Pasture biodiversity after five years of establishment of a walnut silvopastoral system fertilized with different types of sewage sludge

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Abstract
Silvopasture is the combination of woody vegetation with forage and animal production on the same land that allows the diversification of agricultural income and productivity. In the silvopastoral systems, the fertilisation with sewage sludge could increase tree growth and pasture production at the same time that the pasture biodiversity is modified. The objective of this study was to evaluate pasture biodiversity of a walnut silvopastoral system grazed by sheep and fertilized with three types of sewage sludge (anaerobic, composted and pelletized) and with mineral fertilisation after five years of establishment. At the beginning of the experiment all plots were sown with *Dactylis glomerata* L., *Lolium perenne* L. and *Trifolium repens* L. Nevertheless, their presence diminished over the years probably due to the shade generated by the trees, the competence with native and less demanding species and cattle trampling. Moreover, the nitrogenous fertilisation benefited the native species such as *Agrostis capillaris* L., *Bromus hordeaceus* L. and *Holcus lanatus* L., which are less productive and of lower quality but more frugal and nitrophile shade-tolerant species with a higher soil seed bank compared with the sown species.
Keywords: agroforestry, waste, grazing, sowing, water treatment plant

1. Introduction

The European Union promotes the application of sewage sludge in agriculture since it can have valuable agronomic properties and constitutes a source of nutrient elements, especially N and P, and organic matter (Whitehead, 2000). In the silvopastoral systems, fertilisation with sewage sludge can increase tree growth and pasture production whistl botanic composition of the pasture is modified. Moreover, in the silvopastoral systems the botanical composition of the pasture varies through time due to the shade generated by the trees and the competence relationships between sown species and others species that may appear, depending on edaphoclimatic and management factors (Mosquera-Losada et al., 1999). The objective of this study was to evaluate the effect of the application of different types of sewage sludge (anaerobic, composted and pelletized) on the pasture biodiversity of a walnut silvopastoral system grazed by sheep five years after the establishment in Galicia (NW Spain).

2. Materials and Methods

The study was carried out in A Mota (Boimorto, A Coruña, NW Spain) on a plot at an altitude of 380 m a.s.l. with Atlantic climate. In 2013, the plot was planted with *Juglans regia* L. (277 trees ha^{-1}) and sown with *Dactylis glomerata* L., *Lolium perenne* L. and *Trifolium repens* L. The experimental design was randomized blocks, with three replicates and five fertilisation treatments. Treatments consisted of no fertilisation (NF), mineral fertilisation (MIN) with 500 kg of 8:24:16 ha^{-1} and fertilisation with anaerobic (ANA), composted (COM) and pelletized (PEL) sewage sludge (320 kg total N ha^{-1}) before tree planting. Mineral fertiliser was also applied in February 2015 (250 kg ha^{-1}). The plots were grazed by sheep in a continuous stocking system. Pasture samples were collected in each plot within an exclusion cage of 1 m^2 in April and June 2018. These samples were taken to the laboratory to separate each species by hand, weight and calculate their proportion over the total sample. Annual abundance diagrams omitting the percentage of the senescent material (Magurran, 1988) were completed.

3. Results and Discussion

Abundance diagrams for the different treatments are shown in Figure 1. The higher number of species was found in the no fertilisation treatment (NF) compared with the other treatments probably due to the inputs of nitrogen to the soil associated to sewage sludge fertilisation (Mosquera-Losada et al., 2019). Moreover, the presence of the sown species decreased after five years of the experiment establishment. This result could be due to the increasing shade generated by the trees and the competence with the native species, which are less demanding and have a larger seed bank in the soil. The native grass species are frugal, nitrophile, shade-tolerant and acidophilus (Mosquera-Losada et al., 1999) and were probably favoured by the nitrogenous fertilisation with the different types of sewage sludge, which increased their production and decreased the presence of

leguminous. Finally, the most abundant species in all treatments during 2013 were the native grasses *Agrostis capillaris* L., *Bromus hordeaceus* L. and *Holcus lanatus* L. The presence of *Agrostis capillaris* L. over time could have been favoured by sheep grazing due of its regeneration capacity by stolons as it was previously observed by other authors in silvopastoral systems established in the same area with *Quercus rubra* L. and fertilised with anaerobic sewage sludge (Ferreiro-Domínguez et al., 2010).

4. Conclusion

The pasture biodiversity was modified by several factors such as the fertilisation with sewage sludge, the shade generate by the trees and the grazing with sheep. Moreover, the native grass species increased their proportion in the pasture over time compared with the sown species probably due to their better adaptive strategies when the soil and plot conditions change.

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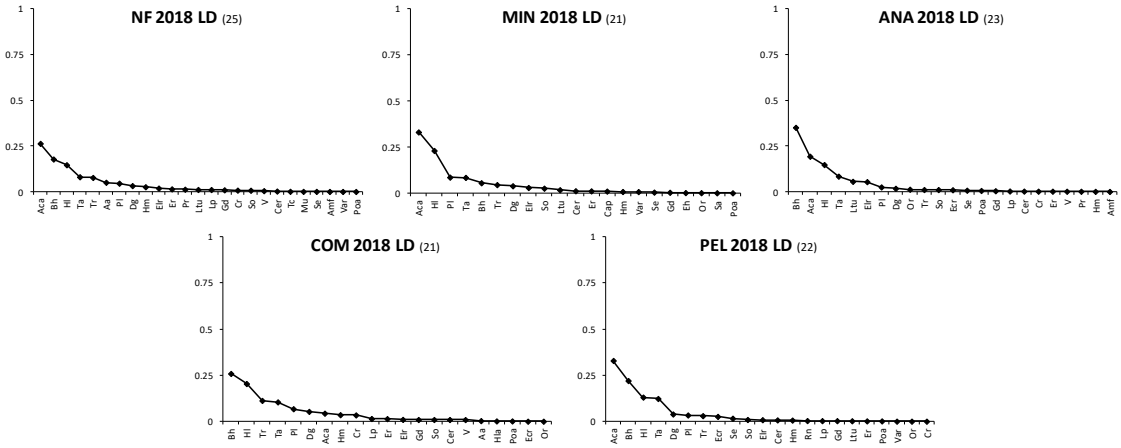

Figure 1. Abundance diagrams for the treatments applied in 2018. The number between brackets indicates the number of species found in each treatment. Aa: *Anthemis arvensis* L., Aca: *Agrostis capillaris* L., Amf: *Achillea millefolium* L., Bh: *Bromus hordeaceus* L., Cap: *Capsella bursa-pastoris* L., Cer: *Cerastium glomeratum* Thuill., Cr: *Crepis capillaris* (L.) Wallr., Dg: *Dactylis glomerata* L., Ecr: *Echium rosulatum* Lange, Eh: *Epilobium hirsutum* L., Elr: *Elymus repens* (L.) Gould, Er: *Erodium moschatum* (L.) L'Hér., Gd: *Greanium dissectum* L., Hl: *Holcus lanatus* L., Hla: *Halimium lasianthum subsp. Alyssoides* (Lam.) Greuter, Hm: *Holcus mollis* L., Lp: *Lolium perenne* L., Ltu: *Lotus corniculatus* L., Mu: Moss, Or: *Ornithopus compressus* L., Pl: *Plantago lanceolata* L., Poa: *Poa pratensis* L., Pr: *Prunella vulgaris* L., Rn: *Ranunculus repens* L., Sa: *Spergula arvensis* L., Se: *Senecio jacobea* L., So: *Sonchus oleraceus* L., Ta: *Taraxacum officinale* Weber, Tc: *Trifolium campestre* Schreber, Tr: *Trifolium repens* L., V: *Vulpia myuros* (L.) C.C.Gmel., Var: *Veronica arvensis* L.