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Management Strategies for a Win-win Relationship between Increasing Productivity an Environmental Protection: Proposal Bases and First Results

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Abstract. Most of Uruguay land is under agricultural use, which remarks the necessity to think about lands with productive systems within a general strategy for biodiversity conservation and ecosystem services preservation. Extensive livestock production is able to reach this objectives but needs to improve productivity for not to compromise economic viability. We present a model for evaluate sustainability in a co-innovation work with 16 pilot farms distributed all around the country. Base line levels of productivity, water quality and biodiversity were established and are periodically monitored. The first results of a study case are presented. The base line of water quality was optimal for streams with a 96 WQI. Regarding to biodiversity a large number of wild species were registered: herbaceous plants (47), trees (25), birds (69) and spiders (19). Ecosystem integrity index was 3.8 for this farm. After diagnosis, a redesign of productive system was accorded with the farmer and one year later productivity has increased 24 % with no environmental changes detected in short term monitoring.

Keywords: Sustainable Production, Ecosystem Services, Biodiversity, Water Quality, Natural Livestock Production.

1. Introduction

Almost all Uruguayan lands are private property and most of them have some agriculture use. [1] Because of this, every strategy of nature conservation must consider production systems. This includes, not only resources that are strongly related to production as soil and water, but also the rest of the ecosystem services, including biodiversity. On the other hand, agricultural production is one of the most active economic sectors in the country, having a high social importance. Livestock production occupies about 80 % of the surface and employs most of the rural population of the country. [1] Then is highly important to develop livestock production strategies to improve productive results while ensuring the maintenance of ecosystem services.

2. Material and Methods

The work was carried out in 16 pilot farms (cattle and sheep) distributed in four regions across the country, representing contrasting agro-ecological zones, using the co-innovation approach. [2] Next steps were followed: 1- characterization and diagnosis, 2- re-design and 3- implementation, monitoring and evaluation. [3] Redesign of production system were accorded with farmers after a first year of diagnostic and for monitoring pilot farms, a set of indicators was selected, grouped in the following areas: soil, pastures, animals, environment and economic results. Then production and environmental variables were monitored. In all farms sampling was done on reference units that consist in some specific paddocks. Each paddock is a

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grazing area that is a sub-division of a grazing management unit and is enclosed and separated from other areas by a fence. [4]

2.1. Hypothesis

Traditionally extensive livestock production has subjected natural grasslands to overgrazing, resulting in a reduction of productive potential and compromising ecosystem health. We hypothesise that a general reduction of animal stock and an adequate ovine/cattle relation, optimizing animal category structure and managing stocking density based on forage availability in every moment of the year, could improve productive results and preserve natural ecosystems, its wild communities and its services running.

2.2. Productive Measures

All Stocking rate (LU/ha), sheep/cattle relation, meat productivity (kg equivalent meat/ha) and economic results as net income (U$S/ha) were calculated for each farm annually. Results after the re-design implementation were compared with the results of the previous 3 years.

Forage mass (kg DM•ha^{-1}) was estimated every 45 days by the comparative yield method. [5] Every 45 days, 9 reference quadrates of 0.25 m2 were cut at ground level and 100 quadrates per plot were visually measured per paddock. Forage samples were dried to constant weight at 60 ℃, weighed, then double-ground using a Willey mill to pass through a 1-mm screen for chemical composition analyses.

2.3. Water Quality

Water was seasonally (four times a year) sampled on streams and dams in at least six points in each farm. Turbidity, dissolved oxygen, total dissolute solids, nitrate, pH and temperature were measured with a Hanna HI 9828 Multiparameter meter. Phosphorus was determined with Hanna HI736 Handheld Colorimeter - Phosphorus Ultra Low Range. A water quality index was obtained with media values of selected variables. [6] The calculation of the index was done through the following formula [7]:

$$ICA = \sum_{i=1}^{n} (C_i . P_i) / \sum_{i=1}^{n} P_i,$$

where n represent the number of total variables, C_i the value assigned to variable i of the normalization and P is the value between 1 and 4, where 4 is assigned to the more important variable for aquatic life (e.g. dissolved oxygen). [8] Normalization values and importance assigned to each parameter is presented in Table 1.

Table 1: Normalization range of parameters used for building water quality index. Total dissolved solids (TDS), Turbidity, hydrogen ionic potential (pH), dissolved oxygen (DO), total phosphorus (TP) and nitrates (NO_3).

			Parameters			
Normalization factor (*Ci*)	**TDS (mg l^{-1})**	**Turbidity (FNU)**	**pH**	**DO (mg l-1)**	**TP (µg l^{-1})**	**NO_3 (µg l^{-1})**
100	50 ≥ X ≤ 100	X ≤ 2.5	6.8 ≥ X ≤ 7.2	X ≥ 7.5	X ≤ 30	X ≤ 100
90	<50, 100 > X ≤ 120	2.5 > X ≤ 5	7.2 > X ≤ 7.4, 6.6 ≥ X < 6.8	7.5 < X ≥ 7	30 > X ≤ 300	100 > X ≤ 1500
80	120 > X ≤ 150	5 0 X ≤ 15	7.4 > X ≤ 7.6, 6.4 ≥ X < 6.6	7 < X ≥ 6.5	300 > X ≤ 1000	1500 > X ≤ 3000
70	150 > X ≤ 200	15 > X ≤ 20	7.6 > X ≤ 7.8, 6.2 ≥ X < 6.4	6.5 < X ≥ 6	1000 > X ≤ 1500	3000 > X ≤ 4500
60	200 > X ≤ 250	20 > X ≤ 25	7.8 > X ≤ 8, 6 ≥ X < 6.2	6 < X ≥ 5	1500 > X ≤ 2000	4500 > X ≤ 6000
50	250 > X ≤ 350	25 > X ≤ 35	8 > X ≤ 8.2, 5.8 ≥ X < 6	5 < X ≥ 4	2000 > X ≤ 2500	6000 > X ≤ 7500
40	350 > X ≤ 400	35 > X ≤ 50	8.2 > X ≤ 8.4, 5.6 ≥ X < 5.8	4 < X ≥ 3.5	2500 > X ≤ 3000	7500 > X ≤ 9000
30	400 > X ≤ 450	50 > X ≤ 70	8.4 > X ≤ 8.6, 5.4 ≥ X < 5.6	3.5 < X ≥ 3	3000 > X ≤ 3500	9000 > X ≤ 10500
20	450 > X ≤ 500	70 > X ≤ 90	8.6 > X ≤ 8.8, 5.2 ≥ X < 5.4	3 < X ≥ 2	3500 > X ≤ 4000	10500 > X ≤ 12000
10	500 > X ≤ 550	90 > X ≤ 110	8.8 > X ≤ 9, 5 ≥ X < 5.2	2 < X ≥ 1	4000 > X ≤ 4500	12000 > X ≤ 13500
0	X >550	X >110	X >9 , X <5	X <1	X > 4500	X > 13500
Relative importance	2	3	1	4	3	2

2.4. Biodiversity

Biodiversity was evaluated through monitoring of four different variables, species composition of the herbaceous community, structure of bird and spider assemblages and an Ecosystem Integrity Index.

Herbaceous plant communities of natural grassland were annually evaluated in the reference units using the point quadrate method. This method was used in each transect recording all species present at contact points every 50 centimeters. Distribution of species was studied by calculating specific frequencies, richness and diversity indices.[9]

Birds were monitored each season following line transects [10] at three reference units in each farm. Transects were divided in several 300 m segments, totalizing 900 to 1800 m long depending on the area of the reference unit. In every case the presence of species using habitat and number of individual was recorded.

Spiders are common generalist predators in terrestrial ecosystems, broadly used in diversity studies. In this case we focused on grassland spider community. Captures were done with sweep netting directly on natural grasslands and sown pastures. [10] Ten samples of 20 sweeps were taken in every reference unit, determining species presence and number of individuals. Species were classified into their belonging guilds.

Ecosystem Integrity Index is a tool in development phase, whose main objective is to evaluate the ecosystem capacity for maintaining services and wildlife while it is properly used for livestock production. It is constructed to quickly assess the status of the ecosystem relative to the same environment in a low intervention, natural condition. It is a 10 points scale index (from 0 to 4.5, 0.5 step) that includes four aspects: vegetation structure, species presence, soil erosion and state of streams including water, riparian zone and vegetation. Values were determined for each paddock and a general value was calculated by prorating the area contribution of each paddock. All farm is evaluated in only one day at the beginning of diagnostic and re-evaluated every two years.

3. Results and Discussion

In order to show advances in the results and considering the amount of information being recorded, we are presenting a study case. It is a 92 hectares farm, situated in a hilly and rocky landscape, in Rocha department in the east region of the country.

3.1. Productive Results

Stocking rate decreased from 0.98 ± 0.3 to 0.91 ± 0.25 LU/ha after re-design implementation compared to the average of 3 previous years, while sheep/cattle relation decreased from 2.3 ± 2 to 1.7 ± 1.5. Meat productivity increased 24% after re-design implementation (100.8 ± 36 v. 125.3 ± 42 kg equivalent meat/kg, for 3 previous years v. after re-design, respectively), while net income increased 85% (58.5 ± 48 v. 108.1 ± 79 U$S/ha, for 3 previous years v. after re-design, respectively).

Forage production increased in most of the paddocks. In Fig. 1 the average forage mass (kgDM/ha) per month for every farm is showed. An increase in forage mass, mainly in the second spring (Nov_13) since the project started, can be observed. This evolution of forage mass can result in more forage grouth and more food available for animals, which can explain improvement in some results as kg of equivalent meat obtained in the farm.

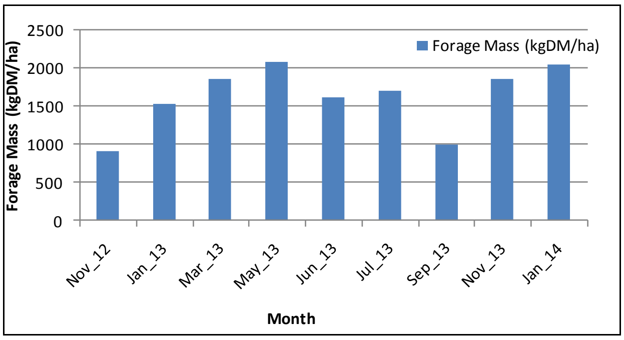

Fig. 1: Forage mass (kg DM/ha) in reference units.

3.2. Water Quality

General water quality was good in both streams and dams, although the turbidity and dissolved oxygen were worse values for dams, reducing respective index. WQI was 96 and 74.7, for streams and dams respectively. In Table 2 selected parameters for the WQI are presented.

Table 2: Parameters registered for analysed water (media ± SD)

Type	DO ppm	pH	Turbidity FNU	TDS ppm	NO^3	TP ppb
Streams	8.75±2.7	6,5±0.4	5,3±14.8	59,4±21.2	0.42±0.1	37±18.8
Dams	3.1±2,9	6,8±0.4	110,0±33.4	107,0±43.8	0.40±0.1	29.8±29.8

The good water quality maybe due to the low density of livestock and the good conservation of vegetal communities which might maintain a low nutrient concentration and erosion. However the increase of turbidity in dams is promoted by the entry of cows to shallow zones for refreshing or reaching clear water in the deep zone. This situation and the higher average temperature of dams probably caused the reduction of dissolved oxygen.

3.3. Biodiversity

Regarding to vegetal biodiversity, at the beginning of project 43 species of herbaceous plants and 25 species of trees associated to grasslands were found. No alien plants were detected. The 15 main species in terms of % soil covering were: *Andropogon lateralis* (26), *Piptochaetium montevidense* (11), *Axonopus affinis* (10), *Richardia humistrata* (9), *Paspalum pumillum* (7), *Panicum sabulorum* (5), *Trachipogon montufari* (4), *Ciperus sp.* (4), *Andropogon ternatus* (3), *Aristida venustula* (3), *Agenium sp.* (2), *Chevreulia sarmentosa* (2) and *Juncus sp.*(14,4).

In terms of bird diversity, in this farm we observed 69 species of birds during the first year of counts, which represents 42 percent of the species observed in the farms of the region. Most of them, 38 percent of the birds observed in the region, were detected in managed areas of the farm. The majority of these areas are natural grassland under cattle grazing.

Three species with some grade of global conservation concern were registered: *Xolmis dominicanus*, *Limnoctites rectirostris* and *Picumnus nebulosus*. These species might be present due to the existence of conserved suitable habitat for them within natural grasslands or non-cultivated areas and field margins. These areas are covered with mostly natural vegetation formations or native and spontaneous plant species that could be providing birds with habitat structure and other favourable resources. [11], [12]

Species richness was greater in natural grasslands than in sown pastures. Thirty-two species were found only in natural grasslands being *Colaptes campestris*, *Xolmis irupero*, *Phacellodomus striaticollis*, *Turdus amaurochalinus*, *Anumbius annumbi* and *Athene cunicularia* (in that order) the most frequent ones.

Birds use of habitat, and thereby species composition and diversity in different environments, might be responding to environmental structure, as reported by other studies in the region. [12], [13] The dominant species detected in artificial grasslands are mainly species that prefer short grass cover and open places whereas in natural grassland there were species with mixed preferences. The proportion of different land covers (majority of natural grasslands) and its structural conservation could be explaining bird diversity levels in this farm. Therefore, this kind of farming systems could prove to be conserving bird diversity provided that they maintain a high proportion of land covers with well-preserved structural complexity.

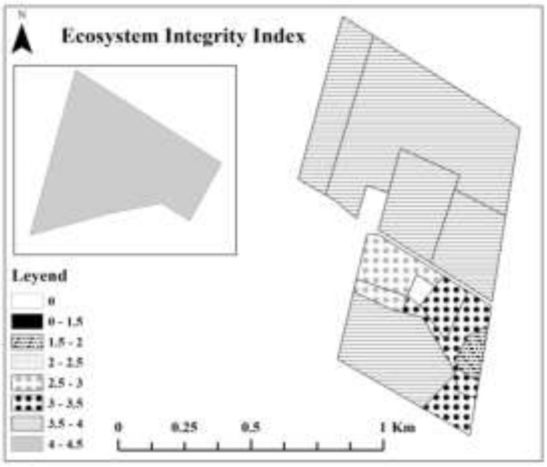

Fig. 2: Ecosystem integrity index values for each paddock of the farm

Regarding to spider communities, nine families belonging to seven different guilds and a total of 19 species were registered. In both evaluated situations, natural grassland (NG) and sown pastures (SP), the most frequent guild was orbicular web weavers and *Larinia vivittata* the most frequent species. Community structure was similar, 14 species were determined for NG and 16 for SP. Irregular web weavers guild was found exclusively in NG and ground hunter runners guild was found only in SP.

General ecosystem integrity index for the whole farm was 3.8, which results from the prorating average of good indexes in the majority of the area and a more intensive production zone with lower values in a relative small zone. In Fig. 2 the distribution of index values for each paddock is shown.

3.4. General Discussion

Most of the studied farms have most of its land covered with natural grassland and other environments as woodlands and wetlands, conserved environments with presence of a large number of native wild species of grasses, herbs, trees, spiders and birds, including rare and species with conservation risk.

The water quality shows signs of low impact from production activities. This may be due to the low intensity of these production systems where cattle density, farm inputs and management practices are low.

These levels of environmental indicators at the starting situation of this farm show a production system with relatively low impact on ecosystem structure. The first changes promoted in the production system, showed to be successful on improving productive results and no evidence of compromising environmental health of the managed ecosystem has been recorded in short term, which reinforce the hypothesis of win-win relationship between production an environmental protection. In the medium and long term, new adjustment will be done in the production system management and probably special management measures would be necessary for ensure maintaining ecosystem services and wildlife.

The first predictable challenge is to maintain the grassland structure diversity that can be compromised by grazing strategies which tend to maximize the grass biomass utilization by livestock and could cause a homogenization of grassland structure and reduction of young trees survival.

4. Conclusions

Only primary conclusions are possible because we are in the first phase of the study, but we found an initial good state of natural resources and associated biodiversity. The co-innovation work is running properly and the first productive results after re-design of production systems show an improving productivity. Also, the set of environmental evaluation tools are showing no negative impacts due to this implementations and they lets us monitor the ecosystem evolution and, eventually, modify management strategies if ecosystem functions are affected.

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