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Spring Forage Stash Module to Prevent Forage Crisis on Uruguayan Livestock Systems: An Evaluation Based on Model Simulations

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Spring forage stash module to prevent forage crisis on Uruguayan livestock systems: An evaluation based on model simulations.

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Key words: dynamical modelling; drought; grazing management; meat production; production systems

Abstract
In Uruguay, rangeland cattle production systems support national economy by beef exportation chain and economic inputs to the country. Soil hydric stress episodes results to forage crisis on grassland-based production systems, having high impact on its trajectory and leaving sequels at several farm levels mainly on rearing cattle systems in drought sensitive regions of the country. In that context, the proposal is to create a spring forage stash module, with a simple management rules as a mechanism to build stability to farms and to buffering drought impact. The concept is to differ spring forage (season with low variation coefficient on net primary production) to summer (season with high variation and susceptible to drought stress episodes). This forage stash module is actually started to be implemented in some monitored farms nevertheless, the use of simulation models can project some concrete result generating future possible evolutions for the system. A predator-prey model for extensive livestock systems -called PPGL- was set to understand the impact of that spring forage stash module on animal securing parameter, expressed as the proportion of adult rearing cows maintaining liveweight at summer grazing on a drought scenario. Results suggest that the stashing 10% of the farm surface can save approximatively 70% of rearing cows, even for drought episodes on closing time or in the summer grazing period. Additionally, a linear direct effect was observed between stashing surface on proportion of rearing cows secured. The resulting carrying capacity of the stash forage module is about 800 to 850 kg liveweight / ha on the grazing period, supporting high grazing pressure. Considering those results, the inclusion of a spring forage stash module is a promising tool to generate more resilient livestock production systems.

Introduction
Uruguayan meat production chain represents a basic pillar for the national economy and are strongly related to culture and rural identity (Diaz et al. 2006; MGAP 2015). Nowadays extensive livestock production systems based on native pastures are studied to enhance knowledge about its dynamics, drivers, and challenges. Furthermore, there are national efforts to differentiate meat produced on grasslands. It can lead to added value to its final products, where research, industry and government efforts to identify meat produced at grassland livestock system as *natural* product (MGAP 2012; INAC 2019).

Extensive rearing systems are located on vulnerable zones to hydric deficiencies (Cruz et al. 2014, Bartaburu et al. 2009). Drought episodes are frequent and their effect on grassland native pastures affects its productivity (e.g. Net aerial primary productivity, NAPP). Variability of NAPP, as a proxy of pasture productivity, is high. Nevertheless, data base study of NAPP estimated by remote sensing (Paruelo et al. 2000; LART 2019) shows lower variation coefficient on southern spring and higher values on summer. The variation coefficient of October is 6% and 24% for January. This fact represents an opportunity to stock standing grass on relative high pasture growth rates season (with relative high confidence) to transfer it to summer season (with relative high variability). From a technical point of view, the summer is a crucial season for rearing systems, where animal's requirements are high by increasing reproductive needs (matting season) and energy demands of rearing calves (Martinez & Pereira 2011).

In that context, there are local models of grazing systems focused on management of grazing pressure of native pastures by regulating forage allowance, and stocking rate (Soca et al., 2013). In this sense, a model is a powerful tool to comprehend the way systems work and modify reality in consequence. Generally, the use of models (specifically simulation models) generates an auspicious space for communication, learning and comprehension of structure and functioning of production systems, as well as understanding and integrating knowledge generated from research studies and local practical knowledge, showing possible deficiencies of information and guiding to future working lines (Thornley & France 2007; Vayssières et al. 2011). Models can help making decisions in relation to natural resources, especially in pastures systems in which climate conditions must be considered, understood and analysed to improve its sustainability attributes as productivity, efficiency, resilience and stability of production systems (Wedderburn et al. 2013).

We present in that work simulations scenarios using PPGL model (Dieguez & Fort 2017) as a tool to answer some questions (Minsky 1995). In our case the question is: what if a farmer reserves a proportion of the grazing area – a *Stash* module- on spring to buffer pasture deficiency on summer drought? The main objective of using PPGL model is to help stakeholders to evaluate a simple mechanism to improve stability and resilience to summer drought episodes on Uruguayan rearing systems.

Methods

The PPGL model was utilised to generate simulations of forage deficiency due by climate effect (droughts) on rearing farms systems placed on the Basaltic region of Uruguay.

As a general description, PPGL model is represented by a differential equation system, where two variables involved: the grass height (cm/ha) and the individual animal live weight (kg/animal; Dieguez & Fort 2017). The stocking rate calculated by the number of animals/ha and initial liveweight is a third user defined input parameter. The pasture growth is modelled using a logistic curve and grass intake is described as a hyperbolic Holling III type function, making the whole system as an ecological "predator-prey" dynamical system (Pastor 2011).

Another main input of PPGL model is the NAPP, provided by de Laboratorio Regional de Teledetección from Buenos Aires University, Argentine (LART 2019). That information is an historical series, from march 2000 to date, for the main ecological regions of Uruguay. The Basaltic region has de particularity of rearing systems are placed on it. Figure 1 indicates the placement of bovine cattle production systems and the Basaltic region of the country. The PPGL model scenarios were built considering the system structure presented on Table 1.

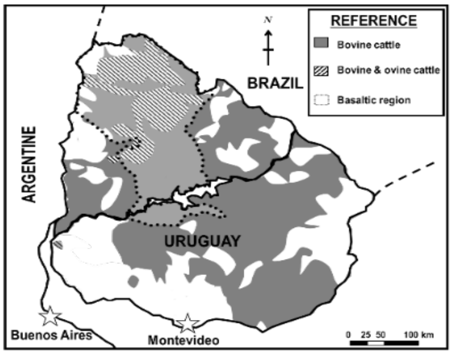


Figure 1. Uruguayan bovine systems and basaltic region placement

Table 1. Animals category and number of animals considered on simulations.

Categories	Number of animals
Breeding cows	330
Heifers +2 years	109
Heifers 1 to 2 years	109
Calves	231
Fattening cows	66
Bulls	5
Sheep	1000

Considering on simulations a total grazing surface of 1000 ha, the resulting total system stocking rate (considering national conversion values; Martinez & Pereira 2011) is 0.7 Gross Units per hectare (GU/ha). That stocking rate is equivalent to 266 kg of live weight/ha.

Simulations where run considering an average grass growth rate for whole year (according to LART data series; LART 2019), except for summer season (December, January and February) where a drought episode is forced. PPGL model uses a *climate coefficient* input that allows to modulate the carrying capacity (*K* parameter) of the logistic grass growth (Dieguez & Fort 2017). To generate the drought episode a *climate coefficient* of 0.25 (25% of average grass monthly growth rate) was used. The stash module is closed to animals on October and November, and initial grass height (IGH) for simulations considered is 5 cm/ha (equivalent to 1500 kg DM/ha).

The simulations consider a *Stash module*, that is an area of the total grazing surface excluded from foraging during a determined period of time. In this case the *Stash module* is closing for grazing on spring, during 60 days (October and November).

As definition we refer as a *Secured cow* considering a rearing adult female that maintains it live weight through the summer drought period (e.g., a cow of 380 kg of weight entering to *Stash module* and leaving it with the same live weight). The *secured cow percentage* (%SC) represents the ratio of number of *Secured cows* of total rearing cow herd.

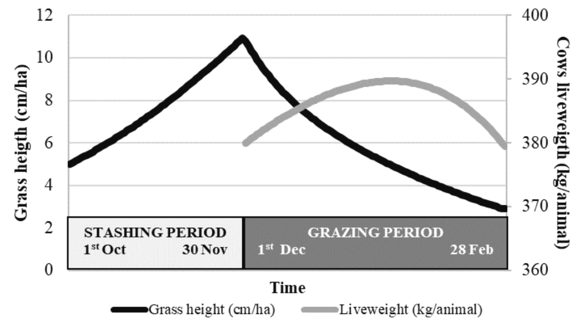
A first approach was excluding 10% of the grazing area to reserve pasture on October and November. The value of 10% emerges form a trade-off to closing area (reducing the forage availability for 60 days period for whole system) and an "insurance" against drought episodes. That *a priori* approach for exclude 10% of the grazing area is negotiable with stakeholders, as they expressed in an informal way, based on a series of previous workshops held with local farmers. Nevertheless, a sensitivity analysis for proportion of surface stashed (%SS) was performed, varying from 0 to 20% to test system performance.

An IGH of 5 cm/ha is considered assuming a controlled animals stocking rate, and average climate conditions on the previous seasons of the closing moment (October 1st). The IGH at the paddock closing moment is crucial to have sufficient cumulated forage at the Stash module to prevent negative impact of drought episodes after closing period (summer drought). For this reason, a second round of simulation we consider the sensibility to IGH of the Stash module varying from 2 to 5 cm/ha.

Results

Simulation outputs for IGH = 5 cm/ha and %SS = 10% scenarios are presented at Figure 2.

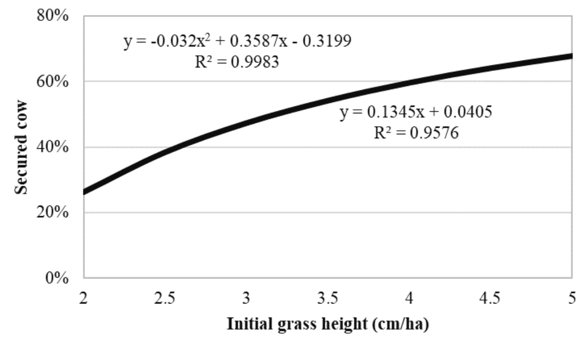
Figure 2. Grass height and rearing cows liveweigth evolution on Stash module.
[scenario: IGH = 5 cm/ha; %SS = 10%]



Results indicates that with a stocking rate of 2.24 GU/ha (equivalent to 850 kg live weight/ha) about two thirds of rearing cow herd can be "*secured*" (%SC = 68%), with summer *climate coefficient* of 0.25. Furthermore, that number of animals represents 38% of whole herd (Table 1).

Is worthy to note that final *Stash module* grass height is 2.9 cm/ha (Figure 2). This grass offer situation is critical after 90 days grazing on the *Stash module*, considering also that period corresponds with a summer forage deficit situation on simulations.

Figure 3. Sensitivity of Secured cow coefficient to Initial grass height (IGH; cm/ha)
[scenario: climate coefficient = 0.25; %SS = 10%]



Considering sensibility to %SS, a range from 5% to 20% (step 5%) was tested. Result suggest a direct lineal behaviour, described by the function: %SC = 6.78 * %SS (R^2 = 1), maintaining a stocking rate of 2.24 GU/ha in the same forage deficiency scenario (*climate coefficient* = 0.25).

Sensitivity analysis to IGH results is presented at Figure 3. The %SC presented a quadratic behaviour when IGH increases. But also, in the range of IGH tested (2 to 5 cm/ha) also a significative ($p<0.01$) direct linear response is also observed for %SC response.

Discussion

Result of simulations suggest that with a Stash module comprising 10% of total grazing surface (excluded for grazing on October and November) it can differ enough forage to meet DM intake of approximately 70% of rearing herd (representing also 40% of total herd requirements). That scenario can be achieved only with a 5 cm/ha (1500 kg DM/ha) at the start of excluding grazing period (October

1st). Considering the size of the *Stash module*, an increment of 6% on %SC is expected for each 1% increase of paddock area. Moreover, linear behaviour suggests that with a %SS = 15% total rearing cow herd can be secured against summer drought.

Sensitivity of IGH scenarios suggest that it exist a reduction on %SC when IGH decreases. Considering the linear response observed, a reduction of 13% of %SC is expected for each cm of IGH reduction (for situations between 5 to 2 cm/ha). In practice, to achieve the IGH needed to start the animal exclusion period, a previous adjusted stocking rate management is required to avoid overgrazing and to achieve the IGH = 5 cm/ha goal on potential *Stash module* paddock. It is worthy to mention that the hight stocking rate supported by the *Stash module* to "*secure*" about 70% of the rearing herd animals is maintained during 90 days maximum grazing period in summer (December, January and February). Due to the low residual grass height after summer grazing (< 3 cm/ha) *Stash module* cannot longer support adequate grass offer to sustain cattle liveweight. A recuperation period (at Fall) is needed for *Stash module* paddock after intensive summer grazing on it.

Others system parameter related to the Stash module can be explored to forecast impact of grazing management, like the exclusion length (other than 60 days on spring season) and closing date, and its interactions.

Nowadays, the *Stash module* concept is implemented at farm levels with the survey of the Instituto Plan Agropecuario, the National Livestock Extension Institute. It represents an *on the field* real situation to test model herein presented. Nevertheless, instead the precision of model results, our aim is to develop conceptual models (and a parsimonious implementation like PPGL model) that answer specific questions and to share knowledge with stakeholders. The inclusion of a *Stash module* can be a strategic and structural change with low cost and high impact measure to buffer frequent summer forage deficiency on rearing systems.

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