frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 16 June 2021
doi: 10.3389/fsufs.2021.547301

# Building the GLENCOE Platform -Grasslands LENding eConomic and ecOsystems sErvices

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**Specialty section:**
This article was submitted to Agroecology and Ecosystem Services, a section of the journal Frontiers in Sustainable Food Systems

**Received:** 31 March 2020
**Accepted:** 26 April 2021
**Published:** 16 June 2021

**Citation:**
Devincenzi T, Jaurena M, Durante M, Savian JV, Ciappesoni G, Navajas EA, Ciganda V, Lattanzi FA and Paruelo J (2021) Building the GLENCOE Platform -Grasslands LENding eConomic and ecOsystems sErvices. Front. Sustain. Food Syst. 5:547301. doi: 10.3389/fsufs.2021.547301

To feed the rising population whilst also preserving ecosystem functions, creative solutions are needed for the ecological intensification of natural grassland-based livestock systems. In Uruguay, natural grasslands are the main nutritional resource for livestock production. In these ecosystems, cattle and sheep graze together all the year round, and grasslands are frequently heavily grazed. Considerable research has been generated concerning grassland management, but there is still no knowledge about the impact of decision rules that supports management actions on long-term ecosystem functioning, at the system level. To meet this deficit, a participatory working group of farmers, researchers, and consultants have developed the GLENCOE platform. This platform is a large-scale facility, supported by INIA-Uruguay, designed to answer the following question: How to intensify the grazing management to improve the sustainability of livestock systems based on natural grasslands? To build the platform three steps were followed: (I) definition of the research problem using a problem tree analysis; (ii) conceptualization of the platform and the design of the grazing systems to be evaluated; and, (iii) spatial allocation of the grazing systems according to the variability of soil, slopes, and seasonal dynamic of vegetation indexes. These criteria were considered across farmlets that were equivalent in the initial stage, allowing causal inferences for the systems trajectories on productive and environmental traits. The platform is composed of three independent farmlets of 50 ha each, where multiparous Hereford cows and Merinos wethers co-graze under three grazing management systems. Each farmlet is managed according to different spatio-temporal decisions of the specific management of vegetation communities, grazing methods, and the stockpile of forage that is allowed by the number of the existing paddocks. Farmlet-1; comprises less decisions (2 paddocks), Farmlet-2; intermediate (8 paddocks), and Farmlet-3; high level of decisions (32 paddocks). This innovative platform will be used as a participatory and

interdisciplinary space for research and co-learning of management on processes that can only be observed in long-term evaluations, and at farmlet scale. We expect that this new approach will contribute to the developement and implemention of sustainable grazing management systems in Uruguay.

**Keywords: sustainable intensification, beef-cattle, rangelands, campos grasslands, mixed-grazing, wool**

## INTRODUCTION

A major challenge for the primary production sector is increasing the production and quality of agricultural products and maintaining the supply of ecosystem services in a scenario of high climatic and price variability. In Uruguay, extensive beef cattle and sheep production, based on native and high-diverse grasslands, has contributed to the Uruguayan economy through the centuries. In these systems, animals graze all through the year, and pastures are often heavily grazed, due to a mismatch between forage demand and supply. In a context of climate and land use changes, developing grazing management and system planning strategies to increase livestock production on native grasslands whilst simultaneously maintaining or improving ecosystem services provision is the new challenge.

Uruguayan research institutions have generated important knowledge on grazing management at the plot and paddock scale, but there is a need for long-term studies on native grasslands to answer questions at the farm (system) level (Jaurena et al., 2021). As discussed by Briske et al. (2008), traditional research with rigid protocols does not consider the systemic perspective which is involved in farm systems. In Uruguayan livestock farm systems, the asynchrony between forage on offer and demand frequently leads to heavy grazing pressure and consequently to low animal productivity and negative environmental impacts, such as reducing plant diversity (Fedrigo et al., 2018) and increasing greenhouse gas emissions (i.e., $N_2O$, Chirinda et al., 2019; $CH_4$, Cezimbra et al., 2021). Therefore, the long-term consequences of alternative grazing management design on production and environmental variables needs to be evaluated in the long-term.

In this short paper, we present a conceptual framework and early methodological steps to build a long-term experimental platform (farmlets) to evaluate the impact of alternative grazing management systems on primary and secondary production and on the supply of ecosystem services.

## MATERIALS AND METHODS

To build the platform, three steps were considered: (i) The definition of the research problem, (ii) The conceptualization of the platform and design, and (iii) The spatial allocation of farmlets. A baseline data set will be collected to obtain a reference point for the evaluation of the system trajectories across four dimensions (economic, environmental, human, and emergent proprieties). We will evaluate regulation and support ecosystem services (according to the Millennium Ecosystem Assessment, 2005 classification) using two approaches: one based on measurements of different dimensions of ecological integrity (Blumetto et al., 2019) and the other through the use of synoptic indicators of ES "bundles," based on remote sensing (Paruelo et al., 2016) at the plot level.

A data repository will be also available as part of the participatory process.

### Definition of the Research Problem

In a workshop (13th-18th August 2018), a multidisciplinary group of 20 experts defined the research problem using a "Problem Tree Analysis" (Cazzuli et al., 2020). Low plant and animal production rates and its high variability were the core problem of livestock systems based on native grasslands. Low digestible forage harvested by ruminants and low forage to animal product conversion efficiency were identified as causes (roots) of actual farm systems, and led to two main effects ("branches"): (i) reduced ecosystem services supplying and (ii) reduced stability and resilience of the system, which embodies economic, environmental, and social traits.

Throughout this platform we will investigate the consequence of paddock size and grazing management of native grassland communities on the structure and functioning of the vegetation, animal production, soil quality variables, economic outputs, and ecosystems services.

### Conception of the Platform and Design of the Grazing Systems to Be Evaluated

We used a co-innovation approach (Albicette et al., 2017) with the participation of researchers, extension agents, and farmers in selecting the platform treatments and management protocols as well as in future evaluation and monitoring. During 2019, three half-day workshops were conducted with the working group to discuss proposals and define strategies for the platform design.

The platform will be placed at INIA-Glencoe Experimental Station (Paysandú, Uruguay) and will cover an area of 150 ha of native grasslands on basaltic shallow soils. The platform will comprise three independent farmlets of 50 ha each, where multiparous Hereford cows and fine wool Merinos wethers will be co-grazing under three grazing management systems. Farmlet-1 comprises less spatial and temporal decisions (two paddocks) and is considered the reference system, Farmlet-2 is intermediate (eight paddocks), and Farmlet-3 has more spatial and temporal decisions (32 paddocks).

For all three farmlets, practices such as breeding season and stocking rate adjustment are assumed to be adopted. Each farmlet will be managed at the greatest intensity of spatial-temporal decisions that the number of paddocks allows, e.g., more possibilities to stockpile forage in Farmlet-3. At the starting

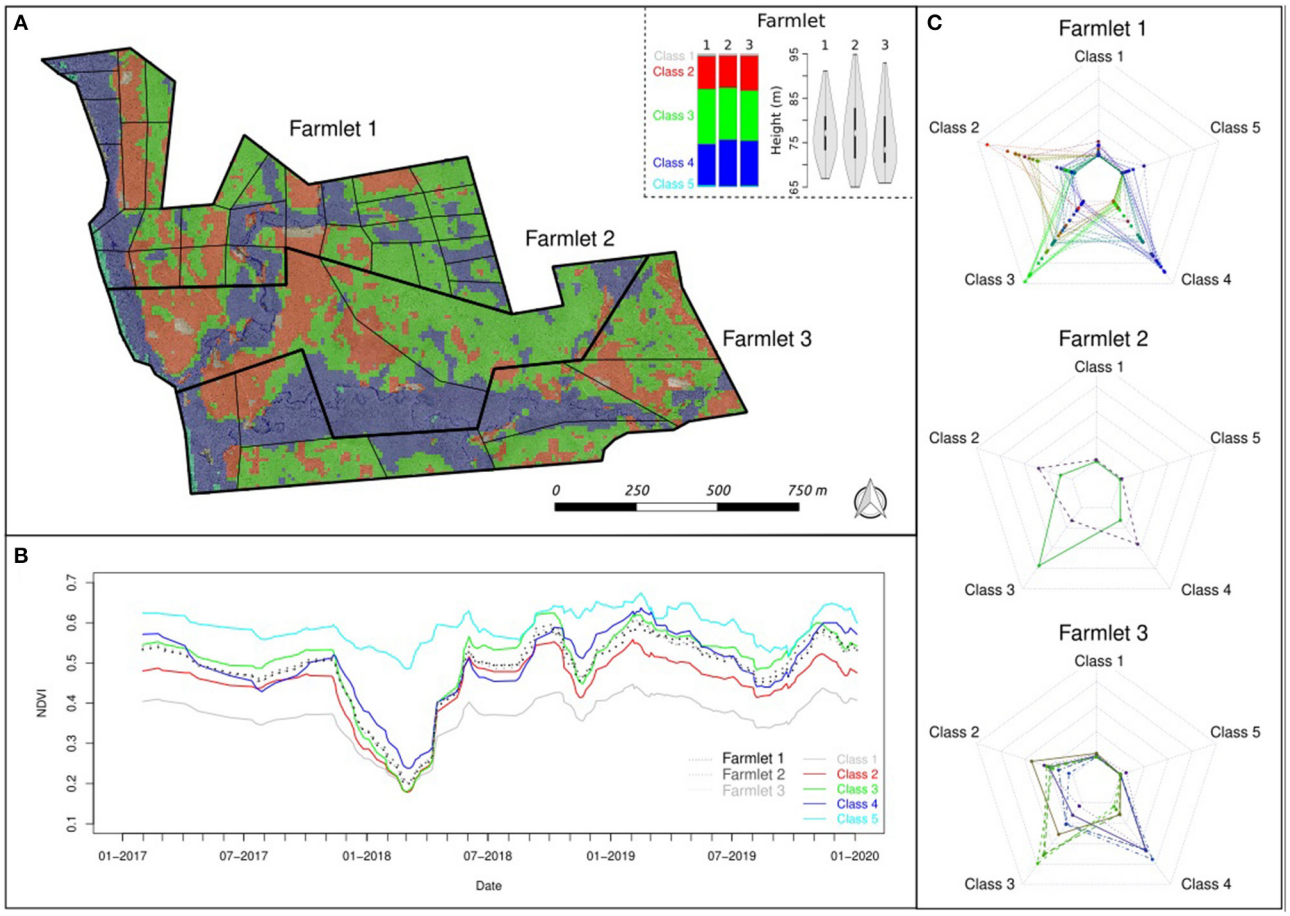


**FIGURE 1 | (A)** Map of vegetation classes (1, low vegetation cover, rocks; 2, shallow soil uplands; 3, deeper soil uplands; 4, depressed areas and lowlands; 5, streams), spatial allocation of farmlets (thick lines) and paddocks inside farmelts (thin lines). Box showing the proportions of vegetation classes and height distribution bay farmlet. **(B)** NDVI time series showing differences between the five vegetation classes (colors) and similarities between the three farmlets (grays). **(C)** Spyder plots showing the proportion of vegetation classes for the different paddocks of each farmlet. Colors of the points and lines representing each paddock are in line with the proportion of the more frequent vegetation classes (2 = red, 3 = green, 4 = blue). The greater the number of plots in the farmlet, the greater the chances of obtaining plots dominated by a vegetation class.

point of the study, all farmlets will have the same animal stocking rate (0.6 AU), defined as the safe stocking rate for basaltic shallow grasslands (Berretta, 1997) and a cow:wether (1:1) ratio. Stocking rates of each farmlet will be adjusted every year using a decision rule that considers the forage availability and body condition of the animals. Short-term decisions of all the farmlets' grazing will be based on pasture height targets, to achieve optimal grazing intensities in some paddocks while others could be stockpiled for future use during forage shortages. A minimum of 10 years of evaluation is planned for this study.

On Farmlet-1, we aim to achieve an acceptable profit from animal production with low investments on fencing and little working-time allocated to monitoring pasture and making decisions (once a month). On Farmlet-2, we intend to improve the profit from animal production though a medium level of investments in fencing and time spent on monitoring pasture and making decisions. Management decisions about animal movements on paddocks and stockpiling of forage will be taken once a month in autumn-winter and every 15 days at spring-summer when pasture growth is highest.

On Farmlet-3, we aim to improve profit from animal production with a higher level of investments in fencing and time spent on monitoring pastures and on making decisions. Monitoring will be made weekly at the autumn-winter season, and twice a week at the spring-summer season.

## Spatial Allocation of Farmlets

The farmlet reflects the spatial variability of typical farms, so we defined a minimum area of 50 ha for each farmlet at the cost of losing the replicating units of the experimental design. This choice led to an important assumption: the farmlets must be under equivalent starting conditions in order to allow the evaluation of the different grazing systems.

To divide the total area into three farmlets with their corresponding paddocks we considered the variability in the seasonal dynamic of vegetation indexes and topography. We

used the Google Earth Engine platform to obtain a total of 161 images from SENTINEL 2 (Level 1C;10 m spatial resolution and <20% of cloud cover) from January 2017 to December 2019, and the 30 m spatial resolution from Digital Elevation Model DEM (SRTM). NDVI time series showed contrasting growing seasons (from October to March): a drought (2018–2019) and a wet year (2018–2019). Second, we used GRASS software v.7.2 (2017) to calculate descriptors of vegetation functioning based on the NDVI, slope, and median NDVI for the dry season and date of maximum NDVI and median NDVI for the wet season. The temporal resolution of the data used was 10 days. Then we performed an unsupervised maximum likelihood classification based on the four descriptors. We obtained five vegetation classes based on NDVI. Third, we used QGIS software to divide the area into the three farmlets with their corresponding paddocks based on the classification, the DEM, and 8 cm resolution drone image from December 2019 (**Figure 1A**). We tried to create farmlets as similar as possible to the proportion of vegetation classes (**Figures 1A,B**) and altitude distribution. After that, grazing management systems were randomly allocated to each farmlet. Finally, farmlets were subdivided into the corresponding number of paddocks considering uniform vegetation classes (**Figure 1C**).

## CONCLUSIONS

This platform is an innovative project in Uruguay and will allow us to identify emerging proprieties of the systems to create resilience and ecosystem services. Moreover, this platform would be useful for monitoring key indicators to assess ecosystem services and, therefore, to advise public and private decision-makers. We expect that this new approach will contribute to developing more profitable and sustainable grazing management systems for Uruguayan livestock production, which will be also useful for livestock production systems in similar ecosystems.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

## ETHICS STATEMENT

The animal study was reviewed and approved by Comité de Uso de Animales de Experimentación del INIA.

## AUTHOR CONTRIBUTIONS

TD, MJ, JS, GC, EN, VC, FL, and JP have contributed on discussions and on platform conception. MD have contributed on acquisition and treatment of satellite images for field desing. All authors contributed to the article and approved the submitted version.

## FUNDING

Ganaderos Familiares y Cambio Climatico (GFCC), Adaptation Found, ANII.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.