Productivity Dynamics of a Native Temperate Grassland in Argentina

OSVALDO SALA, V. ALEJANDRO DEREGIBUS, TOMAS SCHLICHTER, AND HORACIO ALIPPE

Abstract

Studies of aerial net primary productivity (ANPP) were made on a grassland that had been excluded from livestock grazing for four years. ANPP was calculated by summation of individual species and corrections based on fluctuations of standing dead litter. The grassland produced a minimum of 4 kg of dry material $\cdot ha^{-1} \cdot d^{-1}$ in the fall and a maximum of 30 kg of dry material $\cdot ha^{-1} \cdot d^{-1}$ during the spring.

Salado River Basin occupies an area of 5,800,000 ha in Buenos Aires Province, Argentina, 80% of which is covered by native grassland utilized for cattle production. The proximity of the area to the city of Buenos Aires makes it important as a source of beef to this large area of population.

The general aspect of the basin is that of an extensive plain with little or no slope. This results in a great number of permanent ponds and areas subjected to frequent flooding. However, vegetation of the area also suffers from severe summer droughts because of shallow soils. Climate is temperate and humid. Annual precipitation is 900 mm of rainfall that is evenly distributed throughout the year. No snow deposition occurs. This mild weather permits the grasses to maintain productivity during the entire year.

The objectives of this study were to describe the (1) dynamics of the aerial biomass and (2) the dynamics of the aboveground net primary productivity (ANPP) of a native grassland of the Salado River Basin and of its major species throughout an entire year. The study was conducted in one of the most conspicuous communities of the basin. This community was described by Leon (1975) using Braun-Blanquet (1950) techniques and named *Piptochaetium montevidense, Ambrosia tenuifolia, Eclipta bellidioides,* and *Metha pulegium.*

Methods

Estimates of ANPP were made using a method of successive harvests throughout the entire calendar year. Clippings were made in an ungrazed area that had been excluded from livestock grazing for 4 years.

Six harvests were made during the year utilizing rectangular sample plots 0.2 × 3 m. This type of sample plot was selected because it best covered the heterogeneity of the grassland (Fonseca et al. 1976). The number of plots clipped during each sampling period was such that the required level of accuracy for biomass of the main species was fixed at 30% of the mean at 5% level (Milner and Hughes 1970). This resulted in 30 to 40 samples being clipped for each sampling period. Quadrats were randomly located and never occurred in previously clipped places.

Litter was collected by hand from each harvested plot. Standing crop samples were clipped to ground level and kept in a freezer until they could be separated into 32 categories. The categories were 24 grass species, five forbs, two miscellaneous and one standing dead. After separation, the samples were oven dried at 60–70° C and weighed.

The specific ANPP (Pi) was calculated as the positive difference of two successive measurements of the green biomass compartment divided by the number of days between harvests (Δt) (Kelly et al. 1974). When the difference was negative the value calculated was called specific net senescence (Si). All these estimations are, however, biased since productivity and senescence are simultaneous processes. Therefore, the calculated Pi or Si represents a predominance of one process over that of the other during one time period.

The grassland under study had no synchronized growth habits among species. Therefore, the analysis of the dynamics of each species biomass was necessary to avoid the masking effects of specific senescences in total productivity (Sims and Singh 1971). The total ANPP was calculated by

$$ANPP_t = \sum_{i=1}^{n} Pi + Sc + Fc, \qquad (1)$$

Where Sc and Fc are correction factors that account for the senescence and decay processes, respectively. Sc represented the increment of standing dead material not justified by the summation of individual species senescences. Sc is, therefore, material that was produced but did not generate an increase of any green biomass compartment because it occupied the place left by material which was senescent during the same period. Sc is expressed mathematically as the daily increment of the senescence compartment ($\Delta^+SD/\Delta t$) minus the summation of specific net senescence (Si) and is shown in equation (2).

$$Sc = \frac{\Delta^+ SD}{\Delta t} - \sum_{i=1}^{n} Si. \qquad (2)$$

Sc has the restriction of being ≥ 0.

Fc is the correction factor for detached plant material and was developed similarly. In this way, Fc represents the increment of litter not justified by the decrease of the standing dead compartment. Fc is expressed mathematically as the daily increment of the litter compartment ($\Delta^+L/\Delta t$) minus the daily decrease of standing dead (Δ^-) as shown in equation (3),

$$Fc = \frac{\Delta^+L - \Delta^-SD}{\Delta t} \qquad (3)$$

Fc has the restriction of being ≥ 0. The biomass differences among dates were tested for the four functional compartments using a *t*-test. For the biomass data of each species, 95% confidence intervals were calculated.

This methodology for calculating Pi and $ANPP_t$ may be an overestimation because it includes not only the differences of

Authors are research scientists, Department of Ecology, Faculty of Agronomy, University of Buenos Aires, Av. San Martin 4453, Buenos Aires 1417, Argentina. O Sala's present address is Range Science Department, Colorado State University, Fort Collins, Colorado 80523.

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biomass among dates that were statistically significant ($p \leq 0.05$), but all the differences. On the other hand, since the processes of productivity and senescence occur simultaneously, this methodology may underestimate productivity because it utilizes the rate of net accumulation of biomass within a specific compartment as the specific productivity value. If the methodology had taken into account only those differences that were statistically significant, it would have pooled all the other species with different productivity seasonality in one compartment. Therefore, the overlapping of productivity and senescence would have been greater and the underestimation of productivity also would have increased. The solution to this compromise is to increase the total sampling area until all the differences are statistically significant. This solution means an important increase in the cost of the project, however.

Results and Discussion

Total aboveground standing dead, green biomass and litter are shown throughout a year in Figure 1. Significant changes in the standing dead material accounted for most of the changes in total aboveground biomass. Conversely, green biomass and litter showed little change within the year. Seasonal variations were observed in the different compartments. While green biomass and litter were at a minimum during the winter, the standing dead material maintained a constant increment with a maximum slope during spring.

Green biomass of the major species is shown in Figure 2. Two different patterns of biomass distribution throughout the year were observed. *Briza subaristata, Danthonia montevidensis,* and *Carex phalaroides* (Fig. 2a) showed a peak of biomass during spring and were considered cool-season (CS) species. *Ambrosia tenuifolia, Bothriochloa laguroides, Distichlis spicata* and *Stipa papposa* (Fig. 2b) showed maximum biomass peaks during the summer and

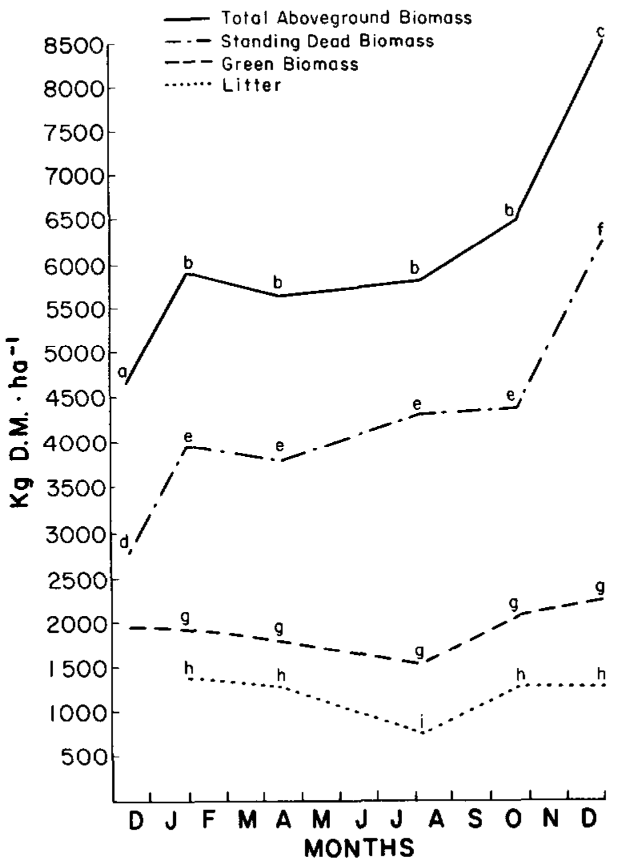

Fig. 1. *Total aboveground, standing dead, green biomass and litter for six harvests during one year. Within any curve, the same letter above each point indicates that they are not significantly different at the 5% level of probability.*

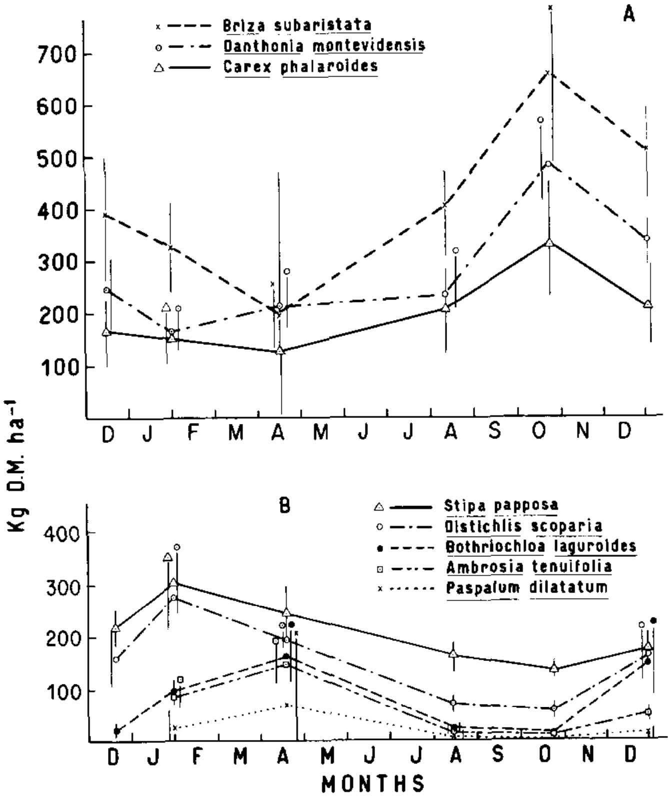

Fig. 2. *Green biomass of the most important species during 1 year. Vertical lines represent 95% confidence intervals for means. (a) cool-season (CS) species; (b) warm-season (WS) species.*

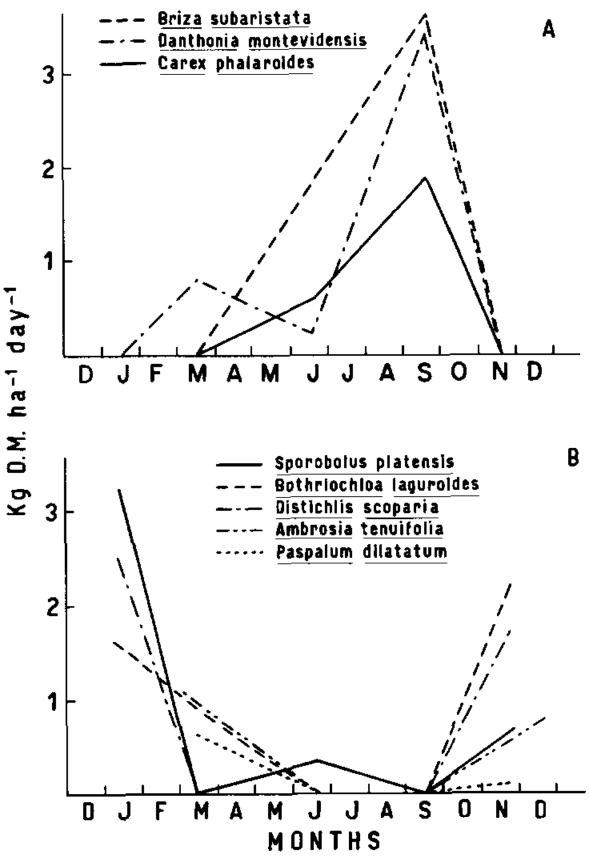

Fig. 3. *Aerial Net Primary Productivity (ANPP) of the principal species throughout the year. (a) cool-season (CS) species; (b) warm-season (WS) species.*

fall and were considered warm-season (WS) species. A similar pattern was also shown by *Paspalum dilatum,* although seasonal differences were not significantly different ($p \geq 0.05$. There was green biomass of both CS and WS species throughout the year.

Aboveground net primary productivity of two major species, *Briza subaristata* and *Danthonia montevidensis,* had maximum values of specific productivity (Fig. 3a), whereas specific productivity values for WS species were lower (Fig. 3b). During summer there were more species growing than during the spring (Fig. 4). Most ANPP during the spring was provided by a few species, *Briza subaristata, Danthonia montevidensis,* and *Carex phalaroides.* Conversely, during the summer and fall ANPP was distributed among a greater number of species.

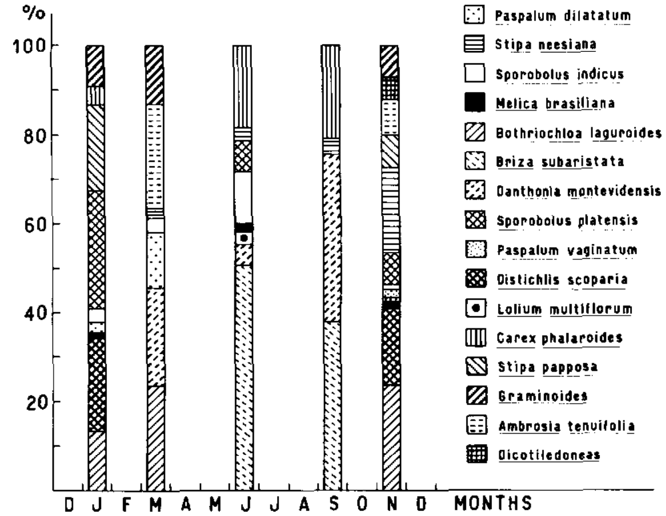

Fig. 4. *Proportional productivity of the different species throughout the year.*

Annual patterns in specific diversity were analyzed using Simpson's (1949) index (Fig. 5). Maximum values of this index occurred during the spring which represents the minimum specific diversity of the grassland. Conversely, maximum diversity values were observed during the fall.

A unique peak of 30.45 $kg \cdot ha^{-1} \cdot d^{-1}$ in total ANPP occurred during the spring and the beginning of summer (Fig. 6). Annual average was 14.6 $kg \cdot ha^{-1} \cdot d^{-1}$ corresponding to an annual production of 532 $g \cdot m^{-2}$ of dry matter. Although this grassland has drought periods during the summer, it has climatic characteristics similar to some of the North American tallgrass sites according to

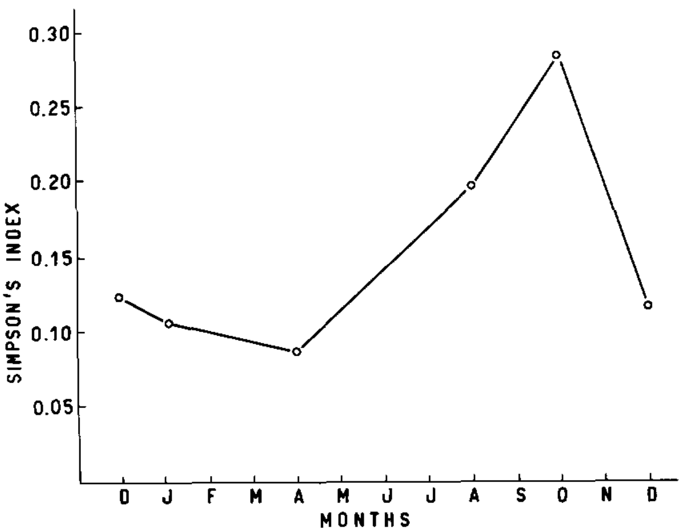

Fig. 5. *Values of Simpson's (Simpson 1949) diversity index throughout the year.*

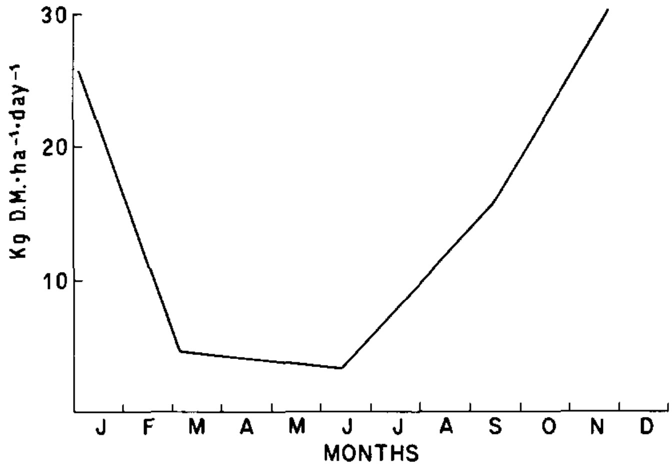

Fig. 6. *Total aerial net primary productivity (ANPP) throughout the year.*

Lauenroth (1979). Several authors have reported annual ANPP data for these grasslands. Lauenroth (1979) reported ANPP of 567 $g \cdot m^{-2} \cdot yr^{-1}$ for Pawhuska, Oklahoma, whereas Sims and Singh (1978) presented a value of 345 $g \cdot m^{-2} \cdot yr^{-1}$ (3-year average) for an ungrazed treatment for the same area. Kucera et al. (1967) reported 634 $g \cdot m^{-2} \cdot yr^{-1}$ for Columbia, Missouri. Owensby and Anderson (1967) reported 387 $g \cdot yr^{-1}$ for Manhattan, Kansas. Therefore, the annual ANPP reported in this paper is within the range of those reported for native grasslands of areas with similar climates.

Spring productivity peak occurred when specific diversity was near its minimum. During the fall when specific diversity was at a maximum, $ANPP_t$ was at the minimum rate recorded.

In order to analyze the specific ANPP independently of the biomass that resulted in this productivity, an efficiency index was

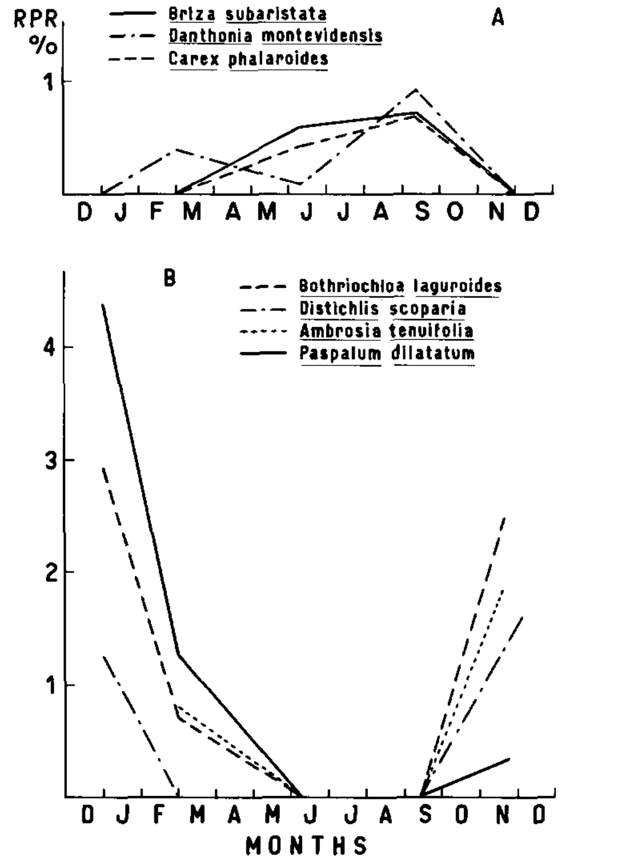

Fig. 7. *Relative Productivity Rate (RPR) of the principal species. (a) cool-season (CS) species; (b) warm-season (WS) species.*

utilized. This index was similar to the one developed by Briggs et al. (1920) and was named the Relative Productivity Rate (RPR). This rate expressed the relationship between the productivity of each species and the biomass measurements used to calculate those productivities. The mathemtical expression of RPR is

$$RPR_i = \frac{PI}{(B_{i1} + B_{i2})/2} \times 100, \qquad (4)$$

where B_{i1} is the biomass of the i^{th} species at time 1, B_{i2} is the biomass of the i^{th} species at time 2, and Pi is the productivity of the i^{th} species.

Use of this index allowed us to compare the production capabilities of the different species. The WS species showed a greater RPR than did CS species (Fig. 7). *Paspalum dilatatum* and *Distichlis scoparia* are known to have the C_4 photosynthetic pathway, while species of the genus *Bothriochloa* were already described as C_4 plants (Smith and Brown, 1973).

Conclusions

This temperate grassland in Argentina has primary productivity throughout the entire year, even during flood conditions during the winter and early spring. An important characteristic of the grassland was its reduced productivity during the fall. This problem is worsened when one considers usable forage production, because two of the most productive species during this season are undesirable *Ambrosia tenuifolia* and *Distichlis scoparia.* The species of higher relative productivity rate also grow during this period. Therefore, an increase in the proportions of *Paspalum dilatatum* and *Bothriochloa laguroides* in the grassland might reduce this problem. An increase in the more desirable species might be obtained by adequate rest of the grassland or seeding of these two species. The high RPR of these two species indicates that it is possible to obtain higher production during this season by small biomass increases. Conversely, to obtain a substantial increase in winter productivity, it will be necessary to provoke very high accumulations of biomass.

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