# Ecophysiology and Management Response of the Subtropical Grasslands of Southern South America

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# ECOPHYSIOLOGY AND MANAGEMENT RESPONSE OF THE SUBTROPICAL GRASSLANDS OF SOUTHERN SOUTH AMERICA

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## Abstract

The subtropical grasslands of Southern South America (campos) are located approximately in the range of 24° S to 37° S latitude. These grasslands are dominated by $C_3$ and $C_4$ grasses, and in a lesser extent to herbaceous plants, shrubs and dispersed trees, with some exceptions in particular regions. Previous to the introduction of large herbivores, at the beginning of the XVII century, like cattle and horses, shrubs and tall grasses dominated the vegetation. Then, associated with greater grazing pressure and partially due to fire, the original campos are maintained, actually in a pseudo-climax herbaceous phase. These native communities are highly stable, adapted to long periods of water stress and flooding. Campos are generally grazed at continuos stocking all year around by sheep, cattle and horses. With the exceptions of the secondary plant successions, the summer growing species ($C_4$) dominate the campos vegetation, having a high relative frequency (75%). Continuos grazing and coarse summer grasses contribute to decrease the frequency of winter species ($C_3$). There is a high spatial and temporal variation in the native communities related to the type of soil, texture, water capacity, topography, altitude, management, etc., which determinate the different proportions of vegetation types and botanical compositions. The temporal variation is mainly associated with climatic factors, principally rainfall, affecting the variability of the annual dry matter production of campos vegetation (CV = 40 to 50%). The range of annual forage production of campos vegetation varies between 2.5 (shallow and low fertility soils) to 7.0 ton DM $ha^{-1}$ (deep and fertile soils). Most of the annual forage production is mainly concentrated in spring and summer, reaching 70-80% and 60-70% in shallow and deep soils, respectively. Grazing management, and particularly the stocking rate utilised, is the principal factor determining changes in the botanical composition in this type of vegetation. In general, the use stocking rates greater than 1 stock unit $ha^{-1}$, for longer periods, causes reductions in forage production, associated with increases and decreases in the frequency of productive species and weeds/shrubs/forbs, respectively. Pasture degradation is even greater, when high stocking rates are applied in conjunction with the use of high sheep/cattle ratios (e.g. 5:1). The use of rotational grazing systems enhances pasture production by 12% as well as pasture utilisation. When continuos stocking is applied, it is difficult to achieve pasture utilisation greater than 50%. Avoiding overgrazing in degraded vegetation, it is possible to obtain a recovery in pasture conditions, while the degradation caused by continuos cropping is unrecoverable. Animal production is negatively affected when herbage mass or sward height are lower than 1000 kg DM $ha^{-1}$ or 5-6 cm, respectively. Animal selectivity allows sheep and cattle to have a greater crude protein (33 and 22% respectively) and metabolisable energy (15 and 11% respectively) levels than those obtained in the pasture offered. The use application of low quantities of nitrogen and phosphate on native vegetation increase forage production and nutritive value by 50%, enhancing the contribution of winter species ($C_3$) in the sward. Legume introduction by overseeding increases native pasture production by 60-100% and pasture

nutritive value by 50-100%, particularly during winter. This response is associated with the contribution of the introduced species and additionally by the increments in proportions of the native winter species ($C_3$), resulting in a higher plan community biodiversity. Improved pastures permit to obtain 4 to 5 times greater secondary production than those unimproved. The generated scientific knowledge has contributed to apply better pasture management practices, which resulted in biological and economical benefits to the farmer community and the whole society in the longer time, with special care of animal and plant communities biodiversity and water conservation for human and animal use. Both animals and plants will be for a long time our main source of food and fibre in the world, hence conditioning our actions and behaviour in the manner that we conserve our natural resources for the future generations.

## Introduction

This ecological region of South America is located between 25° and 36° South latitude. It includes South Brazil, East Argentina and the whole Uruguay, covering an approximate area of 450.000 $km^{2.}$ In the North extreme of the region are found elevations near 900 m high, but the height is generally lower than 300 m. The warmest month average temperature (January) is about 22°C, while the coldest month is about 8°C. The rainfall values are higher from South to North, from 1000 to 1500 mm respectively. These rainfalls are not markedly seasonal, but is do registered an ample seasonal and annual variation, with periods of high deficits or excesses that provoke flows, though droughts during spring and summer are the ones which, most negatively affect the forage production with the subsequent reduction in secondary production, that according to the deficit magnitude its consequences remain for years (Soriano, 1991; Deregibus, 2000, in press; Nabinger, 2000, in press).

The most numerous botanical family and most important in the region as well, is the *Gramineae* = *Poaceae*, with about 200 species, between warm season (C4) and winter (C3) ones, being this association a singular feature of these pastures. The most important tribes are: *Paniceae*, that includes the genus with the largest number of species *Paspalum*, *Panicum*, *Axonopus*, *Setaria*, *Digitaria*, etc.; *Andropogoneae*, with the genus *Andropogon*, *Bothriochloa*, *Schizachyrium*, etc.; *Eragrostea*, with the genus *Eragrostis*, *Distichlis*, etc.; *Chlorideae*, with the genus *Chloris*, *Eleusine*, *Bouteloua*, etc., with few species. The tribes of winter grasses, where a large number of cultivated species adapted to these conditions, are: *Poeae* (= *Festuceae*), with the genus *Bromus*, *Poa*, *Melica*, *Briza*, *Lolium*, *Dactylis*, *Festuca*, etc.; *Stipeae*, with the genus *Stipa* y *Piptochaetium*, with most native species; *Agrostideae*, with the genus *Calamagrostis*, *Agrostis*, etc., with scarce species. In general, the existence of winter species is associated to soil type, topography, altitude, fertility and cattle management. Along with the Gramineae live different vegetative type species, belonging to other botanical families such as: *Compositae* (= *Asteraceae*), *Leguminosae* (= *Fabaceae*), *Ciperaceae*, *Umbelliferae*, *Rubiaceae*, *Plantaginaceae*, *Oxalidaceae*, etc.. (Rosengurtt *et al*.,1970; Boldrini,1993)

The natural pastures are the main source of food for over 85% bovine and ovine of the region, which, generally grass together, mixed grazing, in most part of the region, the whole year in the open air. The bovine are about 45.000.000, whilst the ovine reach 20.000.000, though their number has remarkably decreased in the last ten years due to the international wool prices drop. To cattle and sheep must be added horses, which, relatively short in number, share these grasslands too. Except in extensive cattle farming areas, in reduced ones, does not exist a clear natural pasture differentiation for each one of these animal species.

In Uruguay and South Brazil the most often used term in vernacular language to refer to natural pastures at grazing is campos, which, is defined as a vegetal coverage constituted by gramineae, herbaceous plants, bushes and shrubs, where trees are rare (Berretta and do Nascimento, 1991). In Argentina the term pampas is used, though in the Argentinean Northeast is used too the term campos or pastizales. The trees generally are at the edges of watercourses or in stony sierras where short trees are found spread. The low frequencies of trees would be related to the region weather conditions, especially to the South, due to its being an environment with a negative hydro balance during a large part of the year and due to its use for fuel along with the population growth, from colonial times.

In this work will be presented results of the response to grazing management obtained mainly in Uruguay, on different types of natural vegetation managed with different stocking rate, grazing methods and sheep/cattle relationships. Also reference will be done to the introduction of N to the ecosystem, with the application of organic fertilisers or through the introduction of legumes in the natural pasture, without destroying the vegetal coverage and its effects on production, quality and botanical composition of the grass.

## Main vegetal communities

### Climax Vegetation (?)

The scarce data purveyed by the first colonists of these lands let make some inferences about the existing vegetation. The primitive population, due to hunting in order to get food or inter – tribal conflicts, had provoked changes in vegetation through the use of fire, as the existing herbivores were small compared to current cattle and horses, being the most important the deer (*Odocoileus bezoarticus*), who lives together with cattle, but is displaced by sheep that in Uruguay have superated 24.000.000 heads, though actually this figure has reduce to approximately the half, therefore the quantity of existing deers is very small and located in protected area. The ñandú (*Rhea americana*), a running herbivore bird of about 1.5 m high, lives currently in extensive rangelands, where the action of man is rarely remarkable. In Figure 1 the different stages of vegetation are schemed, and the natural and anthropic factors that act in these secondary successions with different degrees of artificialisation.

The climax vegetation, hypothetically, before the introduction of cattle breeding, would have had a larger proportion of bushes and shrubs, particularly the genus *Baccharis*. In some wetter habitat, could prevail big tall herbs and grasses, commonly named straws. Generally the campo would have more humidity due to the big forbs and bushes dead material accumulation that would stop rain waters run off, while mulch would protect soil from water stress, thus keeping humidity excesses during much longer periods. The annual native species and small forbs have probably a rupestral origin; at present the most frequent annual species are exotic.

Cattle and horses were the first domestic large herbivores introduced in the region by the Spanish colonists in the beginning of the XVII century; the ovine arrived in the half of the XIX century. Man action, through the entry of the domestic animals in the natural prairie system, has caused changes in vegetative types, so the grazing would be the main factor that keeps our campos in herbaceous pseudoclimatic phase (Vieira da Silva, 1979).

The natural grasslands actual condition would be far apart of their natural potential. In the climax there would have a prevalence of bushes and tall grasses, of low appetibility and scarce nutritional value, though can be biologically productive, but of low cattle and horses feeding aptitude. Therefore, the actual situation of pastoral disclimax seems to be more apt to grazing animals feeding.

In this situation of pastoral disclimax, the soil that has never been cultivated can suffer from degradation, particularly due to high stocking rate grazing. It is possible to recover, except in those situations of impoverished and eroded soil extreme degradation, excluding grazing for long periods and with a careful subsequent management. The application of low dose inorganic fertilisers and the introduction of legumes species in some of these stages allow taking the pasture to a better condition.

When areas that have been grazed for centuries are excluded from grazing, as is the case of an area of the "Glencoe" Experimental Unit, located in 32° 01' 32'' South latitude and 57° 00' 39'' West longitude, belonging to INIA Uruguay, which has been excluded from grazing from 1984, is observed the beginning of caespitose grasses that form tufts, with the reduction of small ones; also begin to grow under – bushes and bushes like *Eupatorium buniifolium*, *Baccharis articulata*, *B. spicata*, and *B. trimera*, while *B. coridifolia* decreases for its being a species that thrives when grasses are weakened due to grazing. After six years *B. dracunculifolia* is registered, a bush 3 m high, with branches easily breakable by domestic animals. *B. articulata* population has remained for about five years, when plants have died almost simultaneously; after a similar period the population has re – settled and died again and actually new plants are developing. The primitive individuals of *E.buniifolium* are kept and there are younger ones too. The size of the grass tufts increases and decreases the number of individuals like *Stipa neesiana*, *Paspalum dilatatum*, *Coelorhachis selloana*, *Schizachyrium microstachyum*. The grasses that have very low frequency and scarce flowering under grazing conditions, like *P. indecorum*, *Schizachyrium imberbe*, *Digitaria saltensis*, have a large development in this situation. The native's legumes, though low in frequencies, have also a larger development. With the continuation of the exclusion of grazing is also produced a high storage of mulch that provokes important alterations in soil water retention, which, together with the height of grasses and bushes, modify the microclimate. On stopping the action of a factor that has taken the vegetation to an new equilibrium point, this returns to a similar level, though not exactly to the former one (Laycock, 1991). Therefore, the described situation can be somewhat similar to the previous to cattle introduction one.

Tillage provokes dramatic changes in the botanical composition of the natural pastures, eliminating a large part of native flora. Once a campo is no longer cultivated diverse stages in different lapses are determined, according to climate condition, soil type and grazing management. At the first stage (aftermath campo) the vegetation is composed by gramineae and dicotyledoneae arvense annual species, anthropophyte generally, of low forage value, some of them weeds, and a high percentage of bare soil. After two or three year short cycle perennial species begin to increase, decreasing annual and herbaceous weeds (raw campo). From the fourth or fifth year perennial species become prevalent, being frequent some shrubs; the caespitose grasses remain as individualised tufts and appear new species whilst other extinguish. During the subsequent years perennial species become prevalent with a frequency of about 90 %, plants lose their individuality when mixing tillers of different species, the first stages pioneer plants go disappearing, and, a vegetation with a structure like the one from the beginning is being recomposed, but inferior to the existing before the crops. At this stage (recovered campo) the vegetation has a marked prevalence of warm season species (C4), and scarce individuals of temperate (C3) fine species. Generally some bushy weeds and coarse grasses as Bermuda grass (*Cynodon dactylon)* remain, and in some situations can have a frequency near 100 %, decreasing markedly pasture quality and affecting negatively cultivated pastures by reduced their persistence. Recovered campo composed by native and adapted species, has a forage production 30 to 50 % lower to the one the pasture had before grazing. On the other hand, the nutritional value is also lower on decreasing high quality grasses and being replaced by coarse grasses.

The use of herbicide when direct drilling, that has gained importance in the last years, provokes too remarkable changes in vegetation. After several years of non – selective herbicides for annual winter crops sow, native species trend to disappear, annual summer growing plants reach a relative frequency of about 75 %, represented by two species, appear some shrubs, and some rhizome or tuberose root species, having disappeared caespitose grasses. This vegetation structure is situated between aftermath campo, due to the high frequency of annuals, and raw campo stages, due to some perennial species and bushes. 70 % of the species registered after herbicide applications are different to the original (Berretta *et al*. 1997). These vegetation modifications provoke a degradation of itself due to good quality perennial species being substituted by annual and non-productive bushes for cattle feeding, affecting the preservation of the species too.

**Campo types**

This vegetal coverage is variable in botanical composition and density according to the geological matter, that gives place to different texture, fertility and depth soils, topographic position, climate factors and altitude. In order to plant communities study, species are gathered in productive types, which, relate their quality, productivity and their relationship with grazing (Rosengurtt, 1946; 1979). This author proposed the classification of productive types to supply nutritional value data of hundreds of species composing pasture, in order to be able to reason or think of the present and future campo management. This classification was based on the observation of localised area species and the performance evolution of the grazing animals. The hierarchy given to species with this empirical classification has been proved by later nutritive value analysis (Berretta, 1998 a).

In Figure 2 different communities developed on different types of soil are observed, with different texture and depth, that have had been grazed by both bovine and ovine, and equine occasionally, in different proportion, with fluctuating stocking rates according weather and economic variations, and, generally with continuous stocking. Species grouping has been made according productive types; within weeds are included those wide leaf grasses that can be eaten by animals and other can be toxic, with variable height from prostrated to erected habit. In this group is also included area not covered by vegetation, constituted by bare soil, mulch and stones (Berretta, 1996).

The species relative frequency and therefore productive types change through successive seasons, especially between winter and spring, (1to 2; 3 to 4; 5 to 6; 10 to 11), seasons very different. Generally, forbs decrease and vegetal cover density increase is registered, as well as a fine grasses increase, with the relative decrease of coarse and hard ones.

These represented situations show the community variations in natural grasslands as for density, botanical composition and productivity, which, makes that forage annual yield to be distributed along a wide range. In shallow or low fertility soils the share is about 2500 kg DM $ha^{-1}$ (dry matter), in medium depth soils reaches 3500 kg DM $ha^{-1}$, in deep high fertility and sandy soils productivity can surpass 6000 kg DM $ha^{-1}$ (Rosengurtt, 1943, 1946; Formoso, 1990; Berretta, 1991; Berretta and Bemhaja, 1991; Mas *et al*., 1991; Ayala *et al*.,1999). In grasslands with tall hard grasses (straws) prevalence production can get over these figures, but are not palatable and animals eat them only at extreme situations. This annual production, for most communities, is concentrated mainly in spring and summer, being 80 to 85 % in sandy soils, and 60 to 70 % in autumn growth vegetation. The winter share ranges from 6 to 7 % in sandy soils to 10 to 15 % in communities with cool season species.

Seasonal changes are more or less regular in natural pasture ecosystem, but within seasons the uncontrollable influence of weather with unexpected events, increases forage production variability, and, therefore has a marked influence in those seasons where most of the forage growth is produced (Berretta, 1991). The values of the meteorological parameters vary among years, and, can happen alternate long rainy periods with others without rainfalls. Climatic variations affect differentially forage growth in different seasons. Summer daily growth rate (DGR) has a variation coefficient near 40 %, meanwhile the smallest variability season is spring, which coefficient is about 30 %, being this variation larger for the shallower soils. In autumn and winter the DGR variation coefficient is between the formerly named values. If we consider shorter periods, as monthly daily growth, variability is much higher, with variation coefficient values between 50 and 70 % for summer months.

Within them it is possible to establish a relationship between the % of species, which compose them, and, their participation in soil coverage. Theoretical studies (Daget and Poissonet, 1971) show that relationship is in accordance to the 20/80-concentration law. Research made in different vegetation, show along seasons variable relationships between 30/70 and 20/80 (Olmos and Gordon, 1990). According the number of inventoried species, which, is generally high, about a dozen according to vegetation type, are the ones who make the biggest contribution to forage production. Their identification is of particular importance to follow the communities' evolution and order cattle management.

Studies done in different communities and seasons show that there is a prevalence of warm season species (Gallinal *et al*., Rosengurtt, 1943; 1946; Berretta, 1988; 1990; 1991; Formoso, 1990; Olmos, 1992; Boldrini, 1993). In autumn and winter the relative frequency of winter species increases, but does not prevail over warm season ones. Within winter species, about 50 % are small forbs and coarse grasses, while fine ones are scarce. As formerly expressed, this prevalence of summer growing species is what explains the higher production of forage in spring and summer.

## Grazing Management Responses

### Effect of related to grazing factors on vegetation evolution

Main grazing factors that affect sward botanical composition are stocking rate, grazing method and sheep/cattle relationship. Figure 3 shows the comparison between main species relative frequency of a campo grassed with 0.8 AU $ha^{-1}$(animal unit), continuous stocking, 2/1 sheep/cattle relationship treatments in winters 1985 and 1992. In this situation, the stocking rate effect is reduced; species like: *Carex sp***.**, *Stipa neessiana*, and *Trifolium polymorphum*, all of them cold season (C3) ones, have their contribution increased due to a harder winter. On the other hand, worm season grasses (C4) like: *Schizachyrium spicatum*, *Paspalum plicatulum* y *Coelorhachis selloana* have a decrease in their soil coverage participation, due to formerly mentioned reasons, that also stimulate the leaves senescence. This last species is, furthermore, negatively affected by grazing, even in stocking rates like the one used in this situation. The tendency observed for *Oxalis* *sp* (cold season species), could be explained by an increase in vegetal coverage height increase, which, affects this forb negatively.

When grazing is done with a higher stocking rate, (1.1 AU $ha^{-1}$), higher sheep/cattle relationship (5/1) and rotational stocking, the effect of 1985's milder winter on plant C3 and C4 plant contribution is also manifested (Figure 4). The most frequent warm season grasses in this treatment are: *Schizachirium spicatum, Paspalum plicatulum, Andropogon ternatus,* all of them coarse productive type (Rosengurtt, 1979). These species have a high senescence rate, for which they store dry leaves in short lapses, particularly during winter. Rest periods (60 days in this case), have allowed these three species to accumulate dry matter. This dead leaves accumulation makes the crude protein (CP) content be inferior (5.7 %) to the former treatment (6.5 %). Winter species *Carex sp., Stipa neesiana* and *Oxalis sp.* show the same pattern than in the former case.

Annual forage production calculated as the average of nine years, using a 1.1 AU $ha^{-1}$ stocking rate, rotational stocking and low sheep/cattle relationship, 2/1, is 12 % higher than continuous stocking, high sheep/cattle relationship, 5/1, and same stocking rate. The forage production of pastures whose management included rest periods is 10 % higher than the one obtained with continuous stocking.

The animal rotational stocking and high ovine/bovine relationship combination, with continous stocking, is the one that introduces more modifications into the vegetation (Figure 5). In this case, *Paspalum plicatulum*, *Andropogon ternatus* and *Coelorhachis selloana*, warm season grasses, are negatively affected by winter and grazing, particularly the first one which has erect structure, with long leaf sheath, and does not adapt to grazing in these conditions where the sward surface height is lower than 3 cm high along seasons. In this situation, small forbs begin to be frequent, winter ones, like *Chevreulia sarmentosa* y *Pamphalea hetrophyla* being this one the most frequent species in 1992. The increase of relative frequency of this species indicates pasture degradation. The increase of *Paspalum notatum* soil coverage is related to its prostrated habit and to its adaptation to this grazing conditions. The same happens to *Trifolium polimorphum*, low frequency, low production, tender, cold season, native legume. Palatable winter species, on flowering when the herbage mass is lower, do not reach seeding; then their persistence relies uniquely on in vegetative reproduction mechanisms. These grazing conditions do not allow dead material to accumulate, so N content is 1.5 %. In this situation a decrease of pasture's amount of species is registered.

Figure 6 schemes formerly analysed (Figures 3, 4 and 5) natural pastures state. Stocking rate of 0.8 AU $ha^{-1}$, continuous stocking and relationship 2/1 sheep/cattle has not provoked important changes in the vegetation (a). If besides the stocking rate increase, ovine/bovine relationship goes to 5/1, the substitution of more productive species by less productive ones becomes remarkable (b). If stocking rate exceeds carrying capacity, a change in vegetal community is generally produced, switching to a less productive or less valuable for animal feeding one, associated to changes in vegetative types (Formoso, 1987; Olmos, 1992). This happens because selective grazing places in a less competitive position the most eaten plants. On the other .hand, ovine have a higher potential than bovine to provoke natural pastures degradation. In rotational stocking paddock, dominant species are caespitose ones; the small forbs and rosulate ones trend to decrease under these conditions (c). Possibly, due to an excessive rest period for the analysed vegetation type, an increase in coarse grasses such as *Andropogon ternatus*, *Aristida uruguayensis*, *Paspalum plicatulum* y *Schizachyrium spicatum*, is verified. Nevertheless, it is possible to better administrate and stockpiling forage for winter times (Berretta, 1998b).

According to stocking rate and grazing method, some species as *Papalum notatum*, vary their frequency, which is increased at high stocking rates, and continuous stocking. The decrease in relative frequency of this species, at rotational stocking , is associated to an excessively long rest period and to the vegetative types of the associated vegetation. In this case prevail coarse grasses, with rapid dead leaves accumulation, what reduces its palatability and due to their erected habit reduce the amount of light *P. notantum* gets, stoloniferous prostrated habit species (Figure 7).

This stoloniferous species is frequent in most region's grasslands. Grazing intensity and N different levels have marked incidence in tiller population. The number of expanded leaves per tiller increases along with N level reduction, being this number as four. When the amount of N is reduced, stolon amount in plants' aerial DM increases, as a way of increasing environment exploration in search of more fertile places and as a reservoir of N supply for growth. On the other hand, leaves life span increases with lower grazing intensities and with moderate N levels, varying between 21 and 31 days. This kind of determinations allow to adjust between – grazing rest periods in grasslands where this species prevails, as primary production can be increased, the latest not being reflected in effective animal production (Boggiano, 2000).

Grasslands where coarse C4 grasses prevail, with scarce and low production C3, grazed with 0.8 AU $ha^{-1}$, year rotational stocking rate forage production is 23.4 % higher than production with continual stocking and 2/1 sheep/cattle relationship production. Continual stocking and 5/1 sheep/cattle relationship only rise forage annual production in 12.2 % (Formoso and Gaggero, 1990). The grazing of these vegetation with 0.8 AU $ha^{-1}$ and high sheep/cattle relationship favours the formation of double structure profile formation, with stoloniferous short grasses like *Axonopus affinis* areas, and other areas with coarse grasses, which, accumulate dead material, that cause forage waste and a decrease in animal production. This situation happens mainly under rotational grazing and C4 grasses promoting grazing method. These vegetation's N values vary from 2.2 % in winter, to 1.4 % in summer. Organic Matter Digestibility (OMD) varies between 55 and 58 % (Formoso, 1996). The high grazing intensity uniform profile, and, mosaic double structure that happen when low intensity grazing is applied, have also been registered by Boldrini (1993). Except in shallow soils campos where short species prevail, which do not accumulate dead matter, being grazed only by sheep result in an inadequate grazing management practice given their preference for short and palatable grasses, rejecting hard and coarse ones, what causes degradation in some areas and forage waste in others. To uniform the vegetal cover high ovine stocking rates must be used, what, generally, reduce animal performance. Mixed or only bovine grazing, allows a better vegetation control in the region's grasslands.

There is a grazing method effect that remains along time. In rotate stocking rate paddocks, even with relatively high stocking rate and sheep/cattle relationship, a higher regrowth is registered in those that have had continuous stocking rate and equal or a little bit lower stocking rate. Therefore, grazing resting periods favour photosynthetic tissue rebuilding, and therefore, plants ability to produce food for their own survival. High stocking rate grazing can increase hydro - stress caused by root system weakening, causing excessive over soil water drainage and humidity evaporation, particularly in those vegetation which have degradation.

**Defer grazing**

On whole year open air-conditions natural grasslands grazing, animal production per area unit is low, 50 – 70 kg live weight $ha^{-1}$. Animal weight increases along year's different seasons are very variable, in function of climate factors and quantity of forage available for animals (Pigurina *et al*., 1998). For winter-feeding it is convenient to close natural pasture paddocks during autumn in order to stockpiling forage, in case these pastures had winter species. Based on different seasons forage growth, it is possible to reach winter with enough herbage mass. When from 1300 to 1500 kg DM $ha^{-1}$ are obtained, with a 5 – 6 cm height at the first case, and 7 – 8 at the second, lambs neonatal loses can be reduced from 20 to 10 %, working with a stocking rate of 5 ewes/ha during pregnancy last third (Montossi *et al*., 1998a). Cattle weight increases during winter are about 200 g $an^{-1}$ $d^{-1}$, when offering 1500 kg DM $ha^{-1}$; with no forage storage loses in this season are over this figure (Pittaluga *et al*., 1998). When cold season grasses are scarce, autumn forage accumulation must be done during short periods, because the steams lengthening makes quickly decrease forage quality. Under those autumn low growth and lose of quality at enlarging the rest period, accumulated forage is not enough to fulfil animal needs and get live weigh gains (Ayala *et al*., 1999).

## Campos Improvement

The low natural pastures' winter growth and P and N deficiencies, in most soils of the region, has led to the introduction of N to the system through the application of inorganic fertilisers or through legumes together P fertilisation in order to facilitate the latter settling and production. Herbage fertilisation with P has scarce impact on forage botanical composition and production increase, lower than 15 %, due to the low frequency of native legumes.

**N + P fertilisation**

Relatively low N and $P_2O_5$ dose utilisation (90 kg $ha^{-1}$ $y^{-1}$; 44 kg $P_2O_5$ $ha^{-1}$ $y^{-1}$) favour soil's trophic level increase, specially if this fertiliser amount is applied divided in two, one half on autumn beginning, and the other one on winter end. This strategy can be followed with vegetation which posses good winter perennial grasses at a relative frequency of over 20 %. Autumn application favours winter grasses growth and regrowth, and the lengthening of warm season grasses growth period up to autumn beginnings; on the other hand, winter's endings fertiliser application, keeps favouring winter species growth, and makes the warm season ones regrowth before. Earlier regrowth of C3 and C4 species as well as the decrease in the resting period of C4 species tend to reduce the period of low winter growth (Bemhaja *et al*., 1998).

As long as the trophyc level of the system goes increasing, fertilised soil forage production goes settling down in a value that is 60 % superior to the one of the campo without NP. The seasons which fertilisation can have more influence from cattle management point of view are autumn and winter. The DGR in autumn is higher for fertilised soil (Figure 5). To reserve live forage, to feed during winter rearing categories as much ovine as bovine, autumn growth would be enough to accumulate over 1000 kg DM $ha^{-1}$, besides available forage before paddock closure or a marked stocking rate decrease. During winter, fertilised campo DGR is near 100 % superior to the campo not nutrients added.

Spring forage growth, for campo + NP, is over 1600 kg DM $ha^{-1}$, while, for the campo without NP, the growth is of about 1000 kg DM $ha^{-1}$. Summer growth is closely linked to rainfalls, thus being very variable. The annual incorporation of 92 and 44 kg $ha^{-1}$ of N and $P_2O_5$ respectively, allows increasing forage production with an efficiency of 7.5 kg DM per kg of nutrient for the first year and of about 24.0 kg DM per kg of nutrient for the following years (Berretta *et al.*, 1998) .

Forage N content is always superior for the fertilised campo. For natural pastures, the highest N values are registered in winter and spring, and the lowest in summer, when forage is ripe, and generally happen water deficiencies. Fertilised forage N contents reach 2.3 % in winter, meanwhile not fertilised is of about 1.7 %; in spring, these values are of 2.8 and 1.9 % respectively. In summer, values drop to 1.7 and 1.3 %; in winter rise to 2.2 and 1.7 % respectively. Taking winter for example, natural grassland produces approximately 38 kg $ha^{-1}$ of crude protein (CP), meanwhile fertilised grassland produce about 95 kg $ha^{-1}$ CP. The highest content of P (mgP $gDM^{-1}$), as well as N of grassland forage is registered in winter and spring, and the lowest is registered in summer (Berretta, 1998a). In the first two seasons the content of P is about 2.3 mgP $gDM^{-1}$ for fertilised case, and of 1.8 mgP $gDM^{-1}$ for not fertilised case. In summer these figures are 1.9 and 1.5 mgP $gDM^{-1}$, respectively, and in autumn 1.5 and 2.2 mgP $gDM^{-1}$.

Trough the different seasons of the year winter species' relative frequency is higher in fertilised campo than in the not fertilised. The increase of C3 grasses is related to the addition of these nutrients, which rise the trophic level of the soil. The stimulus to perennial winter grasses through fertilisation is a way to change vegetal coverage composition, improving winter production.

Productive winter species such as *Stipa neesiana*, *Piptochaetium stipoides*, *Poa lanigera* and *Adesmia bicolor* trend to increase their presence along with fertilisation. Good quality warm season productive grasses such as *Paspalum notatum* and *P. dilatatum*, increase their frequency as well. Coarse grasses such as *Bothriochloa laguroides* and *Andropogon ternatus* are less frequent, and, *Schizachirium spicatum* is even less frequent with fertilisation as it is a poor environment species, showing the same behaviour in campo improvements where as fertility increases, this species decreases its frequency up to disappearing. *P. plicatulum* also decreases along with fertilisation, although this decrease can be linked to an palatability increased since its leaves remain green for longer periods than in not fertilised campos. Native legumes increase their relative frequency to values close to 5 %. Weeds have a scarce participation and do not increase with fertilisation; are represented by *Baccharis coridifolia, B. trimera,* and *Heimia sp.*

In situations the campo has a high proportion of warm season species and winter ones are annual, results are very different. Fertilisation at the beginnings of winter favours the presence of annual winter grasses, *Vulpia australis, Gaudinia fragilis,* with a limited productive potential to the end of the season; de disappearance of these species at ending their cycles leave spaces that can be occupied by other not wanted plants. Spring fertilisation increased growth towards summer ending, when summer grasses grow and fructify. The Organic Matter Digestibility (OMD) of the fertilised forage was higher than the not treated sward (Formoso, Pers. Comm.). Fertilisation with N markedly increases spring and summer production, but with a reduced effect in winter. This nutrient stimulates the increase of annual species in detriment of perennial ones

(Ayala and Carámbula, 1994). The + NP fertilisation increases 3 and 4 times beef production per hectare compared with campos without fertilisation application.

## Legume introduction

### Effect of the introduction of legumes species on the botanical composition of natural grasslands

The need to improve the natural pastures of Uruguay primary production, as well as their quality, has led to legumes introduction by zero or minimum tillage techniques, as one of the ways to increase secondary production. The yield of these improved pastures is according to soil and vegetation types, 50 to 100 % superior to pastures with no legumes introduction, being winter yield up to five times higher. Secondary production is up to six times not improved grassland production. This kind of natural grassland improvement allows the introduction of nitrogen to the ecosystem at a reduced cost.

Sward preparation for sowing is possible to only through grazing, and no herbicide application. Depending on vegetation composition and weather conditions, this preparation begins at spring endings or summer with cattle grazing; at final stages, previous to autumn sow, it is convenient to use sheep to reduce grass coverage up to 2 cm, which, is adequate for seed protecting. Through this technique it is possible to get sure places for good soil – seed contact, with no herbicide use, which, in general, affect negatively caespitose species (Risso,1991).

Once the introduced species settled, and along with time, one of the most important observed changes in vegetation is the increase of cool season species (C3) (Berretta and Levratto, 1990; Bemhaja and Berretta, 1991). In other basaltic region similar vegetation, warm season species (C4) frequency is always higher than winter ones' (Formoso, 1990; Berretta, 1990). Winter species relative frequency is about 75 %, with similar values for native grasses and introduced *Trifolium repens.* Higher quality frequency increase makes forage N content be 3.2 %.

In order introduced species to remain in the pasture, they are bound to flower and seed as a way to ensure their next autumn regeneration, going through summer partly as plants and partly as seed. This reduction or total stock withdrawal not only allows cultivate species reseeding, but also would fructify winter native species such as *Poa lanigera, Stipa neesiana, Piptochaetium stipoides* and *Adesmia bicolor.* Therefore, the preservation of these species in natural grasslands is related to rest period which allow them to flower and fructify, and to a trophic soil level increase as well.

In Figure 9 is shown most frequent species' evolution of soil coverage of this improvement with *Trifolium repens* and *Lotus corniculatus* vegetation. It is important to mention the increase in the frequency of *Lolium multiflorum,* introduced by animals and adapted to new conditions. *Bothriochloa laguroides* is the principal summer species.

In more degraded vegetation, composed by unproductive coarse or low palatability grasses, grass-like and forbs, the overseeding of legumes, induces as well positive changes. Legumes relative frequency (*Trifolium repens, Lotus corniculatus*) is about 60 %; productive native winter grasses, *Stipa neesiana* and *Piptochaetium stipoides* and acclimated ones like *Lolium multiflorum*, increase their frequency, and forbs and unproductive coarse grasses are reduced (Berretta and Risso, 1995; Risso and Berretta, 1997). Annual and perennial legumes overseeding in pastures composed almost exclusively by C3, with an annual production of 3400 kg DM $ha^{-1}$, leads forage production to values of 8600 kg DM $ha^{-1}$ (Ayala *et al*. 1999; Berretta *et al*., 2000). When legumes are introduced into campos where prevail coarse grasses and forbs, the resulting secondary production is similar to those grasslands with higher frequency of native fine grasses.

## Sheep and cattle diet selection

Information generated about botanical composition and nutritional value of the diet of animals grazing different vegetal communities has a high impact on animal feeding strategy design, and on cattle systems forage management.

In Table 1 are shown offered forage and gathered diet nutritional values for animals grazing different vegetal communities during springtime.

Diet that is gathered by sheep and cattle is of higher quality than the available forage itself; these differences are registered in the three considered plant communities and in the four seasons of the year. Sheep, in most cases, select a higher nutritional value diet than cattle, thus demonstrating their higher ability to gather higher quality components such as grasses green leaves, legumes and forbs. As available forage amount is larger, quality values decrease. For a better animal performance the herbage mass must be over 1000 kg DM $ha^{-1}$; the figures shown in Table 1 for the three communities vary about 1200 and 1800 kg DM $ha^{-1}$, corresponding to variable heights between approximately 5 and 9 cm sward surface height. Within these values animals gather a high quality diet.

In Figure 10 is shown the vertical distribution of a high herbage mass sward components during winter. Most of forage is concentrated in the sward base (0 – 3 cm), where lie grasses dead leaves and alive and senescent stems. When herbage mass is high, dead leaves spread along all the profile, in superior proportions and heights to grasses' green leaves. Generally, when accumulated forage is over 2000 kg DM $ha^{-1}$, the probability of dead material in animal diet increases, particularly in cattle case. Therefore the diet nutritional value decreases and possibly affects negatively animal and pasture productivity. In general, campo + NP and improved campo's different components vertical distribution follow campo trends (Montossi *et al*., 1998b).

Grazing conditions alter animal voluntary intake, affecting differentially sheep and cattle intake, altering therefore the substitution rate of the different animal species. These animal selection studies shown that the commonly accepted substitution rate of 5 sheep by 1 beef, is underestimated, and could achieve values of 7 to 1, depending on the type of vegetation community, forage productivity, structure, nutritional value, animal class, etc. (Montossi *et al.*, 2000).

## Towards an ecological management in order to preserve campos´ productivity and diversity

Natural grasslands are the region's beef and fibre production main basis and, a large reservoir of indigenous grasses and legumes, which need to be selected and explored in crops. Only through a deep knowledge of the morphological and physiological characteristics of native species, we will be able to preserve and improve our natural herbage and protect soil from erosion and degradation. Research carried out in the region shows that natural grasslands' potential is very high, comparable to cropped pastures and with much higher persistence and adaptation.

Studies carried out on natural vegetation dynamics under submission to man controlled different factors show that changes in them are produced. These changes happen slowly, being more important along the year, seasonal variations than grazing. For longer lapses, continual stocking rate and high sheep/cattle relationship provoke degradation in pasture condition that is manifested by a decrease of primary production. Often, due to economic and social reasons, a high stocking rate is kept, that leads to a lower animal production; higher stocking rates can favour higher benefits, but high loses risk is higher too. The continuation and deepening of natural vegetation study and its main component species will allow more adequately knowing their production and persistence. It will as well allow better understanding the action of those factors which, allow getting a higher secondary production, beef and wool in our case, through a primary production increase, linked to forage resource better exploitation and preservation.

When stocking rates are adjusted to grassland potential, and grazing method includes rest periods, it is possible to keep a campo in good conditions, with variations caused by seasonal changes. The grassland ecosystem is highly stable, and is capable of recovering after violent impacts such a draught.

In most of the region campos exist high spatial variability, due mainly to soil type, which combines with climatic variations and management practices impact. This vegetation management must be adjusted to component species' morphological and physiologic features, therefore, is convenient to manage them separately. In order to design the grazing system to applied is necessary to know precisely the type of species present in each vegetation community, taking into account productive types, particularly when coarse and hard grasses prevail, because with long rest periods and insufficient instantaneous stocking rates can lead to their increase. The most important management decision is to determine a right stocking rate, which let achieving an animal performance goal for each campo type, with no deterioration of the grassland ecosystem. Each vegetation has a potential production that will determine it carrying capacity. The biggest problem in developing an optimal stocking criterion for natural grasslands management is the need to preserve forage in order to use it at moments when grass growth is limited by humidity or low temperature.

Legumes species introduction, phosphorus fertilisation at sowing and phosphorus annual re-fertilisations, and grazing management lead vegetation, through a slow biotic process, to a new equilibrium point where yield and quality are superior to the existing ones at the starting point. In order to keep the pasture at this new equilibrium factors like grazing and fertilisation need to be controlled very closely. This effect is manifested through vegetation with winter species prevalence, where good quality perennial species are outstanding. This is a good alternative to increase annual primary production, and particularly during winter times, with no herbicide use, preserving natural vegetation's productive species.

The rise of soil trophic level due to N and P addition increases natural herbage production and quality. This process is relatively slow, registering from the applications first year, differences that increase as increase the addition of nutrients. The "disturbance" provoked by fertilisation leads vegetation to a new equilibrium point, with changes in botanical composition consisting of an increase in more productive species frequency, and therefore a larger secondary production. This technology is complementary to through leguminous species introduction and P addition campo improvement, as well as temporary grass crops and cultivated pastures. Natural campo fertilisation allows rising vegetation production and quality on soils whose depth is not adequate for most productive adapted forage species development. On the other hand, we must consider campo natural production and quality long term benefits of N and P fertilising, after this stops being applied.

The addition of these nutrients, in particular P, would help to give back to natural campo some of what it has been depleted for centuries of grazing, since cattle introduction at the beginnings of the XVII century, besides contributing to natural grasslands animal and vegetal biodiversity maintenance. We have to conserve our natural resources, without degradation, thinking in a sustainable develop in economical, ecological and social terms.

Generated scientific knowledge has contributed to apply better pasture management practices, which resulted in long term biological and economical benefits for the farmers community and the whole society, with special care for animal and plant communities biodiversity and water conservation for human and animal use. Both animals and plants will be for a long time our food and fibre main source in the world, hence conditioning our actions and behaviour in the way that we preserve our natural resources for future generations.

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## References

**Ayala, W. and Carámbula M.** (1994). Nitrógeno en campo natural. In: Morón A., Risso D.F. (eds) *Nitrógeno en pasturas*. Montevideo: INIA. pp. 33-42. (Serie Técnica; 51)

**Ayala, W., Bermúdez R., Carámbula M., Risso D. and Terra J.** (1999). Diagnóstico, propuestas y perspectivas de pasturas en la Región Este. In: *Producción Animal.* INIA Treinta y Tres. Unidad Experimental Palo a Pique. pp. 1-41. (Actividades de Difusión; 195)

**Bemhaja, M. and Berretta E.J.** (1991). Respuesta a la siembra de leguminosas en basalto profundo. In: *Pasturas y producción animal en áreas de ganadería extensiva*. Montevideo: INIA. pp. 103-114. (Serie Técnica; 13)

**Bemhaja, M., Berretta E.J. and Brito G.** (1998). Respuesta a la fertilización nitrogenada de campo natural en basalto profundo. In: Berretta E.J. (ed) *Anales de la 14ª. Reunión del Grupo Técnico Regional del Cono Sur en Mejoramiento y Utilización de los Recursos Forrajeros del Area Tropical y Subtropical: Grupo Campos, Uruguay, 1994.* Montevideo: INIA. pp.119-122. (Serie Técnica; 94)

**Berretta, E.J.** (1988). El pastoreo como herramienta para mejorar la productividad de las pasturas naturales. In: Silva J. (ed) *Memoria de la 9ª. Reunión del Grupo Técnico Regional del Cono Sur en Mejoramiento y Utilización de los Recursos Forrajeros del Area Tropical y Subtropical: Grupo Campos y Chaco, Uruguay, 1988*. pp. 79-93.

**Berretta, E.J.** (1990). Técnicas para evaluar la dinámica de pasturas naturales en pastoreo. In: Nuernberg N.J. (ed) *Relatório da 11ª. Reuniao do Grupo Técnico Regional do Cone Sul em Melhoramento e Utilizaçaô dos Recursos Forrageiros das Areas Tropical e Subtropical: Grupo Campos, Brasil, 1989*. pp.129-147.

**Berretta, E.J.** (1991). Producción de pasturas naturales en basalto. A. Producción mensual y estacional de forraje de cuatro comunidades nativas sobre suelos de basalto. In: *Pasturas y producción animal en áreas de ganadería extensiva*. Montevideo: INIA. pp. 12-18.

(SerieTécnica; 13)

**Berretta, E.J.** (1996). Campo natural: valor nutritivo y manejo. In: Risso D.F., Berretta E.J. and Morón A. (eds) *Producción y manejo de pasturas*. Montevideo: INIA. pp. 113-127. (Serie Técnica; 80)

**Berretta, E.J.** (1998a). Contenido de minerales en pasturas naturales de basalto. I. Especies Nativas. In: Berretta E.J. (ed) *Seminario de Actualización en Tecnologías para Basalto, Uruguay, 1998.* Montevideo: INIA. pp. 99-111. (Serie Técnica; 102)

**Berretta, E.J.** (1998b). Impacto del pastoreo en el ecosistema de la pradera natural. In: *Recuperación y manejo de ecosistemas degradados.* Montevideo: IICA-PROCISUR. pp. 55-62. (Diálogo; 32)

**Berretta, E.J. and Bemhaja M.** (1991). Producción de pasturas naturales en basalto. B. Producción estacional de forraje de tres comunidades nativas sobre suelos de basalto. In: *Pasturas y producción animal en áreas de ganadería extensiva*. Montevideo: INIA. pp. 19-23. (Serie Técnica; 13)

**Berretta, E.J. and Levratto J.C.** (1990). Estudio de la dinámica de una vegetación mejorada con fertilización e introducción de especies. In: *2° Seminario Nacional de Campo Natural, Uruguay, 1990.* Montevideo: Hemisferio Sur. pp. 197-203.

**Berretta, E.J. and Nascimento Jr. D. do** (1991). *Glosario estructurado de términos sobre pasturas y producción animal.* Montevideo: IICA – PROCISUR. (Diálogo; 32)

**Berretta, E.J. and Risso D.F.** (1995). Native grassland improvement on Basaltic and Granitic soils in Uruguay. In: West N.E. (ed) *Proceedings of the 5th International Rangeland Congress, Society for Range Management, USA.* v. 1, pp. 52-53.

**Berretta, E.J., Marchesi C. and Perez Gomar E.** (1997). Evolución de la vegetación de un campo natural sobre suelo arenoso luego de tres años de siembra directa. In: *Anais do 2º. Seminario Internacional do Sistema Plantio Direto, Brasil, 1997.* pp. 285-287.

**Berretta, E.J., Risso D.F., Levratto J.C. and Zamit W.S.** (1998). Mejoramiento de campo natural de basalto fertilizado con nitrógeno y fósforo. In: Berretta E.J. (ed) *Seminario de Actualización en Tecnologías para Basalto, Uruguay, 1998.* Montevideo: INIA. pp. 63-73. (Serie Técnica; 102)

**Berretta, E.J., Risso D.F., Montossi F. and Pigurina G.** (2000). Campos in Uruguay. In: Lemaire G., Hodgson J., Moraes A., Carvalho P. and Nabinger C. (eds) *Grassland Ecophysiology and Grazing Ecology.* CAB International 2000. (en prensa)

**Boggiano, P.** (2000). *Dinâmica da produçao primaria da pastagem nativa em área de fertilidade corrigida sob efeito de adubaçao nitrogenada e oferta de forragem.* Tese doutorado em Agronomia – Zootecnia, Programa de Pós Graduaçao em Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil.

**Boldrini, I.I.** (1993). *Dinámica da vegetaçao de uma pastagem natural sob diferentes niveis de oferta de forragem e tipos de solos, Depressao Central, RS.* Tese Doutor em Zootecnia, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil.

**Daget, Ph. and Poissonet J.** (1971). Une méthode d'analyse phytologique des prairies. Critères d'application. *Annales Agronomiques*, **22**: 5-41.

**Deregibus, V.A.** (2000). Argentina's Humid Pampa. In: Lemaire G., Hodgson J., Moraes A., Carvalho P. and Nabinger C. (eds) *Grassland Ecophysiology and Grazing Ecology.* CAB International 2000. (en prensa)

**Formoso, D.** (1990). Pasturas naturales. Componentes de la vegetación, producción y manejo de diferentes tipos de campo. In: *3er. Seminario Técnico de Producción Ovina, SUL, Uruguay, 1990.* pp.225-237.

**Formoso, D.** (1996). Estrategias de manejo de las pasturas naturales. *Producción ovina*, **9**: 21- 34.

**Formoso, D. and Gaggero, C.** (1990). Efecto del sistema de pastoreo y la relación ovino/vacuno sobre la producción de forraje y la vegetación del campo nativo. In*: 2° Seminario Nacional de Campo Natural, Uruguay, 1990*. Montevideo: Hemisferio Sur. pp. 299-310.

**Gallinal, J.P., Bergalli L., Campal L., Aragone L. and Rosengurtt B.** *Estudio sobre praderas naturales del Uruguay*. *1ª. Contribución*. Montevideo: Germano Uruguaya.

**Laycock, W.A.** (1991). Stable states and tresholds of range condition on North American rangelands: A viewpoint. *Journal of Range Management,* **44**: 427-433.

**Mas, C., Bermudez R. and Ayala W.** (1991). Crecimiento de las pasturas naturales en dos suelos de la Región Este. In: *Pasturas y producción animal en áreas de ganadería extensiva.* Montevideo: INIA. pp. 59-70. (Serie Técnica; 13)

**Montossi, F., San Julian R., de Mattos D., Berretta E.J., Rios M., Zamit W. and Levratto J.** (1998a). Alimentación y manejo de la oveja de cría durante el último tercio de gestación en la región de Basalto. In: Berretta, E.J. (ed) *Seminario de Actualización en Tecnologías para Basalto, Uruguay, 1998*. Montevideo: INIA. pp.195-208. (Serie Técnica; 102)

**Montossi, F., Berretta E.J., Pigurina G., Santamarina I., Bemhaja M., San Julián R., Risso D.F. and Mieres J.** (1998b). Estudios de selectividad de ovinos y vacunos en diferentes comunidades vegetales de la región de basalto. In: Berretta E.J. (ed) *Seminario de Actualización en Tecnologías para Basalto, Uruguay, 1998.* Montevideo: INIA pp.257-285. (Serie Técnica; 102)

**Montossi, F., Pigurina G., Santamarina I. and Berretta E.J.** (2000). *Selectividad animal y valor nutritivo de la dieta de ovinos y vacunos en sistemas ganaderos: teoría y práctica.* Montevideo: INIA. (Serie Técnica; 113)

**Nabinger, C., Maraschin, G.E., Moraes, A.** (2000). Campos in Southern Brazil. In: Lemaire G., Hodgson J., Moraes A., Nabinger C. and Carvalho P. (eds) *Grassland Ecophysiology and Grazing Ecology*. CAB International 2000. (en prensa)

**Olmos, F.** (1992). *Aportes para el manejo del campo natural. Efecto de la carga animal y el período de descanso en la producción y evolución de un campo natural de Caraguatá (Tacuarembó).* Montevideo: INIA. (Serie Técnica; 20)

**Olmos, F. and Godron M.** (1990). Relevamiento fitoecológico en el noreste uruguayo. In: *2° Seminario Nacional sobre Campo Natural, Uruguay, 1990*. Montevideo: Hemisferio Sur. pp.35-48.

**Pigurina, G., Soares de Lima J.M., Berretta E.J., Montossi F., Pittaluga O., Ferreira G. and Silva J.A.** (1998). Características del engorde a campo natural. In: Berretta E.J. (ed) *Seminario de Actualización en Tecnologías para Basalto, Uruguay, 1998.* Montevideo: INIA. pp. 137-145. (Serie Técnica; 102)

**Pittaluga, O., Berretta E.J. and Risso D.F.** (1998). Factores que afectan la recría vacuna en campo natural de basalto. In: Berretta E.J. (ed) *Seminario de Actualización en Tecnologías para Basalto, Uruguay, 1998.* Montevideo: INIA. pp. 147-151. (Serie Técnica; 102)

**Risso, D.F.** (1991). Siembras en el tapiz: consideraciones generales y estado actual de la información en la zona de suelos sobre cristalino. In: *Pasturas y producción animal en áreas de ganadería extensiva*. Montevideo: INIA. pp. 71-82. (Serie Técnica; 13)

**Risso, D.F. and Berretta E.J.** (1997). Animal productivity and dynamics of native pastures improved with oversown legumes in Uruguay. *Proceedings of the 18th. International Grassland Congress, Canada*. pp. 22-29 – 22-30.

**Rosengurtt, B.** (1943). *Estudio sobre praderas naturales del Uruguay. 3ª. Contribución*. Montevideo: Barreiro y Ramos.

**Rosengurtt, B.** (1946). *Estudio sobre praderas naturales del Uruguay*. *5ª. Contribución.* Montevideo: Rosgal.
**Rosengurtt, B., Arrilaga B. and Izaguirrre P.** (1970). *Gramíneas uruguayas.* Montevideo: Universidad de la República. Departamento de Publicaciones.
**Rosengurtt, B.** (1979). *Tabla de comportamiento de las especies de plantas de campos naturales en el Uruguay*. Montevideo: Universidad de la República. División Publicaciones y Ediciones.
**Soriano, A.** (1991). Río de la Plata Grasslands. In: Coupland R.T. (ed) *Natural Grasslands: Introduction and Western Hemisphere*. Amsterdam: Elsevier. pp. 367-407.
**Vieira da Silva, J.** (1979). *Introduction à la théorie écologique*. Paris: Masson.

**Table 1 -** Nutritional value of diet selected by ovine and bovine on campo, campo + NP and improved campo, with different spring herbage mass.

| | Campo | | | Campo + NP | | | Improved Campo | | |
|---|---|---|---|---|---|---|---|---|---|
| | Herbage Mass (kgDM ha$^{-1}$) | N (%) | ADF (%) | Herbage Mass (kgDM ha$^{-1}$) | N (%) | ADF (%) | Herbage Mass (kgDM ha$^{-1}$) | N (%) | ADF (%) |
| Forage | 2916 | 1.33 | 48.6 | 2283 | 1.73 | 42.1 | 3920 | 1.34 | 46.8 |
| Cow diet | | 1.79 | 39.3 | | 1.98 | 36.4 | | 2.11 | 35.1 |
| Sheep diet | | 2.02 | 39.9 | | 2.37 | 34.5 | | 2.54 | 32.3 |
| Forage | 1180 | 1.60 | 46.1 | 1548 | 1.94 | 41.2 | 1760 | 1.95 | 42.1 |
| Cow diet | | 1.97 | 38.4 | | 1.62 | 38.9 | | 1.98 | 38.4 |
| Sheep diet | | 3.18 | 38.8 | | 2.13 | 33.3 | | 2.27 | 33.3 |

(Adapted from Montossi *et al*., 2000).

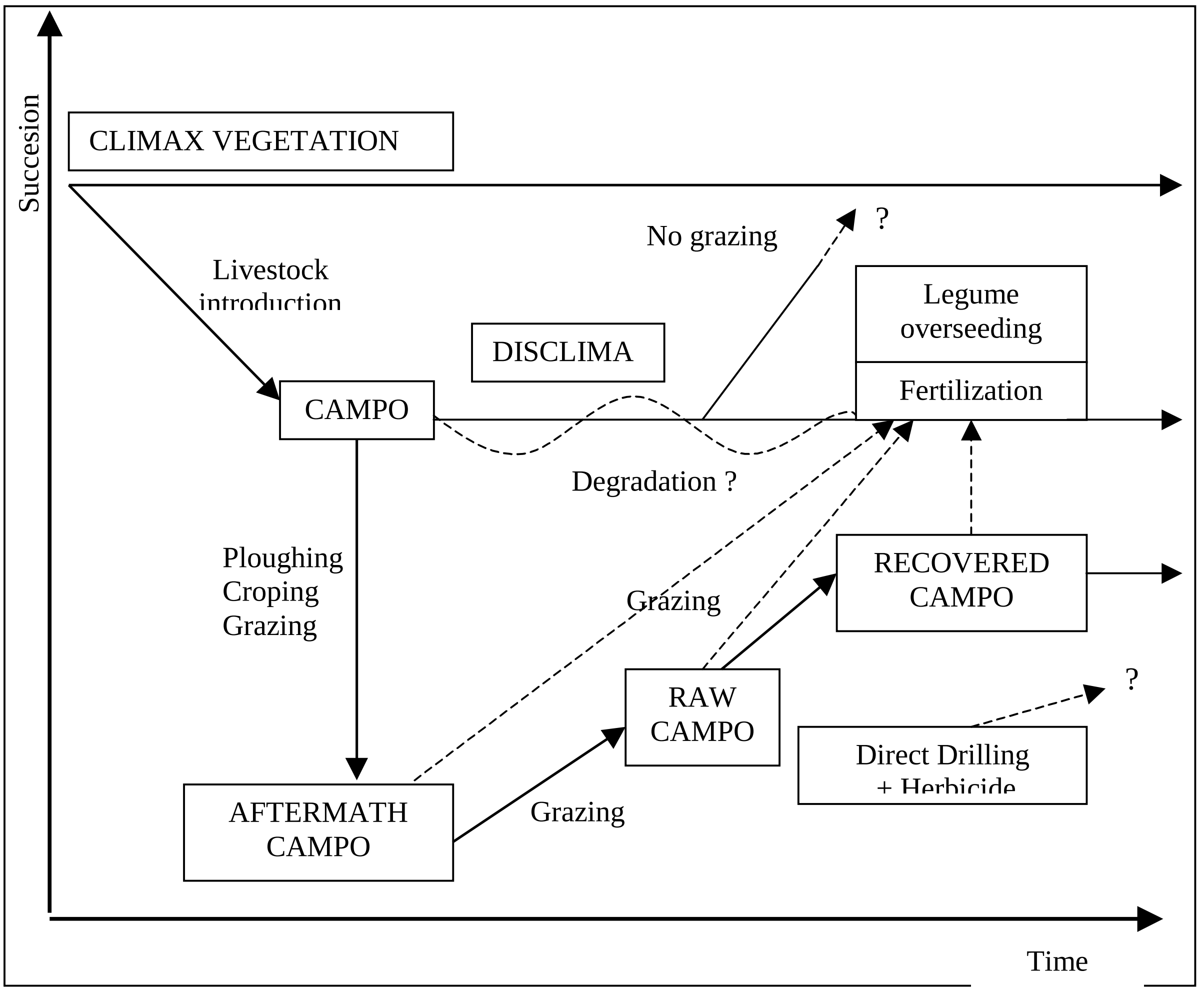


**Figure 1 -** Scheme of relationships between climax vegetation and humane activity induced secondary successions.

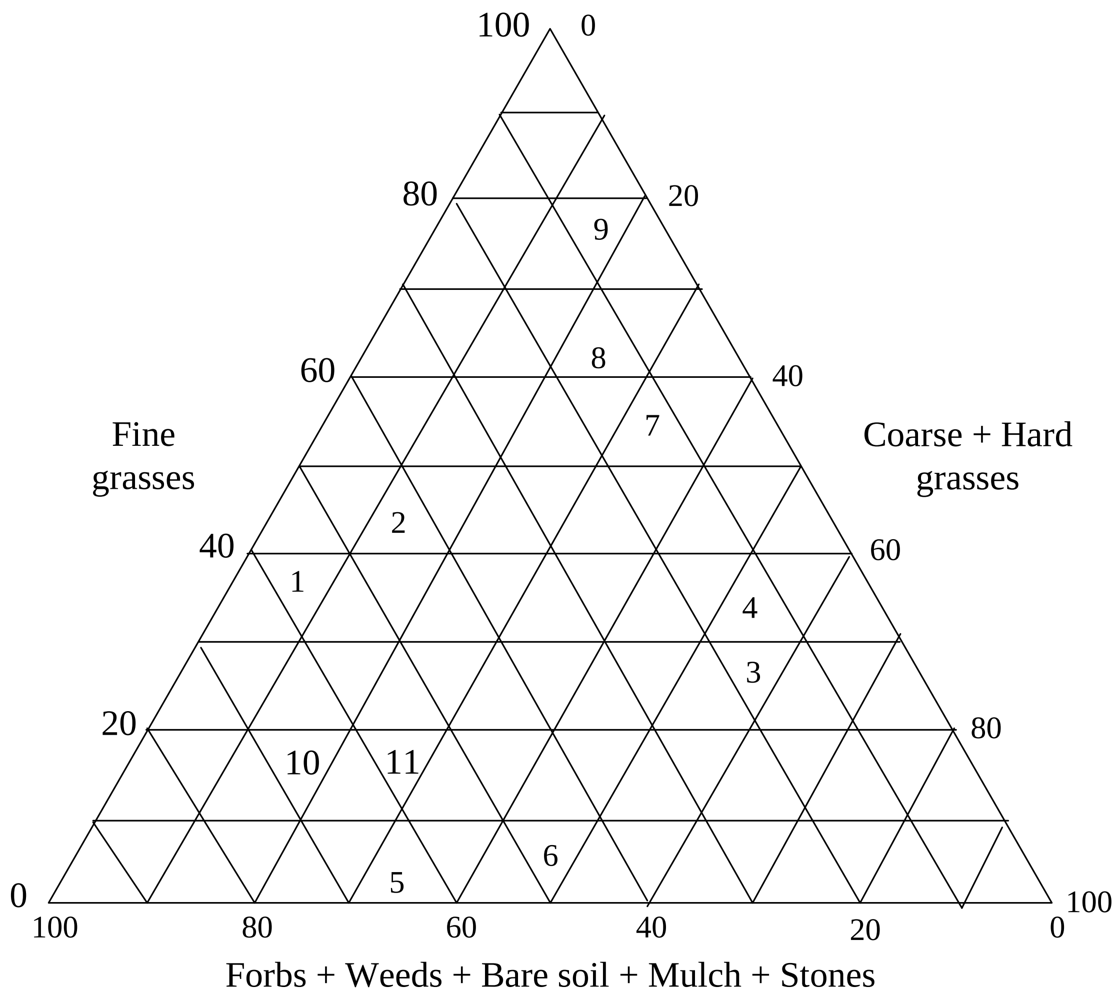


**Figure 2 -** Vegetal community classification according to productive types and not vegetation covered area (forbs, weeds, bare soil, mulch and stones).

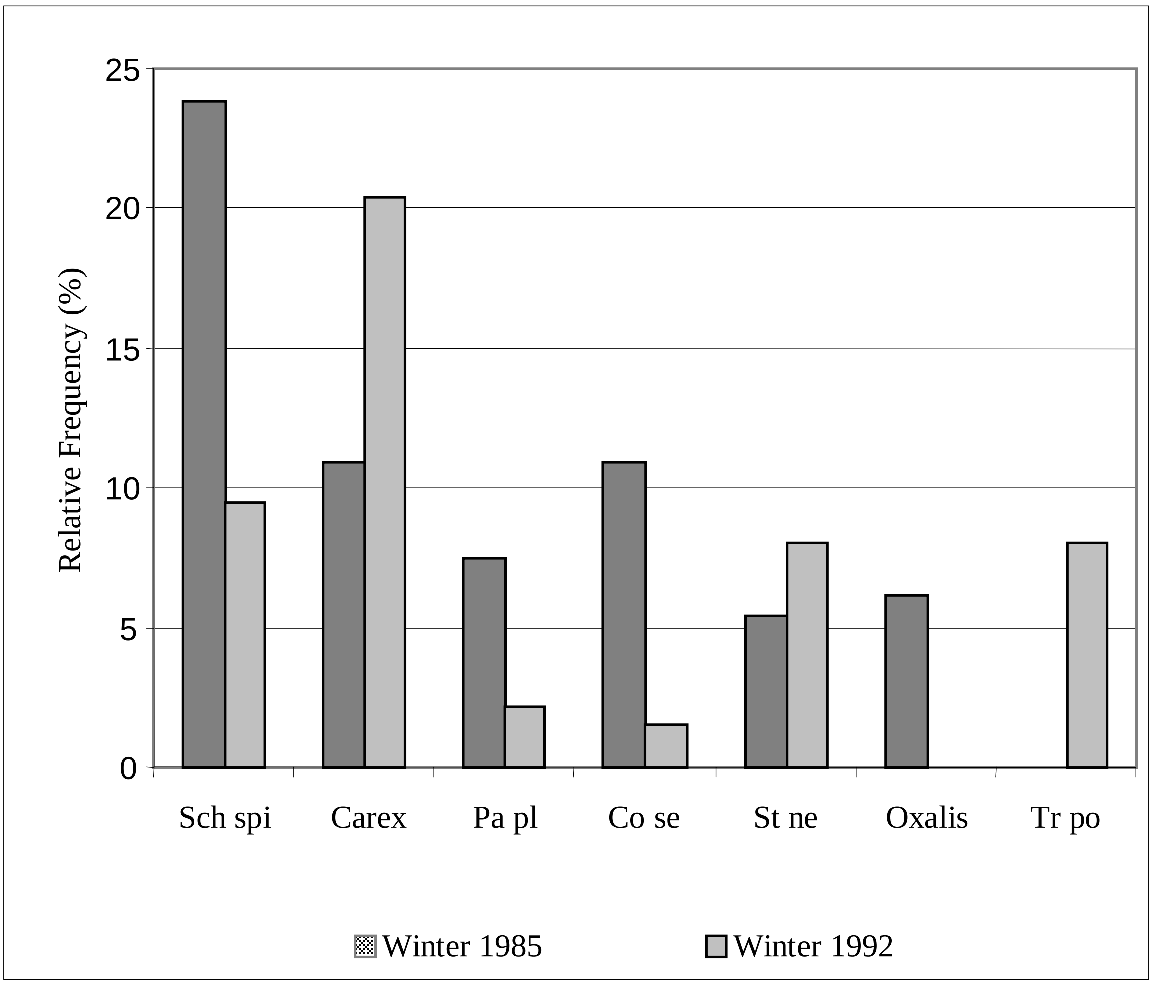


**Figure 3 -** Relative frequency (%) of the most important species of a campo grazed by 0.8 AU $ha^{-1}$, 2/1 sheep/cattle relationship, in winters 1985 and 1992.

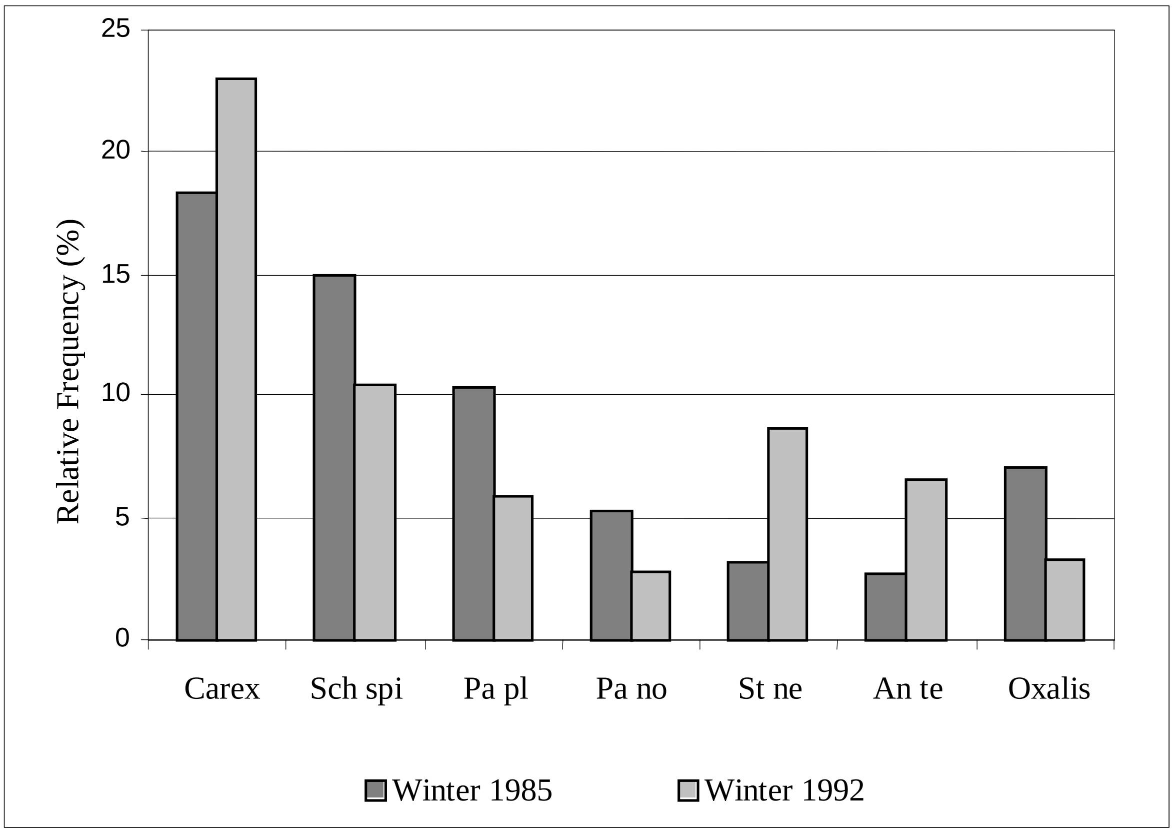


**Figure 4** - Relative frequency (%) of the most important species of a campo grazed with 1.1 AU ha$^{-1}$, rotational stocking, 5/1 sheep/cattle relationship, in winters 1985 and 1992.

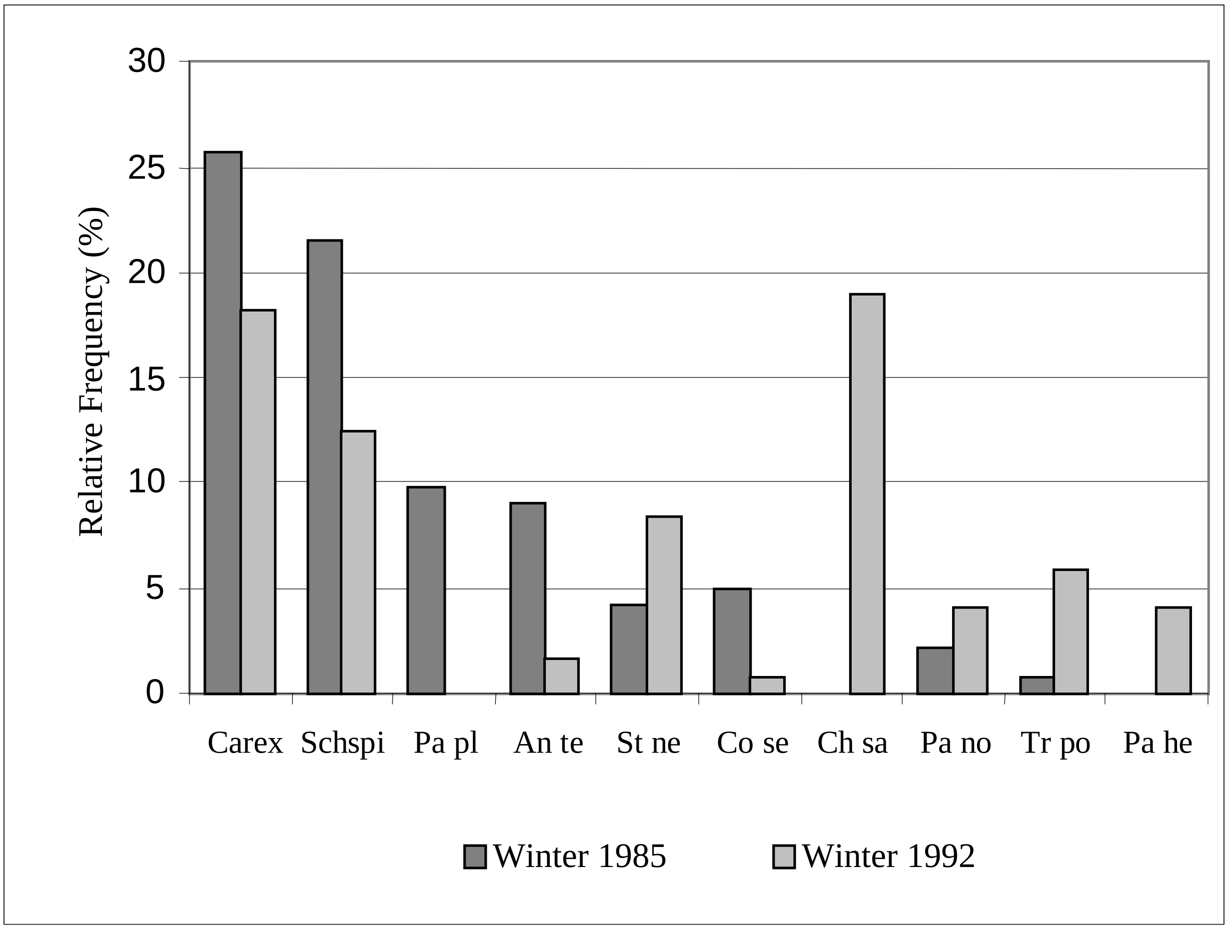


**Figure 5** - Relative frequency (%) of the most important species of a campo grazed with 1.1 UG $ha^{-1}$, continuous stocking, 5/1 sheep/cattle relationship, in winters 1985 and 1992.

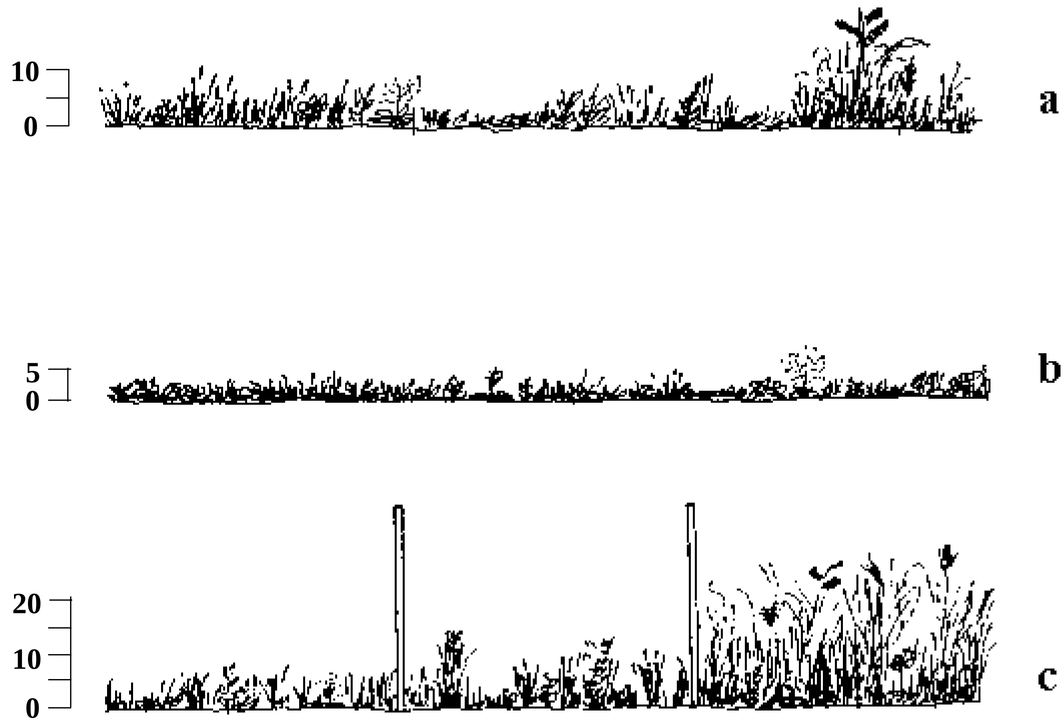


**Figure 6** - Scheme of vegetation grazed with different stocking rates, grazing methods, and ovine/bovine relationships.

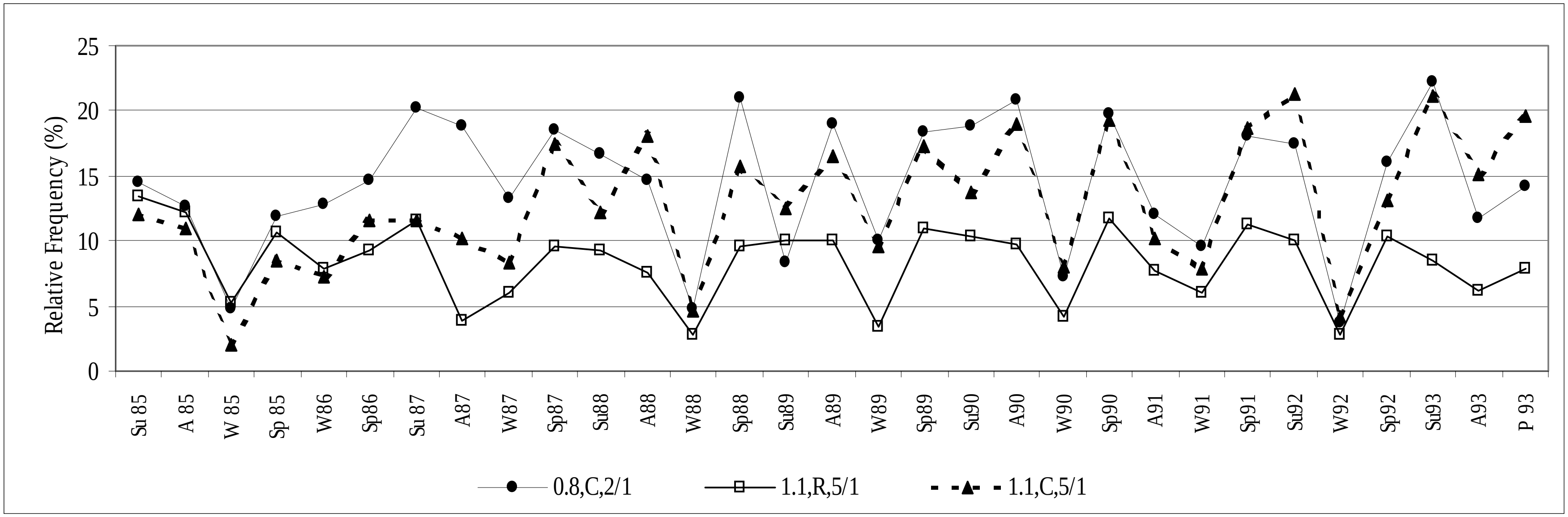


**Figure 7** - *Paspalum notatum* relative frequency (%) evolution at continuous and rotational stocking, same stocking rate and sheep/cattle 5/1and 2/1relationship.

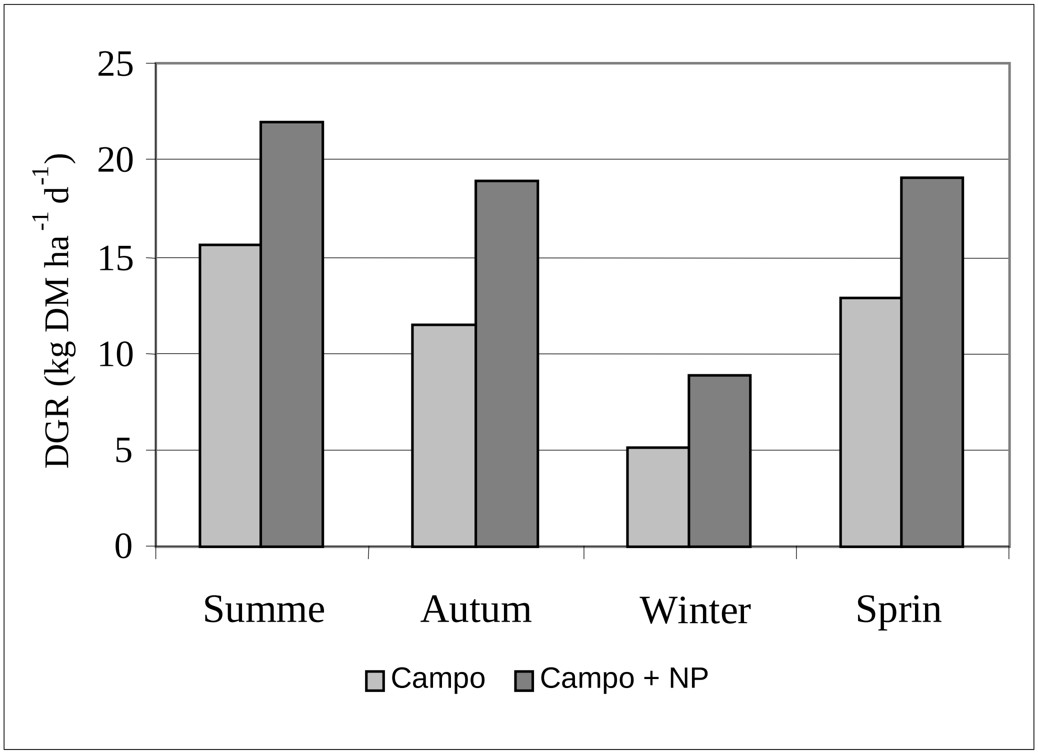


**Figure 8** - Four seasons daily growth rate (kg DM ha$^{-1}$ d$^{-1}$) of not – fertilised campo and N+ P fertilised campo.

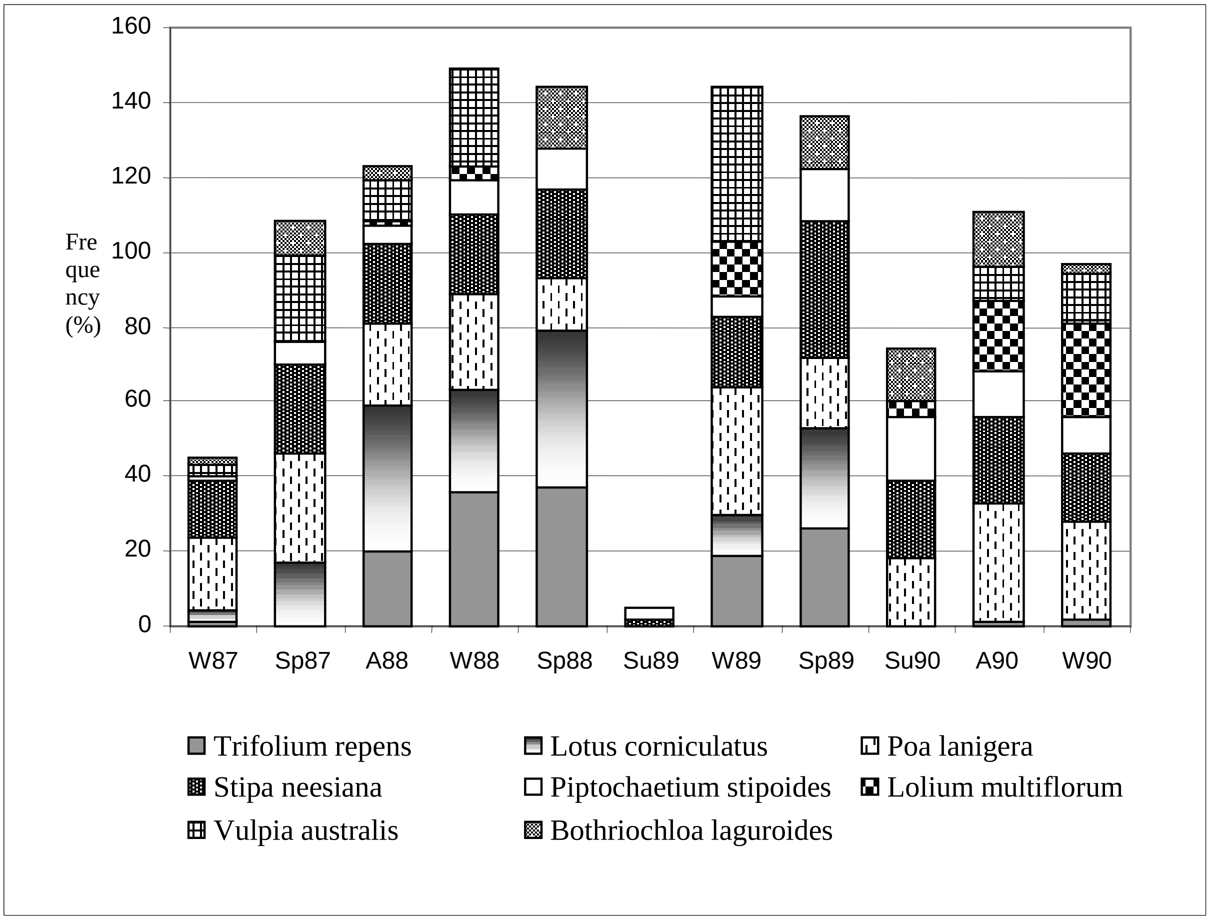


**Figure 9 -** Frequency (%) of the most important species in by legumes introducing improved campo.

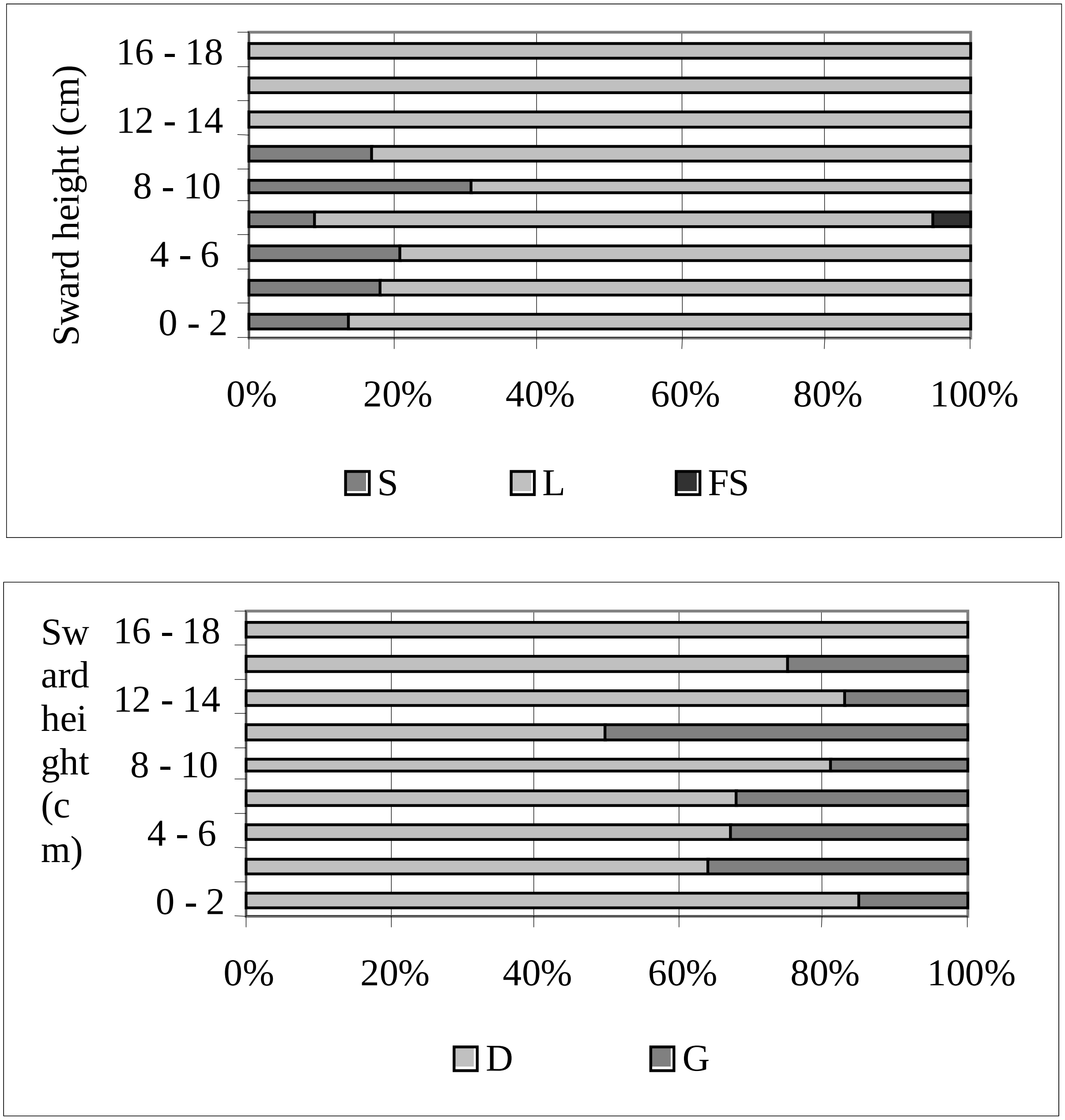


**Figure 10** - Vertical structure of a herbage mass of 2130 kg DM $ha^{-1}$ sward profile, in winter (Adapted from Montossi *et al*., 1998b). S = stem, includes leaf sheath. L = leaf. FS = flowering stem. D = dead material. G = green material.