Chapter 5
The South American Campos ecosystem

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SUMMARY

The *Campos*, grassland with few trees or shrubs except near streams, lies between 24°S and 35°S; it includes parts of Brazil, Paraguay and Argentina, and all of Uruguay. Grassland-based livestock production is very important, based on the natural grassland that covers most of the area. Stock rearing is on large, delimited holdings and is commercial. Both tussock-grass and short-grass grasslands occur. There is a dominance of summer-growing C_4 grasses, with C_3 grasses associated with the winter cycle. Cattle and horses were introduced in the seventeenth century and sheep in the nineteenth. Production is based on spring–summer growing grassland, with little use of sown pastures. Beef cattle predominate; sheep are mainly for wool, but some lamb is produced. Limited winter production and poor herbage quality are major limiting factors in livestock production. Soil phosphorus is generally low and this deficiency affects stock. Campos pastures are highly responsive to fertilizers, which can modify the specific composition of natural grassland; application of phosphate increases legume cover and the phosphorus content of forage. Fattening off grass can take up to four years; intensive fattening of younger stock uses some sown pasture. Sheep may be grazed with breeding herds of cattle. Exotic temperate legumes can be grown and may be over-sown into native swards after land preparation; once established, legumes encourage the development of winter grasses. This paper shows that it is possible to improve forage consumption from natural grasslands, implying an annual increase of 784 000 tonne of liveweight, without cost, in Rio Grande do Sul alone, through a strategy of high forage offer to the grazing animal, which also optimizes forage accumulation rates in the pasture.

INTRODUCTION

The South American *Campos* is an ecological region lying between 24°S and 35°S, which includes parts of southern Brazil, southern Paraguay and northeastern Argentina, and the whole of Uruguay (see Figure 5.1), covering an area of approximately 500 000 km^2. The term Campos refers to grasslands or pastures with a vegetation cover comprising mainly grasses and herbs; scattered small shrubs and trees are occasionally found, generally by the banks of streams.

Figure 5.1
The Campos region of South America.

The grasslands of the Campos have enormous potential for cattle, sheep and horse production for meat, and for various wildlife products. This potential derives from the good environmental conditions, particularly the climate, which allows the growth of a great floristic diversity of edible plants that produce a huge bulk of forage throughout the year.

The climate is subtropical to temperate, with very marked seasonal fluctuations; it is subhumid, because potential evapotranspiration in summer is greater than precipitation, which leads to moisture deficiencies in the soil. Although rainfall is distributed throughout the year, it is characterized by great variations between years; this irregularity is the main source of problems in forage production. The highest precipitation is usually in summer and autumn.

Livestock production is one of the most important agricultural activities of the region, based on the natural grasslands that cover 95 percent of the area. Hence the great importance of this economic resource: its utilization in terms of maximum productivity while avoiding deterioration is an issue that concerns farmers, researchers and others with an interest in natural resource conservation.

GENERAL DESCRIPTION OF THE REGION

Climate

The Campos has a subtropical climate, very warm in summer but with frosts in winter. It is humid, often with moisture surplus in autumn and spring, but moderate deficits in summer (Escobar *et al*., 1996) Average annual temperature in Corrientes Province varies from 19.5°C in the south of the province to 22.0°C in the north. The average of the coldest month varies from 13.5°C to 16.0°C. Meteorological frosts are registered in the whole region, with low frequency, from one to six frosts per year, mainly in June and July, with records of first and last frosts from May to September.

Average annual precipitation ranges between 1 200 and 1 600 mm, increasing from east to west. There is an unexplained increasing trend in mean annual precipitation; in the last 30 years autumn rainfall increased by more than 100 mm, while spring rainfall tended to decrease. Monthly rainfall distribution is variable: April, March and February have averages above 170 mm/month. A second rainfall peak occurs in October–November, with 130–140 mm/month, and lower values are recorded in winter. The moisture balance shows periods of excess (precipitation higher than evapotranspiration) in autumn and spring (March–April and September–October) and deficits in summer (December–January). Annual average relative humidity for all locations ranges between 70 and 75 percent, the lower values in summer and the higher in winter.

Livestock production

Cattle stock is about 4.2 million head in Corrientes Province (Argentina) and 10.1 million in Uruguay, with little variation in recent years. Sheep stocks have been declining consistently, and in 1996 there were 1.2 million head in Corrientes and 13 million in Uruguay. Low wool prices, reduction in domestic consumption of mutton and farmers discouraged by sheep rustling are the main causes.

Wildlife

The Campos Ecosystem, with abundant open tussock ranges and gallery forests along watercourses, provides a suitable environment for the development of a varied and abundant fauna. The great diversity of water bodies, flooded areas, small and big lagoons allowed the development of important populations of *carpinchos* or capybaras (*Hydrochoerus hidrochaeris*) in almost all the territory. Hunting of this animal for its valuable pelt is controlled by provincial authorities, and populations remain relatively stable. Deer are found in aquatic environments. Marsh deer (*Odocoileus blastocerus*) was an endangered species and now is controlled in protected areas in Brazil. In Uruguay, *Ozotocerus* *bezoarticus* is the typical deer. Other abundant species are *yacares* (*Caiman* spp.) and river wolves (giant otters, *Pteronura brasiliensis*). On the grassland part of the Campos there are armadillos (*Dasypus* spp.), viscachas (*Lagostomus maximus*), hares, foxes, partridges, rheas and ducks, which are rarely harmed by humans.

Floristic composition

Within the Campos there are various econiches, defined more by inherent botanical composition than by effect of use. The dominant vegetation in Corrientes is herbaceous, with few or no trees and shrubs, except for the Ñandubay forest. Hence the name Campos or *Campos limpios*. Perennial summer grasses dominate, with sedges next in importance, and are found in every grassland of the region. There are numerous legumes, but at very low frequencies. More than 300 species from 39 botanical families have been listed in the herbaceous strata (J.G. Fernández, pers. comm.), which reflects the great floristic diversity and botanical richness of these grasslands. Perennial grasses contribute 70–80 percent of the total dry matter (DM) yield; Cyperaceae follow, with 7 percent on higher ground and up to 20 percent in the marshy, low-lying wetlands (*malezales*). Legume contribution is always low, ranging from 3 to 8 percent of total DM yield on higher ground, and is practically nil in the lowlands of the *malezales*.

In the Rocky Outcrops (*afloramiantos rocosos*) zone, natural grasslands have been regularly studied since the mid-1980s. In a grazing trial on 70 ha, 178 species were noted. The three most important grasses were *Andropogon lateralis*, *Paspalum notatum* and *Sporobolus indicus*. Other important grasses were *Paspalum almum*, *P. plicatulum, Coelorachis selloana* and *Schizachyrium paniculatum*. Other species seldom contributed more than 10 percent of total biomass. *Desmodium incanum* was the only legume that regularly contributed to summer forage. The most abundant Cyperaceae was *Rhynchospora praecincta.*

A greater range of species contributes to the total biomass of short-grass grasslands, although three grasses – *Paspalum notatum*, *Sporobolus indicus* and *Axonopus argentinus* – are the most frequent. An important feature of this grassland is that winter grasses can contribute from 3 to 20 percent of winter forage, depending on grazing management. The commonest winter species are *Stipa setigera*, *Piptochaetium stipoides*, *P. montevidense* and *Trifolium polymorphum.*

Climax vegetation

Cattle and horses were the first domestic herbivores, introduced by Spanish settlers at the beginning of the seventeenth century; sheep arrived in the mid-nineteenth century. The introduction of domestic livestock to the natural grassland ecosystem has changed the vegetation type, as grazing is the main factor that keeps the grasslands in a herbaceous pseudoclimax phase (Vieira da Silva, 1979). Exotic plants, mainly from Europe, were introduced along with livestock, increasing the disturbance. There is little information about the characteristics of the grasslands previous to the introduction of domestic herbivores. According to Gallinal *et al*. (1938) "We do not know descriptions or precise indicators of existing vegetation prior to livestock introduction nor from the native immigration over areas that now are Campos". Some imprecise references to vegetation were made at the beginning of nineteenth century by travellers such as the foreigners Azara, Darwin and Saint Hilaire, and by criollos such as Father Dámaso Antonio Larrañaga. From their descriptions it can be deduced that there were no forest zones, except for the banks of rivers, and that the landscape was characteristically a prairie with some small trees, shrubs and sub-shrubs.

In an exclosure made in 1984 at the INIA Experimental Unit of Glencoe, Uruguay, (32°01′32″S and 57°00′39″W), where grazing was excluded on land that had been grazed for centuries, tall bunchgrass-like plants began to increase and short-grasses showed reduced cover. There was also an increase of sub-shrubs and shrubs such as *Eupatorium buniifolium*, *Baccharis articulata*, *B. spicata* and *B. trimera*, while *B. coridifolia* decreased, as it is a species that thrives when grasses are weakened by grazing. *B. dracunculifolia*, a shrub of three metres, which has branches that are easily broken by domestic herbivores, was found after six years of exclosure. The population of *B. articulata* remained stable for five years; thereafter all the plants died almost simultaneously, but after a similar period, the population re-established and died again, and now there are new plants developing. Original plants of *Eupatorium buniifolium* remain, and there are other, younger plants. The size of the grass bunches increased and the number of individual plant decreased, as shown by *Stipa neesiana*, *Paspalum dilatatum*, *Coelorachis selloana* and *Schizachyrium microstachyum*. There is a great development of grasses that were of very low frequency and rarely flowered under grazing, such as *Paspalum indecorum*, *Schizachyrium imberbe* and *Digitaria saltensis.* Native legumes, although of low frequency, also increased in vigour. The continued exclusion of grazing leads to increased litter accumulation, which changes the moisture retention capacity of the soil markedly. This effect, coupled with taller grasses, modifies the microclimate. The interruption of a factor that has driven vegetation to a new equilibrium point returns it to an earlier stage, but not exactly to the same starting point (Laycock, 1991). The situation after two decades of exclosure might be similar to that prior to domestic livestock introduction.

GRASSLAND TYPES AND PRODUCTION SYSTEMS IN ARGENTINA

The structure of the main grassland types of the Mesopotamia Region of Argentina was described by Van der Sluijs (1971). A paper on *Grassland types in the Centre-South of Corrientes* was published by INTA Mercedes (INTA-EEA, 1977). Two different canopy structures are found, determined by the growth form and habit of the dominant species.

On the one hand there are the tussock prairies, called generically *pajonales* (straw), with *Andropogon lateralis* being the commonest species, and there are grasslands dominated by *Sorghastrum agrostoides,* others by *Paspalum quadrifarium* and others by *P. intermedium.* These are typical of the ecological regions of Albardón del Paraná Sandy Hills (*lomadas arenosas*); with lateritic hills and malezales on higher sites.

On the other hand there are short-grass grasslands, where dominant species rarely exceed 30–40 cm in height. Here the commonest grasses are *Paspalum notatum, Axonopus argentinus* and *Sporobolus indicus*. Long-term overgrazing causes grassland deterioration, which leads to a lower canopy, reduced floristic diversity and reduced vegetative growth. In this situation, flechilla becomes the dominant grass (*Aristida venustula*), so these grasslands are named *flechillares*. Deteriorated short-grass grasslands dominate the centre-south of the province, in the Rocky Outcrops regions and Ñandubay forest. Intermediate situations are found between the two grassland types, where pajonales and short-grass are mixed. These are mosaic grasslands, characteristic of the *floramientos* region.

Growth and forage production

Annual production from various grassland types and daily growth rates per hectare were evaluated for a 19-year period on Mercedes Experimental Station. A regrowth cutting methodology was employed, with mobile temporary enclosures (Brown, 1954; Frame, 1981). The main results were:

- ***Pajonales*** Mean annual production was 5 077 kg DM/ha. Average monthly growth (Figure 5.2) showed regrowth in every month, including winter, when growth was 5 kg DM/ha/day. The average monthly growth rate was at a maximum in February, March and December. Growth rate distribution

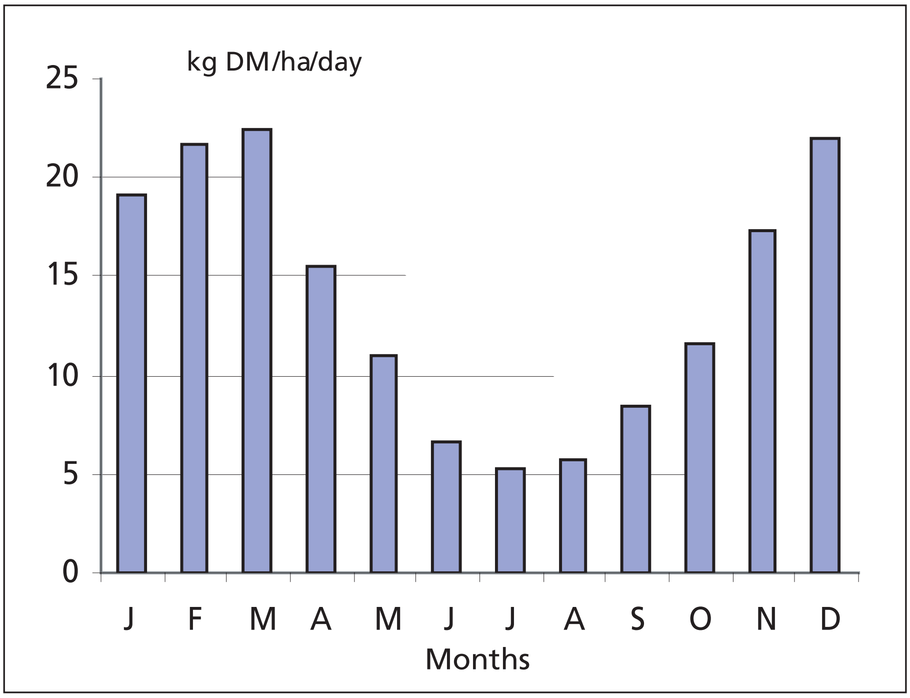

Figure 5.2
Average daily growth rates of a Pajonal grassland (19-year average).

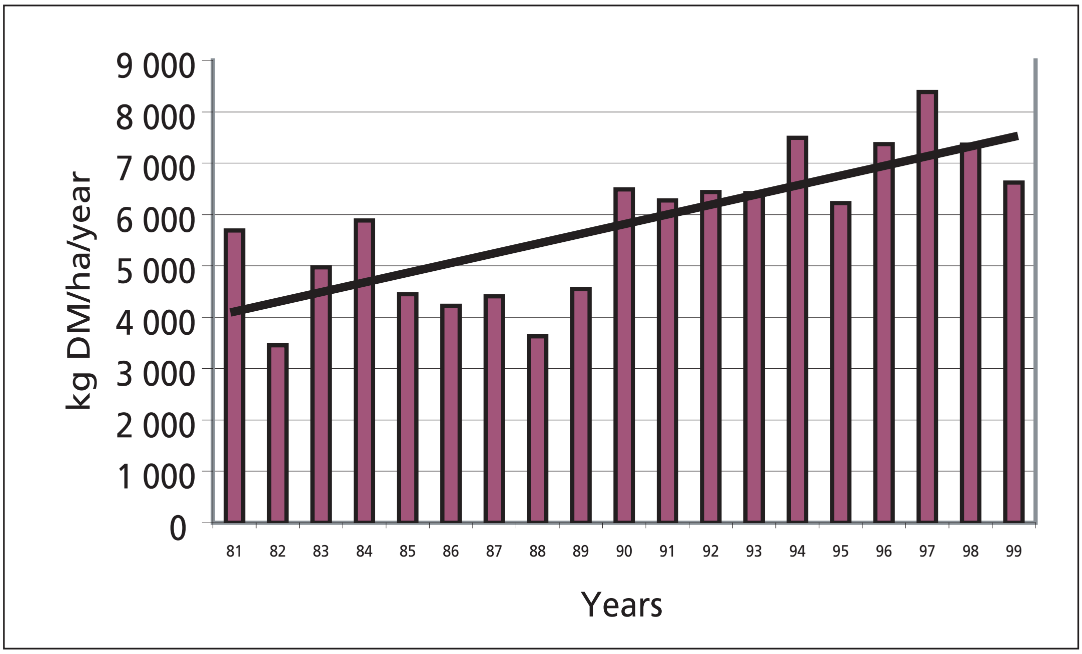

Figure 5.3
Yearly growth rate of a short-grass grassland over a 19-year period.

through the year correlated positively with monthly variations in temperature, showing an autumn peak higher than the spring one. Variability between years is high, particularly in summer, which is related to rainfall variation and high temperatures. Grassland production of the main grassland types of the northwest of the province was studied by Gándara and co-workers (1989, 1990a, b). These authors evaluated three pajonal-dominated sites: malezales, Corrientes and Chavarria, and mean aboveground production for four clipping frequencies was 5 260, 4 850 and 4 120 kg DM/ha/year for the three sites, respectively.

- ***Short-grass*** Average production of a short-grass grassland was 5 803 kg DM/ha/year, with great variation between years and an increasing trend over time (Figure 5.3). Maximum growth rate was attained at the end of the summer or early autumn (February–March), when growth rates were estimated at 25 kg DM/ha/day. July was the month with least growth; it was estimated at 5.5 kg DM/ha/day. Yearly forage production showed an increasing trend over time, but this could be related to an increasing trend in annual precipitation over the same period. Such an increase could lead to a progressive increase in carrying capacity. Nevertheless, the most remarkable conclusion from the data is the great inter-annual variability.
- ***Flechillares*** Average production of the flechillares was 2 774 kg DM/ha/year. The highest growth rate was in February and March, followed by December; the lowest in June–July. This grassland has a seasonal distribution similar to the original short-grasses but has a proportionally better growth distribution between winter and spring. The carrying capacity of such grassland is low, and it becomes critical in years when rainfall is below average.

Production systems

Livestock production is based on the use of spring–summer growing grassland, with little use of sown pastures or other supplementary sources of feed. The main production system is a mix of breeding and fattening, with increasing preference for breeding. Specialized fattening systems are irrelevant. Predominant breeds are Zebu-based, followed by European breeds, Indian breeds and criollas. The main systems are characterized by low production efficiency. The average extraction rate for sale is only 18.9 percent, while the national average in Argentina reaches 23 percent.

Sheep rearing is mainly for wool, and to a lesser extent for lamb. A cattle-sheep production system is applied by 3 400 farmers in the centre-south of the province. Predominant breeds are Corriedale, Romney Marsh and Ideal. Lambing rates in Corrientes average 60 to 65 percent, with a mean greasy fleece weight of 3.18 kg/head. Provincial sheep stocks have declined in recent decades, following the same trend as the national stock. The sheep stock in 1993 was 1.39 million head, with a greasy wool production of 4 427 000 kg.

Productivity levels are low when compared with potential productivity in this environment. The reasons for this have been analysed by Royo Pallarés (1985), who indicated a series of environmental, social, economic and technical factors as the causes of low productivity in an economic inflation scenario. Gándara and Arias (1999) noted recently that resource mismanagement, limited adoption of improved technology, lack of service structures, poor cattle markets and small farm size were factors determining low productivity.

Productivity of the best farms

Many authors have reported productivity increases when some basic management technologies have been applied (Arias, 1997; Benitez Meabe, 1997; Royo Pallarés, 1985, 1999). In the north of Corrientes, average productivity at subregional level is 30 kg/ha/year, while at the Experimental Unit, where basic management practices were applied, 67.7 kg/ha/year were obtained (Table 5.1).

GRASSLAND TYPES AND PRODUCTION SYSTEMS IN URUGUAY

Grassland is defined as a vegetation cover formed by grasses, with associated herbs and dwarf shrubs, where trees are rare (Berretta and Nascimento, 1991). The most numerous botanical family is the Gramineae, both summer (C_4) and temperate (C_3) types; this association is an unusual characteristic of these grasslands. The most important Tribes are: Paniceae, including the genera with most species, *Paspalum*, *Panicum*, *Axonopus*, *Setaria*, *Digitaria*, etc.; Andropogoneae, with *Andropogon*, *Bothriochloa*, *Schizachyrium*, etc.; Eragrostea, with the genera *Eragrostis*, *Distichlis*, etc.; and Chlorideae, with *Chloris*, *Eleusine*, *Bouteloua*, etc. Winter-grass tribes, where most of the cultivated forages belong, are: Poeae, with the genera *Bromus*, *Poa*, *Melica*, *Briza*,

TABLE 5.1

Average productivity in northwest Corrientes in comparison with an experimental unit.

Production indexes		NW Corrientes	Experimental Breeding Unit
Marketing rate	(%)	45	69.2
Weaning weight	(kg)	150	197
Weaning weight per cow	(kg)	67	136
Cows/total stock		0.43	0.65
Liveweight production	(kg/ha/year)	30	67.7
Carrying capacity	(Animal Units/ha)	—	0.56 – 0.73[(1)]

NOTES: (1) September–March.
SOURCE: After Arias, 1997.

TABLE 5.2

Daily Growth Rates (DGR) and their standard deviation (kg DM/ha/day), and Seasonal Distribution (SD) (%) of yearly forage production from grasslands on the main soil types.

Soil type			Season			
			Summer	Autumn	Winter	Spring
Basalt	SBR	DGR	10.1 ± 4.9	6.8 ± 2.9	4.9 ± 2.5	9.9 ± 3.9
		SD	31.4	21.2	15.7	31.7
	SB	DGR	13.6 ± 5.9	8.8 ± 3.9	6.1 ± 2.4	13.0 ± 4.3
		SD	32.1	21.0	14.9	32.0
	D	DGR	17.2 ± 7.8	10.9 ± 4.2	7.3 ±3.1	14.8 ±4.4
		SD	33.3	21.5	15.1	30.1
Eastern Sierras		DGR	15.3	9.2	3.8	11.5
		SD	38.0	23.4	9.7	28.9
Crystalline Soils (granitic)	D	DGR	13.1 ± 7.3	8.6 ± 3.3	6.5 ± 3.2	17.0 ± 6.8
		SD	28.6	19.3	14.5	37.6
Sandy Soils	Upper hill	DGR	27.7 ± 5.6	7.3 ± 4.2	4.1 ± 2.3	17.6 ± 3.3
		SD	48.5	13.1	7.3	31.1
	Low hill	DGR	27.3 ± 8.4	7.5 ± 4.4	3.7 ± 1.5	22.2 ± 4.1
		SD	44.5	13.6	6.1	36.8
North East Soils		DGR	5.1	6.9	4.7	11.0
		SD	18.3	25.0	17.1	39.6

NOTES: SBR = Shallow Brown-Reddish. SB = Shallow Black. D = Deep.

Lolium, *Dactylis*, *Festuca*, etc.; Stipeae, with *Stipa* and *Piptochaetium* – the bulk of the native species; and Agrostideae, with the genera *Calamagrostis*, *Agrostis*, etc., with only a few species (Rosengurtt, Arrillaga de Maffei and Izaguirre de Artucio, 1970). In general terms, the presence of winter species is associated with soil type, topography, altitude, fertility and grazing management. Plants from other families grow with the grasses, such as Compositae, Leguminoseae, Cyperaceae, Umbelliferae, Rubiaceae, Plantaginaceae and Oxalidaceae. Native herbaceous legumes are represented by many genera – *Trifolium*, *Adesmia*, *Desmodium*, *Desmanthus*, *Galactia*, *Zornia*, *Mimosa*, *Tephrosia*, *Stylosanthes* – but their net frequency is low, always below 3 percent in all types of grassland, except in very special habitats (Berretta, 2001). The natural grasslands are used for extensive livestock production, with little improvement, and correspond with the main soil types (see Table 5.2). Vegetation characteristics of each grassland type are defined firstly by the soil type, its physical and chemical properties, and to a lesser extent by topography and aspect.

Some species are present in all grassland types, although with variable frequencies; others are present in some grasslands; others are characteristic and indicators of certain habitats. Within each grassland type there are vegetation gradients associated with topography (upper slope, middle and valley) that with soil depth differences and moisture conditions produce a range of associations. In swampy, flooded places there are *Cyperus* spp., *Heleocharis* spp., *Canna glauca*, *Leersia hexandra*, *Luziola peruviana*, *Paspalum hydrophylum*, *Pontederia cordata*, *Sagittaria montevidensis* and *Thalia* spp.

Perennials from the various families predominate in all grasslands. Annuals are infrequent, but may become more prominent at some seasons of the year or due to management practices, such as grazing methods, fertilization, or the introduction of exotics or legumes.

In grassland communities, a relationship can be established between the percentage contribution of each species to total biomass and its degree of contribution to soil cover. Theoretical studies (Poissonet and Poissonet, 1969; Daget and Poissonet, 1971) indicate that this relationship is commonly close to 20:80 – a Gini-Lorenz relationship. Vegetation surveys carried out in different grasslands and through several seasons showed relationships varying between 30:70 and 20:80 (Coronel and Martínez, 1983; Olmos and Godron, 1990). Despite the number of species found, which is generally high, only about ten species make a major contribution to forage production. Identification of these species is of particular interest when monitoring community evolution and planning cattle management.

Identification of growth habit types (Rosengurtt, 1979) can help in making grazing management decisions. Most summer and winter grasses are of a caespitose vegetative type. Stoloniferous grasses are all summer cycle, except for one. Rhizomatous species belong to various families (Gramineae, Cyperaceae, Compositae, Leguminosae, Umbelliferae, etc.) and there are both winter- and summer-cycle rosette plants, primarily Compositae and Umbelliferae. Growth habit types are used as a substitute where there is a lack of precise data on the nutritive value of forages and enabling the ranking of hundreds of species in a useful way for consideration in present and future vegetation management (Rosengurtt, 1946, 1979; Rosengurtt, Arrillaga de Maffei and Izaguirre de Artucio, 1970).

Table 5.2 shows detailed Daily Growth Rates and their standard deviation, and seasonal distribution of grass production in different types of grasslands. On some soils, forage growth reflects soil depth or topographic position, leading to different botanical compositions.

On basalt soils, three vegetation types can be distinguished, directly related to soil depth. On shallow brown-reddish soils, vegetation cover is about 70 percent, while rocks and stones cover 10 percent and the rest is bare soil and litter. These values have some seasonal variations and show marked changes during droughts. Daily Growth Rates, expressed as kg DM/ha/day, is variable according to season and between years. Most annual forage grows in summer, but this season is the most variable due to high risk of drought on this soil. The commonest species are *Schizachyrium spicatum, Chloris grandiflora, Eragrostis neesii, Eustachys bahiensis, Microchloa indica, Bouteloua megapotamica, Aristida venustula, Dichondra microcalyx, Oxalis* spp. (*macachines*) and *Selaginella* sp. On the same soil type, but where the upper horizon reaches 15–20 cm in depth, other species are found, such as the summer grasses *Paspalum notatum* and *Bothriochloa laguroides,* and winter cycle grasses *Stipa setigera* (= *S. neesiana*) and *Piptochaetium stipoides*. The presence of more productive species changes the seasonal distribution of growth, so highest productivity is in spring and autumn, although total annual production is similar.

Vegetation cover is 80 percent on shallow black soils – the rest is litter and bare soil – and varies between seasons and years. The most frequent species are *Schizachyrium spicatum, Chloris grandiflora, Eustachys bahiensis, Bouteloua megapotamica*, *Aristida murina, A. uruguayensis, Dichondra microcalyx*, *Oxalis* spp., *Nostoc* sp. and *Selaginella* sp. Less frequent are *Stipa setigera, Piptochaetium stipoides, Bothriochloa laguroides, Paspalum notatum, P. plicatulum, Coelorhachis selloana* and *Adesmia bicolor*. When the upper horizon is deeper, the usually less frequent species become more frequent. Total annual forage production on deeper soils is slightly greater, but seasonal distribution is different, with 70 percent of total forage being produced in spring and autumn.

Deep fertile soils have a vegetation cover close to 90 percent, and the rest is litter. The main species on these soils are *Paspalum notatum, P. plicatulum, P. dilatatum, Coelorachis selloana, Andropogon ternatus, Bothriochloa laguroides*, *Axonopus affinis, Aristida uruguayensis, Schizachyrium spicatum*, *S. setigera,* Cyperaceae, *Piptochaetium stipoides, Poa lanigera, Trifolium polymorphum* and *Adesmia bicolor* (Berretta, 1998).

On all three soil types, the deeper the upper horizon, the greater the spring growth, by up to 40 percent. This may be related to higher frequency of winter species which flower in spring and again in autumn when they regrow, and when growth can be as high as 28 percent of the total.

On sandy soils, botanical composition changes are mainly associated with topographic position. Table 5.2 shows daily growth rate and seasonal distribution of forage production from upper and lower parts of a hillside, in the same topographic sequence. Annual forage yields from upper and lower areas averaged 5 144 kg DM/ha and 5 503 kg DM/ha, respectively, over eight years (Bemhaja, 2001). In such grassland, growth peaks in spring and summer, with 80 percent of total production. This is related in part to edaphic factors (depth, texture, moisture retention capacity), but more to the dominance of summer species, such as *Paspalum notatum, Axonopus compressus, A. argentinus*, *Sporobolus indicus*, *Coelorachis selloana*, *Panicum milioides*, *P. sabulorum*, *P. nicorae* (which is a characteristic species of such soils) and *Eragrostis*

Plate 5.1
Landscape in the Sierras zone.

purpurascens. The commonest winter grass is *Piptochaetium montevidense*. Dwarf herbs, such as *Soliva pterosperma*, *Eryngium nudicaule*, *Chevreulia sarmentosa*, and *Dichondra microcalyx*, are relatively frequent. Native legumes are infrequent, with *Desmodium incanum* the most representative. *Baccharis coridifolia* and *Vernonia nudiflora* are the main weeds in invaded fields (*campo sucio*).

Managed burning is common on these soils, as a tool to reduce dead material and to promote green spring regrowth and hence improve forage quality. Summer grasses are rough, clearly overshadow the sward and are little or not liked by livestock, except in very special circumstances; dead leaves and stems accumulate in winter, becoming even less palatable. The main such grasses are *Erianthus angustifolius*, *Paspalum quadrifarium*, *Andropogon lateralis* and *Schizachyrium microstachyum*, associated with some dwarf shrub and shrub weeds that thrive in this conditions and give place to *campos sucios* and *pajonales* (straw fields).

Natural grasslands on Brunosols are species rich. It is possible to find 50 to 60 species in a 12 m^2 plot. Some 30 percent of the species present represent 70 percent of total vegetation cover. Grasses are the most abundant, and 70 percent of them are summer growing. Depending on local management practices, natural grasslands may be covered by small shrubs or native trees. Legume presence under grazing conditions is sparse.

Forage production averages 3 626 kg DM/ha/year in the lomadas zone and about 1 500 kg DM/ha/year in the Sierras zone (Plate 5.1). Most of the plants (80–85 percent) are summer-cycle perennials. In spite of rich biodiversity, the

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Plate 5.2a
Typical grassland scenes on the Campos of Uruguay – Campos on shallow basaltic soil.

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Plate 5.2b
Typical Grassland Scenes on the Campos of Uruguay – Campos on granitic soils.

number of species that contribute to forage production is low; the *Paspalum notatum–Axonopus compressuss* association is notably the main contributor. Forage digestibility is usually low (48–62 percent) (Ayala *et al.*, 2001). Typical grassland scenes on the Campos of Uruguay are shown in Plates 5.2a–f.

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Plate 5.2c
Typical grassland scenes on the Campos of Uruguay – Campos on eastern hillocks.

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Plate 5.2d
Typical grassland scenes on the Campos of Uruguay – Campos on sandy soils.

VEGETATION LIMITATIONS FOR ANIMAL PRODUCTION

The main limitation of the humid subtropical grasslands is their poor herbage quality. Although this is well known, and has been the subject of many papers (Royo Pallarés, 1985; Deregibus, 1988), little progress has been made in overcoming it. C_4-dominated grasslands, with high temperatures and good rainfall produce high growth rates, which leads to a dilution of nutrients and

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Plate 5.2e
Typical grassland scenes on the Campos of Uruguay – Winter sunset over the Campos on granitic soils in southern Uruguay.

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Plate 5.2f
Typical Grassland Scenes on the Campos of Uruguay – Campos in Central Uruguay with cows grazing on basaltic soils.

a marked decrease in digestibility, which rarely exceeds 60 percent; forage crude protein levels barely reach basic cattle requirements. This situation is aggravated in winter by frost. Most of the year there is a "green desert" – a great bulk of low quality forage, in a difficult-to-graze pasture structure. The animals graze in a "sea of forage", but have low intake. Fire is used in most cases to stimulate regrowth and improve grassland quality

Salt deficiency was noted as a problem at the end of the nineteenth century in the Campos. Phosphorus deficiency was identified (Kraemer and Mufarrege, 1965), and since then it has become increasingly obvious that phosphorus deficiency is one of the main constraints on livestock production in Corrientes. The soils have less than 5 ppm of available phosphorus, so forage has a phosphorus content below 0.10 percent. This strongly limits both forage production and quality, which in turn limits the animal output that can be obtained. Research on many aspects of phosphorus nutrition of cattle and pastures have been conducted in Corrientes (Arias and Manunta, 1981; Arias *et al*, 1985; Mufarrege, Somma de Fere and Homse, 1985; Wilken, 1985; Royo Pallarés and Mufarrege, 1969; Royo Pallarés, 1985). Mineral supplementation to correct phosphorus deficiencies is the technology most accepted and adopted by farmers; but there are still doubts, misconceptions and practical problems in its implementation.

Production systems

The main production systems are:

- calf production (*Cría*) only, with sales of weaned male calves and rejected cows, keeping replacement females;
- breeding and growth (*Recría*), where male calves are kept after weaning, to be sold to other farmers at 18 to 30 months, before winter;
- complete cycle, which is the breeding and fattening of all calves to slaughter, which can occur at different ages and weights; and
- fattening, which can be on natural grasslands. In that case steers are finished for slaughter at over four years old, starting with one-year-old or older steers. Intensive fattening starts from weaned calves or young steers, using variable proportions of improved grassland or cultivated pastures.

In any of these cases, cattle rearing may be accompanied by sheep (Plate 5.3). This is commoner in breeding than in fattening systems. Sheep breeding systems are similar. Castrated weaned lambs and rejected ewes are the main income source, but the current trend is to sell heavier lambs of more than 40 kg liveweight.

According to grassland characteristics, mixed set stocking in cattle production has many limitations, mainly nutritional. Some of the major constraints are advanced age of heifers at first mating (a mean of three years old); low calving rate (65 percent); low liveweight gain of calves, with consequently low weaning weight (130–140 kg); advanced slaughter age (4 years); and low extraction rate (18–20 percent). Under such conditions, beef production on natural grasslands is about 65 kg/ha/year.

Table 5.3 compares two management systems, with and without sheep, on basalt grasslands. Both systems were evaluated under grazing conditions with a continuous fixed stocking rate of 1 cow-equivalent per hectare, for four years.

Despite the high stocking rate and simple management, the results show higher productivity levels than those of extensive production systems. Yearly variations in birth and weaning rates are the main factors determining animal

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Plate 5.3
Mixed grazing.

TABLE 5.3
Reproductive performance and productivity of two management systems.

Year	Birth rate (%)	Weaning rate (%)	Weaning weight (kg)	Productivity (kg/ha)	
				Liveweight	Wool
Cattle system					
1	80.0	77.5	141	109	–
2	60.0	55.5	141	78	–
3	87.5	75.0	137	103	–
4	75.0	70.0	143	100	–
Average	75.6	69.5	141	988	-
Mixed system					
1	75.0	70.0	153	107	10.1
2	55.0	50.5	143	72	9.0
3	78.0	75.0	166	125	10.3
4	65.0	60.0	160	96	9.8
Average	68.0	64.0	156	100	9.8

SOURCE: Adapted from Pigurina, Soares de Lima and Berretta, 1998.

production. Weaning rates are higher in the cattle-only system, but weaning weight and total productivity were higher in the mixed system.

Fattening steers on natural grasslands takes a long time because liveweight gains are variable between seasons, related to availability and quality of forage, stocking rate and presence or absence of sheep (Table 5.4).

Different feeding, management and sanitary control strategies affect sheep production. Research programmes focus on increasing wool and lamb production efficiency, and the quality of both products.

Technical options for extensive conditions are presented in Table 5.5. In traditional systems, nutritional levels are insufficient for breeding ewes in the last third of pregnancy, with consequent low weight and low fat score at lambing.

TABLE 5.4
Steer liveweight variation (kg/head/day) and productivity (kg/ha/year) in relation to stocking rate and sheep:cattle ratio (S:C) in continuous set stocking on natural grasslands.

Stocking rate (AU/ha)	0.6(1)	0.8(1)	0.8(1)	0.9(2)	1.06(1)	1.06(1)
S:C ratio	2:1	2:1	5:1	0:1	2:1	5:1
Season			Liveweight variation, kg/day			
Autumn	0.196 bc	0.194 c	0.139 bc	-0.248 c	-0.076 c	-0.130 c
Winter	0.089 c	-0.176 d	-0.086 c	0.075 b	-0.312 d	-0.397 d
Spring	0.915 a	0.858 a	0.828 a	0.758 a	0.667 a	0.720 a
Summer	0.351 b	0.413 b	0.297 b	0.604 a	0.431 b	0.436 b
Yearly average	0.388 A	0.322 A	0.295 AB	0.297 AB	0.178 B	0.157 B
Total steer production						
kg/head/year)	141 A	118 A	108 B	108 B	65 B	57 B
kg/ha(3)	75	84	54	125	62	38

NOTES: a, b, c – Averages in the same column with distinct letters differ significantly (P<0.05). A, B – Averages in the same row with distinct letters differ significantly (P<0.05). (1) Based on UE Glencoe data (1984–92). (2) Adapted from Risso *et al.,*1998. (3) Adjusted by effective area. Lamb and wool production is not included.

SOURCE: Pigurina *et al.*, 1998.

TABLE 5.5
Summary of the experiments carried out by Montossi *et al.* (1998a) using fat condition score and autumn deferment in natural and improved grasslands.

Pasture and animal characteristics	Traditional	Deferred	
		Natural	Improved
Available forage at lambing (kg DM/ha)	400–700	1 300–1 500	1 100(1)–1 900
Sward height at lambing (cm)	2–3	5–8	4 – 7
Stocking rate (ewes/ha)	4 (0.8 AU/ha)	5 (1 AU/ha)	10 (2 AU/ha)
Ewe liveweight at lambing (kg)	35–40	42–45	45–48
Fat score at lambing (grades)	2–2.5	3–3.5	3.3–3.7
Birth liveweight (kg)	2.5 – 3.0	3.6 – 3.8	3.8 – 4.6
Lamb mortality rate (%)	20 – 30	10 –13	9 –10

NOTES: (1) Required forage availability according to amount of legumes in improved grassland.

The effects of poor nutrition on lamb survival (20–30 percent mortality) is the major cause of the low reproductive performance of the national flock. To improve reproductive performance of single-lamb pregnant ewes and to reduce lamb mortality to 10 percent, it is necessary to apply deferred grazing (Plate 5.4), accumulating 1 300 to 1 500 kg DM/ha (5 to 8 cm height) at the beginning of the last third of gestation. The fat score of Corriedale ewes at lambing should be between grades 3 and 3.5 (Montossi *et al.*, 1998b).

In improved grasslands, with a stocking rate of twice that on natural grasslands (10 sheep/ha) with the same fat score at lambing it is possible to reduce lamb mortality to 10 percent. The recommended amount of deferred forage is from 1 100 to 1 900 kg DM/ha, equivalent to heights of about 4 to 7 cm, respectively. The amount of forage available will depend on the proportion of legumes in the improved grassland.

Considering the average autumn growth rate of natural and improved grasslands on basalt soils (Berretta and Bemhaja, 1998) and a normal breeding season, it is necessary to start deferring natural grassland 70 to 50 days before

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Plate 5.4
Grazing management: forage deferred for winter grazing.

lambing and improved grasslands 40 to 30 days before lambing. These values are modified by weather conditions, which affect the growth rate, and also by the amount of forage present at the start of the accumulation period.

Most ewe hoggets are mated at 2.5 years (four teeth) since many of them (40–60 percent) do not reach the minimum liveweight for mating at 1.5 years). This has adverse productive and economic consequences for the industry, as it reduces the number of lambs produced by each ewe in her lifetime, reduces genetic progress of the flock and constrains the overall efficiency of the system. To increase lamb production it is very important to increase the reproduction rate of hoggets.

Several management strategies have been defined to improve the liveweight gain of hoggets on natural grassland on basalt soils (San Julián *et al*., 1998). The use of improved grassland and sown pastures allows winter liveweight gains of 60 to 90 g/head/day. Such rates of gain allow a high proportion of hoggets (80–90 percent) to attain mating weight at two-tooth, implying weights exceeding 32 and 35 kg for Merino and Corriedale hoggets, respectively. To attain these gains in winter it is necessary to provide 1 500 kg DM/ha of deferred forage, with a height of 5 to 6 cm, on natural grasslands or 1 000 kg DM/ha, with a height of 4 to 5 cm, on improved grasslands (San Julián *et al*., 1998).

In a study in the basalt zone (Ferreira, 1997), three groups of farmers could be distinguished according to production systems and technical demands. The first group, 56 percent of farmers studied, had low-potential natural resources and used a defensive strategy in their decision-making, which resulted in very low levels of technology adoption, and the technology available for shallow soils did not show sufficiently attractive response levels and stability to cross the risk aversion thresholds of these farmers. The second group, 18 percent of the sample, responded better to technology adoption and behaved proactively to technical change: they were not only receptive to new technologies, but also experimented and constantly analysed the effects of the introduction of technical changes. The third group (26 percent) were the bigger farmers, with a reactive and imitative attitude that incorporated technologies that have been successfully applied by others. The author concludes that the technology offered must be matched to each group, and – even more important – the technology identification process should be different for each group.

GRASSLAND PRODUCTION SYSTEMS IN SOUTHERN BRAZIL

The natural grasslands of Southern Brazil include native forests and herbaceous vegetation, both as open grasslands and dwarf shrub associations, forming a mosaic with savannah characteristics. Herbaceous vegetation, of diverse forms and botanical composition, is strongly influenced by temperature, showing seasonal productivity variations. Grasses predominate, accompanied by some legumes. Herbage develops under the influence of latitude, altitude and soil fertility, with a dominance of the C_4 species that grow in the warm season, associated with C_3 species in the winter cycle. Relative dominance of species on grasslands determines its growth capacity in each season and the balance of forage production. More than 800 grass species have been recorded, with 200 legume species. These grow in associations with herbs such as Compositae and Cyperaceae, besides shrubs, resulting in a very rich floral biodiversity. Edaphic factors lead to marked variations in botanical composition and substantial productivity differences as a function of the dominance of particular species. Extensive and extractive livestock production has developed in this ecosystem since the colonization of the region.

An ecological understanding of natural processes is the basis for management. Factors include productivity, vegetation cover preservation, pastoral value, environmental limitations and recognition of the natural succession process. Grassland ecology is closely associated with human activity and management of domestic herbivores. Grazing animals are major determinants of vegetation structure, as consumption may reach 50 percent of above ground net primary production (ANPP) and up to 25 percent of subterranean productivity (Sala, 1988). Plants differ in their responses to defoliation, with differential seasonal growing rates, and herbivores select and consume species and parts of plants disproportionately to their abundance in the pasture (Boldrini, 1993). This natural resource is useful for herbivores; grazing influences species, life forms and growth of the vegetation and it can be managed to satisfy economic needs. Different animal species use a wider range of forage and may direct succession to vegetation states that are ecologically and economically attractive (Araujo Filho, Sousa and Carvalho, 1995).

ILSI BOLDRINI

Plate 5.5
Grasslands of southern Brazil. (a) Grasslands with Araucaria trees.

ILSI BOLDRINI

*(b) Representative grassland on the mid-level plateau, with "barba-de-bode" (*Aristida jubata*).*

The 12–15 million hectares of natural grasslands in Southern Brazil show great structural diversity (see Plate 5.5), with grass dominance and few legumes. Ignorance of their nature and potential led to the belief that they were unproductive and should be replaced by sown forages. This was associated with the concept of selective grazing and ignorance about its advantages to promote

ILSI BOLDRINI

(c) Grassland with Melica macra.

ILSI BOLDRINI

(d) Upland grassland in winter.

faster regrowth after grazing. Animal type, their genetics and aptitudes condition the development of natural grasslands. Society is now promoting conservation of natural ecosystems in managed recreation areas, where herbivores are always landscape modellers. A number of technical reports on this situation are available.

Forage from natural grasslands can only be marketed in the form of animal products. Nationally, there is still an instinctive resistance, if not dislike, to exploitation and use of natural grasslands through pastoralism (Tothill, Dzowela and Diallo, 1989). The measure of communal grazing is yield per unit of area, as the number of animals represents the economic value of the activity. In the philosophy of managed ecosystems (ranching), yield per animal and commercial value of the product represent the economic value. This philosophy of forage use is based on management of pastures and stock in delimited areas, with the possibility of external inputs. There are still many natural grassland properties operating with the philosophy and yield of pastoralism, which could attain the yield of managed ecosystems.

Until recently, stock rearers did not understand basic grassland management technology: to maintain vegetation and make long-term decisions on sustainability. The need is now appreciated of understanding natural grasslands and recognizing the availability level that does not restrict animal intake, in order to attain high individual performance and high per-hectare production.

Dry matter accumulation in natural grasslands

The climatic transition strip in the south of Brazil favours summer grasses, which explains the seasonal differences in forage production (Apezteguia, 1994; Correa and Maraschin, 1994; Maraschin *et al*., 1997). In the cool season, which covers from a third to half of the year, there is slower growth due to low temperature, frost and irregular rainfall. Rejected forage increases errors in pasture evaluation (Moojen, 1991). Native winter species contributed 17 percent of yearly DM production in Uruguay (Berretta and Bemhaja, 1991) and 18 percent in Rio Grande do Sul (Gomes, 1996). But the warm season covers two-thirds to half the year (Maraschin *et al*., 1997). Daily growth is termed the DM Accumulation Rate (AR) and represents what can be grazed. Table 5.6 shows ARs (in kg DM/ha/day) in a Rio Grande do Sul natural grassland, influenced by forage offer (FO) levels per head and per day, with corresponding residual DM (Moojen, 1991; Correa and Maraschin, 1994). ARs increase with increasing levels of FO until more than 12 percent of liveweight, and tends to decrease after FO exceeds 16 percent of liveweight. Maximum recorded AR was 16.3 kg DM/ha/day, with an FO of 13.5 percent of liveweight, which corresponded to forage availability of 1 400–1 500 kg DM/ha at any time.

Unfertilized natural grasslands produced 2 075 to 3 393 kg DM/ha considered as available forage, defining the number of animals that could be grazed on

TABLE 5.6
Pasture parameters and radiant energy conversion efficiency on a natural grassland in the Central Depression of Rio Grande do Sul, with dominance of *P. notatum* and different forage offer (FO) levels (5-year average; 21.6 TJ/ha of incident PAR).

Parameters		Dry matter on offer – percent liveweight			
		4.0	8.0	12.0	16.0
Accumulation Rate (AR)	kg DM/ha/day	11.88	15.52	16.28	15.44
DM Production	kg/ha	2 075	3 488	3 723	3 393
Primary Aerial Productivity (PAP)	MJ/ha	40.877	68.714	73.343	66.842
PAR/PAP Efficiency	%	0.20	0.34	0.36	0.33
Daily liveweight gain (DLWG)	kg/head	0.150	0.350	0.450	0.480
Animal-day/ha	no.	572	351	286	276
Stocking rate	kg LW/day/ha	710	468	381	368
Residual DM	kg/ha	568	1 006	1 444	1 882
Liveweight gain (LWG)	kg/ha	80	120	140	135
Secondary production (SP)	MJ/ha	1 880	2 820	3 290	3 173
PAR/SP Efficiency	%	0.009	0.0015	0.017	0.013
PAP/SP	%	4.48	4.53	4.66	4.10

SOURCE: Adapted from Maraschin *et al.*, 1997; Nabinger, 1998.

them. With plant development and dead matter accumulation at the base of the plants, there seems to be a reduction in AR and also a liveweight gain inhibition, as the treatment with an FO of 16 percent of liveweight suggested. The parallelism of both development curves suggests liveweight gain variations are closely related to AR (kg DM/ha/day), as both showed optimal response at an FO of 13 percent liveweight.

Grazing intensity effects can be evaluated on the energy flow of the system, as a function of FO levels. Forage availability (kg DM/ha) and liveweight gain (kg LW/ha) are multiplied by 19.7 and 23.5 MJ/kg, respectively (Briske and Heitschmidt, 1991). Based on normal global radiation and photosynthetically active radiation (PAR), Nabinger (1998) determined conversion efficiency indexes, which represent the quotient between the energy values considered, multiplied by 100 (Table 5.6). With an FO of 4.0 percent LW, conversion efficiency of PAR to DM is estimated at close to 0.20 percent. Conversion increased to 0.34 percent with an FO of 8 percent LW, peaked at 0.36 percent with an FO of 12.0 percent LW and declined to 0.33 percent with an FO of 16.0 percent LW, as a consequence of age and senescence of natural grasslands, influenced by FO levels. Primary production of natural grassland increased markedly (+80 percent) when FO was 12 percent.

The grazing animal prefers green grass to dry, leaf to stem, and the upper half of young leaves; this shows clearly what forage is desirable and what should therefore be encouraged in the sward. It is necessary to distinguish between the total aerial biomass of plants and the available DM for the grazing animal; the former is the forage technically within reach of the animal, while the latter is the forage selected. It has to be clear what should be the optimum height of the pasture after grazing to maintain regrowth capacity (Maraschin, 1993). Understanding this provides understanding of how animals behave on different swards and pasture conditions.

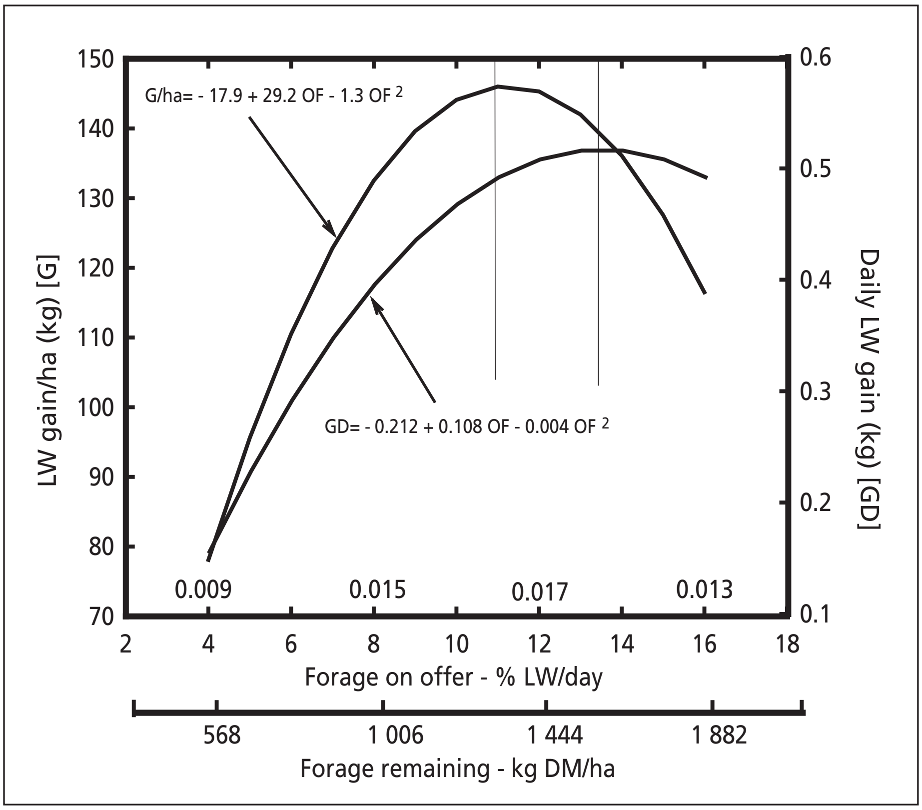
Data in Table 5.6 show that the highest liveweight gain (LWG) per head is when the number of animal-days per ha is low and LWG/ha reaches its maximum close to the maximum pasture AR, with an FO of 12 percent LW. Similarly, observing the efficiency of secondary production as a function of the energy fixed by primary production, the energy flow of the system shows that the efficiency of secondary production (kg LW/ha) in relation to PAR was 0.009 percent with an FO of 4.0 percent LW, increased to 0.015 percent at an FO of 8.0 percent LW, peaked at 0.017 percent at an FO of 12.0 percent LW, and then decreased in the FO of 16.0 percent LW treatment. Increasing FO increases the amount of dead material in the sward profile, which is wrongly considered as a forage component of pasture biomass (Maraschin, 1996). This is an important issue in animal-plant relationships, which has to be better understood, as it relates to quality expression and global yield of grasslands. This dry matter plays an important role in nutrient recycling in ecologically managed natural ecosystems, promotes moisture retention capacity of soils and conservation of soil, flora and fauna.

Optimizing animal production from natural grassland ecosystems

The amount and botanical composition of available forage determines the sustainable animal production level (Moraes, Maraschin and Nabinger, 1995), which depends on forage on offer for a specific animal class (Maraschin, 1996). Firstly, it is necessary to know how much forage is available to feed the stock properly in relation to their biological functions. Knowledge developed by the Forage Plants and Agrometeorology Department of the Federal University of Rio Grande del Sul (UFRGS) on forage transformation into animal products allowed the natural grassland heritage to be rescued and production raised to a level not seen before, due to better understanding of soil-plant-animal relationships. Seasonality of forage production reflects the favourable environment, with rainfall well distributed throughout the year. Grassland growth is different in the cool season (40–30 percent of the year) and warm season (Moojen, 1991). Fixed stocking may contribute to animal yield losses because of seasonal fluctuations, and may damage the grassland ecosystem and increase farmers' vulnerability. Since true forage production is in the warm season, it is mainly in spring that animals gain weight, thus defining overall performance for the year (Correa and Maraschin, 1994), because it is dependent on grassland daily growth rate (Table 5.6) and forage availability (Setelich, 1994; Maraschin *et al.*, 1997). If farmers do not make use of spring forage correctly, capitalizing it as animal products, they will not be able to catch up in summer.

FO levels determine sward profiles. With low FO (4.0 percent LW = high grazing pressure), pasture seems uniform, like a low sward, and forage from new leaves has 8 percent of crude protein. Prostrate summer species pre-

Figure 5.3
Forage offer (FO) and daily liveweight gains per animal (DLWG) and per hectare (LW) and its effect on solar radiation conversion efficiency, on a natural grassland of Rio Grande do Sul, Brazil.



dominate, with near disappearance of winter species and little contribution of legumes, decrease in *Andropogon lateralis*, *Aristida jubata* and *Eryngium horridum*, and increased bare soil. Regrowth does not reflect its forage production and daily LWG is low. With an increase of FO to 8.0 percent LW, animals show better body condition but the grassland is vulnerable, lacking protection for grazing-sensitive species.

At medium and low grazing pressures (12.0 and 16.0 percent LW) and higher FO, the grassland showed greater height, with more bunchgrasses of varying diameter. Winter species were more frequent and increased grassland quality, such as *Stipa neesiana*, *Piptochaetium montevidense* and *Coelorachis selloana*, besides native legumes, with an important presence of *Desmodium incanum*. Forage production and seed production of native legumes was only seen after 8–10 years of this grazing treatment. Under lighter stocking rates, animals graze more selectively and choose higher quality fractions of available forage, leaving higher, less grazed plants. This contributes to maintaining higher leaf area and promotes faster regrowth after each defoliation under continuous grazing. With selective grazing, on lightly stocked swards, forage production is higher, as is the voluntary intake of the animals, which produced daily liveweight gain (DLWG) of 0.500 kg per head (Figure 5.3). This DLWG would not be possible if one considers the average crude protein contents of the forage. The increased FO allows the animals to select a more nutritious diet than average; the animal is harvesting more because it is harvesting better.

With increasing levels of FO, ground cover increases; as leaves increase in relation to stems, forage and animal production also increase. The PAR/SP [Secondary Production] relationship nearly doubles when FO changes from 4.0 to 12.0 percent LW. Maximum LW is attained at lower stocking rates, which are exactly those that promote high DLWG, related to high AR and light grazing. The Primary Aerial Productivity (PAP):SP relationship had an efficiency of 4.48 percent with an FO of 4.0 percent, reaching 4.66 percent with an FO of 12.0 percent, as a consequence of increased DLWG. Lighter grazing pressures allow tall species to make important contributions to increase animal diet quality, and also protects native fauna.

Optimal utilization ranges for natural grasslands can be derived from a curvilinear response model, promoting productivity and ensuring sustainability, which is attained by higher utilization efficiency of incident PAR (Table 5.6 and Figure 5.3). Optimal utilization ranges are estimated from FOs of 13.5 percent of LW (maximum DLWG per head) to 11.5 percent of LW (maximum LW), where there is compromise between individual and per-hectare production. As there is considerable variation between the nutritional requirements of species and classes of animal (cow+calf, ewe+lamb, heifers, steers, bulls, horses, etc.) each pasture has to be managed according to the specific animal class requirements. Stocking rate and carrying capacity can only be defined as a function of the animal product involved and cannot be fixed, because they depend on environmental variations.

Table 5.7 can be prepared as a function derived from the grassland optimization model, which reflects natural grassland grazing optimization and the stocking rate that this pasture could feed at optimal carrying capacity. In the warm season – a nearly 200-day grazing period for natural grassland – these results adjust to the animal product yield equation in the following way:

Yield = Quality × Quantity
Liveweight/ha (LW) = DLWG × Animal-day/ha
146 kg = 0.517 kg × 282

Forage harvest from natural grasslands could be improved, representing an annual increase of 784 000 t live weight, without cost, in Rio Grande do Sul alone through the recommended strategy of high FO to the grazing animal,

TABLE 5.7
Natural grassland and animal performance in the optimal utilization range.

Parameters		Responses	
DM/ha/day	(kg)	16.30	(evaluated)
Animal-day/ha		282	(counted)
Daily LWG	(kg)	0.517	(evaluated)
Liveweight gain/ha	(kg)	146	(calculated)
Carrying capacity		1.17 two-year-old steers	(calculated)
Stocking rate	(kg/ha)	370	(observed)

which also optimizes forage accumulation rates in the pasture. This approach is expanding opportunities in southern Brazil.

Natural grassland dynamics

The natural grasslands of southern Brazil evolved without the presence of large herbivores, and were altered by the introduction of livestock at the beginning of colonization, changing from a climax condition to a productive disclimax with a range of growth habits and life forms. Knowledge of grassland ecology became important when the value of natural grassland was acknowledged in parallel with the need for controlling grazing-induced land degradation. Boldrini (1993) studied vegetation cover variations as part of the long-term grazing experiment described earlier, and then verified that soil type has a greater influence on botanical composition than FO levels. Erect plants were more sensitive to defoliation than prostrate ones, because leaf tissues and growing buds are more exposed to grazing. With lighter grazing, they stood above the sward canopy and dominated prostrate species.

Some important natural grassland species were selected to evaluate vegetation dynamics: *Paspalum notatum* is the one with greatest presence and contribution. Like *P. paucifolium*, it is a rhizomatous species, and they are both pioneers in more eroded and leached areas, with higher cover in FOs of 4.0 and 12.0 percent of LW. *Andropogon lateralis* benefits from high soil moisture levels, but is very sensitive to increases in grazing pressure. Its frequency decreases drastically with low FO (from 2.4 to 4.5 percent of LW) but it remains stable under optimal stocking and offers protection to other highly palatable grasses, allowing them to reseed. *Axonopus affinis*, with long stolons, thrives in damp areas of low fertility and benefits from high intensity grazing under low-FO treatments. *Aristida filifolia* is adapted to drier soils and is favoured by low grazing pressures, where it remains stable. *Paspalum plicatulum* shows lignification at the base of the leaf blades, but still it is well accepted and consumed by animals and damaged by heavy grazing under low FO. It seems to benefit from light grazing and showed marked increases in density and cover after two or three years of light grazing. It benefits from the shelter of more vigorous vegetation and so produces seeds and increases in the grassland. *Piptochaetium montevidense,* which is important because it grows more in winter–spring, shows higher cover on hillsides and seems to suffer from competition in more humid niches, but tends to persist in less dense swards. Another important plant is the legume *Desmodium incanum*, which presents higher cover values under light spring grazing pressure and with the aid of protective species. It shows ecological versatility in the face of competition, and flowers and produce seeds, generating viable plants to increase the population.

In a study where FO levels were associated with soil fertility and deferred grazing (Gomes, 1996), the prostrate species *Paspalum notatum* was more frequent on heavily grazed treatments, whereas the caespitose species *Andropogon selloanus* and *Elionurus candidus* were commoner on lightly and very lightly grazed paddocks. Plant groups that are independent of growth habit, such as *Paspalum paucifolium*, *Eragrostis neesii* and *Eryngium ciliatum*, occurred on drier sites, while *Andropogon lateralis*, *Eryngium horridum*, *E. elegans*, *Schizachyrium microstachyum* and *Baccharis trimera* occurred on sites with higher soil moisture levels, and were also sensitive to heavy grazing.

An interesting issue was the tolerance of heavy grazing shown by *Coelorachis selloana* and *Piptochaetium montevidense*, both low growing with buds close to the soil. However, when FO is higher they grow along with the height of the sward profile and remain as contributors to DM production. The ability to adapt growth habit is also seen in the native legume *Desmodium incanum*: it remains prostrate under heavy grazing, but its branches rise to sward height when grazing is reduced. The legumes *Aeschynomene falcata*, *Chamaecrista repens*, *Stylosanthes leiocarpa*, *Trifolium polymorphum* and *Zornia reticulata* are associated with higher utilization intensities, but need resting periods. Non-limiting FO management practices on natural grasslands seem to be an ecologically efficient procedure to restore and maintain grassland productivity in a sustainable manner.

FERTILIZING CAMPOS GRASSLAND

Fertilization in Argentina

In the past 30 years the Mercedes Research Station has evaluated the effects of fertilizing natural grasslands on animal production in the Rocky Outcrops region. Large increases in stocking rate, liveweight gain per animal and annual beef production per unit area have been registered in all trials. The first study showed that, with NPK fertilization, animal production increases yearly, reaching 210 kg LW/ha/year by the third year, which represented a 138 percent increase over the control (Royo Pallarés and Mufarrege, 1970). Subsequently, different N levels were applied to natural grassland, which raised animal production in the third year to 254 kg LW/ha/year at 120 kg N/ha/year (Mufarrege, Royo Pallares and Ocampo, 1981).

Phosphorus fertilization was evaluated for 11 years at the Estancia Rincón de Yeguas. Average animal production on fertilized paddocks was 40 percent higher, for the three stocking rates evaluated, with production levels that rose to 188 kg LW/ha/year (Benitez, unpublished). In another eight-year fertilization and stocking rate trial by Mercedes Research Station, production reached 176 kg LW/ha/year at the higher stocking rate. The increase in total animal production at the same individual performance level was 76 percent (Royo Pallarés *et al*., 1998). Observed effects of phosphorus fertilization on grasslands are increased forage production, a large increase in the phosphorus content of the forage and increased legume cover.

Fertilization of Campos Grasslands in Uruguay

The reduced winter growth of natural grasslands due to P and N deficiencies in most of the soils of the region led to the use of inorganic nitrogen and to legume introduction with phosphatic fertilization to foster establishment and production. Phosphatic fertilization alone has little impact on botanical composition and production increases are low (less than 15 percent) because of the low frequency of native legumes.

The use of relatively low doses of N and P_2O_5 (90 kg N/ha/year; 44 kg P_2O_5 ha/year) favours an increase in the fertility level of the soil, especially if the fertilizer is split: the first dose at the beginning of the autumn and the other at the end of the winter. This can only be done when relative frequency of winter forages in the total vegetation is above 20 percent. Autumn application promotes regrowth of winter grasses and extends the growth of summer grasses into late autumn. Winter application favours longer growth of winter species and earlier regrowth of summer ones (Bemhaja, Berretta and Brito, 1998).

As the fertility level of the system increases, forage growth starts to stabilize at a level that is 60 percent higher than an unfertilized grassland. The seasons in which fertilization can make significant improvements to livestock production are autumn and winter. Autumn daily forage growth is higher on fertilized grasslands. To defer forage for winter feeding, autumn growth should be sufficient to accumulate more than 1 000 kg DM/ha, plus the available forage prior to deferment or stocking rate reduction. Fertilized grasslands show 100 percent increments in daily forage growth rates during winter, compared with unfertilized grasslands (Figure 5.4).

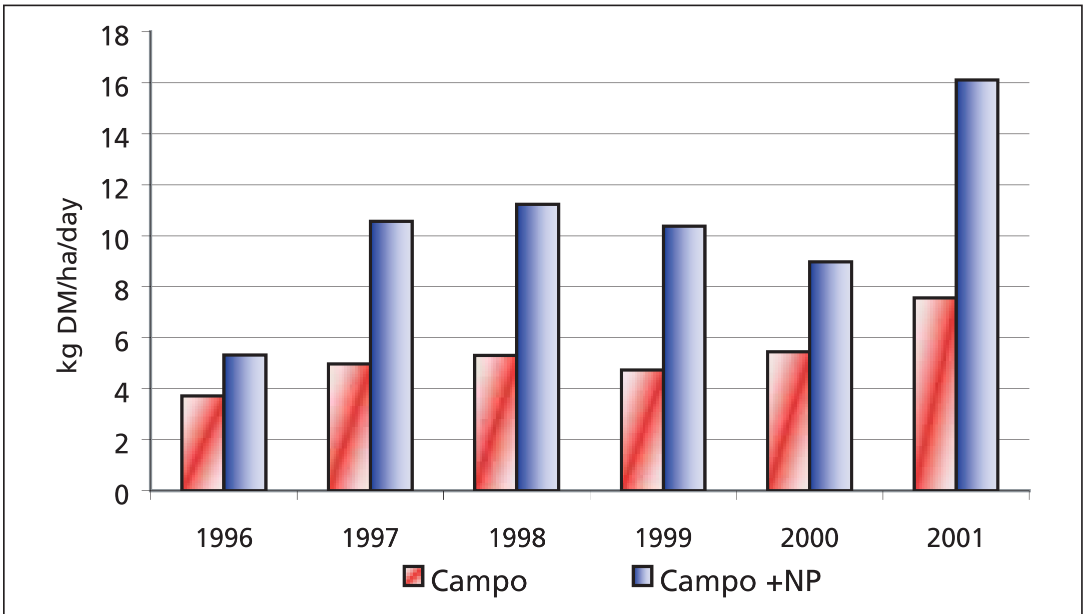


Figure 5.4
Winter daily forage growth rate (kg DM/ha/day) of unfertilized and N+P fertilized natural grasslands.

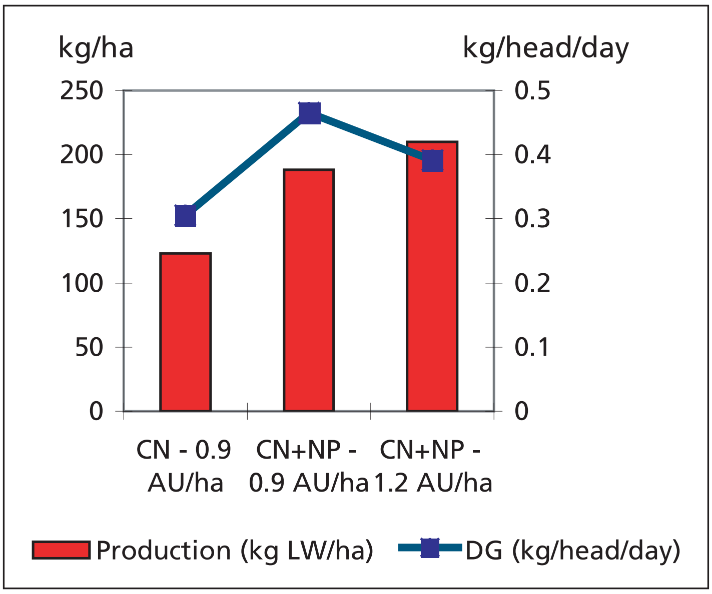


Figure 5.5
Daily liveweight gain (kg/head/day) and beef production (kg liveweight/ha) on natural grasslands with rotational grazing stocked at 0.9 AU/ha, and on fertilized natural grassland with rotational grazing and stocking rates of 0.9 and 1.2 AU/ha.

Spring forage growth for these grasslands exceeds 1 600 kg DM/ha, while unfertilized grasslands produce about 1 000 kg DM/ha. Maximum registered daily forage growth rate without fertilization was 19 kg DM/ha/day, while fertilized grasslands shown a maximum of 35 kg DM/ha/day. Summer growth is tightly tied to precipitation and therefore highly variable. Annual addition of 92 and 44 kg/ha of N and P, respectively, increased forage production, adding 7.5 kg DM/kg nutrient in the first year and about 24.0 kg DM/kg nutrient in subsequent years.

Nitrogen and phosphorus content in the forage is always higher in fertilized grasslands. In natural grasslands, the highest N and P values occur in winter and spring, and the lowest are in summer, when forage is mature and, as usual, there is a moisture deficit (Berretta, 1998). In winter, N content of forage reaches 2.3 percent, while unfertilized grasslands reach 1.7 percent; in spring the values are 2.8 and 1.9 percent, respectively. In summer, N contents decreases to 1.4 and 1.1 percent, respectively. Taking winter as an example, natural grasslands produce about 38 kg/ha of crude protein (CP), while fertilized grasslands produce about 95 kg CP/ha. Forage P content during winter and spring is about 2.3 mg P/g DM with fertilizer and 1.8 mg P/g DM without fertilizer (Berretta *et al.*, 1998). The values are 1.9 and 1.5 mg P/g DM, in summer and 1.5 and 2.2 mg P/g DM in autumn, respectively.

Throughout the year, the relative frequency of winter grasses is higher in fertilized grassland. The increase in the C_3 grasses is related to nutrient input, which raises the fertility level of the soil. Fertilization is a way of changing the botanical composition of grasslands and consequently to increase winter forage production.

Winter-productive species such as *Stipa neesiana*, *Piptochaetium stipoides*, *Poa lanigera* and *Adesmia bicolor* tend to increase their cover with fertilization. Summer grasses such as *Paspalum notatum* and *P. dilatatum* also increase their cover. Ordinary grasses, such as *Bothriochloa laguroides* and *Andropogon ternatus,* decrease and *Schizachyrium spicatum* becomes less frequent than the others following fertilization, as it is most competitive in a poor environment. *Paspalum plicatulum* also decreases with fertilization, although this may be linked to a palatability increase, as its leaves keep green for longer than unfertilized grassland. Native legumes increase in frequency, reaching values close to 5 percent. Weeds, typically *Baccharis coridifolia*, *B. trimera* and *Heimia* sp., are scarce and do not increase with fertilization.

Fertilized grasslands managed under rotational grazing provided the highest beef production per unit area when stocked with 1.2 AU/ha, and the highest liveweight gains per animal at the lower stocking rate of 0.9 AU/ha (Figure 5.5). At lower stocking rates on fertilized grasslands, steers grew to 440 kg liveweight at 2.5 years, while at the higher stocking rate they did not exceed 400 kg.

Results can be quite different if the grassland has a high proportion of summer species and the winter species are mainly annuals, like the soils of the Crystalline and Eastern Hills. Fertilization at the start of the winter favours the presence of winter annual grasses such as *Vulpia australis* and *Gaudinia fragilis*, which have limited productive potential at the end of the season. The disappearance of these species as they finish their growth cycle leaves spaces that can be occupied by undesirable plants. Spring fertilization increases forage growth at the end of the summer, when summer grasses flower and produce seeds. Organic matter digestibility of fertilized forage was greater than unfertilized grassland (Formoso, pers. comm.). N fertilization increases spring and summer production markedly, but has little effect on winter growth. This nutrient increases the frequency of annuals and decreases perennials (Ayala *et al*., 1999). N+P fertilization produces a threefold increase in beef production in comparison with untreated natural grassland.

Fertilization of natural grasslands in southeast Brazil

The quality and production potential of natural grasslands were always considered to be limited. There was uncertainty about their responses until Scholl, Lobato and Barreto (1976) showed forage production increases on natural grassland with N applications in summer, and Barcellos *et al*. (1980) obtained significant responses of natural grassland to high P fertilizer rates. After the results of Rosito and Maraschin (1985) on secondary succession on fertilized grasslands, a new scenario was clear for southern Brazil, with animal production results in the Central Depression (Perin and Maraschin, 1995) similar to those obtained in Campaña fields (Barcellos *et al*., 1980). On poor soils of the Central Depression of Rio Grande del Sul (30°S), blanket application of lime and fertilizers (Moojen, 1991) evaluated five years later (Gomes, 1996) showed a rise of pH and reduction in Al^{+++}, while calcium, magnesium and phosphorus contents of the upper 7.5 cm of the soil increased. Organic matter content of this horizon also increased with fertilizer increase, in the same way as deferment accumulation, which increased the litter content in the pastures. From the beginning of this study, *Desmodium incamun* responded rapidly to increasing fertilizer levels, rising to 12.5 percent (Moojen, 1991) and reaching close to 24.4 percent of contribution to total DM of the natural grassland five years later (Gomes, 1996).

Residual effects of fertilizers reduced the number of species, from 137 species noted by Moojen, (1991) to 122 recorded by Gomes (1996); this was attributed to better conditions offered to species that were formerly limited by low soil fertility. These species become dominant, modifying the flora. The presence and contribution of *Paspalum dilatatum*, *P. maculosum*, *P. pauciciliatum* and *P. urvillei* was noted, yet these desirable grasses were not mentioned in the report of Moojen (1991). There was also development of the legume *Trifolium polymorphum*. Another important observation reported by Gomes (1996) was the increased frequency of *Desmodium incanum*, *Agrostis montevidense*, *Coelorachis selloana*, *Paspalum notatum*, *Sporobolus indicus* and *Stipa* spp. when more than 250 kg/ha of P_2O_5, were applied; the species also increased their contribution to DM production of grasslands. *Elionurus candidus*, *Aristida* spp. and dead material were less. When fertilization rates were below 250 kg P_2O_5/ha, *Paspalum plicatulum*, *Piptochaetium montevidense* and *Axonopus affinis* increased their presence and made some contribution to DM production, while *Andropogon lateralis*, *Elionurus candidus* and *Piptochaetium montevidense* were intermediate contributors.

With blanket N+P fertilization of natural grassland, Moojen (1991) and Gomes (1996) raised forage production to 7.0 t DM/ha. Subsequently, through increasing N and avoiding moisture stress, Costa (1997) reported 12.0 t DM/ha and derived the following DM production model for unit area (m^2) per day of *Paspalum notatum*:

$$DM = 0.44.\ Rs\ (1\ exp(-0.0031.\ ST)) + R$$

where Rs is global solar radiation, ST is thermal addition and R is green residual DM. Following this model, Boggiano (2000) obtained 18.0 t/ha of total DM, including stolons and roots to 8 cm deep, on a natural grassland dominated by *P. notatum.* Liveweight gain per hectare was 700 kg in 200 grazing days, under continuous stocking. This response removed suspicions about limited growth potential of natural grasslands, creating expectations for this natural resource.

Structural changes on fertilized natural grasslands in SE Brazil

As research programmes evolved, fertilizer studies on natural grassland were extended to consider different fodder offers and N fertilization levels applied in a Composite Central Rotation with Uniform Precision experimental design, using three-day spells of grazing on a grazing cycle of 38 days. This study exposed a lack of knowledge about N fertilization responses of natural grasslands. Nitrogen action was reliable on some important species, such as

Paspalum notatum. Following Lemaire (1997), DM production of vegetative grasslands depends mainly on three morphogenic variables: Leaf Appearance Rate (LAR), Leaf Expansion Rate (LER) and Leaf Life Span (LLS). These variables are genetically defined, but modified by environmental factors. The combination of these variables determines the structural characteristics of the grassland, such as tiller density, leaf size and number of leaves per tiller, and the integral outcome gives the Leaf Area Index (LAI). Boggiano (2000) verified that LER and the number and size of leaves and tillers were very sensitive to N effects and defoliation management, leading to different recovery rates of *Paspalum notatum* after grazing. LAR was 5.5–7.0 days, influenced by N and FO, suggesting that lighter grazing increases sheath length, the expansion period and the size of new leaves. With low N applications, there is an increase in the number of small leaves and a longer LLS. Average LLS varied from 21 to 31 days, increasing with FO and with reducing N. It was evident that LAR and tiller density increase with higher defoliation intensities.

Tiller density depends on LAR and increases with lower FO, which provoke higher grazing frequency (more defoliations). At the same time, N increases LAR and stimulates higher tiller densities under lower FO, while contributing to low tiller number in high FO conditions, where defoliations are less frequent. N × FO interaction alters compensatory relationships, with a trend towards higher tiller density on high N–low FO swards. N reduction decreases tiller density and increasing N raises the weight per tiller. This gives us the parameters for an area covered by *Paspalum notatum*, modelling a compact sward with low production. It differs from a productive grazing pasture, with fewer, bigger tillers, in a higher sward profile that ensures high DM accumulation rates and it is more favourable for animal production.

Average final length of the laminae is more dependent on previous defoliation intensity (residual LAI) than on nitrogen supply. Bigger tillers have greater LER (Table 5.8). It seems to be desirable to promote management practices that promote larger tillers. LAI is the main factor determining interception of incident solar radiation, which has direct effect on the DM accumulation rates

TABLE 5.8
Estimated LAI values for *Paspalum notatum* as a function of surface response models for residual LAI and after 33 days of regrowth (Boggiano, 2000).

FO (percent of LW)	N (kg/ha)	LAI after grazing	LAI after 33 days regrowth
4.0	0	1.992	3.956
4.0	100	1.555	4.093
4.0	200	0.644	4.144
9.0	0	0.962	2.536
9.0	100	1.462	3.675
9.0	200	1.614	5.924
14.0	0	1.480	2.816
14.0	100	3.045	6.153
14.0	200	4.130	9.404

SOURCE: Adapted from Boggiano, 2000.

of grasslands (Brougham, 1959; Parsons, Carrëre and Schwinning, 2000). For *Paspalum notatum*, responses to N and FO were observed reaching LAI values of 9.4, which is high for this kind of plant.

With low N, the pasture is more prostrate and less exposed to animal defoliation. With increased FO, grazing is more selective, leaving more residues that contribute to regrowth. With frequent grazing and low N there are smaller leaves with low LAI values, less light interception and lower DM production. Increasing N promotes faster LAI recovery, which in the higher FO promotes a faster regrowth start, with higher LAI at the end of the regrowth period. Therefore there is higher radiation interception, higher carbon sequestration, higher forage production and higher efficiency of applied N.

Green DM of the grassland is produced from the grazing stubble, which increases according to the net AR of the regrowth period, which is increased by the action of N. The effect of management has been well documented, because Boggiano (2000) observed available DM increases of 1 000 kg/ha for each 35 days of regrowth, as this is the response to lighter grazing on fertilized grasslands. The low LLS makes difficult to maintain high LAI values, while low FO, with low LAI, consistently show less leaf length and less final length. Higher grazing intensity leads to reduced forage production, lower forage accessibility for grazing animals and consequently lower intake.

In terms of plants and pastures, with low FO and poor N status, the priority is to accumulate dry matter in stolons and roots, preserving meristems and increasing the proportion of stolons in total aerial biomass, so as to supply the demands of the next growth period. At intermediate FO, stolon biomass is maximal and root biomass minimal. This topic requires more study. Stolons cannot be grazed, so *Paspalum notatum* and its biological forms show greater cover on grazed grassland. Defoliation and shading alter the carbon supply to plants and increase the proportion used for leaf production, while factors that reduce meristem activity (N, moisture) promote higher carbon accumulation in the roots (Lemaire, 1997). Careful use of N increases the capacity of natural grasslands to sequestrate carbon from the atmosphere, storing it in permanent plant structures for growth, organ and tissue development, DM production, and consequently livestock feeding. Better performance tends to reduce methane emissions and the litter that, with animal dejections, constitute the main source for renovation and increment of soil organic matter. This enrichment of the environment promotes favourable conditions for microfauna, which form part of the fertility chain of predator fauna, hence contributing to environmental health, nutrient recycling and strengthening of life expression in natural grassland.

IMPROVEMENT TECHNIQUES

Over-seeding

This technique for introducing valuable forages to the sward has been evaluated for a long time. Many forages, mainly winter legumes, have been

TABLE 5.9
Winter performance and yearly liveweight gain for two treatments on natural grassland.

Treatment	LWG winter period	Year		
	kg/day/head	1997	1998	1999
			liveweight/ha/year	
P fertilization	0.615	151	219	267
P fertilization + over-seeding	0.695	173	245	302

tested and also seeding methods, previous grassland management, fertilization levels, over-seeding, grazing management, etc. Rarely do the introduced species persist for more than three years due to strong competition from native species. Despite this, when some winter species become established, animal production increases are large. Higher productivity has been obtained recently in a three-year grassland improvement trial. Preliminary results of two treatments are shown in Table 5.9 (Pizzio, unpublished).

The most interesting results from this trial are the excellent animal performance in winter, which exceeded 0.6 kg/day when normally there is no gain at this season, and the year-on-year productivity increases.

This experiment considered some factors not previously evaluated: (1) a higher level of phosphorus fertilization in comparison with previous research, which brought the phosphorus content in grass above 0.22 percent, which had not previously been recorded; (2) a sward structure that offered a good quantity of green, easy-to-graze grass; and (3) a diverse and desirable botanical composition, that offered good quality green feed in winter, with species such as red clover, *Lotus* cv. Rincón, ryegrass and oats. These factors, with others, allowed the animals to harvest a large quantity of high quality of forage in the available grazing time, to attain performance similar to those from sown pastures.

Legume introduction

The need to improve the primary production and quality of Uruguayan grasslands led to legume introduction using minimum- or no-tillage techniques, as a way to increase secondary production. Correcting soil P deficiencies is a crucial element in this process (Bemhaja and Levratto, 1988; Berretta and Formoso, 1993; Berretta and Risso, 1995; Risso and Berretta, 1997; Bemhaja, 1998). The study of anthropogenic factors provides an understanding of various aspects of induced vegetation succession, which contributes to success in the application of the technology. To make a proper improvement in natural grasslands, the following must be considered:

- *Vegetation sward* as botanical composition defines the quality of the grassland, related to productive types, vegetative types and growing cycle.
- *Soil* type, topography, stoniness, drought and erosion risks, drainage, etc.
- *Grazing objective* for the improved paddock: cattle, sheep, fattening, weaning, etc.

These factors influence the selection of forages to be introduced and the way the seed will be in contact with the soil, for efficient moisture and nutrient supply to the seedling. The establishment, productivity and persistence of introduced forages depends mainly on the way that competition from natural herbage is reduced, the quality of the seedbed and the adaptation of introduced species to the environment. Forage yield of improved pastures depends on soil type and botanical composition, and can be 50 to 100 percent higher than unimproved grasslands, with winter yield up to three times higher (Berretta *et al.*, 2000).

Sward preparation for seeding

Generally it is necessary to graze with cattle beforehand to reduce tall-grasses and accumulated dead material. Stocking rates will depend on forage availability at the end of the spring and summer, but should be high. If the summer is wet, grass growth will be high and dry matter and seed stalks will remain at the end of the season, so stocking must be increased to eliminate this material. Sheep are used in the final stages, to reduce sward height to 2 cm. This grazing could be continuous, but rotational grazing is better to allow regrowth and regrazing; this reduces wild plant reserves, thus favouring the germination, emergence and establishment of the introduced forages. Depending on grass growth, grazing must be done every 30–45 days. If grazing is alternated with resting, stocking rates must be much higher than with continuous grazing. Sward preparation aims to provide safe sites for good seed-soil contact. Generally it is very difficult to reduce vegetation cover below 50 percent, although sward height may be low. Some herbage at sowing time is, however, important to protect seeds from bad weather.

Chemicals must be used carefully. Non-selective contact herbicides are preferred, to avoid reducing the growth capacity of native plants. When systemic herbicides are used, the dose must be low enough to preserve valuable native species (Berretta and Formoso, 1993).

Legumes for improvement

Many evaluations of different genera and species of legumes have been carried out. Recent studies include several species of *Trifolium*, *Lotus, Medicago, Ornithopus, Desmanthus, Vicia,* etc. (Bemhaja, 1998). On medium and deep soils, the best forages tested have been white clover cvs Zapicán and Bayucuá, and *Lotus corniculatus.* Less reliable have been *L. pedunculatus* cv Maku, *L. hispidus* cv. El Rincón and red clover (*Trifolium pratense*).

Recommended seed rates are 4–5 kg/ha for white clover, 10–12 kg/ha for *L. corniculatus*, 2.5–3.5 kg/ha for *L. pedunculatus* cv Maku, 4–5 kg/ha for *Lotus* cv. El Rincón, 6–8 kg/ha for red clover, and for a mix of white clover and *L. corniculatus*, 2–3 kg/ha of the former and 8–10 kg/ha of the latter are recommended (Risso, 1991; 1995; Risso and Morón, 1990).

TABLE 5.10
Production of steers in rotational grazing on improved native grasslands in different regions of Uruguay.

Soils	Stocking rate (AU/ha)	Liveweight gain (kg/ha)	Individual performance (kg LW/head)
Crystalline	1.55	533	406
Medium and deep Basalt	1.85	680	485
Hills	1.53(1)	700	473

NOTES: (1) Includes mixed grazing with wethers in a ratio of two wethers per steer.
SOURCE: Adapted from Ayala and Carámbula, 1996; Bemhaja, Berretta and Brito, 1998; Risso and Berretta, 1997.

This improvement technique is low-input and environmentally friendly, promotes sustainable development of native vegetation and improves productivity, accelerating fattening by means of better individual performance and higher stocking capacity (Table 5.10). These results were obtained in rotational grazing conditions, 5–8 paddocks, 7–12 grazing days and 30–40 rest days, in grazing seasons of about 300 days (Berretta *et al*., 2000).

Effect of legume introduction on composition of native grasslands

Once legumes have been established for some years, an important change is an increase of winter grasses (C_3) (Berretta and Levratto, 1990; Bemhaja and Berretta, 1991). On similar unimproved grasslands of the basalt region, summer species are always more frequent than winter ones (Formoso, 1990; Berretta, 1990). On improved grasslands, the relative frequency of winter forage species is around 75 percent, with similar values for native grasses and introduced *Trifolium repens*. The increased frequency of better quality species raises the N content of the forage to 3.2 percent.

Flowering and seed production are necessary to maintain introduced species in the pasture. This ensures regeneration the next autumn, since they pass the summer partly as plants and partly as seeds (Berretta and Risso, 1995). Reduction or total exclusion of grazing also favours seed production of native winter grasses, including *Poa lanigera*, *Stipa setigera*, *Piptochaetium stipoides* and *Adesmia bicolor*. Therefore conservation of these species in native grasslands is related both to rest periods to allow flowering and seed production, and to increased soil fertility. In many improved grasslands, there is a remarkable increase in the frequency of *Lolium multiflorum*, which has adapted, and in many cases is introduced and thrives with increased fertility.

Legume introduction can have positive effects in more degraded grasslands, dominated by unproductive or unpalatable grasses and short herbs. Relative legume frequency (*Trifolium repens*, *Lotus corniculatus*) is about 60 percent. Native, productive winter grasses – *Stipa neesiana* and *Piptochaetium stipoides* – and naturalized species, such as *Lolium multiflorum*, increase in frequency, while unproductive grasses and herbs decrease (Berretta and Risso, 1995; Risso and Berretta, 1997). Oversowing of perennial and annual legumes in C_3-dominated grasslands that had a yearly forage production of

3 400 kg DM/ha, increased forage production to 8 600 kg DM/ha (Ayala *et al*., 1999).

Stock management

Managing livestock is one of the most important options for farmers in improving the utilization efficiency of available forage and to increase its productivity. This low-cost technique is based on adapting the nutritional requirements of stock classes to the grassland growth curve. Stock management involves short seasonal mating, early weaning, pregnancy diagnosis, stock classification according to nutritional requirements, and sales organization. An example of the impact of this technology is found in Curuzu Cuatiá Department. While the average liveweight gain for the Department is 56 kg/ha/year, twelve farms that adopted these practices averaged 88 kg/ha/year over five years.

Mineral supplementation

Phosphorus deficiency in diets is one of the limiting factors for animal production in the region. Unsupplemented steers have a liveweight gain of 66 kg/year, while supplemented steers can gain 106 kg/year.

Other management practices

Other management practices that increase productivity include mowing of tussock grasslands, burning, autumn deferments for winter grazing, strategic rests for paddocks, energy-protein supplementation, and "protein banks".

RESEARCH AND DEVELOPMENT PRIORITIES

Advances in knowledge over the last 35 years concerning the structure, function and management of natural grasslands show that there is great potential, at least in the Rocky Outcrops region. The next task should be to evaluate these technologies in other ecological regions where this could be applicable. In regions such as the *malezales*, factors such as drainage and use of fire have to be studied before thinking of any further improvement. The relationship between soil series, grass production and carrying capacity is an issue that has received little attention. Soil has a great effect on grassland production and stability, but research has paid little attention to this topic.

A task that has to be completed, validated and then extended is paddock ranking. Managing natural grasslands means to manage soil, vegetation and stock within the constraints of climate to get the best results from the combination of factors. Each stock class has specific nutritional requirements; each paddock has different FO and potential. Today, the pastoral value of a paddock is subjectively evaluated. Methodology development is required to enable simple objective paddock ranking, and to match paddock FO with animal requirements.

Research has focused on technology for increased production. Monitoring the effects of recommended technology with respect to biological and economic sustainability has received little attention. The search for alternative production from grasslands, such as agrotourism and game harvesting, would allow diversification of use of these ecosystems. There is a need to find reliable sustainability indicators to allow us to ensure that recommended technologies are sustainable, so coming generations receive a better resource than we inherited.

Ecological grassland management for maintaining productivity

Natural grasslands are the main basis for meat and fibre production in the region, and are also a huge reservoir of valuable grass and legume species, which it is necessary to select and screen under cultivation. Only with deep knowledge of the behaviour of native species will it be possible to conserve and improve the natural grasslands and protect the soil from erosion and degradation. Research in the region suggests that the potential of natural grasslands is very high, close to cultivated pastures, with better persistence.

Studies on natural grassland dynamics with several management-controlled factors reflect ongoing changes that occur slowly, with seasonal variations more important than grazing effects. Over longer periods, high continuous grazing and a high sheep:cattle ratio encourages pasture degradation and lower primary production. Quite often, high stocking rates are maintained for economic and social reasons, but ultimately lead to poorer animal production. Higher stocking rates may increase short-term economic returns, but they increase operational risks. Continuous and deeper studies of native grasslands and native forage species will increase understanding of the factors that promote high secondary productivity – meat and wool in this case – through primary production increases related to better use and conservation of forage.

When stocking rates are adjusted to grassland potential and grazing methods include rest periods, grasslands can be maintained, with variations due to seasonal changes. These prairie ecosystems are highly stable and are capable of recovering after severe impacts, such as droughts.

Spatial heterogeneity is high on most of the grasslands, mainly due to soil type, combined with weather fluctuations and grazing management. Vegetation types must have management practices adjusted to the morphological and physiological characteristics of the dominant species, so they are better managed as independent units. When planning grazing systems, it is necessary to know precisely which species are present in the vegetation, concentrating on productive types, particularly when coarse ordinary grasses are dominant, because prolonged rests and low stocking rates may be beneficial. Determining a proper stocking rate that achieve animal performance objectives without ecosystem deterioration is the most important management decision. Each grassland has a production potential that determines its carrying capacity. The main problem in developing an optimum stocking rate criterion is the need to preserve forage to be used when grass growth is limited by moisture stress or low temperatures.

Liveweight gains are highly variable, being a function of weather and forage availability. When pastures have winter species, autumn deferment is recommended to supply forage for winter. When winter grasses are scarce, forage accumulation must be achieved in other periods because of fast declining forage quality in autumn; under conditions of low autumn growth and quality loss as the resting period extends, the accumulated forage is inadequate to supply animal requirements and provide the desired liveweight gains (Ayala *et al*., 1999).

Inadequate grazing management – such as overgrazing, inadequate subdivision and continuous grazing – prevent flowering and seed production of winter grasses, leaving reliance on vegetative mechanisms alone for persistence. This may be the main reason for decreased cover of winter grasses in natural grasslands of the Campos.

Raising the fertility level of the soil by means of N and P fertilization increases the production and quality of natural grassland. The process is relatively slow, with increased responses as more nutrients are applied. Fertilization "disturbance" leads vegetation to a new equilibrium point, with botanical changes consisting of an increase in productive species frequency, and therefore increased secondary production. This technology complements grassland improvement with legume introduction, as well as cultivation of perennial and annual forages. Natural grassland fertilization allows increased production and quality of vegetation on soils too shallow for more productive forages. At the same time, the residual benefits of N and P fertilization must also be considered.

N and P additions, particularly the latter, should help to return to natural grassland something that has been extracted during centuries of grazing, from livestock introduction at the beginning of the seventeenth century, besides its contribution to plant and animal biodiversity maintenance on natural grasslands. It is important to conserve this natural resource without degrading it, maintaining an awareness of the economic, ecological and social aspects implicit in sustainable development.

The introduction of legumes, coupled with fertilizing at sowing, yearly maintenance phosphorous dressings and grazing management, move vegetation, in a slow biotic process, to a new equilibrium point where yield and quality are higher than the original. Grazing management and fertilization have to be closely controlled to maintain the pasture at this higher equilibrium point. The result should be a sward dominated by winter species, where high quality native perennial species are outstanding. This is an alternative route to increasing annual primary production without using herbicides while conserving productive species of the natural grassland.

It is necessary to improve the extension of available technologies and to promote the training of scientists specialized in management and conservation of natural grasslands. This discipline does not exist in Uruguay, despite its main agricultural exports being based on natural grassland outputs.

Scientific knowledge has contributed to better natural grasslands management practice, which has resulted in biological and economic benefits for farmer communities and society in the long term, with special care for animal and vegetation biodiversity and water conservation for the use of all living creatures. Plants and domestic animals will continue to provide the main food and fibre source of the world, conditioning our actions and behaviour to preserve natural resources for future generations.

In 1943, Professor Bernardo Rosengurtt wrote:

"Let us conserve with infinite care the prairie heritage, simultaneously national and private, to transfer it whole to the coming generations."

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