Scientific Paper

*Evaluation of the natural pastureland in a silvopastoral system with willow (*Salix humboldtiana*)*

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ABSTRACT: The objective of this study was to determine, in the pasturelands of the willow forest, the net aerial primary productivity (NAPP), the seasonal botanical composition of the functional groups and the estimated seasonal cattle receptivity. The total annual NAPP was 5 210,6 kg DM/ha/year, from which 2 544,8 kg DM/ha occurred in the summer, with statistically significant differences with regards to the other seasons: spring 1 669,3 kg DM/ha, winter 626,2 kg DM/ha and autumn 370,3 kg DM/ha. The botanical composition of the pastureland per functional group showed that more than 57 % of the biomass of the annual NAPP was dominated by grasses; the highest participation percentage was recorded in the summer, in which this genus represented 80 % of the biomass. On the other hand, the wide functional group of latifoliate plants remained constant with regards to the species present in the biomass throughout the year. The summer was the season with the highest cattle receptivity, with 1,17 CE ha^{-1} day^{-1}. The spring was ranked second, with a receptivity estimation of 0,76 CE ha^{-1} day^{-1}. On the other hand, the winter showed a carrying capacity of 0,29 CE $ha^{-1}day^{-1}$, and the autumn, of 0,17 CE ha^{-1} day^{-1}. It is concluded that the willow forest is a pastureland that should be grazed as summer forage resource.

Keywords: stocking rate, forages, net primary productivity

INTRODUCTION

The islands of the Pre-Delta of Diamante (Entre Ríos province, Argentina) constitute the northern and oldest part of a large swamp which is extended from this zone, continues towards the south throughout the Paraná Delta and ends in a cluster of young islands on the estuary of La Plata River, almost in front of the city of Buenos Aires.

Swamps are one of the most productive and ecologically important ecosystems that exist in our planet, due to the ecosystem goods and services they contribute (Mitsch and Gosselink, 2000; Kandus *et al*., 2010).

The landscape of the Pre-Delta islands is dominated by communities of pasturelands, grasslands and reedbeds for livestock production purposes. The intensity of the farming activity in the entire region is clearly defined by the relief shown by the islands; the lowest and most floodable areas are the ones with higher livestock production risk, being affected by the recurring river floods and inundations (Morello *et al*., 2012).

The best pasturelands of these islands are prairies that grow beneath the open small forests of Humboldt's willow (*Salix humboldtiana*), called willow forests. These communities of willows occupy almost always the highest coastal edges of the islands, and this environment is highly valued by the islands' cattle farmers. The raised lands are the least flooded part by the recurring inundations that affect the islands. On the other hand, at the center of the islands topographically depressed environments prevail and very often the central landscape is dominated by lagoons and marshlands (Franceschi *et al*., 1985; Marchetti and Aceñolaza, 2011).

In fact, willow trees form a silvopastoral system (SPS) integrated by pastureland and an open forest of Humboldt's willow, and are used for beef production with cattle. Silvopastoral systems constitute one of the farming production models with higher advantages to mitigate the climate change and provide a productive environment with good conditions for animal welfare (Alonso, 2011). The island farmers of this region use them actively for grazing since many decades ago (Laclau, 2012).

At present there is a lot of information about the forage species of some pasturelands types of the Delta, but there are few studies regarding the

seasonal productivity, the botanical composition of the functional groups and the carrying capacity of the grasslands of the Humboldt's willow forests in these islands of the Pre-Delta of Diamante (Quintana *et al*., 2014; Rossi *et al*., 2015).

Given the great pastoral importance of the natural pasturelands of the island willow forests for the regional cattle production and their environmental and ecosystem services, which should be preserved (Quintana *et al*., 2014), this study was conducted in order to evaluate a natural pastureland in a silvopastoral system with willow tree.

MATERIALS AND METHODS

Location, surface and characteristics of the trial area. The study was conducted on an island of the Pre-Delta of the Paraná river, Diamante department, Entre Ríos province. The island is geographically located between the main riverbed of the Paraná river and the Las Arañas stream (32º 01'47,0" South and 60º 39' 12,7" West).

The total surface of the island is 278 ha, from which 63 ha correspond to a silvopastoral system of Humboldt's willow forest with natural prairie type pastureland, where the measurements and the samplings were made.

The climate of this region is humid temperate of plains, with an annual daily mean temperature of 18,2 ºC and variation between 24,7 ºC in January (warmest month) and 12 ºC in July (coldest month). The mean annual rainfall is 1 100 mm (Servicio Meteorológico Nacional, 2016). The vegetation is characterized by small willow forests, where woody scrubs, with a large plant density, and the tree stratum, which decreases in density and is naturally thinned as it grows, are combined. In the site of the study the willows averaged a height of 8 m, and their foliage was at 1,5-1,8 m from the soil. The natural pastureland is a typical swamp prairie which has forage quality that makes it apt for an extensive cattle production use. Among the main species that compose it are timothy canarygrass (*Phalaris angusta*), knotroot bristlegrass (*Setaria geniculata*) and Bermuda grass (*Cynodon dactylon*), accompanied by some latifoliate plants such as Guernsey fleabane (*Conyza sumatrensis*) and whitemouth dayflower (*Commelina erecta*) (Massa, 2012).

Cattle production structure and grazing system. The site where the study was conducted responds to a typical island cattle production field of family management. A rearing herd of 90 heads (annual average) of the British cross phenotype grazed continuously throughout the year, because there was no perimeter fence in the island. The categories that formed the herd during the experimental period were 40 cows with calves and 50 breeding steers, of 250 kg of average live weight at the beginning of the trial.

The grazing system during the study was extensive and continuous, as is characteristic in the fields of this region of the Paraná Delta islands. The farmer of this region regulates the stocking rate withdrawing the steers from the field (generally for sale) during the autumn, before the arrival of the winter.

The stocking rate was expressed in cow equivalent: CE ha^{-1} day^{-1}. For its estimation the seasonal and annual receptivity were calculated, based on the product between the net aerial primary productivity (NAPP) of each season and a harvest index –estimated in 50 % of the harvested forage, as factor of use–, and divided between the daily individual animal intake of 12 g DM CE^{-1} day^{-1} (Coccimano *et al*., 1977; Díaz, 2007; Vecchio *et al*., 2008).

Sampling and measurements. The net aerial primary productivity in the willow forest was measured according to the methodology proposed by Singh *et al*. (1975) and Sala *et al*. (1988).

For the exclusion of grazing in the sampling spots, six metallic cages of 0,5 x 0,5 m^2 (0,25 m^2) were used, distributed completely at random and with fixed location. In each of the cages an initial cutting was performed (without collecting the forage) at the moment of placing each cage at zero time.

The cuttings in the pastureland were made with scissors, in each of the seasons (spring, summer, autumn and winter); the plants were cut even, with a frequency every 65 ± 21 days. The period of recorded data corresponds to one year.

In each season six samples were obtained (one for each exclusion cage), which were processed to obtain information of the botanical composition and NAPP.

To determine the botanical composition of the pastureland in each season, the green biomass of each sample cut in three subsamples, corresponding to three functional groups: grasses, latifoliate plants and other species, was classified and separated. The dry matter (DM) of the subsamples was obtained when drying them in forced-air stove at 60 ºC during 96 h, until reaching constant weight.

The dry weight of each sample was calculated as the sum of the weight of the DM obtained from each subsample. The DM percentage contributed to the total DM of the sample was also calculated for each functional group.

The botanical composition of each season was calculated from the sum of the averages of each functional group.

The calculation of the seasonal NAPP was made based on the DM average obtained from the six samples of each season, and the annual estimate of the total NAPP as the sum of the averages of each season and expressed as kilograms of DM per hectare.

Statistical analysis. An ANOVA was made between the seasons of the year (classification variable) and the NAPP (response variable). The mathematical model used was:

Yij = general mean (μ) + Łi + εij

where:

εij is the NAPP of season *i* in the exclusion cage *j*

Łi is the effect of season *i*

εij is the term of random error associated to the observation *Yij*

The mean values of the NAPP, resulting from the ANOVA, were subject and arranged according to a multiple comparisons test (Tukey's test; for alpha = 0,05). The statistical program InfoStat was used.

RESULTS AND DISCUSSION

Figure 1 shows the NAPP values per seasons. The highest NAPP proportion of the pastureland was obtained when the temperatures were warmer, which in this region occur at the end of spring and mainly in the summer (December-March).

Thus, in the summer almost half the total DM productivity was accumulated, with statistically significant difference with regards to the other seasons, which did not differ among themselves.

The spring was the second season in NAPP, with an accumulated average value of 1 669,3 kg DM/ha. On the other hand, the seasons with the lowest averages of accumulated biomass were the winter and autumn.

The sum of the annual NAPP was 5 210,6 kg DM/ha/year. In this sense, in the wide bibliographical review about the Paraná swamp made as part of this study, no scientific information published about the NAPP of the pasturelands of these islands was found.

The percentage results of the botanical composition of the pastureland classified by functional groups (grasses, latifoliate plants and others) for the four seasons of the year are shown in figure 2.

With regards to the functional groups for all the seasons of the year, more than 57 % of the biomass of the NAPP was dominated by the grasses (Poaceae). The highest participation percentage was recorded in the summer, season in which this genus represented 80 % of the biomass.

In the grassland there was predominance of C4 plants and, to a lower extent, C3 plants. The main dominant species in this functional group were, among C4: *Eriochloa punctata*, *Setaria geniculata*, *Cynodon dactylon*, *Panicum laxum* and *Paspalum conjugatum*, and among C3, *Phalaris angusta*. *P. laxum* and *P. conjugatum* showed a remarkable increase in the biomass percentage in the measurements corresponding to the summer,

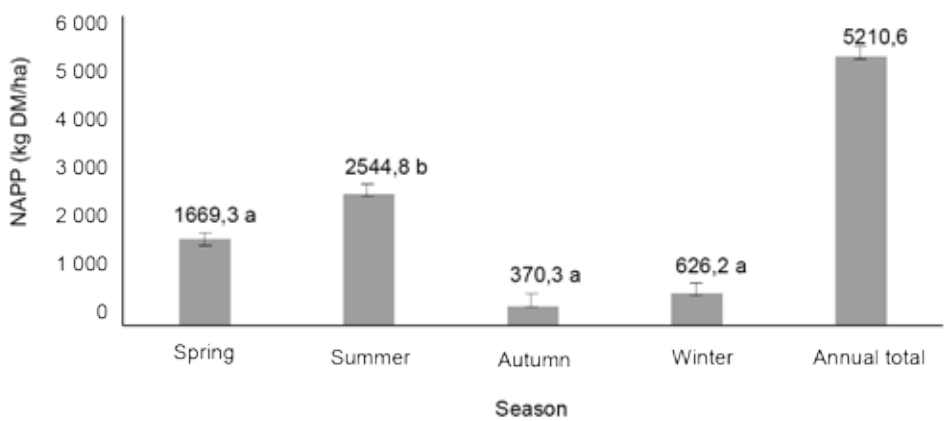

Figure 1. Seasonal net aerial primary productivity (kg DM/ha) and annual total (kg DM/ha/year) in the pastureland of a SPS with willow (Tukey's test: equal letters do not differ significantly for p < 0,05).

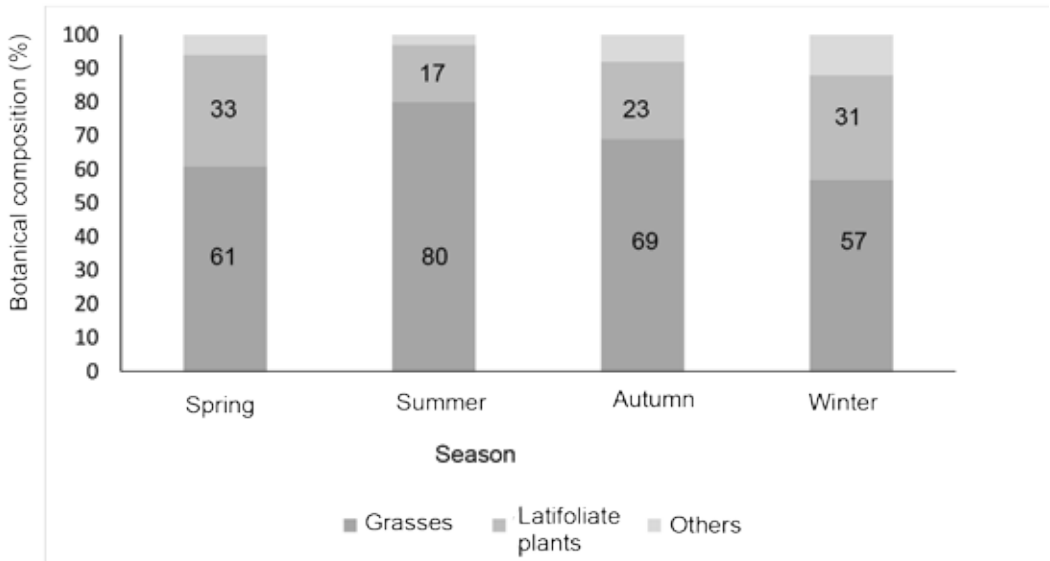

Figure 2. Seasonal botanical composition of the functional groups in the pastureland of a SPS with willow.

which is associated to the environmental role played by the trees, by contributing shade that favors the grassland, decreasing evapotranspiration and moderating the high temperatures during the spring and summer. This also propitiates benefits for cattle, because it provides a comfort environment with characteristics of microclimate for it (Alonso, 2011). These two perennial grasses are preferred by the animals, and in spite of being C4, they also dominated in the pastureland in the autumn and part of the winter. Such phenomenon can be ascribed to the prevailing microclimate environmental conditions in the islands, given that, being a swamp, the effects of the low winter temperatures were remarkably moderated.

On the other hand, the wide functional group of latifoliate plants maintained the species present in the biomass constant throughout the year. Within them, *C. sumatrensis* and *C. erecta* showed higher participation percentage variation in the biomass among seasons.

The functional group of other species always maintained a low participation in the biomass in all the seasons, which varied between 1 and 11 %.

The floristic composition and its dominant functional groups present in this study cannot be compared with previous results, because there are no bibliographic antecedents, as it was stated above. In this sense, Malvárez (1999) only described botanically and listed the main species present in the farm corresponding to the region where this study was conducted, but without mentioning the functional groups or their percentage participation in the pastureland biomass.

The estimated results of the cattle receptivity per season and the annual average are shown in figure 3. These values, based on the data of the NAPP, maintained the statistically significant difference between the summer and the other seasons, which did not differ among themselves.

The data showed that the pastureland of the willow forest had an active growth in the spring-summer, with a high productivity peak during the summer. In this sense, the summer was the season of higher cattle receptivity, with 1,17 CE ha^{-1} day^{-1}. The spring was ranked second, with a receptivity estimation of 0,76 CE ha^{-1} day^{-1}.

The autumn-winter period was the one with the lowest carrying capacity, with 0,29 CE ha^{-1} day^{-1} in the winter and 0,17 CE ha^{-1} day^{-1} in the autumn. This distribution of the receptivity values is explained by the predominance of C4 species in the pastureland of the willow forest. It is evident that this pastureland should be managed in the summer.

The annual average was 0,6 CE ha^{-1} day^{-1}. Such result is in the agreement with the cattle receptivity values reported by Rossi and González (2014) for the Low Delta, in natural pasturelands of SPS with poplars and willows planted with low density.

On the other hand, Peri (2012) also referred similar values and emphasized that in the SPS of

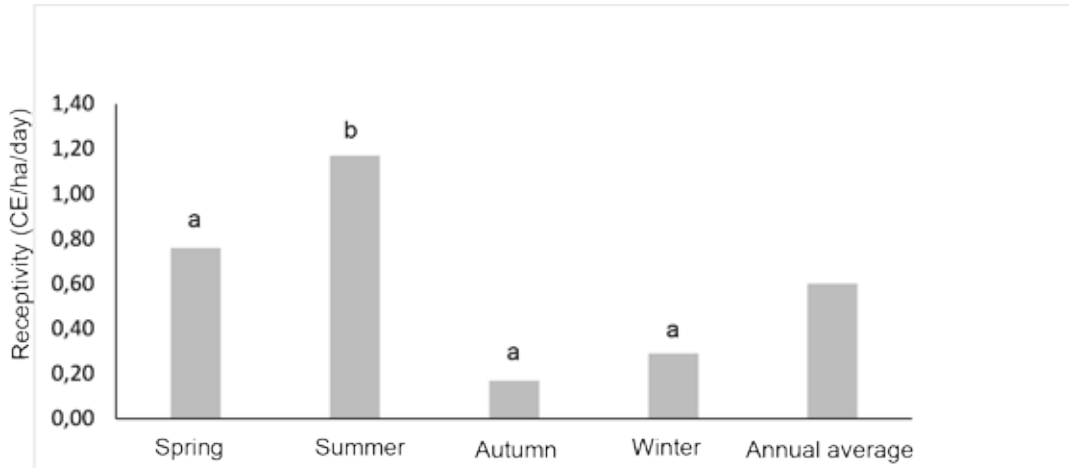

Figure 3. Seasonal cattle receptivity (CE ha-1 day-1) and annual average (CE/ha/year) in the pastureland of a SPS with willow (Tukey's test: equal letters do not differ significantly for $p < 0,05$).

the Low Delta the rearing cattle production is increasing, whose annual stocking rates average between 0,4 and 0,5 CE ha^{-1} $year^{-1}$, with a production of 60 to 100 kg of beef ha^{-1} $year^{-1}$.

The island willow forests of the Pre Delta of Diamante constitute swamp ecosystems that are used for grazing, and due to the ecosystem and environmental services provided by them, they should be managed and protected with sustainability criteria.

As SPS, the willow forests have an acceptable carrying capacity as summer pasturelands. Their autumn-winter utilization is extremely limited, due to the low carrying capacity, and risky, because of the deleterious effects of overgrazing in this period of the year with low temperatures. An alternative for their autumn-winter utilization is as differed standing forage. For such purpose, they must be divided into grazing plots, and thus the enclosed area could be closed during mid-late summer. In order to preserve the structure and forage qualities of the willow forest pastureland and contribute to its sustainability, the overgrazing of the species of good forage value should be avoided in general, for which it is essential to make the calculation of stocking rate estimation for each situation of the year, practice that it is almost not performed at present.

CONCLUSIONS

The willow forest pastureland was highly productive during the late spring and mainly in the summer (December-March), and the carrying capacity of the summer was the highest. On the other hand, the net aerial primary productivity during the autumn-winter was extremely low, for which its utilization as differed standing forage is recommended. Likewise, the willow forest is a pastureland that should be grazed as summer forage resource.

BIBLIOGRAPHIC REFERENCES

Alonso, J. Los sistemas silvopastoriles y su contribución al medio ambiente. *Rev. cubana Cienc. agríc*. 45 (2):107-115, 2011.

Coccimano, M.; Lange, A. & Menvielle, E. *Equivalencias ganaderas para vacunos de carne y ovinos*. Argentina: AACREA. No. 23, 1977.

Díaz, R. O. *Utilización de pastizales naturales*. Córdoba, Argentina: Editorial Brujas, 2007.

Franceschi, E. A.; Prado, D. E. & Lewis, J. P. *Comunidades vegetales y mapa de vegetación: Reserva El Rico e islas aledañas (Santa Fe)*. Argentina: Universidad Nacional de Rosario, 1985.

Kandus, Patricia; Morandeira, Natalia & Schivo, F., Eds. *Bienes y servicios ecosistémicos de los humedales del Delta del Paraná*. Buenos Aires: Fundación Humedales, Wetlands International, 2010.

Laclau, P. Consideraciones económicas y ambientales para la toma de decisiones en sistemas silvopastoriles. *Actas II Congreso Nacional de Sistemas Pastoriles*. Santiago del Estero, Argentina: Ediciones INTA. p. 359-370, 2012.

Malvárez, Ana I. El Delta del rio Paraná como mosaico de humedales. En: Ana I. Malvárez, ed.

Tópicos sobre humedales subtropicales y templados de Sudamérica. Montevideo: UNESCO. p. 35-53, 1999.

Marchetti, Zuleica Y. & Aceñolaza, P. G. Vegetation communities and their relationship with the pulse regime on islands of the Middle Paraná River, Argentina. *IHERINGIA. Serie Botánica*. 66 (2):209-226, 2011.

Massa, E. *Caracterización, productividad primaria y calidad forrajera de diferentes comunidades vegetales de una isla del río Paraná*. Argentina: INTA EEA Paraná. Publicación de extensión No. 67, 2012.

Mitsch, W. J. & Gosselink, J. G. *Wetlands*. 3 ed. New York: John Wiley & Sons, 2000.

Morello, J.; Matteucci, Silvia D.; Rodriguez, Andrea F. & Silva, Mariana E. *Ecorregiones y complejos ecosistémicos argentinos*. Buenos Aires: Orientación Gráfica Editora, 2012.

Peri, P. Implementación, manejo y producción en sistemas silvopastoriles: enfoque de escalas en la aplicación del conocimiento aplicado. *Actas II Congreso Nacional de Sistemas Pastoriles*. Santiago del Estero, Argentina. p. 8-20, 2012.

Quintana, R. D.; Bó, R. F.; Astarda, Elizabeth & Reeves, Cecilia. *Lineamientos para una ganadería ambientalmente sustentable en el Delta del Paraná*. Buenos Aires: Wetlands International, 2014.

Rossi, C. A.; De Magistris, A. A.; González, Gabriela L.; Carou, N. E. & De Loof, E. P. *Plantas de interés ganadero de la región del Bajo Delta del Paraná (Argentina)*. Universidad Nacional de Lomas de Zamora, 2015.

Rossi, C. A. & González, G. L. Zonificación y caracterización de la producción ganadera vacuna en función de las diferentes modalidades presentes. En: R. D. Quintana, R. F. Bó, E. Astrada y C. Reeves, eds. *Lineamientos para una ganadería ambientalmente sustentable en el Delta del Paraná*. Buenos Aires: Wetlands International. p. 23-62, 2014.

Sala, O. E.; Parton, W. J.; Joyce, L. A. & Laurentroth, W. K. Primary production of the central grassland region of the United States. *Ecology*. 69 (1):40-45, 1988.

Servicio Meteorológico Nacional. *Pronóstico y estado del tiempo para la República Argentina*. Argentina: Secretaría de Ciencia, Tecnología y Producción. http://www.smn.gov.ar/, 2016.

Singh, J. P.; Lauenroth, W. K. & Steinhorst, R. K. Review and assessment of various techniques for estimating net aerial primary production in grasslands from harvest data. *Bot. Rev.* 41 (2):181-232, 1975.

Vecchio, María C.; Golluscio, R. A. & Cordero, Miriam I. Cálculo de la receptividad ganadera a escala de potrero en pastizales de la Pampa deprimida. *Ecología Austral*. 18 (2):213-222, 2008.

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