient that determines the soil quality of the patch, *Climacoef* is the climate coefficient, GH_{to} is the initial *GH*, *r* is the growth rate of grass and *GH-consumed* is the amount of grass height, in centimeters, consumed by cattle.

The value of *K* varies with the change of season (Table 3). *SQ* can take values from 0 (bare soil) to 1 (grass grows to its maximum carrying capacity), *Climacoef* takes values from 0.05 to 1.5, representing a "low resource production" (below the average < 1), a "normal production" (equal the average = 1), and a "high production" (above the average > 1).

3.2. Livestock eat and gain weight

When cows eat grass, they gain weight. This *Live Weight Gain (LWG)* depends on the season of the year and the *GH*, following the equation:

(Eq. 2) $LWG = \frac{\mu - \left(\xi \times e^{-v \times GH}\right)}{92 \; \times Seasoncoef}$

Where *μ* is the maximum *LWG* (Table 3), *ξ* and *v* are constants (Table 3), *GH* is grass height, *Seasoncoef* is the seasonal coefficient (Table 3), and *92* is the length of the corresponding season in days.

Cows only eat when the *GH* of the patch is equal or more than two centimeters. Cows in a patch with less than two centimeters of *GH*, loss 0.5% of their *LW*. Born calves, not dependent on grass, increase their initial *LW* of 40 kg by 0.61 Kg per day.

The grass consumption (*DDMC, daily dry matter consumption*) is calculated following the equation:

(Eq. 3) $$DDMC = \frac{[0.107 \times MBS \times (-0.0132 \times GH + 1.5132) + (0.141 \times MBS \times LWG)]}{GE} \times Categcoef$$

Where *MBS* is the metabolic body size (LW ^{¾}), *GE* is the grass metabolizable energy content (1.8 Mcal/Kg DM), and *Categcoef* is a coefficient that varies with the age class of cows (Table 4).

3.3. Feed supplementation

Commercial and environmental farmers can supplement the animals with fodder when they are below a minimum weight (*Min-weight-for-feed-sup* variable, Table 3) and the economic balance of the system is positive.

The number of animals below this threshold are counted, and the difference between the current live weight of these animals and the threshold is calculated. This difference is multiplied by the *Feed-sup-conversion-ratio* variable (Table 3) to obtain the kilograms and price of the forage the farmer has to purchase to maintain the weight of animals above the threshold.

If the balance (savings) of the system is greater than the total cost of the supplements, the farmer can meet the feed needs of all the animals below the threshold.
If the total cost of supplements exceeds the balance, the farmer spends all of his savings to purchase as many supplements as possible, which are then distributed equally among all of the animals below the threshold.

3.4. Cows grow, reproduce, and die

Depending on the age, sex and weight, cattle pass through each of the different age groups (Figure 1). Calves have a 50 % chance of being born as either a male or a female. The regular lactation period lasts 246 days, after which natural weaning takes place. However, early weaning may occur when the mother dies prematurely or, in the case of the commercial farmer, when the live weight of the mother is below a minimum weight (*Early-weaning-threshold* variable, Table 3). In this situation, weaning takes place to relieve some of the nutritional pressure on the mother (to improve her body condition and to ensure a high level of reproductive performance). After 368 days of age, the weaned calf can become a heifer (if female), a steer, or a bull (if male). The male weaned calf becomes a bull if the number of bulls in the system is lower than the desired number of breeding males (determined by the *Bull:cow-ratio* variable, Table 3). Otherwise, it becomes a steer. Heifers became adult cows when they

have reached the age of 737 days and the weight of 280 kg. Heifers, adult cows and cows with calves, when pregnant, have a gestation period of 275 days.

The pregnancy rate follows a logistic equation and depends on *LW*:

(Eq. 4) $Pregnancy\ rate = \dfrac{1}{1 + CoefA \times e^{-CoefB \times LW}}$

Where *CoefA* and CoefB are coefficients that varies with age class and affects the pregnancy rate of animals (Table 4).

For subsistence farmers, breeding can take place at any time of the year (*Uncontrolled breeding*, Table 1), whereas for commercial and environmental farmers, reproduction takes place in summer (*Controlled breeding*, Table 1) to ensure that calves are born in the season with the highest resource availability (i.e., spring).

When cows are 5520 days old, they die. The daily mortality rate of cows (5.4×10^{-5}) increases (*Exceptional mortality rate*, Table 4) when *LW* is under a critical weight (*Minimum Weight*, Table 4).

Table 4. *Attributes of cows by age class.*

Age class	Animal units (AU)	Initial weight (kg)	Minimum weight (kg)	Exceptional mortality rate (%)	Category coefficient (categCoef)	CoefA	CoefB
Cow	LW/380	-	220	15 (30 when pregnant)	1	20000	0.0285
Cow with calf	LW/380	-	220	30	1.1	12000	0.0265
Born calf	LW/380	40	-	0	1	-	-
Weaned calf	LW/380	-	100	23	1	-	-
Heifer	LW/380	-	140	23 (30 when pregnant)	1	4000	0.029
Steer	LW/380	-	140	23	1	-	-
Bull	LW/380	-	220	15	1	-	-

3.5. Post-consumption grass height, and movement of cows

With the parameter *DM-cm-ha*, which defines the kg of dry matter in each centimeter per hectare (180 kg/cm/ha, Table 3), the *DDMC* (*GH* consumed) in each patch can be calculated.

At each daily time step, the height of pasture offered to the animals (pre-consumption height) will be the result of the initial daily height plus the daily growth. The post-consumption height

(difference between pre-consumption height and consumption in cm of pasture) of one day will be the initial height of the following day. Therefore, we update the *GH* subtracting the *GH* consumed from the current *GH*.

After the grass height update, when grass height in a patch is minor than five centimeters, i.e., the minimum height of grass that will allow the animal to maintain its live weight, cows move to another patch. Using the *perception* variable (Table 3), cows have a 50% chance of moving to the nearest patch with the highest grass height or to a random neighboring patch (independently of the grass height).

When rotational grazing is in effect, the grassland is divided into four paddocks of equal size. For the subsistence farmer, animals move from one paddock to another at the end of the season. The commercial farmer moves animals when the average live weight of the herd falls below a certain threshold (*RG-commercial-farmer-live-weight-threshold* variable, Table 3). The environmental farmer moves animals depending of the estimated carrying capacity (*ECC*, in Animal Units) of the paddock. When the animals arrive in a new paddock, the environmental farmer measures the *GH*, *DM-cm-ha* and *Climacoef* at the beginning of a new season and in the first day the cows arrive at the new paddock and uses these fixed values to calculate the carrying capacity according to the equation:

(Eq. 5) $ECC = \dfrac{\left(\dfrac{eGH \; x \; eDM{-}cm{-}ha \; x \; eClimacoef \; x \; \%DM}{Season{-}length}\right)}{DailyDMMC}$

Where e*GH* is the average GH of the paddock without cows, e*DM-cm-ha* is the average kg of dry matter in each centimeter per hectare, *eClimacoef* is the climate coefficient, *%DM* is the percentage of dry matter that will be available for livestock, in relation to the estimated carrying capacity, *Season-length* is the duration of the current season and *DailyDDMC* is the amount of dry matter an animal can consume in a day (8.5 kg/head, Table 3). It is important to emphasize that with "estimated" we mean that the environmental farmer does not update the values of *GH*, *DM-cm-ha* and *Climacoef* on a daily basis, but only when the cows arrive in a new paddock and at the beginning of a new season.

3.6. Market prices, cattle sales and farm economic balance

Cattle prices are updated seasonally (Table 3). On the first day of fall, the ordinary livestock sale takes place, but the decision of which animals to sell varies slightly from farmer to farmer. All farmers sell all of their steers and non-replacement male weaned calves as well as surplus bulls (when the number of bulls is greater than the *bull:cow-ratio* variable, Table 3). However, the commercial and environmental farmers also sell old bulls and cows as well as non-replacement females. This number is determined by the *Keep-MAX-n-breeding-cows* variable (Table 3). Consequently, the sale of non-replacement females occurs when the number of breeding cows exceeds the specified threshold. Under these circumstances, a certain number of females (female weaned calves, heifers and cows) are sold until the threshold is reached. This activity reduces the number of animals in the system, which helps the farmer to maintain a steady number of animals, and increases the farm balance because of the money earned from the sale.

When the effects of a drought are severe, both commercial and environmental farmers make extraordinary sales, which is the "unwanted sale" of some animals (a sale that would not be made under other circumstances). For the commercial farmer, this occurs when the average

live weight of the herd is below a threshold (*Commercial-farmer-ES-min-weight* variable, Table 3), while for the environmental farmer this happens when the animal units of the farm exceed the *ECC* of the system. In the case of free range grazing, this *ECC* is updated each season, while in the case of rotational grazing, it is also updated each time the animals change paddocks. For both farmers, the extraordinary sale of animals is done following the next order: 1) male weaned calves and steers, 2) old cows, 3) female weaned calves, heifers and cows. In other words, if all male animals have been sold and the crisis persists (the average live weight of the herd is below the threshold, in the case of the commercial farmer, or the number of animals is still above the estimated carrying capacity, in the case of the environmental farmer), the farmer will start selling old cows until the crisis subsides or until the system reaches a minimum number of animals (determined by the *Keep-MIN-n-breeding-cows* variable, Table 3). If not, the farmer will sell females until one of these two criteria is met. This sale is justified for two reasons: to reduce the total number of animals to face the drought and to increase the producer 's income to buy supplements for animals.

After that, all income from ordinary and extraordinary sales and costs from the purchase of supplements are taken into account to calculate the farm balance.

3.7. Effort

Finally, at the end of each day, the daily effort is calculated. Each of the management strategies (Table 1) have associated an "effort cost" (*Effort-time* variable, Table 3), which is the time spent by the farmer implementing them.

This effort is calculated in hours, following a daily, seasonal, and annual basis.

4. Soil quality and climacoef scenarios

Each patch has a soil quality (*SQ*, Table 3) value ranging from 0 to 1 that affects the maximum grass height that can be achieved in the patch. The model provides the possibility to select different statistical distributions for soil quality, which shapes the landscape configuration: in addition to the default homogeneous distribution (all patches have the same soil quality), alternatives include a uniform distribution (equal number of patches of different quality), normal (patch quality follows a Gaussian distribution), and exponential with "low" (where the majority of patches have quality close to 0) and "high" (where the majority of patches have quality close to 1) configurations for the landscape (Figure 2).
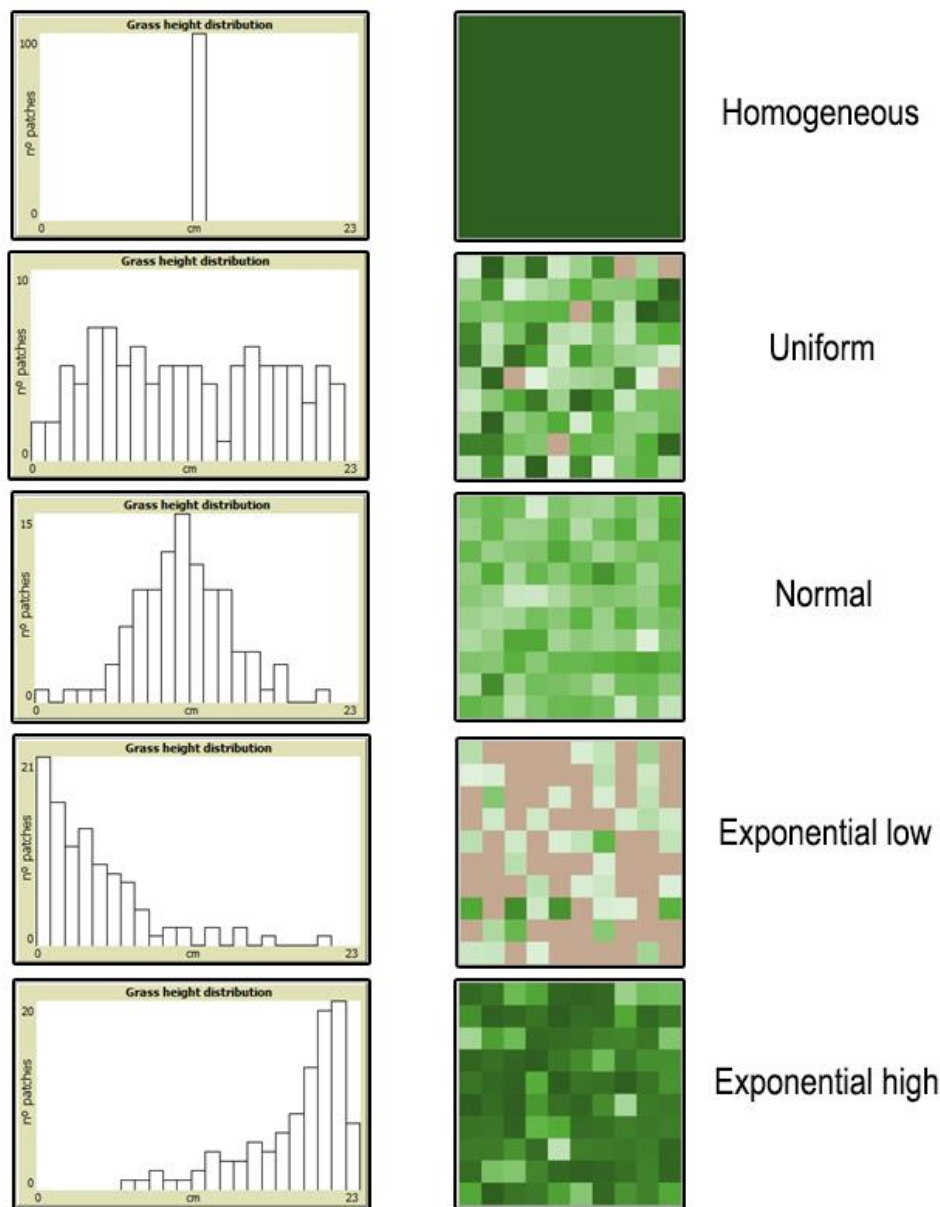
Figure 2*. Landscape configurations.*

The same can be done with the climate coefficient (*Climacoef*, Table 3) with values ranging from 0 to 1.5, which affects the climate uncertainty for each season: homogeneous distribution (no uncertainty, seasons have the same climate coefficient), uniform (equal probability of values from 0 to 1.5 in each season), normal (majority of seasons with a climate coefficient close to 1), exponential "low" ((predominance of seasons with a climate coefficient close to 0), exponential "high" (predominance of seasons with a climate coefficient close to 1.5).

5. Design concepts

Emergence: the main outputs of the model are the live weight of the animals, the resource

level and carrying capacity of the system, as well as the economic balance and effort of the farmer over time. These outcomes result from the interactions between the livestock sub-model (animals that feed on the resource), the biophysical sub-model (grass growth as a function of climate and seasons), and the economic sub-model (market prices and farmer decision making).

Adaptation: both the commercial and the environmental farmer react to the body condition of the animals by the purchase of feed supplements. In addition, the commercial farmer reacts to drought by selling animals when the body condition of the herd is below a threshold, while the environmental farmer reacts when the number of animals in the system is above the carrying capacity.

Objectives: the fitness measure of animals is their live weight. If the live weight is below a critical threshold (Table 2), the mortality rate of these agent increases exceptionally. If this mortality rate is greater than 1, the agent dies. The reproductive capacity of agents (the pregnancy rate) is directly related to the live weight of the agent. Both cattle and farmers have a fixed set of rules that determine what they do given the context of their environment. Animals move to the patch with fewer cows and with the highest grass height.

Learning: agents do not learn.

Prediction: the environmental farmer estimates the carrying capacity of the grassland at the beginning of the season and/or when the animals arrive at a new paddock (if rotational grazing is in effect). This value is then assumed to be constant for the rest of the season (it is assumed that climatic conditions do not change during the season and thus affect the carrying capacity).

Sensing: cows sense the number of animals and the resource level of every patch in the system, including the patch they are on. Farmers sense the number of animals in every age class, as well as the live weight of each animal, the age of animals (in case of commercial and environmental farmers) and carrying capacity of the rangeland (only for the environmental agent).

Interaction: the level of resource in the system depends on the seasons and the climate scenario. Animals interact directly with patches by feeding on the resource, and indirectly with each other by consuming the resource from the landscape.

Stochasticity: stochasticity affects animal movement (determined by the *perception* variable) and mortality (the daily mortality rate of cows is 5.4×10^{-5}). Slightly stochastic processes also affect exceptional mortality and pregnancy rates, although these parameters are mostly determined by the live weight of the animals. Stochasticity also affects soil quality and climate coefficient when uniform, normal, exponential "low", or exponential "high" are selected, affecting landscape configuration and primary production, respectively.

Collectives: animals are divided into seven groups of age (Figure 1): born calf, weaned calf, heifer or steer, bull, cow, and cow with calf. Each of these groups has different thresholds for the same parameters, such as mortality rate, minimum live weight, pregnancy rate, and amount of grass consumed at each stage (Table 4).

Observation: we observe the emergent population (population dynamics by age class and stocking rate) and resource levels (average grass height, total dry matter and dry matter

consumption and carrying capacity), individual live weight gain and animal live weight, as well as the daily, seasonal and annual effort of the farmer and the balance of the system. Other results include daily, seasonal and annual income and costs, as well as the amount of supplements purchased each day.

6. Initialization

Simulations are initialized in *winter*, in a *business-as-usual* climate scenario (Climate coefficient = 1; climate uncertainty = homogeneous; season length = 92), with 15 adult cows and 1 bull (*Bull:cow-ratio* 30) grazing freely on a landscape of 100 ha. *Perception* is set at 0.5. Cows and bulls initialize with a random age within their age range (737 - 5520 days) and an *initial live weight* of 260 kg for cows and bulls. Patches start with an *initial grass height* of 7.4 cm and a homogeneous grass quality distribution. *Dm-cm-ha* is set at 180 kg/cm/ha.
The maximum number of breeding cows (*Keep-MAX-n-breeding-cows)* is set to 100 and the minimum (*Keep-MIN-n-breeding-cows*) to 2. The age at which animals are considered old is set to 10 years (*Age-sell-old-cow/bull*). The early weaning threshold (*Early-weaning-threshold)* is set at 230 kg, and the minimum weight for supplementation (*Min-weight-for-feed-sup*) is set at 240 kg for all animals except heifers/steers, which is 220 kg, and weaned calves, which is 150 kg. The feed conversion ratio (*Feed-sup-conversion-ratio*) is set at 7. The average live weight of the herd during the rotational grazing for the commercial farmer (*RG-commercial-farmer-live-weight-threshold*) is 245 kg and the threshold for the extraordinary sale (*Commercial-farmer-ES-min-weight*) is 225 kg. For the environmental farmer, the percentage of dry matter available for cattle is set to 30 (*%-DM-available-for-cattle*) and the assumption of how many kilograms of dry matter a cow consumes is set to 8.5 kg (*Daily-DM-consumed-by-cattle*). The simulation run for 40 years (each simulation can run from 1 to 100 years).

7. References

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