Canopy structure characteristics of three native perennial grasses with potential for integrated systems

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Introduction
One requirement to establish productive pastures in silvopastoral systems is the use of adapted forage species to optimize the use of natural resources, particularly solar radiation. In general, there is little information in sub-tropical environments related to the ecophysiology of native forages under shade and their potential use in integrated systems (Barro *et al.*, 2012). The canopy structure is a key variable to determine the adaptive potential of forages and influences the radiation use efficiency (RUE) under different light conditions. The light extinction coefficient calculated from the Beer-Lambert formula (k) shows the canopy architecture and light interception patterns of plants and thus their potential ability to convert light energy (photosynthetically active radiation-PAR) into plant biomass (Kiniry *et al.*, 1999).
The objective of this study was to determine the light interception patterns and extinction coefficients of three native grasses (*Paspalum notatum, P. regnellii* and *P. dilatatum*) under two artificial shading levels (50% and 80%) and in full sunlight and relate these characteristics to the their adaptive potential for silvopastoral systems.

Materials and methods
The experiment was conducted at Embrapa South Animal Husbandry and Sheep located at the Campanha region of Rio Grande do Sul State, Southern Brazil. The soil at the experimental area was classified as a Planosol and this study was carried out from October 2009 to April 2010. The effects of two artificial shading levels (50% and 80% shade cloth) on the light interception patterns and extinction coefficient (k) were measured for: a) *Paspalum notatum* ecotype André da Rocha; b) *Paspalum dilatatum* ecotype Virasoro; and c) *Paspalum regnellii* accession BRA-007382 (Embrapa Cenargen) and compared to full sunlight. The seedlings were previously grown in greenhouse and transplanted to experimental units (e.u.) of 1×2 m in December 2008. Additional methodological details are described by Barro *et al.* (2012). The leaf area index (LAI) was calculated from samples collected in a 625 cm^2 quadrat in each e.u.. In the field, herbage samples were stored in a box with ice and taken to the laboratory. The green herbage material was weighed and sub-sampled (using at least 30% of green weight of the sample), followed by morphological separation (green leaves, stems and dead material) and then leaf area were measured using an optical planimeter (LI-3100, LICOR, Inc.). The leaf area index was estimated using the equation: $LAI = LA \times S^{-1}$, where LA is the green leaf area of the sample (cm^2) and S the soil sampled area (cm²).
The photosynthetically active radiation (PAR) was measured with a ceptometer (Decagon model AccuPAR) prior to each cut. To determine both the incident PAR (PARi) and the transmitted PAR (PARt), ceptometer readings were made above and below the grass canopy, respectively. The PAR readings were taken between 11 am and 1 pm local time and on clear

sky conditions. The percentage of light interception (LI) was calculated as the amount of the intercepted PAR (PARi - PARt) divided by PARi and this result multiplied by 100.
The relationship between LAI and LI was fitted according to the model of light attenuation within the canopy, described by Monsi & Saeki (*apud* Hirose, 2005). From the Beer-Lambert formula, k was determined using the regression model: LI = LI max [1 - exp (k × LAI)] where: LI is the amount of PAR intercepted by canopy, LI max is the asymptote of the curve for this exponential relationship and LAI is the leaf area index. For the relationships between variables (LI and LAI), the data were submitted to regression analysis at 5% probability level using the PROC REG feature of SAS (Statistical Analysis System, version 9.2.).

Results and discussion
The relationship between LI and LAI for each forage grass was adjusted to different exponential models, according to shade levels and are shown in Figure 1. The light extinction coefficient (k) was determined from these regressions and, based on the interpretation of their biological responses and by examining the confidence intervals generated; when k (slope of equation) was in the same confidence interval, the relationships were expressed by a single regression for different shading levels.
It was observed high values of LAI from the beginning to the end of the experimental period (up to 150 days of cumulative growth) for the three forages. Still after reaching the standard critical LAI level (90% LI), the leaf area continued increasing at maximum levels of LI (Figure 1). The stabilization of LI by canopy varied according to forage species and shading level. For the three grasses, the relationship between the LAI and LI was equal under 50% shade and in full sunlight. For *P. regnellii*, it was observed a k value of 0.74 under 50% shade and in full sun and of 1.21 under 80% shade (Figure 1a). For *P. dilatatum,* k values ranged from 1.07 under 50% shade and in full sun to 1.34 under 80% shade (Figure 1b). For *P. notatum,* k value increased from 1.72 in full sun and under 50% shading to 1.84 under 80% shade (Figure 1c).
Overall, similar values of k were observed in full sunlight and under 50% shade level, indicating no significant structural changes of grass canopies under moderate shade compared to full sun. Under 80% shade, it was observed a significant reduction of LAI (and thus of LI) for both *P. notatum* and *P. dilatatum*, which was related to low forage yields of these forage species when grown under heavy shade (Barro *et al.*, 2012).
Therefore, in this study, *P. notatum* showed a more horizontal canopy architecture with higher k values than *P. dilatatum* and *P. regnellii*, which were observed as typical erect and upright leaves grasses under shade. Examination of the extinction coefficient values determined by this study revealed that *P. dilatatum* and *P. regnellii* have similar strategy to intercept PAR when grown under shade conditions, with a clear advantage of *P. regnellii*, probably because of the larger size of leaves and other morphological adaptations of this native grass.
Under moderate shading, all three forages showed a positive relationship between LAI and LI and with herbage dry matter yield (DMY) in the same study (Barro *et al.*, 2012). However, *P. regnellii* DMY was unchanged under the heavy shade compared with moderate shade level (Barro *et al.*, 2012). For instance, *P. regnellii* was the only native forage species to reach the critical LAI regardless shading conditions (Figure 1a). Still critical LAI of *P. regnellii* (3.68) was higher than the other two forages grasses (3.45 for *P. dilatatum* and 1.78 for *P. notatum*) in full sun and under 50% shading, showing that this native grass has high plasticity to adapt to shading conditions. Also this species presented RUE values 3.83 times greater under 80% shading compared with the ambient without light restriction. In average (over the three shading levels), RUE estimates of forage species were: 1.69, 2.12 and 3.04 g DM MJ^{-1} for *P. notatum*, *P. dilatatum* and *P. regnellii*, respectively (Barro, 2011). These facts suggests that *P. regnellii* has potential to be used in heavy shaded environments due to its high capacity to

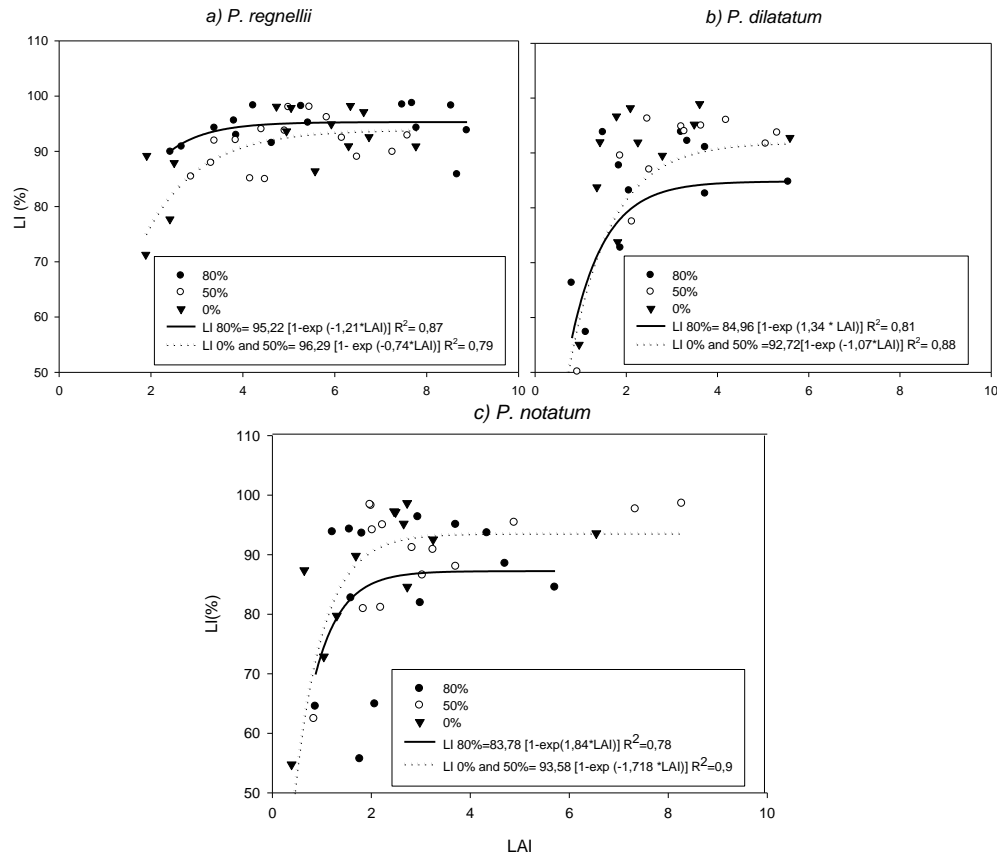capture the incident PAR and covert into LAI and biomass.

Figure 1. Relationship between leaf area index (LAI) and light interception (LI) of *P. regnellii* (a), *P. dilatatum* (b) and *P. notatum* (c) growing in full sun (▼), under 50% shade (○) and 80% shade (●) in Bagé, RS.

Conclusions
The light extinction coefficients were unchanged under moderate shade compared to full sunlight, but increased under heavy shade, for all native forages.
P. regnellii was the only forage species that presented favorable canopy structure characteristics to tolerate shade, indicating better potential to use in silvopastoral systems than *P. notatum* and *P. dilatatum*.

References
BARRO R.S., VARELLA A.C., LEMAIRE G., MEDEIROS R.B., SAIBRO J.C, NABINGER C.; BANGEL F.V., CARASSAI I.J. (2012).Forage yield and nitrogen nutrition dynamics of warm-season native forage genotypes under two shading levels and in full sunlight. *Revista Brasileira de Zootecnia*, 41, 1589-1597.

BARRO, R.S. (2011) Respostas morfofisiológicas e produtivas de genótipos forrageiros nativos em diferentes condições de luminosidade. *Thesis*, Programa de Pós-Graduação em Zootecnia, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, 160p.

HIROSE T. (2005) Development of the Monsi-Saeki theory on canopy structure and function. *Annals of Botany*, 95, 483–494.

KINIRY J.R.; TISCHLER C.R.; VAN ESBROECK G.A. (1999) Radiation use efficiency and leaf CO_2 exchange for diverse C_4 grasses. *Biomass & Bioenergy,* 17, 95–112