https://doi.org/10.22319/rmcp.v13i2.5007

Technical note

Silvopastoral arrangements with *Alnus acuminata* and their effect on productive and nutritional parameters of the forage component

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Abstract:
Silvopastoral systems (SPS) are an alternative for sustainable livestock production. For this reason, the present study was developed with the aim of evaluating productive and nutritional parameters of the forage component (FC) in different silvopastoral arrangements with *Alnus acuminata* and their comparison with open field systems. A randomized complete block design was established, for which 16 plots with characteristics of homogeneity in age and type of FC were selected. The floristic composition, functional classification of herbaceous species, biomass, dry matter and nutritional composition were evaluated. The results obtained recorded the presence of 22 species, with the family Poaceae (8 species) predominating, it was also found that silvopastoral arrangements have the highest percentage of desirable species, a situation contrary to what happened in open field systems. On the other hand, the productive and nutritional parameters showed significant differences ($P<0.05$) between the production systems, being the arrangement with trees in alleys the one that registered better yields of biomass (16.60 t /ha), dry matter (3.65 t/ha), crude fiber (27.23 %), total protein (17.39 %) and gross energy (4,864 kcal/kg).

Key words: Floristic composition, Nutritional composition, Species desirability, Forage yield, Silvopastoral system.

Received: 02/08/2018

Accepted:30/08/2021

In Peru, the rate of deforestation increased by 2,672,554 ha(1,2) during the years 1975 to 2000, with the increase in the agricultural sector (extensive production)(3) being the main cause of this discouraging panorama, followed by mining activity, fires and illegal logging of forests(2,4); this situation is further aggravated by limited land use and tenure policies, as well as by a lack of knowledge of new sustainable production systems(5).

In 2012, the Peruvian agricultural area amounted to 38,742,000 ha, of which 46.5 % represent natural pastures(6), characterized by being an open field productive system, that is, without the presence of tree cover. The lack of trees and tree cover in general cause several ecological problems, such as extreme weather events, soil erosion, water pollution, decrease in biodiversity(7), and consequently economic problems(8), due to low productivity because of the limited soil fertility(9).

However, the negative impacts associated with extensive livestock production can be reduced if livestock farming is focused on systems that increase productivity, improve sustainability and provide ecological services to the ecosystem(8,10). In this sense, studies demonstrate the importance of pastures associated with trees for the conservation of biodiversity(11,12). Thus, silvopastoral systems are an option for the exploitation of ruminants, since they diversify the products (milk, meat, wood, poles and firewood), provide shade, improve the diet of animals and reduce the use of external inputs(13,14). Therefore, the objective of this study was to evaluate the floristic composition and functional classification of herbaceous species, as well as the productive and nutritional parameters of the forage component established under silvopastoral arrangements.

The study was conducted in the district of Molinopampa, specifically in the localities of Molinopampa, Santa Cruz del Tingo, Pumahermana and Ocol; located at an altitude above 2,421 masl, between the coordinates 06°12’20” south latitude and 77°40’06” west longitude. They have a slightly humid and warm temperate climate, with an average annual temperature of 14.5 °C and an average annual rainfall of 1,200 mm(15).

Four silvopastoral arrangements (SPAs) [living fences (LFs), trees scattered in the paddock (TSP), trees in alleys (TIAs) and open field system (OFS)] were studied, which were selected due to the homogeneity in the forage component, age of the trees and area between 1 to 2 ha. In each SPA, the floristic composition was evaluated through the transect method[16], which consisted of stretching a 50-m rope with marks between (01) meters (contact point) for sampling with a census ring (four transects per each SPA). The functional classification was determined according to the degree of preference of herbaceous species [desirable species (DS), less desirable species (LDS) and undesirable species (US)][17,18]. The biomass of the forage component (BFC) was determined by the square meter method[19], for which 40 samples per each SPA (10 per each locality or repetition) were weighed. For the dry matter (DM) content, the 40 samples obtained from the biomass evaluation were mixed, then 100 g of forage from each SPA was weighed and placed at 65 °C in a BINDER FD 115 forced-air circulation oven (BINDER GmbH, Germany). The nutritional composition of FC: total protein (TP), ethereal extract (EE), crude fiber (CF), ash (A) and crude energy (GE), was quantified in 1 kg of forage (obtained from the mixture of the 40 samples collected per each SPA) using the guidelines established by the AOAC[20]. It should be noted that the analysis was conducted over a period of 12 months, considering two periods for sample collection: rainy season (November 2016 to April 2017) and dry season (May to October 2017).

For the statistical analysis, a randomized complete block design consisting of four treatments (OFS, LFs, TSP and TIAs) was used, in four localities (Molinopampa, Santa Cruz del Tingo, Pumahermana and Ocol) or replicates considered as blocks. The results were processed using the statistical software SPSS 15.0, in which they were subjected to the analysis of normality and homogeneity of variances with the Shapiro-Wilk and Levene tests. Nutritional composition data were processed using an analysis of variance with a confidence level of 95 % (P<0.05) and the Tukey test for multiple comparisons. The BFC was analyzed with the Mann-Whitney U test[21].

The results of the joint study of the productive systems (OFS, TIAs, TSP and LFs) recorded the presence of 22 species, grouped into 11 families. The greatest richness was found in the family Poaceae (8 species), with *Lolium multiflorum* being the most representative species, with a presence between 15 and 32 % within each production system. On the other hand, species such as *Equisetum giganteum*, *Ageratina azangaroensis* and *Verbena litoralis* were the least abundant, being found only in the OFSs (Table 1).

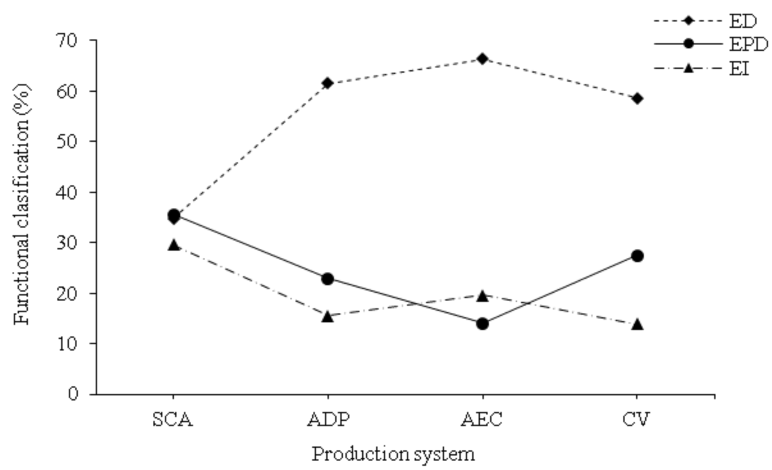
Table 1: Herbaceous species recorded in different grass production systems (%)

Floristic composition	OFS	TSP	TIAs	LFs
Poaceae				
Brachiaria brizantha	9.09	2.29	2.30	6.17
Lolium multiflorum	15.78	19.08	31.12	21.08
Paspalum penicillatum	1.87	-	-	-
Dactylis glomerata	3.74	6.36	7.65	6.17
Sporobolus indicus	3.74	-	-	-
Pennisetum clandestinum	0.80	16.03	11.48	16.45
Paspalum bonplandianum	-	8.14	1.28	8.23
Setaria sphacelata	-	3.05	1.28	4.88
Asteraceae				
Taraxacum officinale	6.95	1.02	0.51	-
Ageratina azangaroensis	0.80	-	-	-
Philoglossa mimuloides	8.82	6.62	4.59	7.20
Fabaceae				
Trifolium repens	7.49	12.72	11.73	8.48
Trifolium pratense	-	3.31	2.55	1.54
Cyperaceae				
Cyperus sp.	4.01	2.80	2.81	2.06
Eleocharis geniculata	7.22	2.29	2.30	2.06
Polygonaceae				
Rumex obtusifolius	12.03	5.85	5.87	5.91
Plantagnaceae				
Plantago lanceolata	4.01	2.29	7.40	3.60
Equisetaceae				
Equisetum giganteum	4.01	-	-	-
Primulaceae				
Anagallis arvensis	0.80	3.56	3.57	0.51
Araliaceae				
Hydrocotyle vulgaris	3.48	2.04	2.04	0.51
Verbenaceae				
Verbena litoralis	0.80	-	-	-
Thelypteridaceae				
Thelypteris sp.	4.55	2.54	1.53	5.14

OFS= open field system; TSP= trees scattered in paddock; TIAs= trees in alleys; LFs = living fences.

The functional classification indicates that SPAs report a higher abundance of DS (*Trifolium repens*, *Taraxacum officinale*, *Lolium multiflorum*, *Dactylis glomerata*, *Pennisetum clandestinum*, *Setaria sphacelata* and *Trifolium pratense*), with a percentage that ranges from 58.0 % to 67.0 %; on the other hand, the highest percentage of LDS (*Brachiaria brizantha*, *Rumex obtusifolius*, *Paspalum penicillatum*, *Sporobolus indicus*, *Philoglossa mimuloides* and *Paspalum bonplandianum*), as well as that of US (*Cyperus* sp., *Plantago lanceolata*, *Equisetum giganteum*, *Anagallis arvensis*, *Hydrocotyle vulgaris*, *Ageratina azangaroensis*, *Verbena litoralis*, *Eleocharis geniculata*, and *Thelypteris* sp.) were reported in OFSs with 33.0 % and 28.0 %, respectively (Figure 1). Among the 22 species recorded, the most prominent within the DS group belong to the family Poaceae, with *L. multiflorum* and *P. clandestinum* being the most representative of the group.

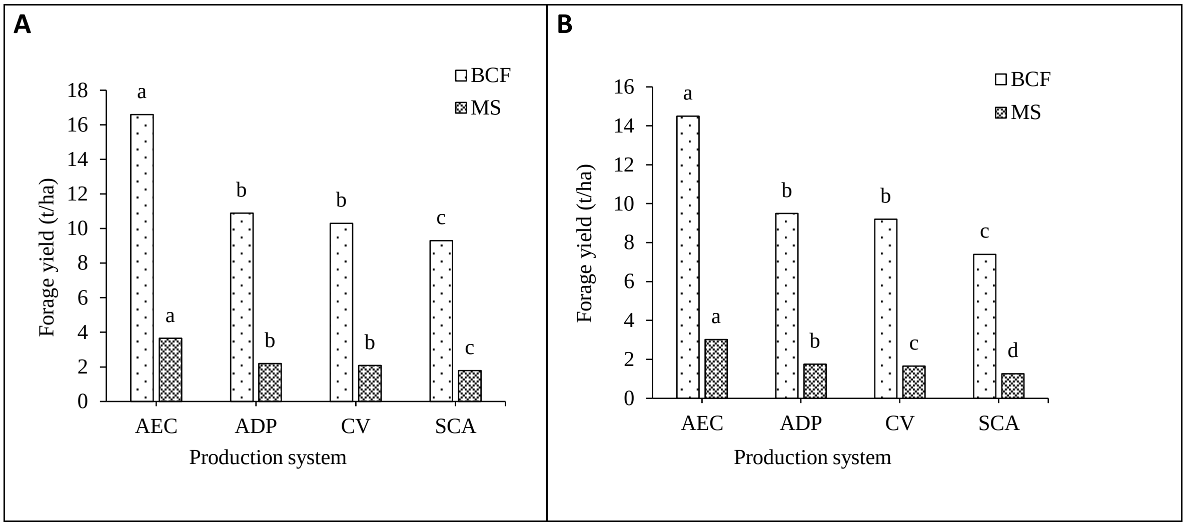
Figure 1: Functional classification of species



ED= desirable species (DS); EDP= less desirable species (LDS); EI= undesirable species (US); SCA= open field system (OFS); ADP= trees scattered in paddock (TSP); AEC= trees in alleys (TIAs); CV = living fences (LFs).

Regarding BFC production, evaluations during the rainy and dry seasons showed significant differences ($P<0.05$) between SPAs and OFS. In this sense, the SPA that reached the highest yield during the rainy and dry seasons was TIAs, and the OFS was the one that registered the lowest level of this parameter. Regarding the analysis of DM, the productive systems (SPA and OFS) showed significant differences ($P<0.05$) both in the rainy and dry season, evidencing that the SPA with TIAs registered better levels in both evaluation periods (Figure 2).

Figure 2: Yield of the forage component

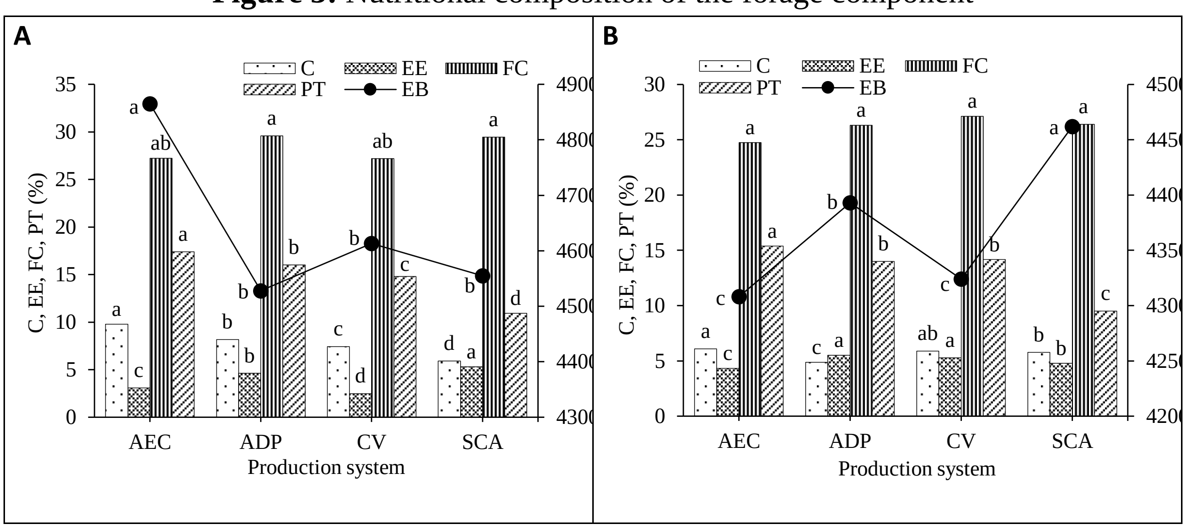


A) Evaluation in rainy season. B) Evaluation in dry season.

BCF= biomass of the forage component (BFC); MS= dry matter (DM); AEC= trees in alleys (TIAs); ADP= trees scattered in paddock (TSP); CV= living fences (LFs); SCA= open field system (OFS).

The nutritional components (A, EE, CF, TP and GE) recorded in the rainy and dry seasons were significantly different (*P*<0.05) between the production systems (SPA and OFS), except for the CF content recorded during the dry season since it showed no statistical difference. The results of both seasons show that the content of A and TP was higher in the arrangement with TIAs, and that the levels of CF ranged from 24 to 30 %. The highest level of GE during the rainy season was recorded in the system with TIAs, on the contrary, during the dry season, the highest value was reached in the OFS (Figure 3).

Figure 3: Nutritional composition of the forage component



A) Evaluation in rainy season. B) Evaluation in dry season.

C= ash (A), EE= ethereal extract, FC= crude fiber (CF), PT= total protein (TP), EB= gross energy (GE); AEC= trees in alleys (TIAs); ADP= trees scattered in paddock (TSP); CV= living fences (LFs); SCA= open field system (OFS).

The species with the greatest dominance in the FC of the productive systems belong to the following families: Poaceae, Fabaceae and Asteraceae; among them, the latter is more present in the OFSs and may be related to the modification of seeds typical of this family, thus allowing their easy dissemination favored by the free circulation of air flow. The results are similar to those reported in the basin of the Ilo River (Moquegua), where it was found that the greatest species richness belongs to Asteraceae and Poaceae(16), which indicates the wide distribution of these families in Peru.

The SPAs had the highest abundance of DS, but an opposite case occurs in the OFSs, where low soil fertility and the high presence of weeds are limiting to pasture development(7). In general, the results of the present study agree with the report for grasslands of the high Andean areas of Cusco (Peru), where the percentage of DS was higher (approximately 70.0 %) compared to species of another functional classification(22). On the contrary, they differ from the reports for grasslands of the high Andean areas of Pasco (Peru), where the presence of LDS (34.0 %) and US (54.7 %) exceeded that of DS (11.3 %)(17).

The yields recorded in the different production systems (in rainy and dry seasons) allow demonstrating the positive impact of SPAs on grass production, as confirmed by the results of a study, in which an SPA reached a yield of 12.78 t GF/ha, while the OFS only reached 6.79 t GF/ha(23). The presence of trees can increase the productivity of FC because it influences soil fertility by increasing the content of organic matter, as a result of the decomposition of the tree, shrub and herbaceous strata(24,25). In addition, trees take advantage of nutrients from the deepest layers, and these in turn can be used in grasslands due to recycling effects(26,27). The influence of trees can be even more pronounced when using species that can increase the availability of nitrogen in the soil, such as *A. acuminata*. Regarding the content of DM, the highest yields of this study were obtained in the SPAs, however they are below what was reported for an SPA of *A. acuminata* associated with *P. clandestinum*, where the percentage of DM reached was 29.5 % for the SPA and 28 % for the OFS(28), demonstrating that the yield is also influenced by the forage species that makes up the silvopastoral system.

The EE levels recorded in this study (between 2.48 % and 5.52 %) were higher than the report made in an SPA of *Leucaena leucocephala* with *Cynodon nlemfuensis* (1.28 %) and an OFS of *C. nlemfuensis* (1.13 %)(29). On the other hand, an SPA of *L. leucocephala* with improved pastures and an OFS with grasses reported 2.74 % and 1.72 % of EE, respectively(30). The variation in the results of these studies suggests that the energy values represented by the EE are influenced by the cultivated forage species, but not by the production system.

In this study, the ash level recorded in the arrangement with TIAs (during the rainy season) exceeded the reports for an SPA of *L. leucocephala* with *C. nlemfuensis* (9.35 %) and an OFS of *C. nlemfuensis* (9.02 %)(29). The ash content is related to the availability of minerals that fulfill an electrolytic function, which are involved in osmotic pressure, balance and permeability of membranes and tissues, as well as catalytic functions[(31)], so it is important that grasses show an adequate level for the diet of cattle.

Compared to the OFS, the level of CF recorded in the SPAs was slightly lower. A similar behavior was reported for the stem and leaf fractions of *C. nlemfuensis* grown under OFS and in association with *L. leucocephala*[(29)]. These results may be related to the shade effect produced by treetops, which can reduce evaporation and improve nutrient dynamics[(32)]. In addition, silvopastoral systems provide better quality and easy-to-digest fiber, reducing methane emissions by 30 % to 40 % compared to the OFS[(33)].

On the other hand, the high levels of TP reported for SPAs suggest that *A. acuminata* trees perform symbiosis with nitrogen-fixing microorganisms, allowing improving the protein and nutritional content of FC[(34)]. These results are similar to the report for an SPA of *P. clandestinum* with *Sambucus nigra* (16.6 %), since it was higher than the record of OFS (13.9 %)[(28)]. On the other hand, another study did not show a marked difference between the systems, reporting 15.61 % crude protein in the SPAs (*A. acuminata* with *P. clandestinum*) and 15.51 % in the OFS[(35)].

The level of GE reported in the rainy season shows that the SPAs (except in TSP) reached values higher than that of OFS (4,555 kcal/kg). Results with a similar trend were described in an SPA with *Buddleja incana*, *Buddleja coriaceae* and *Polylepis racemosa*, where grasses reached GE of 4,182.78, 4,179.11 and 4,182 kcal/kg, respectively, being higher than the value reported in the OFS (3,838.56 kcal/kg)[(36)]. Finally, it is worth mentioning that, in the dry season, the level of GE in the OFS (4,462 kcal/kg) was higher than the GE in the SPA.

In conclusion, the open field system had the largest number of botanical families, but most desirable species for grazing animals were found in silvopastoral arrangements with trees in alleys. The families with the greatest importance for the forage component of the productive systems were: Poaceae, Fabaceae and Asteraceae. Levels of productivity, dry matter and nutritional composition (total protein and gross energy) were higher in all silvopastoral arrangements, especially in the area of trees in alleys, this being important for dairy cattle production.

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