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ANALYZING POSSIBLE EFFECTS OF SILVOPASTORAL SYSTEMS ON BIODIVERSITY AND ECOSYSTEM SERVICES IN TEMPERATE GRASSLANDS OF SOUTHERN SOUTH AMERICA

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Abstract: Silvopastoral systems (SPS), beyond their productive potential, have been promoted as a strategy for carbon sequestration and contribute to the conservation of biodiversity. The review carried out shows that when it comes to the implementation of these systems in tropical regions, especially where agricultural or livestock activity has displaced natural vegetation, the effects are positive in terms of carbon sequestration, biodiversity, hydrological dynamics and water quality. In subtropical and temperate regions, SPS may be an environment friendly option in those bioregions where natural vegetation is dominated by open woody communities and grasslands, by the association of well managed grazing livestock. In regions where the natural vegetation is grasslands, there is few information obtained in SSP, for which some information derived from forest systems was analyzed. The scant evidence shows that carbon sequestration could be a reality if soil carbon and aerial biomass are added, but it could alter water dynamics and affect the biodiversity of flora and fauna.
Keywords: Biodiversity, ecosystem services, carbon stocks, sustainability, livestock systems, fauna

INTRODUCTION

Livestock systems in the world are under the watchful eye of multiple actors due to the environmental effects attributed to them, mainly greenhouse gas emissions and the substitution of natural environments, especially deforestation. In this context, silvopastoral systems (SPS) have been proposed as a favorable integration of productive and environmental interests. The conception of the design of these systems from the productive point of view and from the perspective of society in general has evolved.

Researchers' interest in the knowledge of SPS has also evolved. They initially focused on the characterization of silvopastures and soil physical factors, whereas in the last decade, research redirected objectives toward improving the sustainability of these systems, introducing the search for strategies such as ecosystem restoration and the implementation of better practices (Torres et al, 2023).

In the other hand SPS could be relevant for the economic perspective to diversify products and reduce risks for producers. From the environmental perspective some ecosystem services could be enhanced compared with cropping systems or pure pastoral system, especially those related to climate change. In this aspect, carbon sequestration appears as the first line argument, but this also depends on soil dynamics and the destination of wood production.

In this sense, the incorporation of trees in grazing systems developed on soils that were originally occupied by forests, can mean very different things than in areas where the natural ecosystem is grasslands, which may also have different natural trees cover. It would also seem that the effect may be different if the planted species are native of the own region or exotic species. Many times, these tree species are from different continents and with greater genetic homogeneity when they are commercial varieties or clones of cultivated forestry species.

Natural grasslands represent valuable ecosystems with unique biodiversity and ecological functions. The introduction of trees into these landscapes has gained attention as a potential strategy to combat climate change and enhance some ecosystem services. However, it is crucial to understand the multifaceted environmental effects associated with tree planting in natural grasslands to make informed decisions regarding their implementation. This implies a major challenge since general recommendations are often made based on strategies developed on tropical regions that are not valid for all parts of the world. This is especially critic for biodiversity, which is site specific and therefore the functioning of ecosystems is also site specific, although they have some general principles.

This article seeks to analyze the evidence of the possible environmental effects related to biodiversity and ecosystem services of silvopastoral systems in South America temperate regions where the main native ecosystem are grasslands.

In the analysis it was decided to start with what is most linked to general interests, such as ecosystem services (ES), to then analyze aspects of biodiversity that are linked to aspects of the supply of ES, but also to strategies for the conservation of species and ecosystems.

ECOSYSTEM SERVICES

For this aspect of the analysis, two examples were selected based on the importance that traditionally is given by society and academy. First, carbon sequestration as key issue for ecosystem functioning and climate change mitigation strategy, and second, the relative to the influence in the water dynamics.

CARBON SEQUESTRATION

Tree planting is argued as a strategy to increase carbon sequestration capacity in biomass storing atmospheric carbon dioxide (CO_2) through photosynthesis, thereby mitigating climate change by reducing greenhouse gas concentrations in the atmosphere. Many times, the argument that SPS can improve the possibilities of carbon sequestration refers to the comparison of these systems with silvo-croping systems (Ferreiro-Dominguez et al, 2016) or comparing SPS with degraded pastures (Mosquera et al, 2012)

The sequestration potential varies depending on tree species, age, and site conditions. Some research has shown that natural grasslands with native trees can have a big carbon stock (Andrade et al, 2008; Aynekulu et al, 2020) and tree planting initiatives in grasslands can effectively enhance carbon sequestration rates (Haile et al, 2010; Hoosbeek, et al 2018; López-Santiago et al, 2019)

Aboveground biomass production of trees in SPS depends on the planting framework and densities. Although lower density and single-row planting frames increase biomass per individual tree, schemes with higher numbers of trees per hectare increase total tree biomass (Ares and Bauer, 2005). Woody biomass, calculated for two different wood densities in Ecuador, varied from 10.99 to 66.1 Mg per hectare, but carbon pools in the soil was superior ranging from 85.0 to 97.6 Mg per hectare, independent of stem density or pasture age (McGroddy et al, 2015). These authors found no effects on productivity of pastures, suggesting that having a high density of trees in these pastures could substantially increase the associated carbon sequestration without affecting cattle production.

In other tropical region (Tabasco, Mexico), it was shown that livestock ranches with scattered trees in grazing pastures stored 58.8% more carbon (30 cm depth) than those grass monocultures (Valenzuela et al, 2022). In dry tropical conditions of Mexico, the total carbon stocks in SPS with legume trees (*Leucaena leucocephala*) was significantly higher (120.9 ± 6.38 Mg C ha−1) than grazing monoculture of African stargrass (*Cynodon plectostachyus*) (78.2 ± 8.41 Mg C ha−1). (López-Santiago et al, 2019)

Similarly in grasslands regions of Colombia under grazing management and a diverse tree cover ranging from 10% to 30%, both tree cover and carbon stocks have increased in a fifteen-year period (Aynekulu et al, 2020). They detected an important spatial variability and argued that local conditions affect stocks and inclusive those regions with low tree cover have significant potential for increasing carbon stocks. Other research shows primary evidence of positive correlation between aboveground biomass and soil organic carbon concentrations in sylvopastoral system which have a diverse community (29 species) of trees (Aryal et al, 2019)

In Costa Rica, three indigenous tree species established in a silvopastoral system had a carbon stock in above and below ground phytomass, varying between 3.5 and 12.5 Mg C ha^{-1} in treeless pasture controls and silvopastoral systems respectively. Total soil organic carbon (SOC) averaged 110 Mg ha^{-1} (60 cm depth), with an estimated increase annual increase of 9.9 Mg ha^{-1} in SPS. (Andrade et al, 2008)

In Florida (USA) SPS, research results indicated that most of SOC in deeper soil profiles and the relatively stable <53 μm C fraction, were derived from tree components in all the sites, suggesting that the tree-based pasture system has greater potential to store more stable C in the soil compared with the treeless system (Haile et al, 2010).

In the high biodiversity SPS (SPSNUCLEUS) in Santa Catarina (Brazil) soil carbon accumulation capacity was like that of the primary forest area, and higher than those of the other areas (Zin Battisti, et al, 2018). Compared to the pasture management systems without tree patches, soil total organic carbon content in the 5-40 cm layer increased and total nitrogen content increased in the layer 5-30 cm.

In the Cerrado region of Brazil, SOC stock values (1 m depth) ranged from 260 Mg ha-1 under pasture to 167 Mg ha-1 under native forest, with 174 Mg ha-1 for Eucalyptus plantation and about 195 Mg ha-1 for SPS (Pinheiro, et al 2021). The pasture system had significantly higher SOC compared to the degraded native forest, especially in the lower soil-depth classes. Eucalyptus hybrid SPS had lower SOC stock compared to open pasture, differing from the general trend of SPS having higher stock.

Beyond this last case, most of the evidence in tropical regions seems to affirm that the incorporation of trees into monocultural grazing systems increases their potential for carbon sequestration. In most of these regions, forests or savannas were the original vegetation, and then the incorporation of trees is moving conditions to ecosystems more similar to the original, recovering it carbon capture capacity. Also is evidenced that native multispecies communities on natural grasslands would also have a positive effect on carbon stocks.

In subtropical or temperate zones, the information is less abundant, but some research have been published. In Northwestern Spain for example, Howlett et al, 2011 did comparisons between treeless pastures and SPS with pines or birch. Soils under birch at 0 to 25 cm stored more C in the 250 to 2000 μm particles size as compared with those under radiata pine. However, pasture at the same depth had more C in the smaller soil fractions (<53 and 53–250 μm), which are the most stable carbon fractions in the soil. In the 75 to 100 cm depth, there was significantly more storage of C in the 250 to 2000 μm fraction in both silvopastures as compared with the pasture. These authors conclude that the higher storage of soil C in larger fraction size in lower soil depths of silvopasture, suggests that planting of trees into traditional agricultural landscapes will promote longer-term storage of C in the soil.

In Argentina several regions have developed SPS, some on native forests and some on tree plantations. Peri et al, (2017) presented information about same different cases. For Chaco region where forest is the natural ecosystem, a mature forest of *Aspidosperma quebracho blanco* stored 67.6 Mg C ha^{-1} and this value decreased 17% when managed incorporating livestock due to the reductions in tree density and shrub cover. In the same region, in a silvopastoral system of *Prosopis alba* trees with *Chloris gayana* pasture, SOC stored (100 cm depth) was higher than in an adjacent grazing beef cattle pasture (84.7 vs. 64.6 Mg C ha^{-1}). In the south, in Patagonia, C stored in the SPS showed an intermediate

value compared with primary forest and adjacent open grasslands. Ponderosa pine plantation added carbon (65–210 Mg C ha^{-1}) to the *Festuca pallescens* grasslands ecosystem (2.6 Mg C ha^{-1}) which represents the baseline system under study.

In Uruguay, Schinato et al (2023) compared SPS with *Eucalyptus grandis* trees and an adjacent native grasslands under grazing management. Carbon storage was promoted in the SPS due to the biomass accumulation in trees, but SOC contents had differences between treatments depending on depth. From 0 to 15 cm carbon content did not present differences between the open pasture and the alley in SPS. However, at the 0-5 depth under the trees there was a reduction of carbon content. From 15 to 60 cm of soil depth, the SPS under trees position presented significantly higher carbon storage levels than open pastures or alleys.

For all the region of grasslands of Argentina, Brazil, and Uruguay Eclesia et al (2012) tree plantations increased SOC stocks in arid sites but decreased them in humid ones.

The presence of animals in silvopastoral systems plays an important role in carbon sequestration by the direct or indirect modifications of the pH, the soil bulk density, and the soil fraction proportions (Ferreiro-Domínguez et al, 2016), strongly influenced by the stocking rate. Low stoking rates promoted carbon sequestration linked to macroaggregates in the upper soil layers when compared with the high stoking rate grazing treatment and the no grazing treatment. However, in deep horizons, the NG treatment enhanced the soil organic carbon storage more than did the grazing treatments and this carbon was linked to microaggregates, increasing the soil density (Ferreiro-Domínguez et al, 2016). In Table 1, a synthesis of carbon storage in silvopastoral system is presented.

WATER DYNAMICS

From the point of view of ecosystem services, one key aspect is the water supply of the ecosystems. This essentially has two major dimensions, the availability of water in the soil for all biological processes (plant growth, degradation of organic matter, survival of soil organisms, among others) and runoff into watercourses or infiltration into aquifers to allow environmental flows.

Trees are commonly assumed to decrease groundwater resources due to their higher interception and transpiration compared to shorter vegetation (Fisher et al., 2009; Ellison et al., 2017). However, it has been demonstrated that trees possess the ability to yield beneficial outcomes by mitigating surface run-off, enhancing soil infiltrability, and promoting groundwater recharge. This effect is particularly significant in numerous tropical ecosystems known for their intense rainfall and vulnerable soil conditions (Benegas et al, 2021).

Different types of plants interact within ecosystems, sometimes with a competition for resources such as light, water and nutrients, but also can be positive (facilitation) or neutral (Gea-Izquierdo et al, 2009). The ecological role of trees in low density tree systems has been widely studied in several kinds of ecosystems, from the tropics to temperate biomes (Mosquera et al. 2005). Pasture production and the composition of functional groups are variable not only in space but also in time, both within and between years (Gea-Izquierdo et al, 2009).

The international literature posits that positive interactions are preponderant in stressful environments; however, the net balance between positive and negative interactions at the community level is still under debate (Mazía et al, 2016; Dohn et al, 2013). In savanna conditions, for example, trees and grasses used water from the topsoil after rainfall indicating overlap of water-source use (Priyadarshini et al, 2016).

Cites	Silvopastoral Systems (trees species)	Pasture	Stock biomass (Mg ha-1)		Stock in soil (Mg ha-1)	Region	Climatic conditions
			avobe-ground	below--ground			Average rainfall and medium temperature
McGroddy et al (2015)	Natural regeneration: 5 to 8 species	*Axonopus scoparius*	10.99 to 66.1		85.0 to 97.6	Tropical America	3325 mm/ year, 22°C
López--Santiago et al (2019)	Plantation: six-year-old Leucaena leucocephala	*Panicum maximum*	29.1 ± 4.45	16.4 ± 1.95	91.6 ± 4.92	Tropical America	924 mm/year, 28.3°C
Aryal et al (2018)	Natural: 21 species	*Cynodon dactylon, Cynodon plectostachium, Hiparrhenia rufa*	10.75 ±1.79 (trees) 0.78 ± 0.15 (grass)	2.53 ± 0.41 (trees) 1.47 ± 0.29 (grass)	49.71 ± 3.49	Tropical America	800-1500 /year , 20–26 °C
Aryal et al (2018)	Natural: 14 species	*Cynodon plectostachium, Brachiaria dictyoneura, Hiparrhenia rufa*	12.72 ± 5.49 (trees) 1.91 ± 0.19 (grass)	2.60 ± 0.96 (trees) 3.60 ± 0.36 (grass)	75.62 ± 5.09	Tropical America	1000–2500 mm /year. 16–26 °C
Andrade et al (2008)	Plantation: native spp. monoculture (Pithecellobium saman, Dalbergia retusa, Diphysa robinioides)	*Brachiaria brizantha, Hyparrhenia rufa*	* 1 to 7 (trees) 1 to 4 (grass)	* 1 to 1.5 (structural roots) 1 to 2 (fien roots)	110.3	Tropical America	1,500 mm / year, 28°C (23-36°C)
Pinheiro et al, (2021)	Eucalyptus hybrid (Eucalyptus grandis x E. urophylla)	*Urochloa decumbens*			* 190 to 200 (1m depth) 80 (0,3 m depth)	Tropical America	1350 mm/year
Howlet et al (2011)	Plantation: Pine (Pinus radiata)	*Dactylis glomerata, Trifolium repens and T. pratense*			* 80 (0,25 m depth) 80.9 to 135.3 (1 m depth)	Temperate Europe	1080 mm/year, 11.5°C (range, 5.8–18°C)
Howlet et al (2011)	Plantation: Birch (Betula pendula)	*Dactylis glomerata, Trifolium repens and T. pratense*			* 80 (0,25 m depth) 96.3 to 176.9 (1 m depth)	Temperate Europe	1081 mm / year ; 11.5°C (range, 5.8–18°C)
Peri et al (2017)	Natural: Apidosperma quebracho blanco forest	*Cenchrus ciliaris and native forage species*	6.34 (trees) 1.5 (grass)		17.1	Temperate America	
Peri et al (2017)	Natural: Prosopis alba	*Chloris gayana*	* 3,5 to 3,6	* 5.8 to 6.0	* 106.7 to 110.4 (1m depth)	Temperate America	
Schinato et al (2023)	Plantation: Eucaliptus grandis	*Native grasslands (polyphitic grasslands)*	17.9 (trees) 0.43 (grass)		91.68 (0.6 cm depth)	Temperate America	1300 mm, 17°C. monthly average max. 23 °C and min. 12 °C

Table 1 – Synthesis for carbon storage in soil and biomass reported by multiple authors for SPS

* smated from graphical results

Ludwig, et al (2001) conclude that whether trees increase or decrease production of the herbaceous layer depends on how positive effects (increased soil fertility) and negative effects (shade and soil water availability) interact and that these interactions may significantly change between wet and dry seasons. Gea-Izquierdo et al (2009) found that in a dry year, the increase in fertility could not be utilized and the effect of the crown was neutral. The effect of shade seems to be beneficial for growth, contrary to the situation in an average climatic year. Indeed, there are changes in the interactions between trees and grasses during different periods of the year. Piriyadarshini et al (2016) found facilitation of the trees to the grasses of their understory and show that the hydraulic redistribution of the trees to the grasses during the dry season. Water status of the intercropped grass in the dry season resulted from the balance between reduced evapotranspiration and reduced soil water availability (Dulormne et al, 2004), they consider less important the competition with the trees.

Respect to soil water availability Mordelet and Le Roux (2006) in their revision found that the prediction of the tree effect on the soil water balance, in comparison to a grassy area, presents challenges due to the intricate interplay of opposing processes. Tree transpiration intensifies water output, potentially depleting the available soil water more rapidly. Conversely, the trees' influence promotes higher macroporosity, thereby enhancing water infiltration. Furthermore, the shading effect of trees reduces evapotranspiration from the soil surface and the grass layer, limiting water losses.

Nevertheless, the results in terms of biomass production of the interactions depends on the gradient of aridity conditions and type of plants. Deciduous and leguminous trees enhance grass biomass growing beneath them. Increasing soil sand content, the presence of C4 grasses and tropical and natural systems all increased the biomass of grasses growing beneath trees (Mazía et al 2016)

Other aspect of the analysis is the possible influence of grazing in ecological aspects that affect water availability. The Dehesa ecosystems are open woodlands with scattered oak trees as their main component in central western Spain and eastern Portugal. Some SPS have been developed there, with oak trees and native grass vegetation (grazed) and some zones are not grazed and can have abundant understory shrubs (encroached). Cubera and Moreno (2007) found that encroached plots in general showed lower average available water content than grazed plots (3.7 and 6.2% in encroached and grazed, respectively). This reduction in water availability at encroached plots was particularly observed in the deeper soil layers beyond the tree trunk. This suggests that shrubs utilize a portion of water that is not easily accessible to trees. It is noteworthy that the existence of a shrub understory seems to have increased water constraints on trees, especially in the summer season. Conversely, in grazed plots, a substantial quantity of water appears to have remained untapped by both trees and grasses.

In some circumstances the intensive management (grazing or cutting) of the herbaceous vegetation is promoted by the argument that herbaceous species at early stages of tree development compete for soils resources (water and nutrients), negatively affecting tree growth (Mazzacavallo and Kulmatiski 2015). By contrast, it has been shown that the adverse effect of the herbaceous vegetation on tree growth fades in favor of trees with time. (López-Díaz, 2020)

For SPS with eucalyptus, during dry periods, soil water availability (SWA) until 1-m depth was higher at the inter-row than under the trees, which indicates a faster water uptake by the trees; however, when the inter-row was shaded, SWA was lower at the open pasture than at the inter-row. It occurred as a consequence of the shading and windbreak effects on evapotranspiration. Soil water recharge, during rainy days, was higher close to the trees, because of large water interception by trees and its subsequent deposition into the soil, increasing the amount of SWA at this position (Bosi et al, 2020).

Evapotranspiration and groundwater recharge is one of the main concerns in the case of fast-growing species such as eucalyptus. Although for SPS the information is scarce, results coming from conventional afforestation showed some clear effects. Although of course they have a different planting framework, give some notions about the behavior of planted species.

Eucalyptus plantation affected seasonal and annual hydrology of the study area by increasing evapotranspiration rates and, consequently, leading to a decrease in recharge and groundwater levels. Annual recharge estimates are lower in the eucalyptus plantation than in pastures, even with the increase in the annual rainfall amount (Mattos et al, 2019). In some regions inclusive the water used for eucalyptus is greater than rainfall input (Calder et al, 1997)

In drylands agricultural systems, establishing eucalypt stands and belts result in a deep and rapid penetration of subsoils, resulting in the de-watering of soil profiles, both vertically, to depths of 10 m, and laterally to distances of 6–20 m from belts (Robinson et al, 2006).

Other important aspects to consider are those related to runoff water quality and its effect on streams. In areas such as the Colombian Andean region, Chará and Murgueitio (2005) in their review reported that there has been a marked negative environmental effect in areas where the native forest has been replaced by pastures for cattle. Sometimes, supporting very intensive livestock systems, clearly affecting the water quality of the streams in multiplicity of parameters. The biodiversity of these systems has also been affected by reducing the number of species, with the disappearance of the most sensitive taxa, although it is also reported that the pasture basins that had protection of the riparian zone less affected aquatic macroinvertebrates.

Under these conditions, it is proposed by these authors that SPS can improve the environmental situation of that region, although the type of strategy will depend on the topography and soil types. Good results in aquatic organisms have been seen when the sources of streams and riparian zones are protected with trees and shrubs. In pasture areas, the incorporation of trees also has positive effects on water quality in streams, mainly attributed to reducing the impact of rain, protecting, and improving the soil structure that reduces erosion and increases its water retention capacity.

The reduction of runoff can promote a reduction of particles or nutrient reaching the watercourses but also to reduce caudal. Zhu et al (2020) found a 58% average reduction of surface runoff under agroforestry systems, specifically in silvopastoral systems and reported reductions of surface runoff between 45% and 88% compared to other land-uses. Hussain (2007) found 47% less surface runoff in the silvopastoral system with a high density of trees (1.2 m spacing) compared with open pasture.

But in New Zealand, contrary to previous agroforestry research, surface runoff was significantly greater in silvopastures with kānuka trees (*Kunzea robusta*) compared to open pasture per rainfall event, and the cumulative surface runoff over the year was over seven times greater in pasture associates with these trees. Sediment and nutrient (N and P) loads were 10-100 times greater in pasture with trees compared to open pasture (Mackay-Smith, et al, 2022). Authors express that the likely reason for the increased surface runoff beneath the trees was the reduced grass biomass, decreasing the amount of grass present as a physical barrier to slow surface runoff movement. They think that livestock are the most likely reason for this, preferentially grazing the pasture beneath the trees because of the more desirable pasture species.

BIODIVERSITY AND HABITAT CONSERVATION

The conversion of natural environments into managed ones contributed to major environmental problems, such as pollution, land degradation and loss of biodiversity. In this context, sustainable SPS are suggested as a key solution to the conflict between expanding agricultural production and conserving natural ecosystems (Peri et al, 2016). The promoters of silvopastoral systems argue among the environmental advantages, their contribution to the provision of habitat for biodiversity.

Recent research provide evidence that the insect fauna changes upon conversion of a Brachiaria monoculture to a silvopastoral system. Since sustainability of pastures depends upon of organisms that play important roles in maintaining ecological systems, among these insects, the implementation of silvopastures improve the sustainability in this conditions Paiva et al, (2020).

Simioni et al (2022) reported a positive influence of applied nucleation in the design of high biodiversity SPS, integrating pasture-based animal production with ecological rehabilitation and conservation of bird biodiversity on Brazilian Biomes. According to these authors SPS with tree nuclei of native trees, in pasture areas close to forest remnants, increased the connectivity of the landscape. This presented important positive effects on the diversity and composition of birds in densely anthropized agricultural landscape.

Regarding to other regions, mainly the temperate zones in which many different ecosystems convive and large extensions of native grasslands develops, the main questions are: can the benefits for biodiversity that are argued for other ecoregions be extended to temperate zones? and: are there differences depending on which ecological community was the natural one in that area or which species are planted?

SPS still using eucalyptus as a planted species, could bring opportunities for fauna grassland specialists due to the persistence of important areas of grasses land cover, but information is not clearly consistent. Information of influence of tree densities or spatial arrangements about primary production of grasses is quite available (Olivera et al, 2022; Junior et al, 2022; Schinato et al, 2023), soil properties (Lana et al, 2018; Schinato et al, 2023), animal health and welfare (Pezzopane et al, 2019; Bello et al, 2020; Huertas et al, 2021) but studies about the impact on biodiversity are not so frequent. Due to the scarcity of specific information on the effect on biodiversity of tree plantations specifically carried out for silvopastoral use, one possible approach is to see the effect of tree plantations with other objectives.

The value of plantations for biodiversity varies considerably depending on whether the original land cover is grassland, shrubland, primary forest, secondary forest, or degraded or exotic pasture, and whether native or exotic tree species are planted (Bremer and Farley, 2010). Grassy biomes, including ancient and biodiverse grasslands, savannas, and open-canopy woodlands, are currently under significant threat due to human-induced environmental changes. However, these ecosystems are often considered to be of lower conservation priority compared to forests (Parr et al, 2014, Veldman et al, 2015).

Afforestation of natural ecosystems substantially alters habitat for native flora and fauna (Van Wesenbeeck et al, 2003; Alrababah et al, 2007; Lantschner et al, 2007). The evidence of negative effects is especially clear on specialist grassland and shrubland species, due to several factors such as site preparation, shade, allelopathy, physicals barriers and management, (Andres and Ojeda, 2002; Maccherini and De Dominicis, 2003; O'Connor, 2005; Chirino et al, 2006; Buscardo et al, 2008, Prangel et al, 2023).

In a study performed in Argentina, species richness and species composition of mammal differed between native forests and other environments, but not between grasslands and plantations. The variations in composition between the environments differed among ecoregions: the species composition in the plantations was different from the grassland assemblage only in the Iberá marshes, which suggests that the impact of tree plantations depends on the local pool of species (Iezzi et al, 2020).

Natural forest area was positively associated with mammal species richness and detections of threatened mammals and overall detections of mammals decreased within, and close to, industrial Acacia plantations (Ng et al, 2021). Similar findings were obtained for birds' assemblages by (Phifer et al, 2017) in the north-east of Argentina, where clearly SPS in native ecosystem (Espinal savanna) had the highest richness and abundance of birds and

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the lowest was recorded in mature eucalyptus plantations. Both richness and abundance increase in young plantations, although still under all other land use studied.

The grazing management is also an important factor. For livestock ranches in Espinal xerophytic forest, ground birds did not respond homogeneously to grazing intensity or vegetation structure (Dardanelli et al, 2022). Wherever is possible, managing livestock farms to maintain heterogeneity in grazing intensities and vegetation structure seems to be the adequate to promote ground-foraging birds' conservation.

Cravino et al (2023) found a reduction of medium-large mammals across a Eucalyptus plantation for pulp production in relation with native ecosystems, However, in intermediate ages 2-4 years, because of the similarity in the structure of vegetation, richness of mammal species was more similar to native forest. Pulp plantations tend to achieve high canopy cover and consequently low understory vegetation and high homogeneity (Iezzi et al, 2020, Timo et al, 2015, Trentini et al, 2017,). Heterogeneous age plantations would increase landscape mammal diversity and provide more resources for generalist and forest species maintenance (Cravino et al, 2023). Nevertheless, for grassland specialist mammals, management measures considering the maintenance of grassland patches at the landscape level should be emphasized, besides managing the stand-level dynamics.

Another species commonly used in forest plantations are pines, for which there is also evidence that lower tree densities increase the diversity of the herbaceous community but, in this case, as the age of the plantation advances, the accumulation of needles on topsoil reduces the number of herbaceous species. For northeastern Argentina, was seen that thinning on pine plantations can contribute to maintaining biodiversity and related ecosystem functions of subtropical forests. Management practices involving lower plantation densities and fewer interventions should be developed to achieve more positive effects (Trentini et al, 2017).

For pine plantations, populations of small mammals also varied with the age of plantation. Herbivores continued to be most abundant in five-year-old plantations, but total catch of all forms declined when canopy closed at the age of seven years and total catch declined further, despite increased capture of woodland species. Fifteen-year-old stands supported very few animals. Ground cover increased with plantation age, and this may have caused the succession of small mammals observed. (Atkeson & Johnson, 1979).

In the steppe areas pine plantations can provide habitat for some generalist native bird species, but both dense and sparse plantations, are unsuitable for most steppe species, thus it is necessary to manage them at higher scales, maintaining the connectivity of the native matrix to prevent the fragmentation of bird populations (Lantschner et al., 2007).

In modified wetland ecosystem, Nanni et al (2022) established that silvopastoral systems negatively affect ground-dwelling arthropod communities compared to planted forest. A decrease in the intensity of management practices favors the understory growth, offering more resources for the arthropod families already established and facilitating the establishment of new ones. This increase in arthropod diversity promotes the presence of benefic species and the conservation of biodiversity.

Even compared to monocultural grazing systems, SPS did not show significant differences total abundance or species richness of insects, although there were differences between different Orders. (Paiva et al, 2020).

Results presented from tropical and sub-tropical studies show that production of cattle and other animals can be better, biodiversity much increased, animal disease reduced, and animal welfare improved in three-level silvopastoral systems (Broom, 2017).

Based in the evidence shown, the promotion of biodiversity seems to hold in some ecological conditions but not always. Some of these conditions are linked to tropical ecoregions where the original vegetation had an important tree component and human activity has replaced them with crops or pastures. Is more probable when plantations are implemented on degraded lands as opposed to the substitution of natural ecosystems such as forests, grasslands, and shrublands. Additionally, the utilization of indigenous tree species, rather than exotic species, enhances the potential contribution to biodiversity.

FINAL CONSIDERATIONS

From the analysis of the information revised, it emerges that from the environmental point of view, silvopastoral systems can represent different things depending on the region of the world where they are developed. In tropical areas of the world, especially the humid ones, where livestock and agricultural systems have replaced the natural forest vegetation, the effect tends to be positive. In this sense, incorporating trees into productive systems tends to transform the landscape, bringing them characteristics closer to the physiognomy of the original ecosystem, being especially clear in wooded savannahs. This effect would act to improve biodiversity and ecosystem functions by evolving towards conditions more like those in which native organisms evolved.

In subtropical or temperate regions of Latin America where the natural vegetation is made up of communities where more or less dense woody vegetation and herbaceous communities coexist (eg. Chaco, Espinal or Cerrado), SPS appear to be the friendliest form of productive use of these ecosystems. These systems can be productive while conserving a great biodiversity and ecosystem functions, always keeping in mind that they are very sensitive to the livestock grazing intensity. In these areas, if trees are incorporated into degraded areas, the effects appear to be positive.

In temperate zones originally occupied by grasslands, SPS development could have different effects depending on each environmental aspect. Ecology researchers agree that tree planting is one of the threats to the conservation of natural grasslands. Although the positive effect on increasing carbon stocks seems to be maintained, at least if both SOC and aboveground biomass are considered together, this would not be the case for biodiversity and water dynamics.

The biggest questions arise from the use of trees of exotic species such as eucalyptus or pines, which are the most used. There is very little information on biodiversity and water dynamics in silvopastoral systems with these species, but the data obtained in conventional forestry indicate that caution principles must be maintained. The generation of research related to biodiversity and ecosystem services specifically in SPS is essential.

The same precautionary principle indicates that to avoid large problems that negatively interfere with the ecology of grasslands or rangelands, small-scale initiatives with low tree density could be safer.

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