

Review

Integration of tree crops and pastures: Literature review

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Sustainable rural development, integration, and interaction of the livestock, agricultural and forestry components can contribute to reducing the impacts of the productive sector in the environment. In forest environments, plant biomass (mainly of trees) is the main reservoir of mineral nutrients. The forest presence contributes to the elevation of mineral nutrient concentrations in the soil, through leaf deposition. Due to increasing awareness of the importance of environmental preservation and the creation of laws to discipline human action in forests, this paper discusses the integration of tree crops and pastures. In this sense, we discuss the introduction of this model for regional and national cattle production, to expose the weaknesses and the beneficial aspects of the system.

Key words: Cattle production, agroecological system, sustainable development.

INTRODUCTION

In general, human populations value quality food, drinking water, environmental comfort, and leisure, among other aspects. But, they also prioritize the best cost-benefit opportunities in the consumption relationships with the productive sector. In response to these assumptions, the rural environment needs to produce to meet the needs of the population for food and other products at competitive costs, but it needs to be done sustainably in time and space, since it is necessary to ensure the maintenance of productive capacity of the future generations (Haile et al., 2008).

In the perspective of sustainable rural development, the integration and interaction of the livestock, agricultural and forestry components can represent a solution for the reduction of the impacts of the productive sector to the environment. This would be possible from the

development of a new posture of the agricultural sector, in order to reduce the pressure on natural resources, including forest remnants, allowing the maximum possible biodiversity, the conservationist use of soil and water (Paciullo et al., 2015).

Thus, to maintain productivity, any system must include as many species as possible in the same crop or in succession, maintain high levels of biomass and be as efficient as possible in the use of natural resources. Forest removal represents a drastic reduction in biomass, affecting nutritional balance, energy flow, and consequently the ecosystem sustainability (Garcia et al., 2015).

Agricultural activity, with emphasis on monoculture, has been a factor which accelerates the ecosystems degradation, a serious problem in many countries of the

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world, not only for the opening of natural areas of forests for pasture formation, but also for the management, fire and super-grazing, which contribute to the process of loss of soil structure and gullies (Paciullo et al., 2008). The objective of this article is to discuss the integration of tree crops and pastures.

Research questions

The reviewer developed the following research questions: (1) What are the trends of pasture integration? (2) What are the implications of integrating pasture in the current scenario?

LITERATURE REVIEW

Background and system description

Studies indicate that at least half of the pasture areas in ecologically important regions, such as Amazonia and Central Brazil, would be degraded or degraded (Dias-Filho and Ferreira, 2007). This process is associated with the degradation of soils, water courses and aquatic environments, the loss of biodiversity and the emission of polluting gases (Chará and Murgueitio, 2005). Thus, the recovery of productivity and the conservation of productive areas become a priority due to environmental restrictions that make it unfeasible to incorporate unaltered areas to form new pastures (Dias-Filho and Ferreira, 2007).

In an attempt to reverse the ecosystems environmental degradation, technologies that promote sustainable development with minimum social, economic and environmental costs are sought (Vanzela et al., 2013; Porfírio da Silva, 2015).

The name Agroforestry Systems (SAFs) is given to production systems and technologies that consortiate trees in the production of grains, vegetables and dairy or cutting animals. In these, species are introduced in spatial and temporal arrangements, with the aim of promoting interactions among the components of the system (Coelho, 2012).

This type of production arrangement is also called Plow-Livestock-Forest Integration (ILPF). ILPF is a sustainable production strategy that integrates agricultural, livestock and forestry activities. It consists of the implantation of different productive systems in the same area, in consortium, rotation or succession, through the planting of trees, grains and pastures (Lucas et al., 2015).

This form of land use has two main objectives: productivity, related to the diversification of production and the multiple outputs of the system aiming at income generation, and sustainability, which implies conservation or even improvement of the environmental aspects of the system.

The Silvopastoral System (SSP) is a type of concomitant APS, in which trees live permanently with other small plant species with shorter cycle times and with domestic animals (Coelho, 2012). In these production systems, the intentional combination of trees, pasture and animal component simultaneously occurs in the same area unit and managed in an integrated way, aiming at increasing productivity. This system is also a form of Forest Livestock Integration (ILPF), and has been viewed as an important sustainable land use strategy, especially in areas potentially subject to degradation (Ribaski et al., 2012).

CROP-LIVESTOCK INTEGRATION BENEFITS

The integration of trees into pastures results in several benefits to the components of the ecosystem: climate, soil, microorganisms, forage plants and animals. In traditional systems, an important problem is the burning of pastures (native or cultivated) caused by frost. In an SSP in which pastures are protected between rows of trees, the probability of losses with frost is lower, thus allowing a place with pasture reserve at the critical moments of the year (Lucas et al., 2015).

In the SSP, the trees acquire a complementary or supplementary character of the livestock activity, serving as shade for the herd, helping in the replacement of nutrients of the soil and, as a consequence, improvement of the pasture conditions, being able to serve as forage (Coelho, 2012).

In addition, the use of wood or other products extracted from the forest does not generate income, integrating and increasing the rural property income without the producer having to abandon his traditional vocation for livestock (Ribaski et al., 2012). The introduction of pioneer tree species of multiple use contributes greatly to the success of the system. Among others, they are multiple use species: grandiúva (*Trema micranta* (L.) Blüme Cannabaceae, used in recovery of degraded areas, firewood, cellulose and fodder), bracatinga (*Mimosa scabrella* Benth, Fabaceae, used in intercropping with yerba mate, lining, flooring and furniture, and for firewood), cambia (*Sesbania virgate* (Cav.) Pers., Fabaceae, used for firewood and honey production, roasted fruits can substitute coffee), ingá-beans (*Inga marginata* Benth, Fabaceae, used for firewood, honey production, N-fixing and fruits are edible), aroeira-periquita (*Schinus molle* L., Anacardiaceae, wood is used for fence posts and external works, produces industrial oils of high commercial value and the fruits are used for the insecticides production) (Coelho, 2012).

The integration of trees with pastures in the same area can occur through the conservation/maintenance of previously existing trees, by planting trees, or by driving those that emerge naturally in the middle of the pasture. This system allows to intensify the production and, with the integrated management of the natural resources, it

avoids its degradation (Porfírio da Silva, 2007; Vanzela et al., 2013).

In this context, agroforestry systems, and in particular SSP, are recommended as a viable option for the recovery of degraded areas, reconciling animal and vegetable production with environmental conservation (Coutinho et al., 2007b; Andrade et al., 2008). Thus, the introduction of the forest component in production systems must take place in an approach that no longer allows for the separation of agriculture, livestock and forest, but rather a real integration of these components in the rural environment, with benefits to the quality of life, sustainability and stability of production (Porfírio da Silva, 2015).

The introduction of trees in pastures, besides other benefits to the environment, provides shade to the animals, avoiding that temperature oscillations decrease the production, because the thermal stress changes their behavior, preventing the animals' grazing in the hot hours of the day. In addition to the radiation, several other climatic factors are influenced by the presence of trees, with reflections on the local microclimate and consequent impacts on the performance of agricultural crops and animal creations. In general, the presence of the forest component provides less variation in temperature and relative humidity, making the environment less vulnerable to climatic extremes (Ribaski et al., 2012).

In SSP, the presence of trees can conserve and / or improve soil quality, favoring erosion control, nutrient cycling and addition of organic matter and capturing nutrients and soil moisture at different depths, thus reducing dependence of external inputs of nutrients or establishing a more positive benefit/cost ratio (Coelho, 2012). Pezarico (2009), concluded that the systems whose organic matter input is higher and uses and management of these environments do not revolve the soil, providing higher soil quality. However, it stresses that the stability is influenced by the adaptation time of the system, so that it promotes the increase of organic matter in quantity and quality, favoring the development of the soil microbial community.

ECO-EFFICIENT APPROACHES TO LAND MANAGEMENT

Planting can be done by planting seeds, or cuttings, depending on the mode of reproduction and growth of the species and the method of forming the system (Vanzela et al., 2013). In this regard, animal's introduction should be careful, especially before the trees reach three years of age or 4 m in height, or when the trees acquire sufficient height so as not to be damaged by the presence of livestock. The entry of animals for grazing in areas without electric fence should be performed only when the trees reach twice the animals height, either cattle or sheep (Lucas, 2015).

In the case of areas with more pronounced relief, the

trees should be planted in a level, cutting the terrain slope. In flat areas, you must do the planting in the east-west direction, allowing ample passage of light, which will facilitate the development of grass between the lines (Vanzela et al., 2013). The criteria used in the choice of spacing refer to the ideal spaces for the trees development, because for the pasture development that will be affected by the shading, thinning or thinning of the trees will be carried out in favor of the luminosity required by the forages (Lucas et al., 2015).

Double-line planting consists of an arrangement with two rows of trees planted in close proximity, rather than just one (Vanzela et al., 2013). The planting method in forests consists of planting small clusters of trees distributed in the pasture. This planting method has two drawbacks.

The first concerns the pasture growth, which is reduced within the forests due to excessive shade. The other concerns nutrient recycling, which is impaired along the pastures, as the animals tend to concentrate more deposition of feces and urine into the woods by spending more time in shaded areas during the day. Over time, there may be a decrease in soil fertility in pasture areas among forests (Vanzela et al., 2013).

This model, however, presents greater potential for timber, due to the greater density of tree plants that make it possible in their arrangement. The consolidation of this potential can take place with the use of adequate spacing and management, in order to guarantee the timber production, the animal's thermal comfort and the pastures development (Nepomuceno and Silva, 2009).

Scattered Planting in Pasture is a form of implantation in which trees can be planted in a random distribution in the pasture, without defined spacing, or may result from the conduction of natural regeneration of trees that arise spontaneously in the pasture. This method is the one that presents the lowest implantation cost among SSP, since it does not require expenses with seedlings or opening of pits and manpower for planting (Porfírio da Silva, 2007). The objectives of this planting arrangement are: soil protection, shading for livestock and improvement of the nutrient cycling provided by the trees, besides obtaining products derived from the trees (wood, oils, resins, etc.) (Vanzela et al., 2013).

Another benefit of this system is that animals receive benefits in the forest habitat. In temperate countries, protection against the cold is an important factor in conserving their energy. In addition, the soil protection by the trees prolongs the period of the pastures palatability in the beginning of the winter, or of the summer in dry climates, besides maintaining in the system the natural biotic and abiotic components and their interrelationships.

FOREST FARMING

For a good result, silvicultural practices must be

appropriate and associated with the genetic material of quality to reduce possible negative effects resulting from the SSP (Porfírio da Silva, 2007). Oliveira Neto et al. (2007) commented that the pruning is one of the practices that should be used whenever necessary in the SSP, to reduce the occurrence of nodes in the wood, improving its quality for use in sawmill, and also to favor the availability of light necessary for the good productive performance of pastures occupying the lower stratum.

This practice, however, must be used on the basis of technical criteria, since, depending on the intensity of removal of live branches, as well as the age at which it occurs, there may be a compromise of tree growth and final production. Araújo et al. (2007) found that cattle needs to be handled cautiously in the wet season to avoid damage to the trees root system, with a close and inverse relationship between the intensity of land use and its quality, with the most pronounced quality effects on the soil layer from 0 to 5 cm.

The crowns of the trees contribute to the reduction of the soil erosive process, to reduce the rains impact, besides serving as windbreaks. On the other hand, their root system, which is generally dense and deep, forms barriers preventing soil particles from dragging, as well as, it can absorb nutrients from the deeper layers by translocating them to the leaves. After the fall, the leaves deposition and decomposition, these become excellent sources of organic fertilization, improving the physical and chemical characteristics of the soil. In drought periods, soils have a higher moisture content under their canopy than in areas exposed directly to the sun and wind, contributing to improve the quantitative and qualitative performance of forage grasses (Vanzela et al., 2013).

From an environmental and productive perspective, one of the main advantages of SSP is to carry out the proposal of multiple use of the land by increasing the efficiency of resource use on a spatial and temporal scale, reducing risks, increasing systems stability, and to promote the social and recreational use of land, as quoted in the Silvopastoral Declaration (Mosquera-Losada et al., 2006).

Nepomuceno and Silva (2009) observed associations of eucalyptus (*Eucalyptus* species, Myrtaceae) and grevilea (*Grevillea robusta* Cunn., Proteaceae) with native species such as the canafístula (*Peltophorum dubium* (Spreng.) Taub., Fabaceae), gurucaia or angico-red (*Parapiptadenia rigida* (Benth) Brenan, Fabaceae), guabiroba (*Campomanesia guaviroba* (DC) Kiaersk., Myrtaceae), aroeira and yellow-ipê; the authors did not mention the species of aroeira or ipê-amarillo, being in question *Schinus terebintifolius* Raddi and *Myracrodium urundeuva* Fr. (aroeiras, Anacardiaceae) and *Handroanthus chrysotrichus* (Mart.) Mattos, *Hemicentrotus pulcherrimus* (Sanduith.) SOGrose and *Polyporus umbellatus* (Sond.) Mattos (yellow-ipês, Bignoniaceae).

Most SSPs carried out in Brazil are composed

of Eucalyptus species L' Hér., and a good part of the recent studies are concentrated in the Southeast region of the country, where species of this genus have been cultivated mainly for the production of firewood in cycles of short rotation (Paciullo et al., 2007b; Nepomuceno and Silva, 2009). The preference for eucalyptus is associated with the possibility of obtaining several products, their high growth rate and ease of regrowth, and variations in crown density, which facilitates the availability of incident solar radiation in the understory, making it feasible to establish of the herbaceous forage species and, consequently, the SSP sustainability (Oliveira Neto et al., 2007; Oliveira et al., 2007a, b).

The system using eucalyptus tends to have problems with nitrogen (N) immobilization in the soil, due to the high deposited C/N ratio, which favors the competition between grasses and eucalyptus and the reduction of the amount of N available to the forage (Carvalho and Pires, 2008). In this case, studies have indicated that the association of legumes to eucalyptus plantation may represent future gains in terms of fertility, synchronism to the nutritional demand of eucalyptus and relevance due to N also required for herbaceous forage species, particularly grasses and studies have been performed, in order to evaluate the behavior of different species in SSPs (Dias et al., 2007a).

Thus, when planning a SSP based on eucalyptus, it is important to consider alternatives to minimize possible negative interactions between the pasture and the trees (Paciullo et al., 2007b). Annual application of nitrogen fertilizers increases the dry matter yield of forages, however, the response to fertilization is directly related to the degree of shading, because the greater the shading, the less the response of grasses to fertilization.

One of the requirements for the success of sustainable SSPs is due to the species selection to compose these systems. Concerning the trees, the diversity of species directly influences the system stability (Pezarico, 2009).

The choice of forage species is important in an SSP. One can opt for a system with exclusively cultivated forages or an improvement of the native field. The improvement of native pastures by introducing cultured species should be done by direct seeding over sowing or without the use of desiccants (Lucas et al., 2015). Grasses of the genus *Paspalum* and *Panicum* have flexibility of use because they have satisfactory production potential, regrowth vigor, satisfactory nutritional value, tolerance to shading, besides being adapted to the most varied climate and soil conditions. Thus, they become important as forage species to be used in SSPs (Alvim et al., 1996).

The species of the genus *Brachiaria* (Trin.) Griseb., has also been shown to be quite tolerant to shading, responding structurally to environmental changes, without loss of productivity and forage quality (Martins et al., 2009). *Mimosa tenuiflora* (Wild.) Poir is a species indicated to be introduced successfully in the pastures of

Brachiaria decumbens Stapf. Prain., without the protection of their seedlings and in the presence of cattle (Dias et al., 2007b).

In systems where livestock production is integrated with the forest, grazing can be implemented before or after tree planting. Preferably, pasture must be implanted before the tree component, which allows a greater ease of mechanized operations in the area and anticipation of the use of forages.

Grazing in the initial stage of tree development is possible, provided that initiatives are taken to prevent animal damage to them. Thus, in the first year of establishment, an electric fence can be used to keep animals grazing at a safe distance from the plants, but it is important that the animals are accustomed to handling this type of fence, which can be obtained if the animals experience previous electrical shock in other areas of the property (Menarim et al., 2009).

Another alternative is the exclusive use of the area for the production of hay or silage in the first years, while the seedlings do not reach the ideal size for the integration with the animals, or to keep the pastures without grazing so that they can produce seeds, to ensure the natural reseeding of the species and maintain the system productive potential in subsequent years (Lucas et al., 2015).

For species that have a good natural resemblance, it is important that in the reproductive stage of the species (from the flowering), a reduction of the animal load or even the fallow of the area is carried out, so that the species can produce seeds in good quantity and quality and restore pasture in the next productive cycle. Likewise, it is important to consider the characteristics of each forage species, such as growth habit, flowering season and forage cycle.

In addition to the benefits of SSP adoption, a number of studies have been carried out, especially those aimed at improving the physical, chemical and biological quality of the soil (Tripathi et al., 2005; Lok, 2006; Nair et al., 2007). In the present study, it is possible to evaluate the quality of the pasture (Paula et al., 2007a, 2008), animal comfort and, more recently, the environmental services provided by these systems and other factors that contribute to the disease development. The use of tree and shrub species in SSP for the purpose of forage production has also been the subject of studies in Brazil (Silva et al., 2007; Dias et al., 2007b; Paciullo et al., 2007a) and abroad (Shelton et al., 2005; Ainalis et al., 2006).

It is possible to take advantage of the initial growth stage of the tree component for an adequate implantation of forage species, especially focusing on the establishment of species of slow initial development, such as perennial winter legumes (Lucas et al., 2015).

POTENTIAL HABITAT AND BIODIVERSITY LOSSES

From a technical point of view, the benefits

of SSPs represent a long-term strategic interest for environmental conservation, for producers, afforestation of pastures should present a real benefit in the short and medium term. According to Porfirio da Silva (2007), the producer's main objectives when associating trees with pasture are: (a) to increase the total income of pasture lands; (b) increase the role of what to produce and, thus, reduce economic risks; c) preserve their way of life and their survival while conserving resources (Radomski and Ribaski, 2012).

Regarding grazing management, it is important to always observe the height of the forage plants before entering and during the animals' grazing (Carvalho, 1998). Due to the light restriction because of the presence of trees, a conservative management is recommended, and it is essential to adjust the animal load in order to maintain pasture with a minimum residue height between 15 and 20 cm (Lucas et al., 2015).

In a SSP, the amount of available light is one of the main factors that determines the growth and production of forages, and is conditioned basically to the management of four variables (Varella et al., 2008): (a) spacing, by density tree planting arrangement; (b) selection of species with not very dense crown; (c) thinning and pruning of trees; (d) shading tolerant forages.

CONCLUSIONS

Productive systems that include the combination of tree fodder can contribute to increased management efficiency and use of natural resources, as well as to the sustainability of rural properties, especially small ones. This avoids environmental degradation and improves the quality of life of rural producers by increasing pasture productivity, gaining livestock and harvesting forest products, and diversifying income in rural properties.

The SSP is a strategy to optimize the existing differential in regional and national cattle breeding: herds in pasture. With this, it can help to consolidate Brazilian cattle breeding as environmentally adequate in the world scenario.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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