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Horse grazing systems: understory biomass and plant biodiversity of a *Pinus radiata* stand

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ABSTRACT: Horse grazing systems may affect productivity and biodiversity of understory developed under *Pinus radiata* D. Don silvopastoral systems, while acting as a tool to reduce the risk of fire. This study compared continuous and rotational grazing systems effect upon biomass, fractions of stem, sprouts, leaves and woody parts of *Ulex europaeus* L. and alpha (Species Richness, Shannon-Wiener) and beta (Jaccard and Magurran) biodiversity for a period of four years in a *P. radiata* silvopastoral system. The experiment consisted of a randomized block design of two treatments (continuous and rotational grazing). Biomass, and species abundances were measured - biodiversity metrics were calculated based on these results for a two years of grazing and two years of post-grazing periods. Both continuous and rotational grazing systems were useful tools for reducing biomass and, therefore, fire risk. The rotational grazing system caused damage to the *U. europaeus* shrub, limiting its recovery once grazing was stopped. However, the more intensive grazing of *U. europaeus* plants under rotational had a positive effect on both alpha and beta biodiversity indexes due to the low capacity of food selection in the whole plot rather than continuous grazing systems. Biomass was not affected by the grazing system; however the rotational grazing system is more appropriate to reduce *U. europaeus* biomass and therefore forest fire risk at a long term and to enhance pasture biodiversity than the continuous grazing system.
Keywords: silvopastoral, species richness, livestock management, shrub biomass control, fires

Introduction

Livestock production plays an important role for increasing the value and multifunctional management of forests (Havstad et al., 2007; Rigueiro-Rodríguez et al., 2009). However, the use of domestic animals in extensively managed forest systems of Europe is not widely used due to the shortage of shepherds and economic changes driven mostly by subsidy. Galician endangered horse breed can be raised in forests with a clear understory dominance of Ulex europaeus L. (gorse). Gorse is the most important type of understory found in the forests of the North of Spain (Zas and Alonso, 2002) usually related to fire ignition and dispersion of forest fires in Galicia, one of the most fired regions of Europe (Rigueiro-Rodríguez et al., 2009).

The effects of land-use change of *Pinus radiata* D. Don afforested lands on production, C sequestration and biodiversity have been evaluated in the Atlantic region of Europe (Mosquera-Losada et al., 2009 and 2010; Fernández- Núñez et al., 2010). Nevertheless, the effects of grazing systems in mature *P. radiata* stands on these variables have not been studied yet. Continuous and rotational grazing system management modifies herbaceous plant productivity, depending on the stocking rate (Parsons and Penning, 1988; Briske et al., 2008); but few studies have been carried out comparing grazing systems in woody pastures. Continuous management is preferred by farmers because it is easy to manage and it has less establishment costs compared with the rotational. Pasture recovery during the rest periods under rotational management and animal higher selection capacity under the continuous grazing system are important factors that would modify the productivity and biodiversity evolution of gorse understory (Karki et al., 2000; Holechek et al., 2001; Dumont et al., 2007; Mayer et al., 2009)

This study aimed to evaluate how continuous and rotational horse grazing affect biomass, fractions (woody part, leaves, sprouts and stems) and biodiversity of the gorse understory developed under a mature *P. radiata* stand during four years.

Materials and Methods

This study was conducted in the San Breixo forest (Lugo, Spain, 43°09′ N, 7°48′ W, and 500 m a.s.l.) in the bioclimatic Atlantic region of Europe (EEA, 2003). The forest stand used in this study is privately owned by a forest community that signed a contract with the public administration, which performed the forest management. Before planting, grassland was the main land use of the area, but animals did not graze after planting until the present experiment was established. The initial tree density was 833 trees ha^{-1}, as it was artificially afforested with *P. radiata* planted at a distance between trees of 3 and 4 m. No thinning or pruning had taken place since the stand was established in 1970. The total mean annual precipitation and mean annual temperature for the last 30 years are 1,300 mm and 12.2 °C, respectively. Soil was classified as Umbrisol (FAO, 1998) with a sandy clay texture (63 % sand, 20 % clay and 17 % silt). The initial water pH (1:2.5) was 4.51. The initial understory vegetation was dominated by *U. europaeus* (over 80 % of plant cover).

<table>
<tr><td colspan="6">2000</td><td colspan="12">2001</td><td colspan="12">2002</td><td>2003</td><td>2004</td></tr>
<tr><td>JUL</td><td>AUG</td><td>SEP</td><td>OCT</td><td>NOV</td><td>DEC</td><td>JAN</td><td>FEB</td><td>MAR</td><td>APR</td><td>MAY</td><td>JUN</td><td>JUL</td><td>AUG</td><td>SEP</td><td>OCT</td><td>NOV</td><td>DEC</td><td>JAN</td><td>FEB</td><td>MAR</td><td>APR</td><td>MAY</td><td>JUN</td><td>JUL</td><td>AUG</td><td>SEP</td><td>OCT</td><td>NOV</td><td>DEC</td><td>PVIII</td><td>PIX</td></tr>
<tr><td colspan="6">PI</td><td colspan="5">PII</td><td colspan="4">PIII</td><td colspan="3">PIV</td><td colspan="5">PV</td><td colspan="4">PVI</td><td colspan="3">PVII</td><td colspan="2">POST</td></tr>
<tr><td colspan="30">GRAZING</td><td colspan="2">GRAZING</td></tr>
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Figure 1 – Timing of grazing (2000-2002) and post-grazing (2003-2004) periods evaluated in the study. PI: period 1. PII: period 2. PIII: period 3. PIV: period 4. PV: period 5. PVI: period 6; PVII: period 7. PVIII: period 8. PIX: period 9.

This study was conducted from Jul. 2000 to Dec. 2004 on 24 ha. The design was a randomized block with two treatments: continuous and rotational grazing. Each treatment had two replicates (blocks) of 6 ha each. Each replicate of the 6-ha rotational plots was sub-divided into four plots of 1.5 ha each. A global stoking rate of 0.33 animal ha^{-1} was used for continuous and rotational grazing treatments; while 1.33 animal ha^{-1} represented the instantaneous stocking rate in the rotational grazing system. Stocking rate was chosen based on previous study results (Rigueiro et al., 1999), which indicates that around one horse every 4 ha should be used in these systems to reduce fire risk. There were four water sources homogeneously distributed per replica. No salt blocks were placed in the plots. The initial weight of the horses was approximately 300 ± 20 kg. Horses began to graze in Jul. Jul. 2000 (Figure 1). Animals grazed in the whole plot (6 ha) in the continuous grazing treatment. In the rotational grazing treatments, horses had free access to one subplot (1.5 ha) per month; the other three subplots were not grazed within the same rotation. During the first grazing period, the animals had free access to one rotational subplot for two months, and the total rest period was approximately six months due to the initial high pasture biomass availability. Grazing was ceased in Dec. Dec. 2002.

U. europaeus biomass production was estimated by harvesting three randomly selected quadrats of 1 × 1 m, per treatment and replica, with a brushcutter at 2.5 cm every month from Jul. 2000 to Dec. 2002. During the grazing period and in the rotational grazing system, samples were taken before the horses entered each subplot. Three exclusion cages (2 × 2 m) were used to quantify understory biomass production in continuous plots by harvesting an inner quadrat of 1 m × 1 m at 25 mm with a brushcutter. After sampling in the continuous grazing system, cages were randomly moved within each experimental unit. Samples were taken monthly at the same time as in the rotational grazing subplots. In the post-grazing period, two samplings were carried out in Sep. 2003 and Feb. 2004. All samples were labeled, transported and weighed in the laboratory, and plant biomass was classified by species to perform biodiversity analyses for each year except 2003. Additionally, 100 g of *U. europaeus* per sample of shrub material was taken and separated into two fractions: stems (diameter > 5 mm) and sprouts (diameter < 5 mm). Each fraction was then split into woody part (sum of woody components in the fractions above and below 5 mm) and leaf subfractions (sum of leaf components in the fractions above and below 5 mm). The fractions were oven-dried (48 h at 60 °C) and weighed to determine the dry matter (DM) biomass production overall and for each fraction. Stem and sprout fraction percentages were calculated relative to the sum of the stem and sprout weight. Similarly leaf and woody part fractions were also estimated relative to the sum of the leaf and woody part fractions.

Plant biodiversity analyses were carried out using the relative proportion of each species based on weight. Species richness (SR) and the Shannon-Wiener Alpha biodiversity indexes as well as Jaccard and Magurran Beta diversity indexes were determined as Magurran (2004). Species richness is the most used biodiversity index when vascular plants are evaluated. Shannon-Wiener alpha biodiversity index is also a widely used alpha biodiversity index, which takes into account the rare species in a more specific way than SR. Jaccard index allows us to evaluate the relative percentage of shared species between two situations (treatments but also initial and final period). Finally, Magurran beta index allows us to obtain an index which is increased when the number of species increases in two different situations (treatments or initial and final situation) but also when the species in the two different situations are different.

Biomass variables and diversities were grouped within each of the six grazing periods or rotation in order to compare the global stocking rates in both rotational and continuous grazing system during the grazing (2000-2002) and post-grazing (only 2004) periods, respectively. All variables were statistically analyzed with repeated measures ANOVA with the PROC GLM procedure (SAS Institute, 2001).

Results

Monthly distributions of temperature and rainfall (Figure 2) during the study period showed a drought between Jul. and August and cold temperatures (below 6 °C) in winter 2001, and as consequence understory growth was reduced. Before grazing, the initial total *U. europaeus* biomass production available for animals was similar in the continuous and rotational treatments (approximately 2.5 t ha^{-1}). Throughout the grazing period, a reduction in total *U. europaeus* biomass production was found in both continuous and rotational treatments

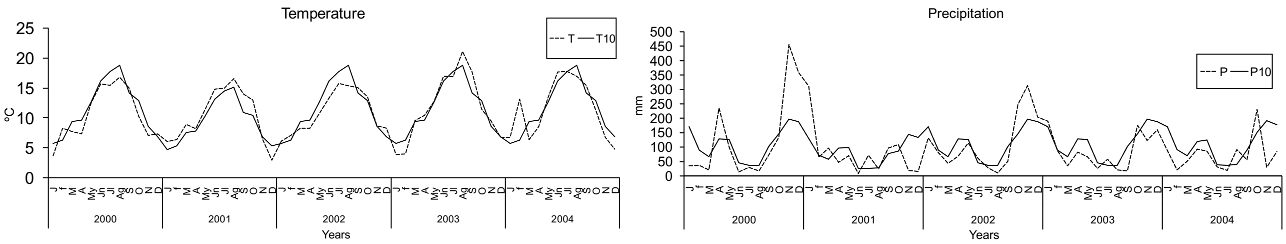

Figure 2 – Monthly mean rainfall and temperature recorded in the experimental grazing system, where T is average monthly temperature , P is average monthly precipitation during the study (2000-2004), and T10 and P10 are average monthly temperature and precipitation, respectively, for the 30 years leading up to the start of the experiment (Ministry of the Environment; Stations (Parga-Guitiriz)).

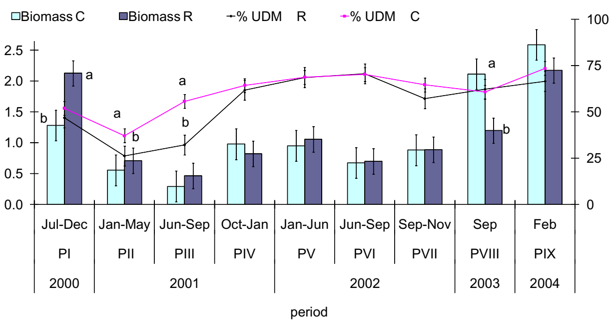

Figure 3 – Biomass (t DM ha^{-1}) and dry matter (% DM) of *U. europaeus* under continuous (C) and rotational (R) grazing systems. PI: period 1. PII: period 2. PIII: period 3. PIV: period 4. PV: period 5. PVI: period 6; PVII: period 7. PVIII: period 8. PIX: period 9. Different letters indicate differences between treatments within each period.

since the second grazing period. However, the average production at the end of the first grazing period (PI) was statistically higher for rotational grazing (2.1 t ha^{-1}) than for continuous (1.3 t ha^{-1}) grazing ($p < 0.05$), indicating a reduction of *U. europaeus* biomass through continuous grazing compared with rotational grazing. This difference was not kept in the second grazing period although a similar tendency was found, but the differences between treatments were reduced to less than 0.1 t ha^{-1} during the following grazing periods (from PIII to PVII). Total mean for *U. europaeus* biomass production of the last two periods (PVIII and PIX), and therefore biomass recovery, was higher ($p < 0.05$) in the continuous grazing system (2.35 t ha^{-1}) relative to the rotational grazing system (1.7 t ha^{-1}).

The percentage of UDM, which is considered a fire risk index, was highly variable throughout the grazing periods in the experiment, with a mean value of 57 % (Figure 3). UDM was affected by grazing treatment ($p < 0.05$) but only in PII and PIII, when continuous grazing had a higher proportion of dry matter in the understory relative to rotational grazing.

The percentage of stems and sprouts were affected by the treatment and period interaction ($p < 0.001$), and the amount of sprouts was independently and affected by the treatments ($p < 0.05$) and period ($p < 0.001$) factors (Figure 4). *U. europaeus* stem biomass production and the percentage of stems were higher in the rotational grazing system relative to the continuous grazing system between PI and PIII ($p < 0.05$ for PI and PII; and $p < 0.01$ for PIII) and between PII and PIV ($p < 0.001$ for PII and PIII; $p < 0.05$ for PIV), respectively. Sprout biomass production was higher in the rotational than in the continuous grazing system in the first period ($p < 0.05$). However, when the sprout percentage was taken into account, the continuous grazing system was found to have a higher percentage of this component than the rotational grazing system in the second ($p < 0.001$), third ($p < 0.001$) and fourth ($p < 0.05$) grazing periods (Figure 4). Production of the woody part component of *U. europaeus* was not affected by the treatments (Figure 5). However, when the production of leaves (period: $p < 0.001$; treatment: $p < 0.05$) and the percentage of the total woody part and leaves fractions were taken into account, the period and treatment interaction was found to affect these variables ($p < 0.01$). Biomass and the percentage of leaves were higher in the rotational system than in the continuous system for the two first grazing periods. There were no differences between treatments regarding the biomass or percentage of stems, sprouts (Figure 4) or woody parts (Figure 5) variables when the post-grazing period was considered. However, the recovery of sprout (Figure 4) and leaf (Figure 5) biomass were higher under continuous grazing one year after grazing was stopped.

Throughout the four years of study, a total of 5 and 14 species were registered in plots where continuous and rotational grazing systems, respectively, were implemented (Table 1). The appearance rate of new species was progressive in both types of grazing systems, but was slower in the continuous grazing system. During all periods, a clear dominance of *U. europaeus*, which was always above 96 % (Figure 6), was seen. Only species from the Leguminosae, Ericaceae, Asphodelaceae, Poaceae and Rosaceae families appeared in both treatments. Species from the Boraginaceae, Asteraceae and Hypolepidaceae families appeared only under the rotational grazing system. Species of the Ericaceae family began to appear later in the plots of the continuous grazing system than in the rotational grazing system. Only two Ericaceae species

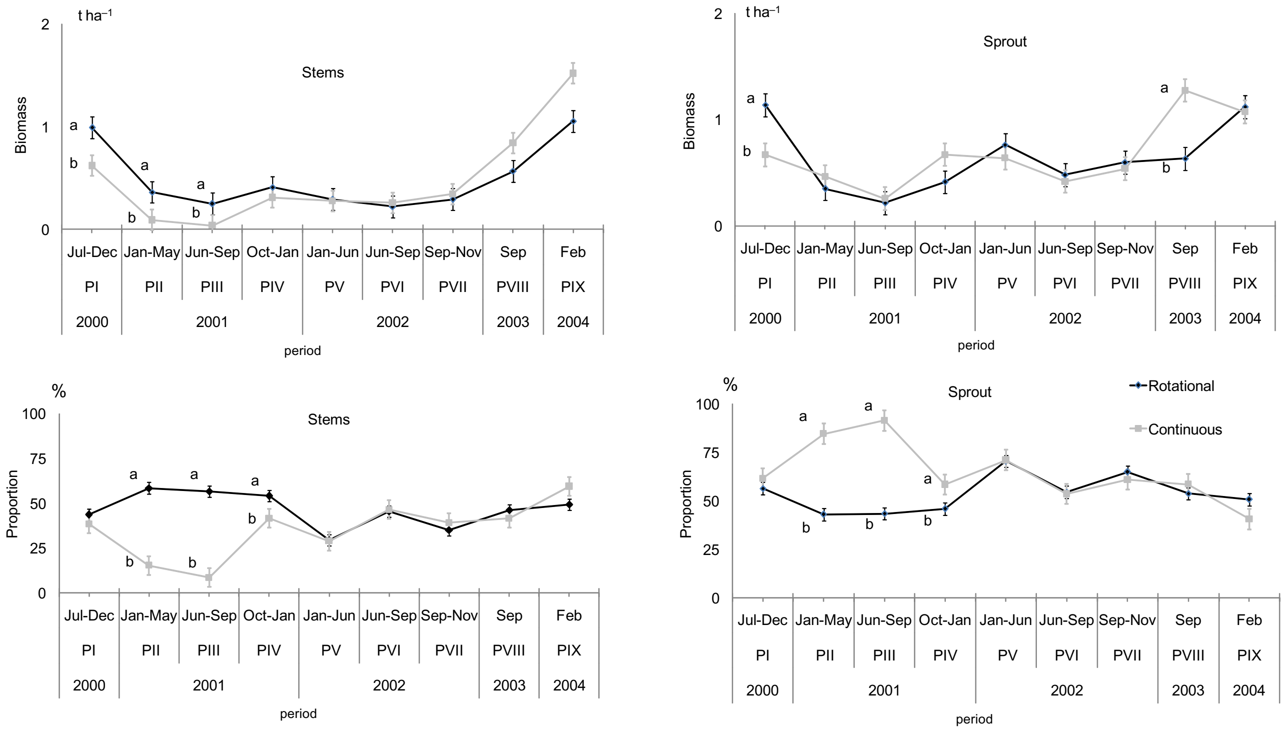

Figure 4 – Biomass and percentage of the total percentage of stems and sprouts of U. europaeus under continuous and rotational grazing systems. PI: period 1. PII: period 2. PIII: period 3. PIV: period 4. PV: period 5. PVI: period 6; PVII: period 7. PVIII: period 8. PIX: period 9. Different letters indicate differences between treatments within each period.

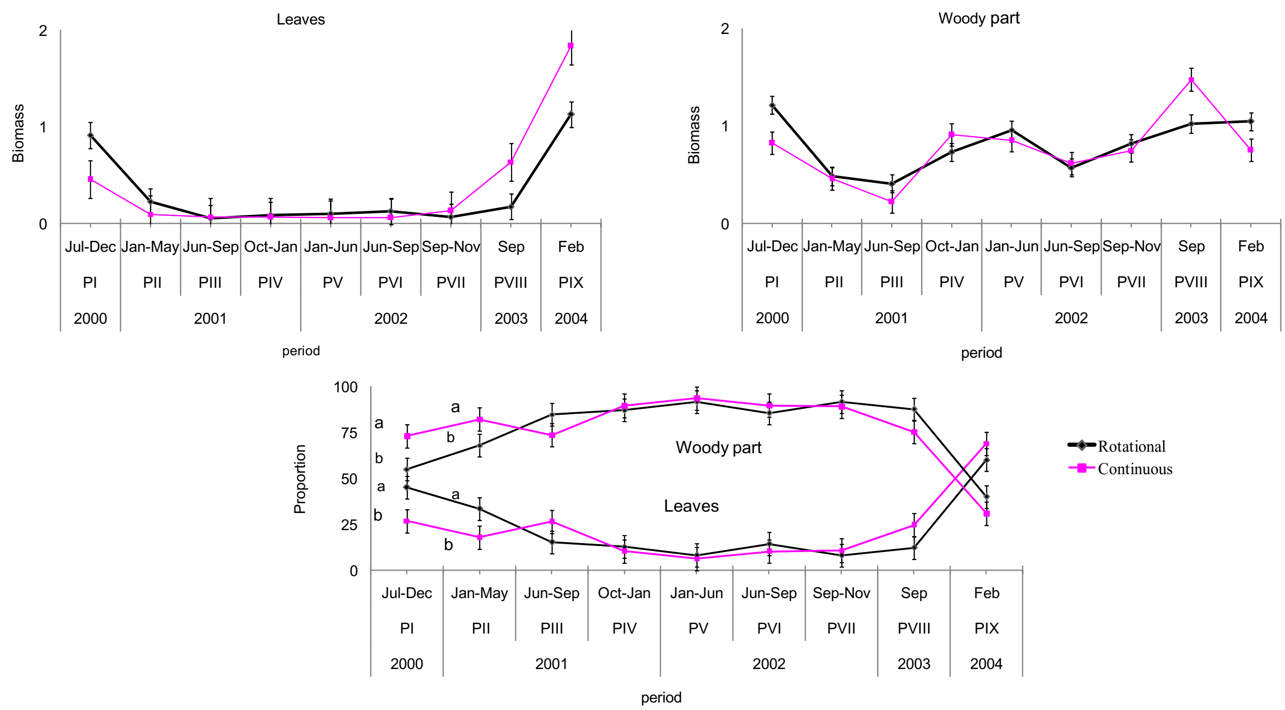

Figure 5 – Biomass and proportion of woody part fractions and leaves of *U. europaeus* under continuous and rotational grazing systems. PI: period 1. PII: period 2. PIII: period 3. PIV: period 4. PV: period 5. PVI: period 6; PVII: period 7. PVIII: period 8. PIX: period 9. Different letters indicate differences between treatments within each period.

Table 1 – Species that appear during the seven periods of grazing and the two periods of post grazing in scrub of *U. europaeus*. W= woody species, H= herbaceous, Cycle: P = perennial species A= annual species. PI: period 1, PII: period 2, PIII: period 3, PIV: period 4, PV: period 5, PVI: period 6, PVII: period 7, PVIII: period 8, PIX: period 9.

Classes	Family	Species	Code	H/W	Cycle
Monocotyledones	Asphodelaceae	*Simethis mattiazii* Vand.	Sm	H	P
	Boraginaceae	*Lithodora prostrata* Loisel.	Lp	H	P
	Asteraceae	*Taraxacum officinale* Weber.	To	H	P
Dicotyledones		*Calluna vulgaris* L.	Cv	W	P
	Ericaceae	*Daboecia cantabrica* (Huds.) K.Koch	Dc	W	P
		Erica cinerea L.	Ec	W	P
		Agrostis capillaris L.	Ac	H	P
		Avena sativa L.	Av	H	A
Monocotyledones	Poaceae	*Dactylis glomerata* L.	Dg	H	P
		Pseudarrhenatherum longifolium L.	Pl	H	P
Filicopsida	Hypolepidaceae	*Pteridium aquilinum* (L.) Kuhn	Pq	W	P
		Pterospartum tridentatum L.	Pt	W	P
	Leguminosae (*Fabaceae*)	*Cytisus striatus* (Hill) Roothm	Cs	W	P
Dicotyledones		*Ulex europaeus* L.	Ue	W	P
		Potentilla alba L.	Pa	H	P
	Rosaceae	Rubus sp.	Rs	W	P

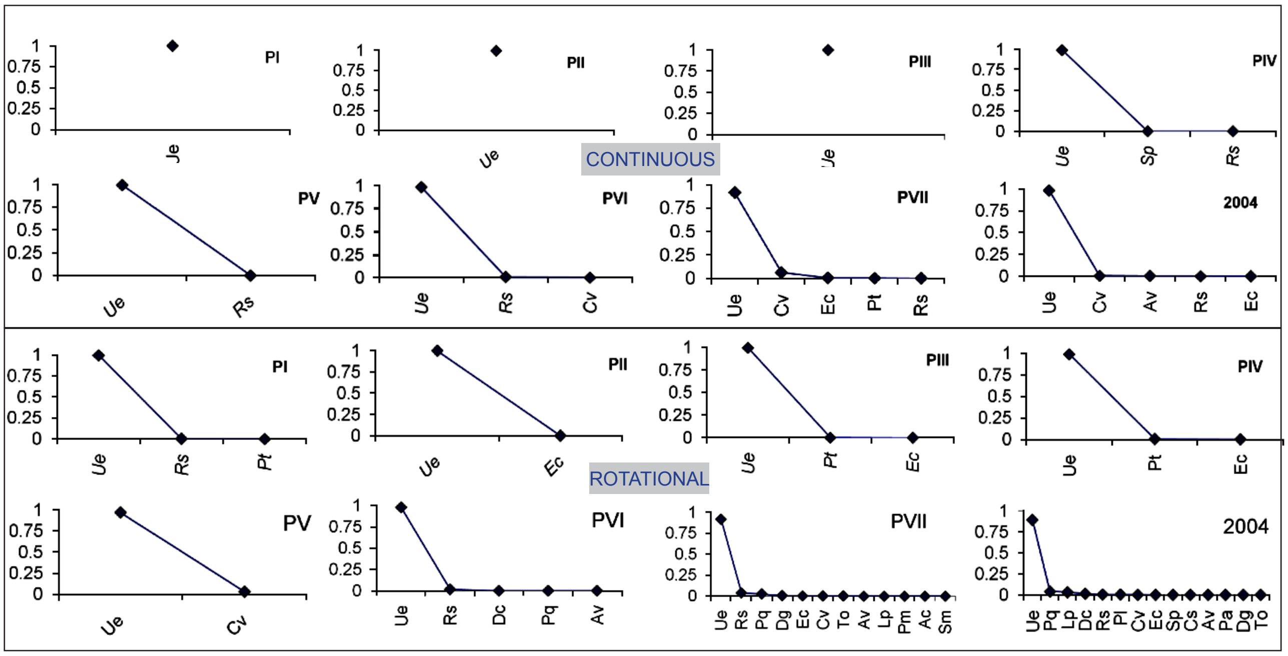

Figure 6 – Abundance diagrams corresponding to continuous and rotational grazing systems. Species name abbreviations are given in Table 1. PI: period 1. PII: period 2. PIII: period 3. PIV: period 4. PV: period 5. PVI: period 6; PVII: period 7. PVIII: period 8. PIX: period 9. Different letters indicate differences between treatments within each period.

were observed under continuous grazing: *Calluna vulgaris* L. and *Erica cinerea* L. after PVI and PVII, respectively. However, *E. cinerea* was recorded in PII, and *C. vulgaris* and *Daboecia cantabrica* (Huds.) K.Koch. were recorded in PV and PVI, respectively, under rotational grazing (Figure 6). Rotational grazing had a greater positive effect on species richness than continuous grazing.

Plant biodiversity indexes under both grazing systems were modified throughout the four years of study; the changes in the plant biodiversity indexes were highest under the rotational grazing system (Figure 7). Species richness (SR) was affected by the period and treatment interaction ($p < 0.0001$). The Shannon-Wiener index was affected by periods ($p < 0.01$) and treatments ($p <$

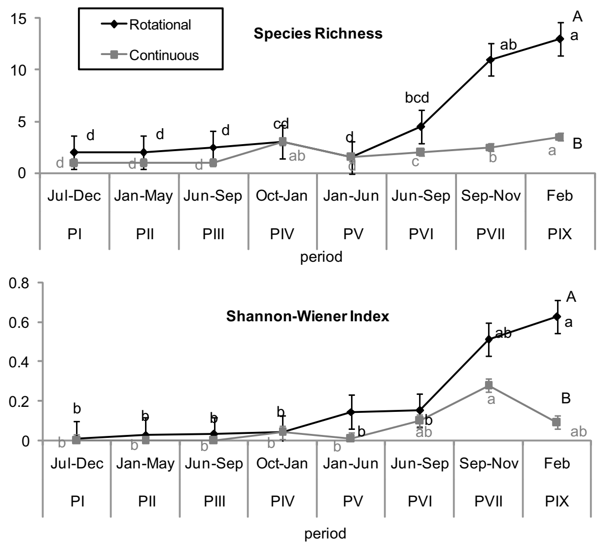

Figure 7 – Species Richness and Shannon-Wiener indexes determined for the continuous and rotational grazing. P: period 1. PII: period 2. PIII: period 3. PIV: period 4. PV: period 5. PVI: period 6. PVII: period 7. PIX: period 9. Different low case letters indicate differences between periods in the same treatment. Different capital letters indicate differences between treatments within the same period.

Table 2 – Jaccard Index (Ij) and Magurran index (β) determined by the initial situation (2000) and final situation (PIX) of the established plots where: a2000 = species present in the plots at the beginning of the experiment (2000 PI); b2004= species present at the end of the experiment (2004) and c = number of species present in both situations.

	a_{2000}	b_{2004}	c	I_j	β
Continuous	1	5	1	0.25	3.75
Rotational	3	14	2	0.13	14.33

Table 3 – Jaccard Index (Ij) and Magurran index (β)) determined for both treatments (continuous and rotational gazing systems) during the grazing and post grazing periods where: a PI = species present in the first period of grazing time; b PVII = species present in the last period of grazing time for grazing period; a PVII = species present in the last period of grazing time; b 2004 = species present in the period of post grazing time; c = number of species present in both situations

		a_{PI}	b_{PVII}	c	I_j	β
Grazing	Continuous	1	5	1	0.20	4.8
	Rotational	3	12	2	0.15	12.70
		a_{PVII}	b_{2004}	c	I_j	β
Post grazing	Continuous	5	5	4	0.66	3.33
	Rotational	12	14	11	0.73	6.93

0.01). Under the continuous and rotational grazing systems, SR and Shannon-Wiener indexes were increased from the first grazing period until the last grazing period (PVII). When the global period was taken into account, biodiversity described in terms of SR (4.88 in rotational *vs*. 2.05 in continuous), and Shannon-Wiener index (0.19 in rotational vs. 0.07 in continuous) was higher under the rotational grazing system.

Table 4 – Jaccard Index (Ij), Magurran index (β) and Complementarity index (CAB) determined for each period of the study where: acontinuous = species present in the continuous grazing systems; brotational = species present in the rotational grazing systems and c = number of species present in both systems.

Period	$a_{continuous}$	$b_{rotational}$	c	I_j	β
PI	1	3	1	0.33	2.67
PII	1	2	1	0.50	1.50
PIII	1	3	1	0.33	2.67
PIV	3	3	1	0.20	4.8
PV	2	2	1	0.33	2.67
PVI	3	5	2	0.33	5.33
PVII	5	12	4	0.31	11.77
2004	5	14	4	0.26	13.93

The Jaccard index indicated that under rotational grazing, only 13 % of species were shared between the initial (2000) and final periods (2004). Under continuous grazing, however, this percentage was increased to 25 % (Table 2). The low number of shared species between the initial and final period as well as the greater number of total species in the rotational grazing system compared with the continuous caused an increase of the Magurran index in the rotational grazing system. Beta biodiversity (Jaccard, and Magurran indexes) differences between the initial and the final grazing periods were higher (Table 3) than differences between the final grazing period and the post-grazing period for both systems. When we compared the Jaccard index between treatments within each rotation (Table 4), we found that treatments generally share only 30 % of species. The Magurran index was increased at the end of the experiment (Table 4), mainly due to the increase of the number of species and the reduction of the proportion of shared species.

Discussion

The initial *U. europaeus* biomass in this study was below that described by Rigueiro-Rodríguez et al. (2009) in *Pinus sylvestris* L. and *Pinus pinaster* Ait. understories (25-50 t DM ha^{-1}). This is due to the high initial stand density in this study and the tree structure of *P. radiata*, which intercepts a higher quantity of light, limiting understory development (Knowles et al., 1999; Rozados-Lorenzo et al., 2007). On the other hand, the initial production of *U. europaeus* (woody + leaf biomass) in our study is within the optimal rank for offered herbaceous pasture for grazing (between 2 and 4 t DM ha^{-1}) for one harvest according to Mosquera-Losada and González-Rodríguez (1998). This is indicative of the low more palatable leafly biomass production for animal grazing of *U. europaeus* species under *P. radiata*, which had a height of approximately 1 m compared with 20-30 cm for herbaceous pasture. Moreover, when sprout or leaf production is considered, the initial biomass is actually ~1 t ha^{-1}, which is very low for this type of pasture and also reveals a very low potential for productive grazing systems.

U. europaeus biomass was higher in rotational than in continuous grazing systems in the first grazing period due to the free access of animals in continuous grazing to the whole plot. However, total biomass was reduced in both treatments, particularly since the second and third grazing periods. Biomass reduction as a result of grazing by lignivorous animals has been recorded in many experiments and is considered an important tool for reducing fire risk in the Atlantic and Mediterranean biogeographic regions of Europe (Etienne et al., 1996; Scarascia-Mugnozza et al., 2000; Moreira et al., 2001; Pardini et al., 2007; Rigueiro-Rodríguez et al., 2009). This is especially important in this experiment because gorse dry matter content above 60 % could cause a burn that would leave the area clear (Richardson and Hill, 1998) and therefore could be associated with high fire risk as in most of the periods of this study. Rotational grazing is not superior to continuous grazing for plant or animal production across numerous rangeland ecosystems world-wide, when herbaceous pastures are considered (Briske et al., 2008). A similar response was found in our experiment with a shrubby understory. Nevertheless, continuous grazing system is more advisable for forest farmers due to the lower cost of the establishment and the easier management than the rotational grazing system.

As a result of grazing and the consequent *U. europaeus* biomass reduction, the production of sprouts and stems was lowered in the two treatments studied after the initial grazing. However, this reduction occurred earlier for the more palatable fraction of sprout biomass than for stems and was more important in continuous than in rotational grazing systems. Rotational grazing caused an instantaneous strong intake of *U. europaeus* sprouts as animals can only graze in 1.5 ha every month and they are not allowed to choose the more palatable parts of the plants (Briske et al., 2008) in the rest periods. Moreover, the rotational grazing system drastically reduced the proportion of photosynthetic tissue of *U. europaeus*, coinciding with other author´s findings (Hodgkinson and Bass Becking, 1978; Holechek et al., 2001), which is not able to recover despite the rest periods in the rotational grazing system. Furthermore, when the leaf and woody part fractions were taken into account, the rotational grazing system showed a higher proportion of leaves than continuous grazing system, due to the higher proportion of fractions with a diameter greater than 0.5, where most leaves are concentrated. However, the initial higher proportion of leaves did not allow *U. europaeus* recovery in the rotational grazing system in the subsequent grazing periods. When *U. europaeus* grazing is not so intense (animals are allowed to graze and therefore to choose their food in the whole plot of 6 ha), as occurs in continuous grazing plots, *U. europaeus* plants are able to respond by increasing the proportion of sprouts to reach equilibrium between the fractions of stems and sprouts (Hodgkinson and Bass Becking, 1978). Moreover, low damage caused to *U. europaeus* plants under the continuous treatment during the grazing period would explain the faster *U. europaeus* recovery, once grazing ceased in the continuous grazing system compared with the rotational treatment.

All plant biodiversity indexes were generally low. Species richness was low when compared with permanent or sown grasslands (Calvo et al., 2002) in Galicia (NW Spain), but similar to that found in *P. radiata* forests once tree canopy cover is high enough to limit light inputs into the understory (Mosquera-Losada et al., 2009). Moreover, a good diversity level is characterized by a Shannon-Wiener index between 3 and 4 (Magurran, 2004). In our study, this index did not exceed 0.75, which is also much lower than those described in Galicia sown (2.80) and permanent grasslands (2.94) as shown Calvo et al. (2002). The low value of the Shannon-Wiener index is explained by the low number of species involved and the high dominance of *U. europaeus* shown in the abundance diagrams, probably due to the reduced light inputs to the understory.

The grazing strategies affected *U. europaeus* understory biodiversity differently. Approximately 87 % of species were registered in the rotational grazing system compared with 31 % in the continuous grazing system, being the proportion of shared species (Jaccard and Magurran indexes) between treatments also low.

Due to the reduced instantaneous grazing in the continuous system compared with the rotational treatment, the dominance of *U. europaeus* persisted until the third rotation under the continuous grazing system (Figure 3). This can be explained by the free access of animals to the whole plot, which increases their capacity for selection and, therefore, their ability to choose high quality sprouts, causing less damage to the *U. europaeus* plants. Under the continuous grazing system, the vegetation developed is mainly composed of woodv species, better adapted to shading species. These species include *U. europaeus*, *Calluna* spp., *Erica* spp., *Rubus* spp. and *Pterospartum tridentatum*, which are very well adapted to acidic and very poor acidic soils. When a selective dietary choice occurs, the animal interferes with the competitive advantage of the plant species by direct removal of the phytomass (Briske et al., 2008). If available, herbaceous species are usually palatable and preferred by the horses in this study area. These species can be more easily consumed by the animal before flowering in the continuous grazing system due to the lack of the rest period, thereby reducing dispersion.

Dumont et al. (2007) also found that herbivore presence did not affect the disappearance of species, but continuous grazing systems inhibited the regeneration of new species. On the other hand, rotational grazing produced an increase in most of the biodiversity indexes due to the greater damage to *U. europaeus* plants, as was previously described. A high stoking rate (1.33

horse ha^{-1}) for a month diminished the density of *U. europaeus*, allowing other woody and herbaceous species growth during the rest periods. Species such as *Daboecia cantabrica* and *Rubus* sp. appeared under the rotational grazing system. According to Stokes et al. (2003), this is a transitory type of vegetation that is interposed between communities of *U. europaeus*. There are also other animal activities, such as uneven distribution of liquid or solid excrement (Buttler et al., 2009), which has a direct influence on the fertility of the soil, that modify biodiversity, allowing more nitrophilous herbaceous species to develop in these areas compared with less nitrophilous woody species. Within a shrub community the herbaceous layer showed higher diversity than the shrub layer under *P. radiata* (Gómez et al., 2009).

Grazing systems can induce changes in the seasonal dynamics of the productivity and relative proportion of species (González-Hernández et al., 1998). Increased damage to *U. europaeus* caused by the rotational grazing system with a rest period allowed the establishment of herbaceous species with better qualities for animal production as well as enhanced biodiversity, as highlighted by the alpha and beta indexes calculated in this study. In addition to biomass reduction, rotational grazing systems relative to continuous grazing systems resulted in better pasture quality and biodiversity. This trend continued two years after grazing was stopped. Moreover, SR was low during most of the grazing period, but more recovery could be observed under the rotational grazing system relative to the continuous grazing system by the end of the experiment. A rotational grazing system with horses should be promoted and preferred relative to continuous grazing systems for reducing fire risk and enhancing pasture quality and biodiversity when high stocking rates are applied.

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