Regenera$^+$.uy: designing a co-innovation process to apply the principles of regenerative livestock production

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Abstract
Consumers around the world are beginning to demand products whose production systems have environmental guarantees. Among them, those derived from regenerative agriculture have a growing demand in many markets. A comprehensive environmental assessment was carried out in 9 case studies of mixed livestock production farms (cattle and sheep) in Uruguay as a basis for the development of a system redesign process following the principles of regenerative agriculture. The results show that emission intensity was 16.0, 10.5, and 49.2 kg CO2 eq kg-1 of beef, sheep meat, and greasy wool, respectively. Also, a simulation exercise shows a significative reduction of emission through animal genetic improvement. Soil carbon stocks (59.6 to 93.6 Mg ha-1) and the different level of biodiversity assessment show a very good situation with an Ecosystem Integrity Index above 3.5, which implies more a necessity to conserve rather than regenerate. Considering this analysis, the path that farmers begin to walk following the principles of regenerative agriculture is a challenge towards maximizing biological efficiency and environmental optimization through process technology application. All these indicators and the recommended good management practices will integrate into a protocol for making verifiable the prosses and the results.

Introduction
The demand for products from livestock has been changing its international profile, with an increase in consumers who are very concerned about the environmental effects of the systems that produce them. A special interest arises from greenhouse gas emissions due to their impact on climate change and, more recently, regenerative agriculture (RA) has emerged, with special emphasis on factors associated with the soil. RA has had a great impact in areas where a high degree of degradation had been reached. However, although the guiding principles of regenerative agriculture are widely accepted and contribute to the sustainability of the activity, there are production systems that have very good levels of care for resources and therefore must focus on conserving rather than regenerating.
The objective of this work was to analyze the state of environment in broad terms, in nine commercial livestock farms used as case studies. We diagnosed the environmental status of these systems, becoming the basis for a process of redesigning production systems following the principles of RA: minimize tillage, maintain soil cover, build soil C, relying more on biological nutrient cycles, foster plant diversity, restore natural habitats, integrate livestock, avoid pesticides and encourage water percolation (Giler et al., 2021), all of them seeking to improve soil and water health, carbon storage and reversing the loss of biodiversity.

Methods and Study Site
Nine farms of mixed livestock production (cattle and sheep) with production of superfine wool situated in the north of Uruguay were studied. For these farms, greenhouse gases (GHG) emissions, theoretical scenarios with animal genetical improvements, carbon stocks, ecosystem mapping and integrity, water quality and bird assemblages were obtained.

Greenhouse gases emission

The methodology used for the evaluation of emissions of GHG was the life cycle analysis (LCA). The evaluation was spatially delimited from the cradle to the animal's mouth for the supply chain phase and from the animal's mouth to the gate of each farm for the animal phase. Then, the study was integrated as from cradle to gate of the farm, and later emission as transport, industry or consume were not included (Fig. 1). The farms analyzed are characterized by generating several products: beef, sheep meat and wool. Therefore, to calculate the carbon footprint of different co-products, following the recommendations of the ISO 14044:2006 (ISO 2006) standards and the LEAP guidelines (LEAP 2015a, b), the allocation was made regard protein mass (PMA-protein mass assignment). The total weight (kg) of each product was transformed into protein, considering a protein concentration of 18 and 84% for meat and greasy wool, respectively.

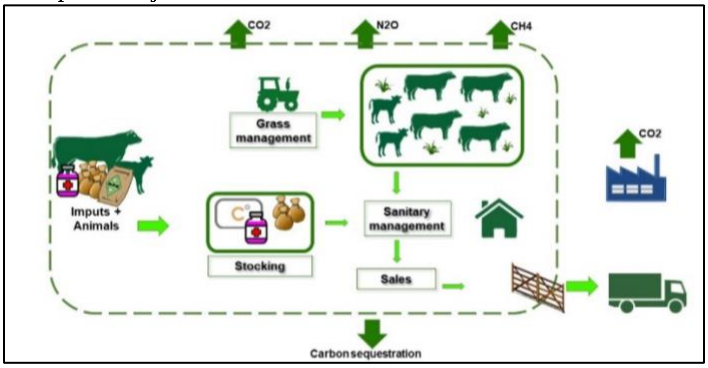

Figure 1 – Limits (dotted line) of the studied system for Life Cycle Analysis (LCA)

Additionally, an estimation of the effect of potential scenarios of animal genetic improvement in farms´ flocks was performed, considering information of the genetic values for certain characteristics of an important Uruguayan population of the Merino breed. These scenarios were estimated changing animal factors in IPCC methodology (efficiency of energy use, feed intake, methane emission or wool production per animal) by values obtained by the top quartile of the animals included in the national genetic evaluation.

Soil carbon stock

The soil carbon stock calculation was developed for two farms representative of two types of soils (basaltic and sandstones-based soils). It had three different stages: a) a remote sensing classification of soils in categories for sampling, b) soil sampling and laboratory analysis to determine carbon concentration and c) calculation of carbon content for each unit defined based on the two previous results.

The stock calculation was made by correcting the carbon content values of each sampled site by the bulk density determined for each site, to obtain g C cm^{-3}. For each soil class, an average value was obtained from ten sampling sites, which was multiplied by the total volume of soil to estimate total C stock (Mg). Total soil volume was calculated as the product of total area of the class resulting in the initial mapping and the average depth of each class in the case of basaltic soils or 30 cm depth for sandstone soils.

Biodiversity analysis at ecosystem level

For this assessment, communities mapping, Ecosystem Integrity Index (EII) and a Water Quality Index (WQI) where performed. Mapping implies the spatial distribution of different land use and communities in each farm, by means of photointerpretation of satellite images, field validation and grassland cartography of Uruguay (MGAP, 2020)

The EII (Blumetto et al., 2019) is an environmental assessment tool which its main objective is to carry out an evaluation of the state of the ecosystem in relation to a "theoretical optimum", established for each ecoregion of the country. It is a continuous scalar index (from 0 to 5), where 5 is the best possible condition and includes four aspects evaluated: vegetation structure, species, soil erosion, and the state of watercourses and their riparian zones. The evaluation method allows to obtain an index value for each paddock and a general value for the entire farm. During the field procedure, the evaluator does not establish the score for each of the components but records the presence of certain detailed characteristics described in a structured field sheet to evaluate the four dimensions mentioned.

Water quality was determined by sampling streams at 5 points of each farm, in the four seasons of the year. The variables measured were turbidity, dissolved oxygen, total dissolved solids, nitrates, pH and phosphorus. A 0-100 scale water quality index (WQI) was elaborated with the mean values of the recorded variables, according to Michalos (2014) applying the formula:

$$WQI = \sum_{i=1}^{n} (C_i \cdot P_i) / \sum_{i=1}^{n} P_i$$

Where "n" represents the number of total variables, "Ci" the value assigned to variable "i" after normalization, and "P" a value between 1 and 4, which factors are assigned in relation to the importance of the variable for aquatic life.

Biodiversity analysis at community level

Bird assemblages was selected as indicator for species/community level. Bird sampling was conducted by applying Mackinnon's lists methodology (MacKinnon and Phillips, 1993). They consist of visual and / or auditive records along paths where the observed species are recorded until reaching a certain amount (10 in this case); then a new list is started where the already observed species can be included again. This methodology was applied in the predominant environments of each farm (native grassland, cultivated pasture, native forest and eucalypt plantations). Species with high conservation value were identified based on the Uruguayan lists of priority species for conservation (Soutullo et al., 2013).

Results and Discussion

Life Cycle Analysis for GHG emission

In average the emissions was 2214 kg CO_2 eq ha^{-1} $year^{-1}$ with a maximum value of 2469 and minimum of 1880 kg CO_2 eq ha^{-1} $year^{-1}$. When the emissions were expressed as intensity (by co-product), the values obtained were 16.0, 10.5, and 49.2 kg CO_2 eq kg^{-1} of beef, sheep meat, and greasy wool, respectively. Methane from enteric fermentation constituted an average of 75.2 and 79.5% of total emissions for cattle and sheep, respectively. The CH_4 emitted by the manure deposition on pastures participated with 1.4 and 1.5%, while the total emissions of N_2O were responsible for 23.4 and 19.0% of the total emissions for cattle and sheep, respectively. The supply chain phase only represented 6.4 % of total emission.

For the simulation of scenarios of sheep genetic improvement in farms´ flocks, traits that directly affect emission factors were modeled. The magnitude of improvement in each variable was established as the difference between the median of the data and the upper quartile of the animals in the national genetic evaluation. Thus, it was established that: in Scenario 1 the dry matter intake is 13.0% lower, in Scenario 2 the metabolizable energy consumed is 14.4% lower, in Scenario 3 the methane produced per animal is 17.1% lower and in Scenario 4 the greasy fleece weight is 12.8% higher.

The simulation resulted in a reduction of 12.0, 19.9, 12.7 and 6.0 % per unit of product (greasy wool in this case) in emissions for scenarios 1 to 4 respectively. These results show a realistic opportunity of improvement of emission performance in a prosses of gradually incorporating top valuated genetics in flocks. These genetic values are available also in other sheep breeds and in bovine for Hereford breed, then this way is viable for other products. Other important improvement to reduce GHG emissions is via the incorporation of a set of good management practices summarized by Jaurena et al (2019).

Soil carbon stock

Regarding to carbon stocks, soils on sandstones reach an average of 56.9 Mg ha^{-1}. In the case of basaltic soils, the values were higher (93.6 Mg ha^{-1}) even though 58% of the area does not reach a depth of 30 cm. According to some preliminary experimental information these levels can be increased, but it would be a very slow process, depending for example on increasing grasses and/or trees biomass production.

Ecosystem level biodiversity

The ecosystem classification produced individual maps for all study cases and revealed that farm areas were covered in average with 78 % of native grasslands and 5% of native forests (example in Fig. 2).
The application of the Ecosystem Integrity Index (EII) showed global values ranging between 3.6 to 4.1 and the values of individual paddocks ranged from 2.1 to 4.2.

The values showed the dominance of natural native ecosystems and a good state of ecosystem integrity (values greater than 3), although there are opportunities for short-term improvement in matters of vegetation structure and the state of the riparian zones. This could quickly improve the value of the EII and in the medium term improve biodiversity in grasslands.

Water quality overall was considered good in all the evaluated farms, where the lowest WQI value obtained was 82 and the highest 95. Water parameters in general indicated signs of low impact of production activities, possibly due to low animal stocking rate and low use of agricultural inputs. The lowest value of WQI obtained corresponds to a farm with the highest agricultural activity in the surrounding zones (rice and sown pastures).

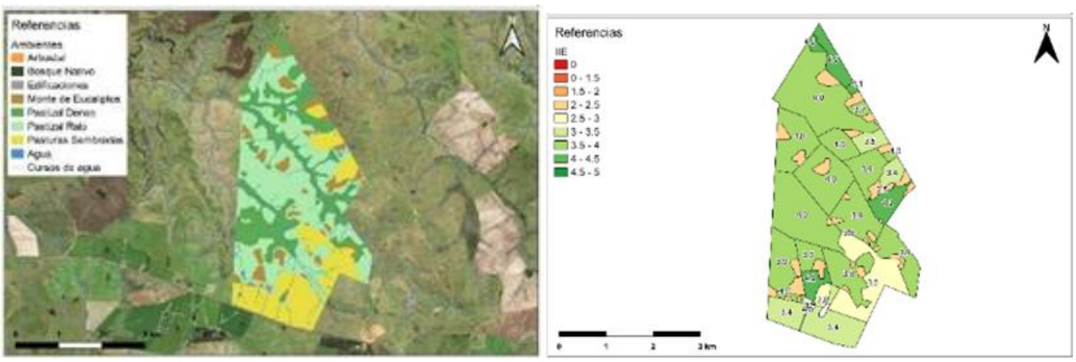

Figure 2. Examples of ecosystem mapping and spatial graphical representation of EII for one farm.

Community level biodiversity

For all the involved farms, 171 bird species were recorded, among which 21 species are considered priority for conservation. Richness by farm range from 50 to 135 and Shannon-Weaver Index from 3.28 to 4.46. The trophic analysis of bird assemblages evidenced that more than half of the bird species belong to the guild of insectivores, which feed on insects or other arthropods; this highlights the importance of the possible role as biological controllers of these populations.

Conclusions

In terms of environmental performance, these systems have the capacity of reducing emissions through the incorporation of genetically improved animals in the flock/herd and the application of process technologies to improve grazing management of native grasslands. These systems have a high reserve of carbon in the soil, which, although possible, makes it difficult to increase sequestration. The good state of biodiversity and water quality means that the main objective is to conserve rather than regenerate. However, the management of grazing strategies, standing forage reserves, planting native trees for livestock shade and shelter and restoring the state of riparian zones are important actions of the strategy to be developed. The current environmental status of the studied cases demonstrates that most of the principles of regenerative agriculture are fulfilled, however we are proposing a co-innovation process to redesign the systems to meet greater environmental demands.

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