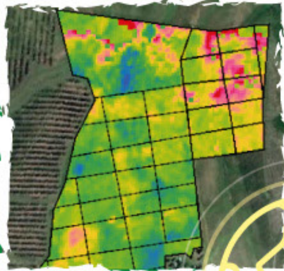

REPORT
2024

Satellite monitoring of quantity and quality of available biomass in pastoral livestock systems
(ATN/RF-19787-RG and ATN/RF-19788-RG)

REGIONAL FUND FOR AGRICULTURAL TECHNOLOGY (FONTAGRO)

MINISTRY FOR PRIMARY INDUSTRIES (MPI) OF NEW ZEALAND

GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES (GRA)

Te Kāwanatanga o Aotearoa
New Zealand Government

GLOBAL RESEARCH ALLIANCE
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Executive Summary

To develop robust models for estimating the quantity and quality of forage biomass from satellite data, a representative field database is essential. While many trials conducted by participating institutions measure these variables, methodologies often vary and are not designed for spatial compatibility with satellite data scales. This project aims to standardize data collection and establish a regional field monitoring network, with the primary objective of reducing the cost of real-time forage biomass estimation using a satellite-based tool.

In its first year, the project developed a harmonized set of field sampling guidelines and digital tools to systematize information. The project also established a sampling protocol based on forage resource type, incorporating new tools and digital methods developed during the project, including: (i) an application to assess vegetation heterogeneity, (ii) an application to record field data, (iii) a website to monitor sampling activities across project sites, and (iv) a method to estimate biomass through oblique photographs taken with a mobile phone.

In the second year, efforts focused on strengthening the field sampling network and collecting and compiling field and satellite data. A consortium of more than 79 researchers and technicians was established, and over 1,000 ground-truth satellite measurement pairs for various forage resources have been compiled to calibrate predictive models. Additionally, an application is being developed to provide satellite-based estimates at the system scale and initiate evaluations in productive systems. The approach, based on a unified protocol and traceable data, will strengthen forage monitoring in the region, foster collaboration with other research groups, and generate scalable models suitable for livestock systems, including those in New Zealand.

I. Introduction

Pasture-based livestock production contributes 46 percent of the agricultural gross domestic product (GDP) and is essential for food and social security in Latin America and the Caribbean (LAC). However, these grazing systems face increasing pressure to improve profitability while simultaneously reducing their contribution to global warming, due to their high production costs and growing concerns about their environmental impact. Knowing accurate information on the quantity and quality of available biomass is essential for effective management decisions that improve productivity and profitability, while also supporting the monitoring, reporting, and verification of greenhouse gas (GHG) mitigation strategies. However, conducting frequent field surveys across entire farms is costly and often impractical.

Over the past five years, the availability of satellite data with spatial and temporal resolutions compatible with weekly paddock management decisions has grown significantly. Additionally, predictive models for biomass quantity and quality based on remote sensing are emerging. For this technology to translate into productive improvements, it is essential to have reliable, locally validated models and tools that make this information accessible to different users.

The main objective of this project is to reduce the cost of real-time estimation of forage biomass quantity and quality in grazing livestock systems with adequate accuracy through a satellite-based tool. To achieve this, the project developed a protocol, a mobile application, and a website for recording ground-truth data, including biomass and forage quality measured in the field. The project also established a field monitoring network involving more than 79 researchers and technicians. Currently, over 1,000 ground-truth satellite measurement pairs for various forage resources are being used to calibrate predictive models for forage quantity and quality. Additionally, an application is being developed to provide system-scale satellite estimates.

The accuracy of the predictive models will be tested during demonstration modules at the experimental stations of participating institutions and at commercial farms that are part of the measurement network. Outreach and training activities will be carried out to ensure that the developed products reach potential users and that they can use them effectively.

II. Project portfolio execution and results

II.1. Satellite monitoring of quantity and quality of available biomass in pastoral livestock systems (atn/rf-19787-rg and atn/rf-19788-rg)

II.2. Objective

The main objective of this project is to reduce the cost of estimating, in real time and with adequate precision, the quantity and quality of biomass available in livestock systems in lac countries through a satellite-based tool.

II.3. Summary of project activities

The project is divided into three sequential stage components. The first component consists of calibrating forage quantity and quality prediction models at pixel scale using medium spatial resolution satellites (~900m2) within experimental and commercial farms. The second component consists of validating the models at management unit scale (plots). Finally, the third component consists of training and dissemination of the tools generated. The three project components and their respective activities are summarized in Table 1 below.

Component	Activities	Results	Current Status
1- Generate and calibrate forage quantity and quality prediction models from remote sensors	1.1- Generation of a common ground-truth data measurement protocol compatible with satellite data.	Product 1. Technical note with a sampling protocol according to type of forage resource.	Completed
	1.2- Ground-truth metadata base generation.	Product 2. Technical note with published database metadata.	In progress
	1.3- Calibration of forage quantity and quality estimation models using satellite data.	Product 3. Technical note with calibration of forage quantity and quality estimation models published.	In progress
2- Validate the models generated in demonstration units and commercial properties	2.1- Validation of prediction models for the quantity and quality of biomass available at the system level in demonstration units and commercial properties.	Product 4. Biomass and forage quality estimation tool implemented in validation sites and disseminated through a technical note.	In progress
	2.2- Evaluation of the cost of remotely predicting the quantity and quality of biomass available in demonstration units and commercial properties.	Product 5. Technical note with validation of prediction models at system scale published.	Not Started
	2.3- Evaluation of the cost of remotely predicting the quantity and quality of biomass available on a regional or national scale.	Product 6. Technical note with evaluation of the cost of remotely predicting the quantity and quality of biomass available at system scale published.	Not Started
		Product 7. Technical note with evaluation of the cost of remotely predicting the quantity and quality of biomass available in regions or countries published.	Not Started
3- Knowledge management, transfer and communication	3.1- Training workshops and dissemination products.	Product 8. Training and dissemination workshops carried out.	In progress
		Product 9. Videos disseminating results published.	Not Started

II.4. Project implementation and final results

The first component, focused on the development and calibration of predictive models, has made progress across all activities. In 2023, a protocol was developed for sampling both forage biomass quantity and quality under field conditions (see Technical Note 1). Designed to be compatible with satellite data and adaptable to various forage resources, the protocol provides guidelines for field sampling and incorporates digital tools to streamline data collection. It was first implemented at three sites in Argentina.

During the project's initial phase, field sampling criteria were established through a series of virtual meetings involving technical leaders from the five participating institutions (see Photo 1). These meetings facilitated discussions on the most relevant forage resources in each participating country and the capabilities of each institution. Additionally, a workshop was held in Argentina with 29 technicians (15 men and 14 women) from across the country. Over two days, participants defined specific criteria for different forage resources and received training on the use of the developed tools.

Photo 1: Workshop on forage resources, held on 9/27/23

Based on discussions held during the workshops, participants developed a decision tree to guide field sampling according to vegetation characteristics. The decision tree operates at different levels, as illustrated in Figure 1. At the regional level, eligible forage resources are identified based on their relevance to livestock systems. At the site level, factors such as paddock size, accessibility, and landscape heterogeneity define the sampling strategy. Finally, at a finer scale, the variability in vegetation structure among patches determines the number of required repetitions.

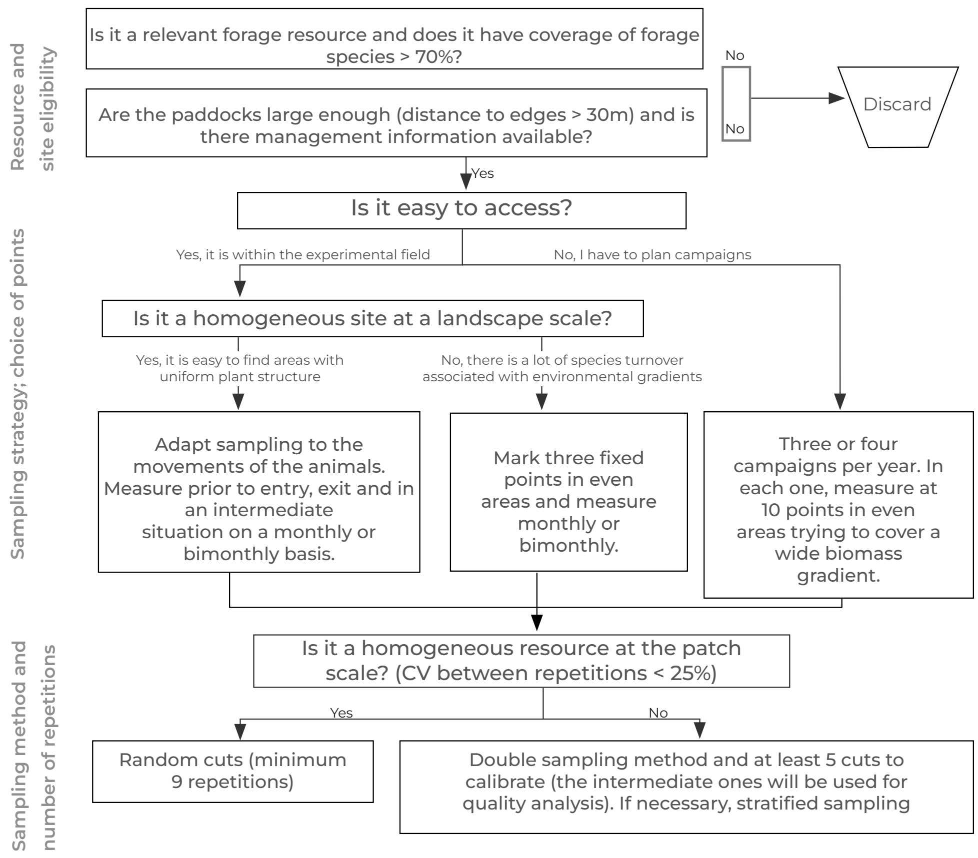


Figure 1: The decision tree to define forage sampling

To support the decision-making process outlined in the decision tree and facilitate data collection, several digital tools were developed and evaluated, including:

1. A website for planning and monitoring field sampling hosted in a GitHub repository which allows users to access the latest version of the protocol. Additionally, users can view satellite calendars and weather forecasts for sampling locations (Appendix 1). Currently, the page serves as a platform to access all digital tools and project data, providing participants support while also allowing external stakeholders to follow the project's progress.
2. An application for characterizing landscape heterogeneity developed in Google Earth Engine, based on a previous application[1]. This application generates a map representing environments with similar characteristics using the vegetation index

[1] Durante, M y Jaurena, M. 2022. Una APP sencilla para la clasificación de ambientes basada en el índice verde. 3° Seminario Internacional "Restauración en el Bioma Pampa". 28-30 de septiembre. https://www.researchgate.net/publication/375689889_Una_APP_sencilla_para_la_clasificacion_de_ambientes_basada_en_el_indice_verde

from SENTINEL-2 satellite images through a user-friendly interface. Within the protocol, the application is used to select sampling points. Beyond this specific application, the ability to easily characterize a field's environment is useful for other decisions, such as pasture subdivision and identifying areas to visit before field inspections. To enhance accessibility, an instructional video demonstrating the app's use was created, accumulating over 1,100 views, while outreach events were also held, engaging more than 200 participants.

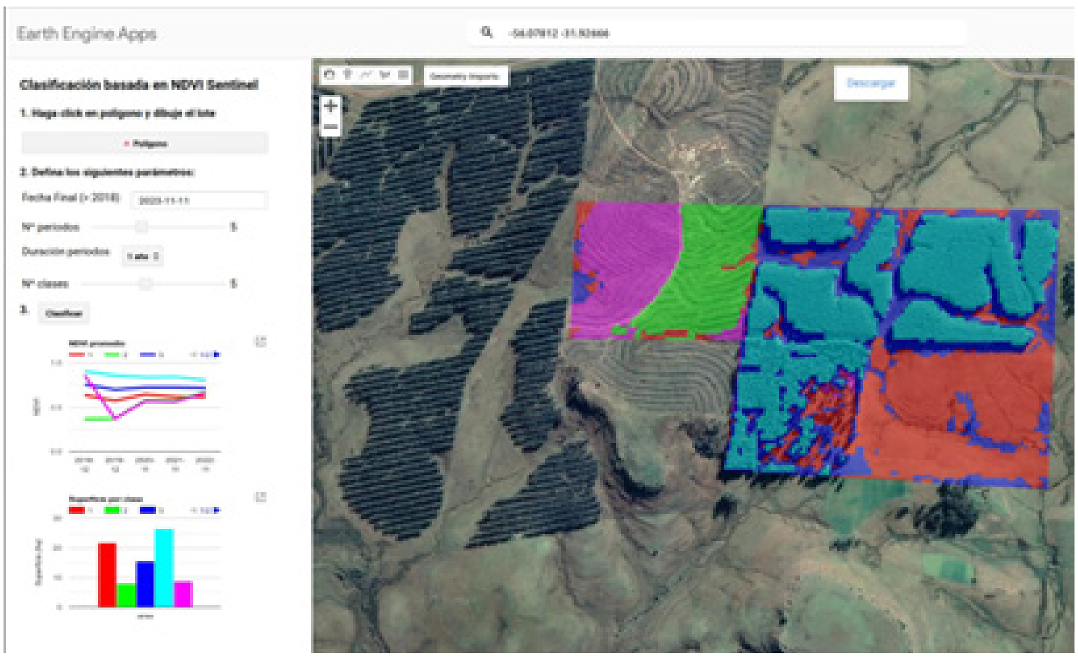


Photo 2: Screenshot of the application for characterizing landscape heterogeneity

3. An indirect biomass estimation method called "PhenoPhoto," based on oblique photos on a white background. The method was evaluated on natural grasslands of Entre Ríos (Argentina) and Uruguay. These are diverse grasslands (~40 species/m^2), mainly C3 and C4 grasses. When compared with biomass harvest data, a good fit was observed (R2=0.88, N = 60 samples), with a slightly lower error than other double sampling methods (relative error 5-15 percent lower than the height and visual estimate). The method was presented at the Annual Ecology Meeting in Argentina[2], generating interest and attracting new project collaborators (Appendix 2).

[2]Durante, M y Jaurena, M. 2023. Phenophoto un metodo indirecto rapido y preciso para estimar biomasa aerea en pastizales. XXX Reunión Argentina de Ecología (RAE). https://www.researchgate.net/publication/375690344_Phenophoto_un_metodo_indirecto_rapido_y_preciso_para_estimar_biomasa_aerea_en_pastizales

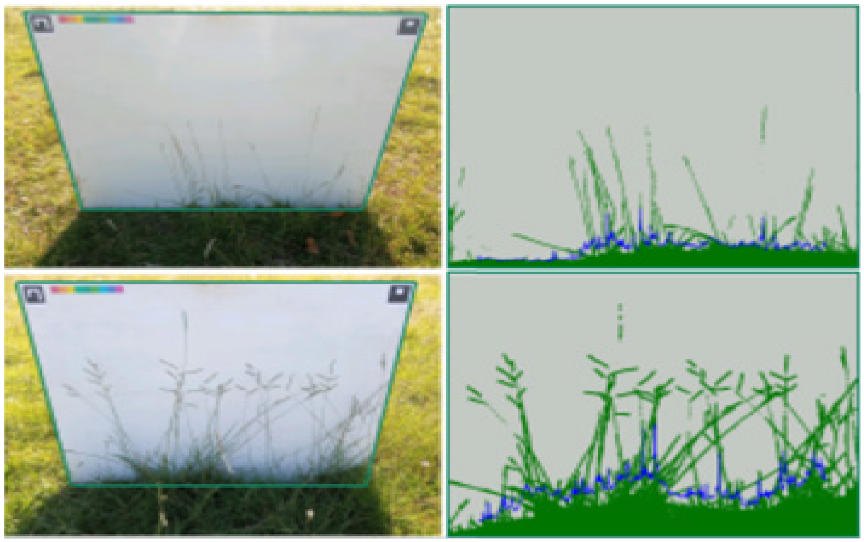


Photo 3: Oblique photos taken with a phone (left) and the processing result (right). The area occupied by vegetation (green) and the height distribution (blue) in the processed image are used as biomass estimators.

4. An application for recording information systematically, accessible via phone or computer. This application, developed on the AppSheet platform, allows project participants to load and view data in a Google spreadsheet stored in the project's cloud-based email account. The use of this application aims to reduce errors and streamline data recording processes, while also facilitating metadata registration. Each location will have its own independent application and corresponding spreadsheet to ensure data privacy and organization. The adaptable nature of the no-code platform used for the application allows for adjustments based on specific data recording requirements on each location.

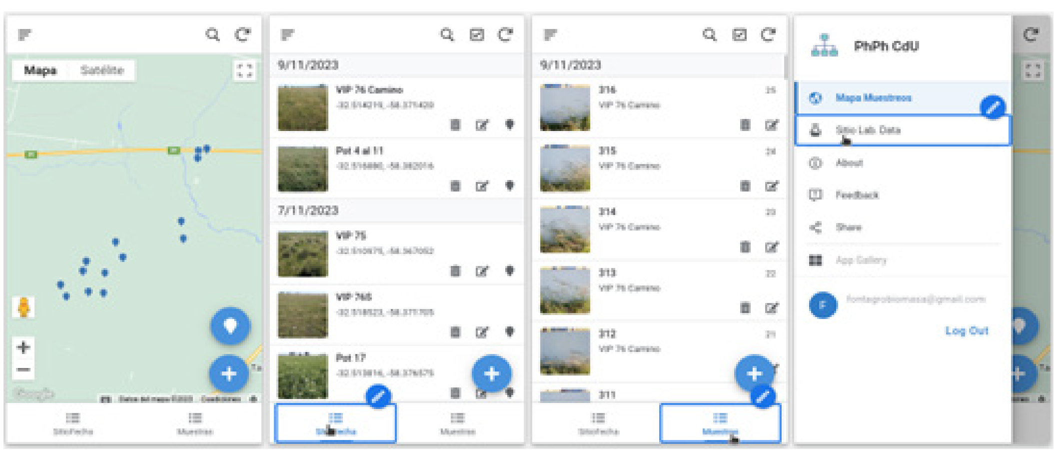


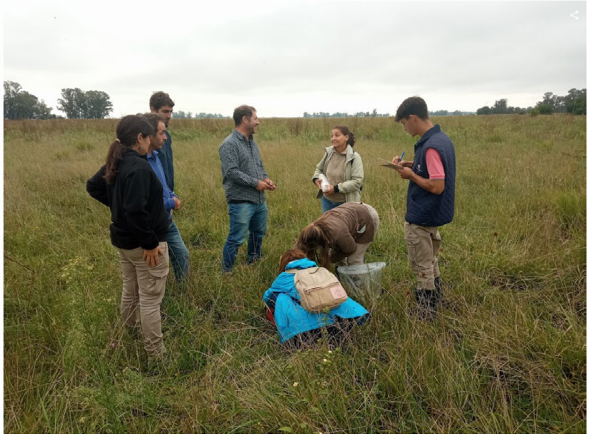
Photo 4: Screenshots of the application to record field data. From left to right: map of sampling points; display and loading of new points; display and loading of new repetitions within a point; and loading data of a point after processing the samples.

During 2024, the project made significant progress in field sampling. Eight internal workshops were conducted to ensure that all technicians became familiar with the sampling protocol. Thanks to the efforts of the 79 technicians involved, they recorded more than 1,000 ground truth data points (biomass samples at a scale compatible with satellite observation) to calibrate satellite-based models. The metadata is now accessible on the sampling planning and monitoring website (see Figure 6 and Appendix 3). The model calibration phase is also underway, although results are still preliminary (Product 3, planned for the upcoming year). For this analysis, the team used data collected up to the end of October 2024. Beyond the planned work—including three doctoral theses— the project signed a collaboration agreement with Argentina's National Commission for Space Activities (CONAE) to work with SAOCOM satellite data. It also established agreements with two AgTech companies, PLANET and Cibolabs, to evaluate their algorithms for forage biomass estimation.

Photo 5: Screenshot of the [website where metadata from field measurements can be viewed.]

Some activities under the second component, model validation demonstration units and commercial farms, have begun, though not all. Among the launched activities, the project has begun developing two applications to provide satellite-based estimates at the system scale. Additionally, a new graduate student in Argentina has joined the project to work on evaluating satellite-based estimates. Both activities correspond to Products 5 and 4, scheduled for the upcoming year.

Under the third component, which focuses on knowledge management, technology transfer, and communication, the committed product for this year (Product 8) was a technical note on a specific dissemination workshop organized by the project. This workshop was intended to complement the dissemination of project outcomes carried out by participating institutions. However, it was postponed to allow for further progress in model development. In the meantime, the project has leveraged other outreach opportunities, presenting its work at a conference and in various talks aimed at students (2), technicians (2), and producers (4), reaching a total of 250 direct trainees.



III. Conclusion

In the project's second year, efforts focused on strengthening the field sampling network and building a comprehensive database of biomass and forage quality measurements, based on the protocol developed in the first year. Internal training activities helped reinforce this network, and significant progress was achieved in field sampling. To date, over 1,000 field records, representing 25 percent of the expected total, have been collected and are being used for the initial calibrations with satellite data.

The availability of a structured field database, with metadata accessible online, has streamlined both internal organization and collaboration with external partners, including CONAE and two private companies engaged in evaluating forage biomass estimation algorithms.

IV. Digital References

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FONTAGRO project website:
https://www.fontagro.org/new/proyectos/monitoreosatelital/en

Appendix 1. Field sampling planning and monitoring website

The website, hosted on GitHub, provides access links to the sampling protocol (Product 1) and helpful digital tools, such as the application for characterizing landscape heterogeneity (Photo A1). Additionally, it allows users to view the quality of the latest satellite images and the cloud probability for future images (Photo A2).

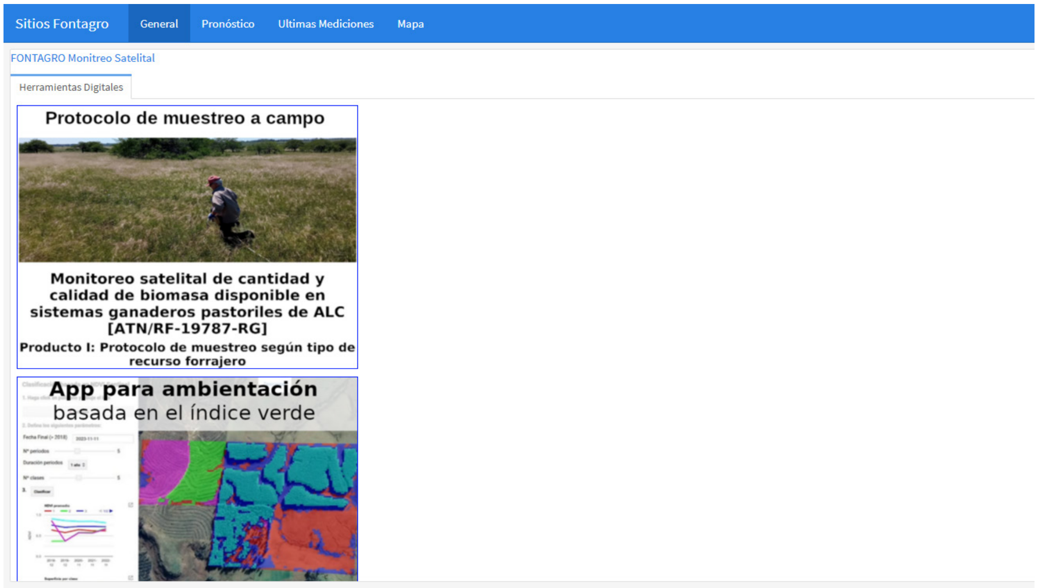


Photo A1: Screenshot of the main project page, with links to the FONTAGRO website and digital tools to assist with field sampling.

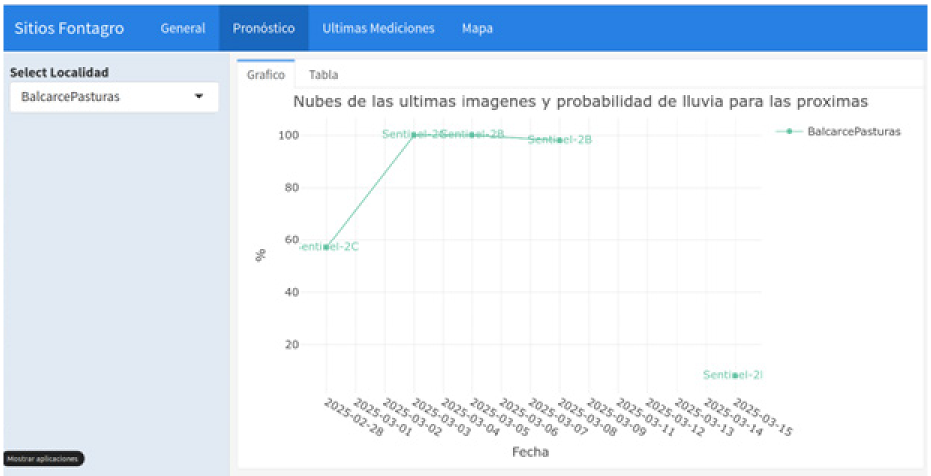


Photo A2: Screenshot of the page where users can view cloud cover for the latest satellite images and the probability of rain (as an indicator of cloudiness) for future passes at each sampling site.

Appendix 2. Phenophoto

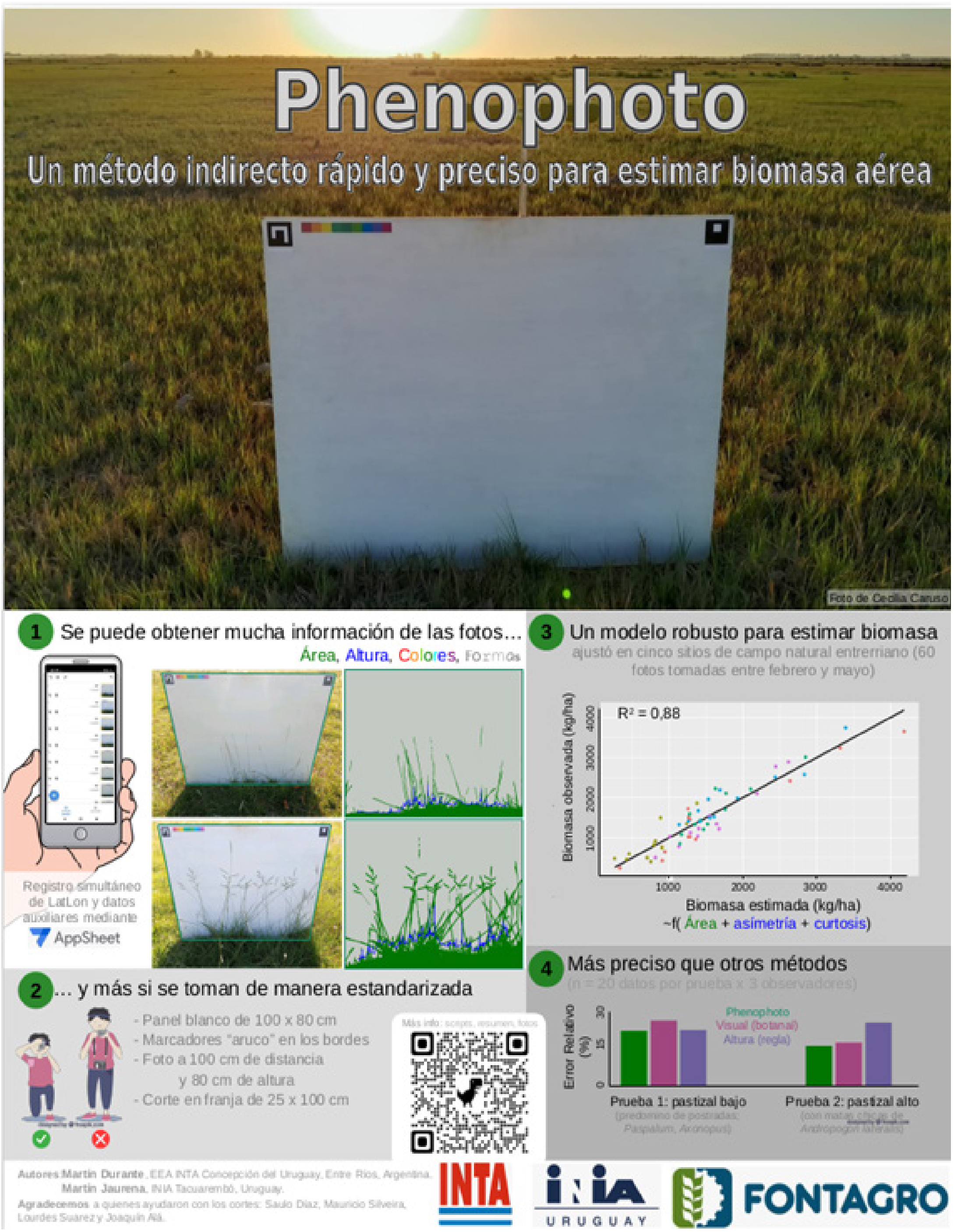
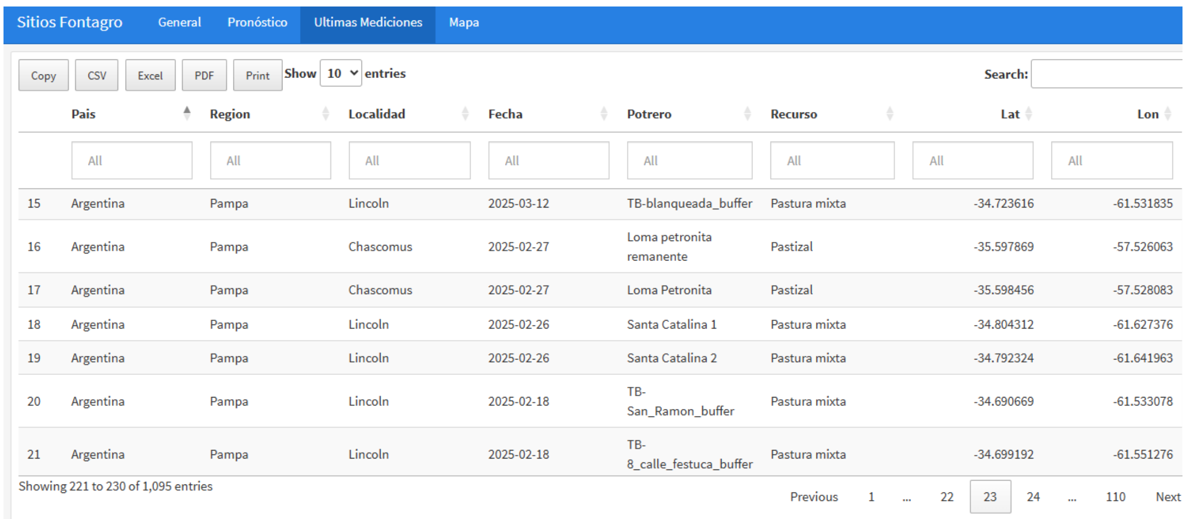


Photo B1: Poster presented at the XXX Argentine Ecological Meeting (RAE), Bariloche, October 2023.

Appendix 3. Field sampling metadata

The field sampling planning and monitoring page provides access to the metadata for each sample. This page is regularly updated with data recorded through the mobile application developed on the AppSheet platform. It displays the coordinates, date, and forage resource associated with each field sample.


Sitios Fontagro | General | Pronóstico | Ultimas Mediciones | Mapa

Copy | CSV | Excel | PDF | Print | Show 10 entries | Search:

	Pais	Region	Localidad	Fecha	Potrero	Recurso	Lat	Lon
	All	All	All	All	All	All	All	All
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16	Argentina	Pampa	Chascomus	2025-02-27	Loma petronita remanente	Pastizal	-35.597869	-57.526063
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18	Argentina	Pampa	Lincoln	2025-02-26	Santa Catalina 1	Pastura mixta	-34.804312	-61.627376
19	Argentina	Pampa	Lincoln	2025-02-26	Santa Catalina 2	Pastura mixta	-34.792324	-61.641963
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Showing 221 to 230 of 1,095 entries

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Photo C1: Screenshot of the table with the metadata for the field samples.

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