

Supplementary Material

1 Case description

Supplementary Table 1. Member institutions and organizations of the Board of Livestock on Natural Grasslands ("Mesa de Ganadería sobre Campo Natural", MGCN, for its acronym in Spanish) at the time of the workshops. The description is based on how each one presents or defines itself in their websites or official documentation. Their representation in the workshops was variable, they were present in 1, 2 and/or all 3 workshops.

MGCN Organizations and Institutions	Type of Institution	Description
Ministerio de Ganadería Agricultura y Pesca	Public institution	Public institution responsible for planning and management of public policies that contribute to the permanent development of the agricultural, agro-industrial and fishing sectors and to sustainable rural development, with emphasis on economic, social, and environmental development (MGAP, 2020).
Instituto Plan Agropecuario	Public institution	Public institution aimed at contributing to the sustainable and innovative development of livestock production and its producers, mainly small and medium-sized producers, to improve their economic, family, and human situation, through training, extension, information generation and coordination with other institutions (Instituto Plan Agropecuario, 2021).
Instituto Nacional de Investigación Agropecuaria	Research and Development institution	Public institution oriented to generate and adapt knowledge and technologies to contribute to the sustainable development of the agricultural sector and the country, considering government policies, social inclusion and the demands of markets and consumers (INIA, 2021).
Facultad de Agronomía, Universidad de la República	Education and Research Institution	Public institution with national leadership and regional recognition in education in Agricultural Sciences. Its objective is to contribute to the sustainable development of the country by training professionals with a critical spirit, social commitment, and a solid scientific-technological base, and to cooperate with other institutions and organizations for the training of Technical Staff of the National System of Teaching, Research, Innovation and Extension (Facultad de Agronomía UDELAR, 2021).

Facultad de Ciencias, Universidad de la República.	Education and Research Institution	Public institution for teaching, research, and extension activities in natural and exact sciences. Specifically, the Grasslands Ecology Group develops lines of research oriented to the analysis of changes in land use, its patterns and environmental controls, cattle production on grasslands and biodiversity conservation (GEP, 2021).
Secretariado Uruguayo de la Lana	Research and Development institution	Institution of reference in the sheep industry at national and regional level. It is dedicated to research, technology generation and transfer, health assistance, extension, market analysis and is led by sheep producers (SUL, 2021).
Comisión Nacional de Fomento Rural	Public institution	Entity responsible for overseeing and guaranteeing the proper operation of rural development associations and for providing them with support, advice, and management training. It is projected as the main representative organization of small and medium farmers, through the grassroots organizations that bring them together all over the country (CNR, 2021).
Cooperativas Agrarias Federadas	Producers' associations	This association represents a network of more than 20 agricultural cooperatives and rural promotion societies, with more than 13,000 associated producers, distributed throughout the country (CAF, 2021).
Asociación Rural del Uruguay	Producers' associations	Private trade association whose objective is the defense and promotion of the agricultural production interests and complementary and derived industries. Its activities consist of the search for policies that empower entrepreneurs in an environment of free enterprise, market economy and healthy competition (ARU, 2021).
Grupos CREA	Producers' associations	Groups of producers and technical experts whose objective is to improve the economic performance of producers through peer-to-peer exchange and discussion of specific farm problems, based on the resources available on their farms (FUCREA, 2021).
Federación Rural	Producers' associations	Federative institution of associations of rural producers whose objective is to promote the increase and improvement of production to achieve its intensive character; the care and conservation of the soil; the settlement of the family in rural areas and a balanced distribution of the country's production between urban and rural areas.

Ex- Dirección Nacional de Medio Ambiente (actual Ministerio de Ambiente)	Public Institution	Agency responsible for the formulation and implementation of national environmental policy, environmental planning, sustainable development and the use and conservation of natural resources as determined by the government.
Dirección Nacional de Ordenamiento Territorial	Public Institution	It is an agency of the Ministry of Housing and Territorial Planning in charge of promoting and developing territorial planning processes, ensuring their implementation at all territorial scales (Ministerio de Vivienda y Ordenamiento Territorial, 2021).
Instituto Interamericano de Cooperación para la Agricultura	International cooperation institution	Specialized agency of the Organization of American States whose purpose is to stimulate, promote and support the efforts of its 34 Member States to achieve the sustainable development of agriculture and the well-being of rural population (IICA, 2021).
Alianza del Pastizal	NGO	Its objective is to promote the conservation of the natural grasslands of southern South America and their biodiversity, through coordinated actions among the four countries (Argentina, Brazil, Paraguay, and Uruguay) and among the different sectors of society (producers, civil organizations, academia, and governments), through responsible production and consumption models (Alianza del Pastizal, 2021).
Instituto Nacional de Carnes	Public Institution	Its mission is the planning, assessment, and implementation of the national meat policy, which is determined by the Government. Specifically, its function is to promote, regulate, coordinate, and monitor the activities of production, transformation, commercialization, storage, and transportation of meat (INAC, 2021).
Asociación Uruguaya de Ganaderos del Pastizal	Producers' associations	Association of producers derived from Alianza del Pastizal, made up of almost one hundred Uruguayan producers. Its objective is to promote livestock production in natural fields, ensuring the conservation and improvement of the quality of life of producers and workers (AUGAP, 2021).

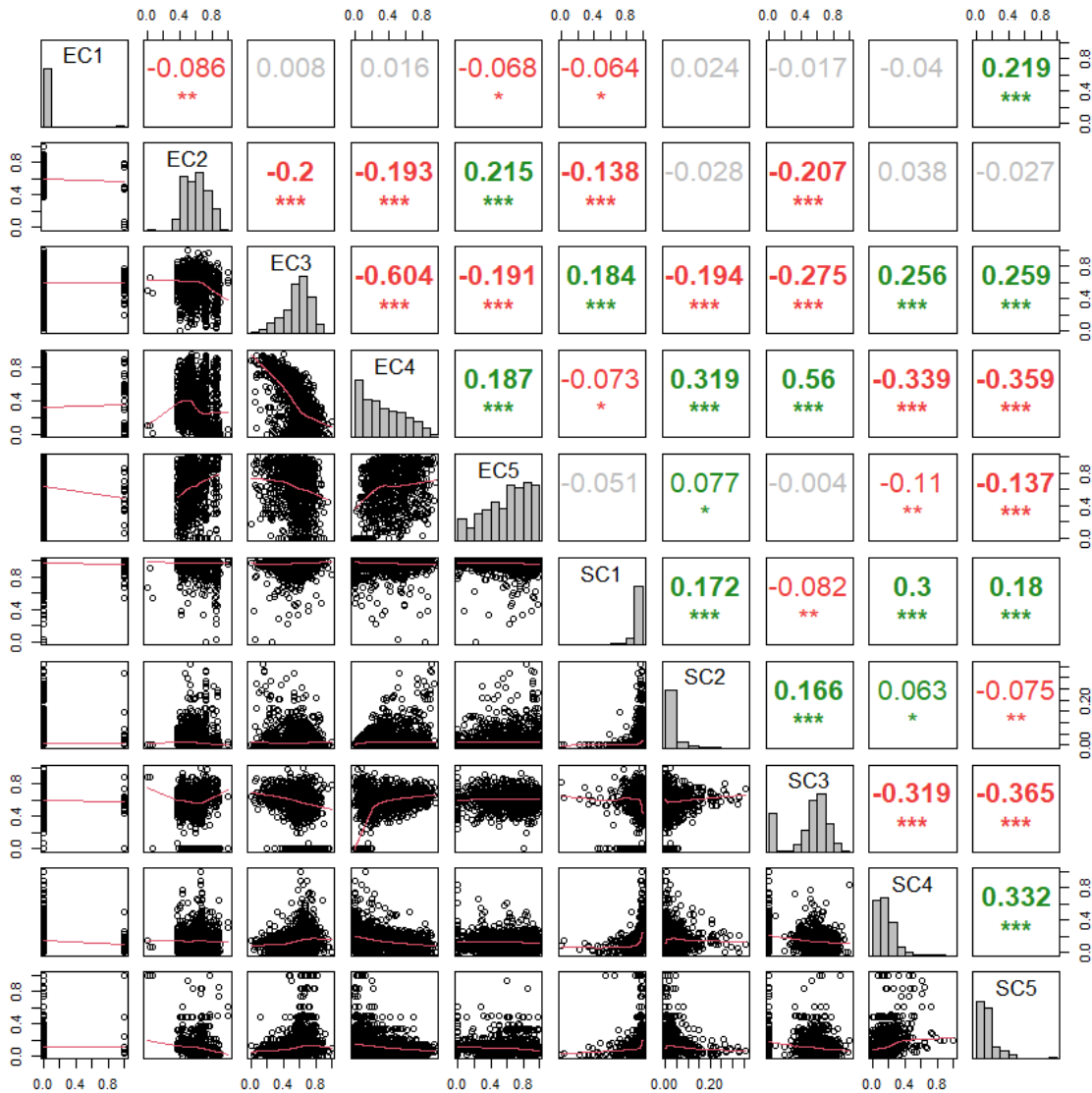
2 Criteria and indicators for the socio-ecological diagnosis

Supplementary Table 2. Main dimensions, criteria and indicators incorporated in the territorial diagnosis that were mapped at the 5x5 km cell level. The asterisks indicate the 10 indicators that were finally included to determine the Grasslands' Conservation Value (GCV).

Dimensions	Criteria	Indicators and data source used
Protected areas	Protected areas Network of priority sites	Presence/absence of protected areas and priority sites* [presence=1, absence =0](SNAP, 2015).
Biodiversity	Faunal	Potential richness of birds, mammals, reptiles, amphibians, and fishes* (Brazeiro et al., 2008)
	Floristic	Species richness mean estimated in sparse grasslands, in dense grasslands and in native forests (Brazeiro et al., 2008; Lezama et al., 2019)
	Functional	Most frequent Ecosystem Functional Type (EFT) Shannon index of functional diversity based on EFT* estimated from remote sensing data and land-cover map (Baeza and Paruelo, 2020)
Native grasslands' area	Proportion of grasslands communities	Proportion of area occupied by dense and sparse grasslands* from land cover-map (Baeza and Paruelo, 2020).
Ecosystem Services	Regulating and support Ecosystem Services Supply	Mean Ecosystem Services Supply Index (ESSI, (Paruelo et al., 2016; Staiano et al., 2021) for the period 2000-2015 of the total cell estimated from remote sensing data. Mean ESSI for the period 2000-2015 of the cell's grasslands (Baeza and Paruelo, 2020) Proportion of the cell area without negative trends in ESSI over the period 2000-2015. Proportion of grassland area (Baeza and Paruelo, 2020) without negative trends in ESSI over the period 2000-2015*.
Landscape structure and configuration	Landscape indices	Percentage of grasslands on the landscape, Number of patches, Average patch size, Perimeter-area ratio, Effective mesh size (Baldi et al., 2006)(Baeza and Paruelo, 2020).

Farm size	Cadastral parcel size descriptors	Mean, median*, standard deviation, minimum, and maximum size of cadastral plots [ha] (Dirección Nacional de Catastro, 2017).
Size of family farms	Cadastral parcel size of family farmers	Number, total [ha] and relative area, area on grasslands [ha] and relative area on grasslands(Baeza and Paruelo, 2020).
Productivity	Grasslands Primary productivity	Aerial Net Primary Productivity (ANPP) [kg*ha ⁻¹ *yr ⁻¹], estimated from remote sensing data using the Monteith model (Monteith, 1972; Piñeiro et al., 2006; Paruelo et al., 2019). Mean annual ANPP and inter-annual coefficient of variation.
	Grasslands' cattle carrying capacity (CC)	$CC = \frac{ANPP * HI}{AIC}$ where, CC is the cattle carrying capacity[heads*ha ⁻¹]*, ANPP is Aerial Net Primary Productivity [kg*ha ⁻¹ *yr ⁻¹], HI represents the Harvest Index [kg consumed/kg produced](Golluscio et al., 1998) and AIC is the Annual Individual Consumption [kg consumed*head ⁻¹ *año ⁻¹].
Agricultural and forestry potential	Productive capacity of the rural plots	Mean, minimum, and maximum cell CONEAT ¹ productivity index (CONEAT, 2021).
Infrastructure	Roads, rural schools, health centers and localities	Total cell road kilometers [km]*, distance from the cell center to the nearest school [km], to the nearest health center [km] and to the nearest town [km](Ministerio de Transporte y Obras Públicas, 2017).
Population	Rural population	Number of inhabitants reported in the National Census of Population, Housing and Homes (Instituto Nacional de Estadísticas, 2011).

¹ National Commission for the Agronomic Study of the Land (for its name in Spanish Comisión Nacional de Estudio Agronómico de la Tierra)



Supplementary Figure 1. Correlations between the indicators corresponding to the 10 criteria incorporated in the determination of the grasslands' conservation value (EC1: Presence/absence of protected areas and/or priority sites, EC2: faunal diversity as potential mean species richness of mammals, birds, amphibians, reptiles and fishes; EC3: Functional diversity as Shannon index of Ecosystem Functional Types; EC4: proportion of grasslands area; EC5: proportion of grasslands without negative trends in Ecosystem Services Supply Index; SC1: Farm size as median cadastral plot, SC2: Family farming as proportion of grasslands on family farms; SC3: Cattle carrying capacity of grasslands; SC4: Infrastructure as Km of road; SC5: Population as number of inhabitants of the census segment). The diagonal shows the frequency distribution of the scaled values of each indicator in the 1217 5x5 km cells that integrate the South-Central region. Above the diagonal is the Pearson's correlation coefficient. Green values indicate significant positive correlations, red values indicate significant negative correlations and gray values indicate non-significant correlations (p -value >0.1). Asterisks indicate significance values: * corresponds to a p -value < 0.05 , ** to a p -value < 0.01 and *** to a p -value < 0.001 . Below the diagonal plots of each pair of correlations are shown.

Supplementary Table 3. Details of the estimation of the ecological criteria indicators.

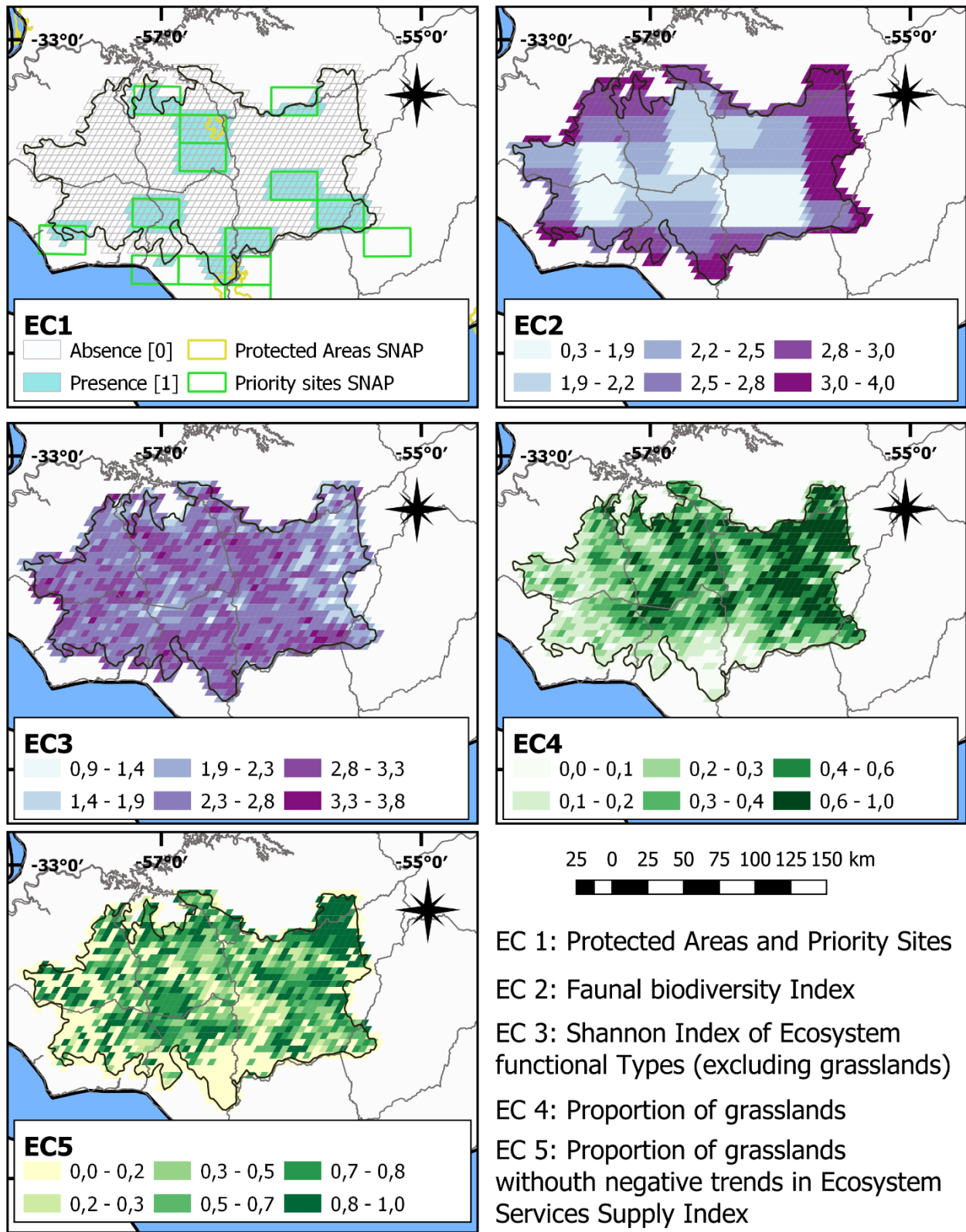
Ecological Criterion (EC)	Indicator
Protected areas (EC1)	The National System of Protected Areas (SNAP for its acronym in Spanish, Sistema Nacional de Areas Protegidas) has spatially explicit information on protected areas and the network of priority sites corresponding to its 2015-2020 Strategic Plan (SNAP, 2015). Based on this information, each 5 x 5 km cell was characterized according to the presence/absence of protected areas and/or network of priority sites.
Faunal Diversity (EC2)	Characterized through 5 maps of potential species richness for mammals, birds, reptiles, amphibians, and fishes in ~66,000 ha cells for all of Uruguay (Brazeiro et al., 2008). For each of the 5 maps, species richness at the 5x5 km cell level was obtained from the following equation: <div data-bbox="824 821 1052 926" data-label="Equation-Block"> $Si = \sum_{j=1}^n Sj * Aij$ </div> <p data-bbox="427 961 1455 1171">Where, <i>i</i> corresponds to each 5 x 5 km cell, <i>j</i> represents the ~66,000 ha cells that fall in cell <i>i</i>, <i>S</i> is the potential species richness in cell <i>j</i> and <i>Aij</i> corresponds to the proportion of the area shared by cells <i>j</i> and <i>i</i> with respect to the total surface area of cell <i>i</i>. The 5 specific richness' were scaled to [0-1] following Equation 1. Then, a potential faunal diversity index was determined as the sum of the 5 richness', following the equation:</p> $ FDI_i = SM_i + SB_i + SR_i + SA_i + SF_i $

the values to the range [0-1] according to Equation 1. Then, 4 classes with fixed intervals were generated: low annual mean (from 0 to 0.25), medium-low (from 0.25 to 0.5), medium-high (from 0.50 to 0.75) and high (from 0.75 to 1). Similarly, low VI_{CV} (from 0 to 0.25), medium-low (from 0.25 to 0.5), medium-high (from 0.50 to 0.75) and high (from 0.75 to 1). For the moment of maximum productivity (VI_{MAX}) 4 classes were generated corresponding to year's seasons: maximum in spring (during the months of October, November or December), in summer (maximum in January, February or March), in autumn (maximum in April, May or June) or winter (I, maximum in July, August or September). The EFT of each pixel was derived from the combination of the corresponding levels in the three attributes and the EFT map was generated with a spatial resolution of 250 meters. The 250-meter pixels corresponding to grasslands (identified from the EC4 land cover map corresponding to the same year) were excluded for each cell of 5x5 Km, and the Shannon Index was calculated to describe the functional diversity of the grassland surroundings:

$$H'i = - \sum_{k=1}^n pi * \log_2 pi$$

Where, H' is the Functional Diversity Index, i represents each 5x5 km cell, n is the number of EFTs present in the cell (the richness of EFTs) and pi is the proportion of 250-meter pixels of $EFT k$ with respect to the total pixels in the cell (relative abundance of $EFT k$).

Grassland's area (EC4)	Proportion of remaining grassland area on each 5x5 km cell, obtained from a land-cover map for year 2015, with a spatial resolution 30 meters (Baeza et al., 2019).
Ecosystem Services supply (EC5)	Regulating and support ecosystem services supply was determined by trends in the Ecosystem Services Supply Index (ESSI) (Paruelo et al., 2016; Staiano et al., 2021). It is based on two attributes of vegetation index annual dynamics, the annual mean (VI_{MEAN} , a proxy of total C gains) and the intra-annual coefficient of variation (VI_{CV} , an indicator of seasonality): $ESSI = VI_{MEAN} * (1 - VI_{CV})$. From the annual dynamics of EVI (derived from MODIS sensor images, product Mod13q1 with a spatial resolution of 250 m and a temporal resolution of 16 days), the annual ESSI values for period 2000-2015 were obtained. To determine if ESSI values were constant or showed changes, the trend over the period was calculated using a linear regression model (ESSI vs. year) and those regressions with p-values < 0.01 were considered significant trends. Since the criterion aimed to capture the ecosystem services supply supplied by grasslands in each cell, we calculated the proportion of pixels corresponding to grasslands (identified from EC4 mapping) without negative ESSI trends (i.e., where the supply of ecosystem services has been maintained or increased) to the total number of grassland pixels in the cell.



Supplementary Figure 2. Maps of indicators for the 5 ecological criteria

Supplementary Table 4. Details of the estimation of the socioeconomic criteria (SC) indicators.

Socioeconomic Criterion (SC)	Indicator
Farm size (SC1)	The farm size was characterized through the median of cadastral plots (Dirección Nacional de Catastro, 2017). All cadastral units with an area greater than 2 hectares were considered rural cadastral units. 99% of the rural cadastral units have an area between 2.3 and 694 hectares. The median area of the rural cadastral units in each 5x5 km cell (2500 ha) was calculated.
Family farming (SC2)	The Office of Rural Development of the Ministry of Livestock, Agriculture and Fisheries provided the information of the family farms, protecting the identity of the owners. Based on this information, we calculated the proportion of grasslands on family farms in each 5x5 km cell with respect to the total area of grasslands of the cell.
Grasslands carrying capacity (SC3)	The grasslands cattle carrying capacity was estimated as following equation: <div data-bbox="797 930 1045 1003" data-label="Equation-Block"> $CC = \frac{ANPP * HI}{AIC}$ </div> <p data-bbox="410 1037 1435 1178">Where, CC is the cattle carrying capacity (heads*ha⁻¹), ANPP corresponds to the Aerial Net Primary Productivity (kg*ha⁻¹*yr⁻¹), HI represents the Harvest Index, the proportion of ANPP harvested by cattle (kg consumed/kg produced), and AIC is the Annual Individual Consumption (kg consumed*head⁻¹*año⁻¹):</p> <p data-bbox="410 1213 1435 1354">1. The ANPP was estimated from remote sensed data (EVI derived from MODIS sensor images, product Mod13q1 with a spatial resolution of 250 m and a temporal resolution of 16 days) using the Monteith model (Monteith, 1972; Piñeiro et al., 2006; Paruelo et al., 2019):</p> <div data-bbox="732 1390 1101 1423" data-label="Equation-Block"> $ANPP = Ri * fPARi * RUE$ </div> <p data-bbox="410 1459 1435 1705">Where, Ri is the incident radiation (MJ *ha⁻¹*yr⁻¹), fPARi is the fraction of photosynthetically active radiation incident, and RUE is the radiation use efficiency (kg*MJ⁻¹). Ri was obtained from satellite images of the Solar Global product of INPE (Instituto Nacional de Pesquisas Espaciales, Brazil), fPARi was estimated from EVI images of the Mod13q1 product provided by the MODIS sensor and an RUE of 0.35 kg*MJ⁻¹ was used for the grasslands of the Central-South region (Paruelo et al., 2019).</p> <p data-bbox="410 1743 1435 1911">From the land cover mapping used to characterize the proportion of grasslands (EC4), the 250-meter MODIS pixels corresponding entirely to grasslands were selected and the EVI time series from July 2000 to June 2015 were extracted. The EVI time series of each pixel was transformed to fPARi using a linear model calibrated for the Río de la Plata grassland region (Grigera et al., 2007). On the other</p>

hand, the Ri time series were extracted, whose images have a spatial resolution of 0.04 degrees and a monthly temporal resolution. For each 250 m MODIS pixel, the time series of the coincident INPE pixel was extracted or an average value of Ri was used for cases in which a MODIS pixel coincided with more than one INPE pixel. Then, the Monteith model was applied for each growing season year (July-June) and the 15 annual ANPP values were obtained for each pixel. From these values, we calculated the mean annual ANPP for the period 2000-2015. This information was summarized at the 5x5 km cell level through a spatial mean of the annual mean ANPP of the grassland pixels included in each cell.

2. Considering the HI varying as a function of ANPP, it was calculated from the estimation proposed by (Golluscio et al., 1998) applying the following function:

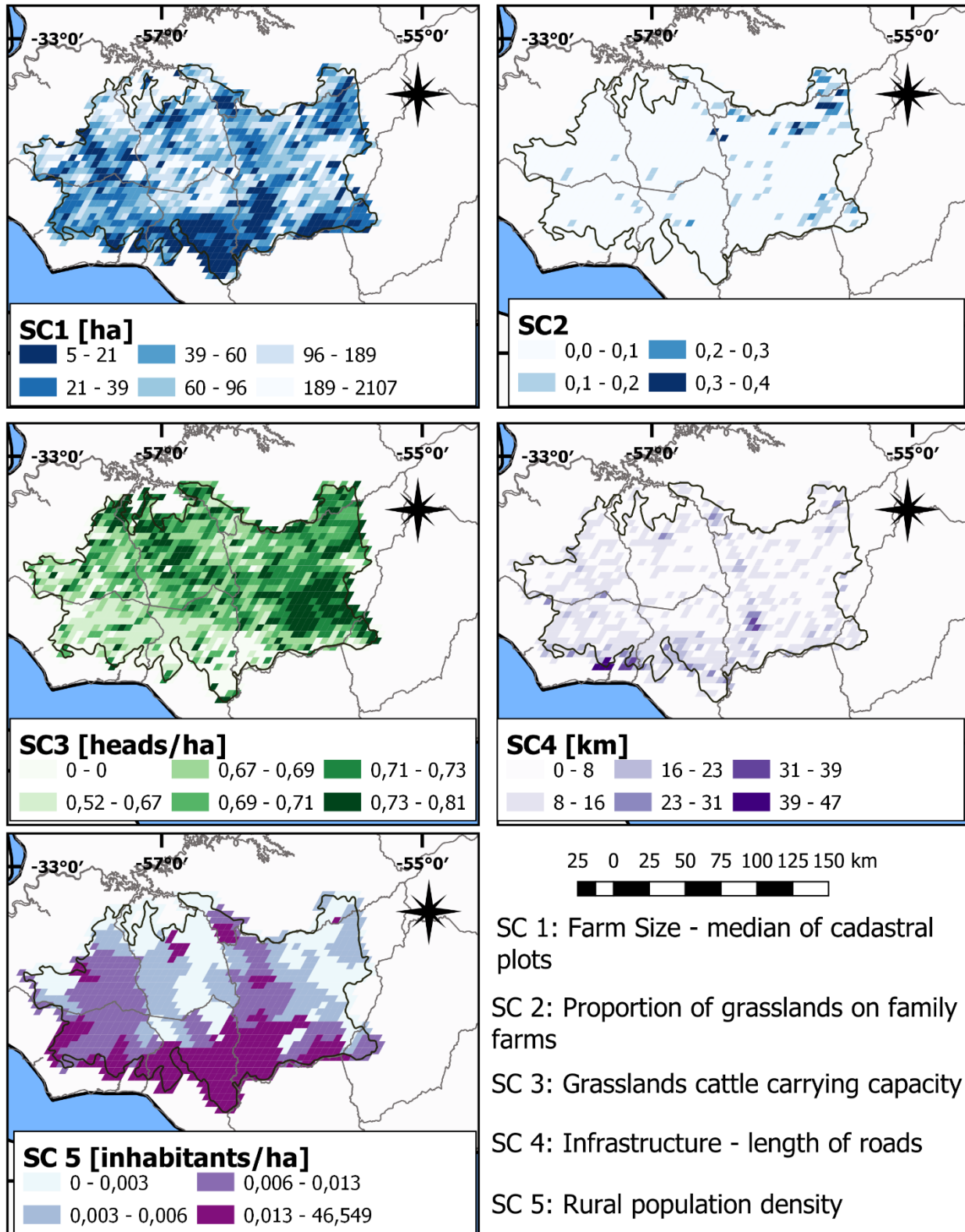
$$HI = 0.715 * ANPP^{0.5} - 5.71$$

Where, ANPP corresponds to the Aerial Net Primary Productivity ($kg \cdot ha^{-1} \cdot yr^{-1}$) and HI represents the Harvest Index ($kg \text{ consumed} / kg \text{ produced}$), the proportion of primary productivity harvested by cattle.

3. For AIC a value of $2,774 \text{ kg} \cdot yr^{-1}$ was taken as a reference suggested by experts of the "Instituto Plan Agropecuario".

Finally, combining the three inputs (ANPP at the 5x5 km cell for grassland areas, HI and AIC), the mean cattle carrying capacity (CC) ($heads \cdot ha^{-1}$) of natural grassland areas was mapped.

Infrastructure (SC4)	An index of infrastructure of each cell was characterized through the sum of the kilometers of road of the official national road network (Ministerio de Transporte y Obras Públicas, 2017).
Population (SC5)	The rural concentrated population was characterized based on information from the 2011 Census of Population, Housing and Households provided by the National Statistics Institute (INE, for its acronym in Spanish Instituto Nacional de Estadísticas). Article 3 of the National Statistical System Law (Law 16.616) establishes that statistical confidentiality obliges to treat the data provided individually with total confidentiality. Therefore, the most detailed spatial resolution to which it is possible to access the information corresponds to the census segment, which usually comprises more than one cell of 5x5 km. For this reason, each cell was characterized according to the rural population density ($inhabitants \cdot ha^{-1}$) of the census segment in which its centroid was located.



Supplementary Figure 3. Maps of indicators for the 5 socioeconomic criteria

3 Weighting of criteria: Saaty scale and consistency analysis

One of the advantages of using the Saaty scale is that it allows obtaining a measure of the consistency of the weights to assess whether the preferences were made through an informed and consistent judgment (Saaty, 2014). For this, the matrices must satisfy the properties of reciprocity (e.g., if criterion A is moderately more important than B, then B must be moderately less important than A), transitivity (e.g., if criterion A is more important than B and B is more important than C, then A must be more important than C), and proportionality (e.g., if A is moderately more important than B and B is moderately more important than C, then A must be extremely more important than C). To verify that the comparison matrix complies with these properties, the method proposes to perform an analysis of the consistency of the decisions through the Consistency Ratio (CR):

$$CR = \frac{CI}{RI}$$

Where, CI is the Consistency Index of the matrix and RI is the Random Index. The CI is a measure of the deviation in the consistency of the comparisons matrix and is calculated as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where, λ_{max} is the product between vector B (Supplementary Table 2) and the priority vector C (Supplementary Table 2) and n corresponds to the total number of elements to compare. In a perfectly consistent matrix, the vector C multiplied by the vector B is equal to the number of elements to compare. The RI is the mean consistency index of 50,000 randomly generated matrices, with forced reciprocals, that are consistent. It was calculated and tabulated for different sizes of comparison matrices (for 5-criteria matrices RI = 1.12) (Saaty, 1977). A CR \leq 10% assumes an informed and consistent judgment and implies accepting up to 10% of the inconsistency that would have been obtained by chance.

4 Results

Supplementary Table 5. Weighting values of the 12 individual stakeholders for the ecological criteria (EC1: Protected areas, EC2: Faunal diversity, EC 3: Functional diversity, EC4: Remaining grassland area, and EC5: Supporting and regulating ecosystem services supply) and Consistency Ratio (CR) of the matrices of comparison with the Saaty scale. Each row from column EC1 to EC5 corresponds to the individual weighting vector of each stakeholder.

Stakeholder	EC1	EC2	EC3	EC4	EC5	CR
1	0.10	0.10	0.06	0.44	0.29	0.17
2	0.06	0.09	0.04	0.60	0.21	0.10
3	0.03	0.05	0.07	0.63	0.22	0.26
4	0.21	0.09	0.02	0.45	0.24	0.27
5	0.05	0.05	0.05	0.34	0.52	0.06
6	0.45	0.07	0.08	0.11	0.29	0.11
7	0.13	0.13	0.07	0.23	0.44	0.06
8	0.18	0.27	0.24	0.16	0.16	0.41
9	0.09	0.09	0.09	0.64	0.09	0.00
10	0.07	0.15	0.04	0.47	0.26	0.08
11	0.07	0.04	0.07	0.57	0.25	0.12
12	0.09	0.05	0.05	0.66	0.15	0.08

5 References

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