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USE OF LEGUMES AS A TREE COMPONENT IN INTEGRATED PRODUCTION SYSTEMS: AN OVERVIEW OF SUSTAINABILITY

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ABSTRACT

Integrated systems emerge as an alternative for ruminant production, as they provide environmental services and promote animal welfare. Due to the world scenario that is increasingly concerned with the environmentally appropriate production system, investing in new technologies is essential for the success of the exploration, and the inclusion of tree legumes plays a central role in improving the efficiency of these systems. Legumes contribute significantly to biological nitrogen fixation (BNF), a symbiotic process that allows the conversion of atmospheric nitrogen into forms that can be assimilated by plants. This fixation reduces the need for nitrogen fertilizers, promoting the sustainability of the system. Therefore, the use of tree legumes in silvopastoral systems not only increases livestock productivity and reduces input costs, but also promotes agroecological integration that results in more resilient and sustainable systems, both economically and environmentally. In view of the above, the objective of this work is to provide information about the importance of integrated systems, especially in relation to the importance of legumes in these systems, focusing on ruminant production and its environmental impacts through a systematic

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literature review. 56 academic papers were selected on related topics in various means of technical and scientific production, such as articles published in journals, books, theses, among other types of technical papers available in the scientific community. Integrated systems have been adopted in tropical livestock production areas, and their benefits in thermal comfort and performance have been recognized and encouraged by scientific research due to the promotion of sustainability in the field.

Keywords: Animal Welfare. Tree Component. Sustainability.

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INTRODUCTION

The intensification of production systems involves the adoption of new technologies and investments aimed at efficiently using available resources. Integrated Crop-Livestock-Forest (ICLF) systems emerge as an alternative, the practice is associated with an increase in land use efficiency, diversification of income on properties, additional products, environmental benefits and reduction in deforestation rates and degraded pastures (BALBINO et al., 2011).

There is a social demand that disrespects the sustainability of production systems that requires changes in the way activities are developed (MORAES et al., 2018). The adoption of Integrated Systems (ICLFS) can contribute positively to the sustainability of pastures and the resilience of production systems, in addition to expanding opportunities for the exploitation of products of plant origin (CORDEIRO et al., 2015).

Integrated systems (ICLFS), when well managed, are able to meet the needs of the animals, such as water, food in quantity and quality, sociability, mobility and thermal comfort, compared to traditional grazing systems, which do not use trees and do not provide a quality environment for the animals, negatively affecting their physiological processes and productivity (ALVES et al., 2015).

ICLFS are a dynamic production system and the choice of components (agricultural, animal, forage and arboreal) must be well planned, as the effects of the interaction of the coexistence of these components will be expressed over time and the losses can be cumulative (VENTURIM et al., 2010). The components to be used in ICLF systems must have agronomic, zootechnical and silvicultural characteristics appropriate to the adopted system and the needs of the producer (BEHLING et al., 2013).

The use of tree legumes in silvopastoral systems has been widely studied due to their multiple agroecological benefits, mainly related to biological nitrogen fixation (BNF), improvement in forage quality and positive impact on the microclimate. Legumes, in association with bacteria of the genus Rhizobium, play a crucial role in improving soil fertility by reducing the need for synthetic nitrogen fertilizers (REINHOLEZ, 2024). This contribution is particularly important in tropical soils, often poor in nutrients, where legumes can significantly increase the productivity of forage grasses.

Among the tree legume species most used in silvopastoral systems, Leucaena leucocephala, Gliricidia sepium, Albizia lebbeck and Sesbania sesban stand out. According to Rivest et al. (2013), Leucaena leucocephala is one of the most studied and used species

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globally in silvopastoral systems due to its high nitrogen fixation capacity, forage productivity and adaptability to various edaphoclimatic conditions. In addition, studies by Shelton et al. (2005) highlight that Leucaena leucocephala is an excellent source of crude protein for ruminants, with levels higher than 25%, which improves animal performance, especially in regions where the quality of herbaceous forage is seasonal.

Studies show that the incorporation of Gliricidia into pasture systems improves nutrient cycling and soil structure, as well as providing shade for animals, reducing heat stress (ASCENCIO-ROJAS et al., 2019).

In addition to providing high-quality forage, tree legumes significantly influence the microclimate in pasture areas. The presence of trees in pastures reduces soil temperature and evapotranspiration, providing a more favorable environment for grass growth and greater thermal comfort for animals (CORDEIRO et al., 2019). Albizia lebbeck, for example, is a legume that stands out for its ability to generate shade and improve the microclimate without aggressively competing for water and nutrients with grasses (RIVEST et al., 2013).

From an ecological point of view, the inclusion of these tree legumes in silvopastoral systems contributes to the biodiversity and resilience of the system. According to Murgueitio et al. (2011), these systems integrate the ecological functions of trees with livestock production, increasing nutrient cycling, improving soil structure, and sequestering carbon. This contributes to climate change mitigation and improves long-term sustainability.

In view of the above, the objective of this integrated literature review was to provide information about the use of legumes as a component of integrated production systems, as well as the benefits of these systems for animal welfare, based on scientific research and other technical productions on this subject.

METHODOLOGY

In order to achieve the objective proposed by this research, a bibliographic research of a qualitative, exploratory and descriptive nature was carried out (PACHECO et al., 2021). This type of research is based on reviewing the existing literature in the scientific community on the main works related to the proposed theme, and can be used as a consultation: scientific articles published in journals, books and book chapters, abstracts published in conference proceedings, theses and dissertations, newspaper articles, internet sites, among other sources (PIZZANI et al., 2012).

For the present study, the technical-scientific literature was used. In addition, the methodology used was based on a qualitative-quantitative approach, using techniques related to bibliographic research (PACHECO et al., 2021). The bibliographic survey was carried out between August and October 2024.

Thus, reading was the main instrument used for the choice and selection of bibliographic material and their respective knowledge about integrated systems with the use of legumes with a focus on ruminant production. The analysis of the content of the articles was carried out to explore the themes and main results of the analyzed studies (PACHECO et al., 2021).

This article was based on the reference of bibliographic research produced between the years 2000 and 2024. It involved the basic activities of identification, analysis and interpretation of information. The platforms used for the data search were: Elsevier, SciELO, Capes Journal Portal, Sci-hub, Google Scholar and digital books. The inclusion criteria were articles in Portuguese and English, available in full, totaling 56 reference articles.

This review is descriptive, and provides information about the importance of the use of legumes in integrated systems in ruminant production, as well as northeastern livestock, animal welfare and the choice of the forage and tree component of the integrated systems and their types.

RESULTS AND DISCUSSION

ABC PLAN

Brazil has established specific legislation and public policies to direct measures and solve problems related to GHG emissions in the country (MAPA, 2012).

In this regard, it is worth noting that the Federal Government, within the scope of the National Climate Change Plan, initiated the Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of the Low Carbon Economy in Agriculture (ABC Plan), in this same plan the ICLF is mentioned, considering the different modalities of systems, accepted as technology and, therefore, including specific credit lines for the Program.

Among the government actions proposed to achieve these goals is the adoption of intensive measures in agriculture for the recovery of degraded pastures; actively encourage the implementation of integrated crop-livestock-forest systems (ICLFS); expand the use of No-Till (NTS) and biological nitrogen fixation (BNF), (MAPA, 2012).

3.2 INTEGRATED SYSTEMS – ICLFS

Agroforestry systems are efficient systems in which land management is done from a shrewd combination of different tree species, agricultural crops that can be intercropped with animal production in order to promote economic and ecological impact in the region. Due to the dissemination of results and the growth of scientific studies in the area of agroforestry systems, crop-livestock-forest integration has emerged, which adds technologies for these types of production systems (NICODEMO, MELOTTO, 2015).

What defines the different modalities of these production systems are the combinations between the components, made in a planned way, aiming to allow greater use between the existing interactions.

Regarding the different types of combinations within agroforestry systems, according to Balbino et al., (2011) four distinct models can be named:

Integrated Crop-Livestock-Forest (Agrosilvopastoral) systems known for proposing the combination of trees with crops of agricultural cultivation with the introduction of the animal component. In this type of system, the crop element can be aggregated at the beginning of the implementation together with the forest component or in cycles during the establishment of the system;

Crop-Forest Integration System (Silviagrícola) defined as an agroforestry system that uses the combination of trees intercropped with annual or perennial agricultural crops, which can be inserted either in the initial phase of implementation or in cycles.

Silvopastoral system: this third format is characterized by allowing the presence of trees in its arrangement along with the forage component and the presence of the animal.

Crop-Livestock Integration (agropastoral); combination of crops for agricultural purposes with the introduction of animals, in rotation, intercropping or in a different period, in a single year or for multiple years in the same area.

ICLFS is an ecologically dynamic, complex and sustainable system, which offers the opportunity to resemble natural forest on agricultural land with economic return. However, it requires land use management and careful planning.

CHOICE OF PLANT SPECIES FOR SYSTEM IMPLEMENTATION

When the deployed systems are sized appropriately, the trees and pasture interact successfully in order to optimize both yields. In addition to the selection and use of forage species with moderate tolerance to shade, the level of competition in the system can be minimized by the choice of tree species, density and arrangement of trees in relation to the sun and the relief of the area, as well as by the use of techniques for canopy management and tree thinning (POLLOCK et al., 2009).

The intercropping of pastures with grain-producing crops is being widely used to provide positive results. The introduction of agricultural production together with forage brings a series of benefits, such as better use of fertilizers, better rooting and use of the soil at different depths, soil cover, nutrient cycling, allowing greater longevity in soil use (ALVARENGA et al., 2010).

The introduction of the agricultural component is carried out through annual crop species for the purpose of producing grains or making silage. Species can be sown in conjunction with forage species (permanent forage component), between the spacing of the forest component lines, until the moment when the forest component is properly established to allow the entry of animals (KLUTHCOUSKI et al., 2000; KLUTHCOUSKI et al., 2003)

Generally, a financial return with the implementation of the tree component in the system happens in the medium to long term. Thus, as a measure to amortize the costs in the implementation of the system, the use of annual crops in the first and second year is an option. In this aspect, the costs generated in soil correction and fertilization for annual crops can be partially recovered with the first harvest. Corrected soil will generate benefits for pastures in succession as well as trees will use residual soil nutrients (GONTIJO NETO et al., 2014)

Compared to other crops, the cultivation of corn (Zea mays L.) for silage or grains is well adapted when integrated with pasture, due to the larger size of corn plants, which allows them to compete with forage and be harvested, at ear insertion, without interference from forage plants (ALVARENGA et al., 2010).

TREE COMPONENT

Regarding the tree component, traditionally the most planted species in Brazil are *Eucalyptus*, Pinus*, Acacia and Tectona, mahogany*. The choice of this component needs to take into account the purpose of silvicultural production, allopathic effects of the species, canopy structure and the production chain (GONTIJO NETO et al., 2014).

Among the reasons for the greater use of the eucalyptus species, we can highlight its good adaptation to different climatic conditions, in addition to its rapid growth, potential for logging and pulp exploitation for multiple purposes, the existence of available seedlings, in addition to a vast field of technical knowledge about the species and the existence of genetic improvement of species (OLIVEIRA et al., 2015).

However, the use of legumes for the implantation of tree components, nitrogen-fixing species being planted in intercropping systems, to increase the nitrogen available in the soil and reduce dependence on agricultural inputs is increasing. Tree fertiliser systems can fix nitrogen in the soil where a lack of nitrogen is a limiting factor for crop growth (SUNDERLAND, ROWLAND., 2019).

Among the most used species in systems involving ruminant production, gliricidia and leucaena have been widely used in agroforestry systems, this use is basically due to its potential as a plant because it has good reproduction, can be propagated by seeds, fast growth, drought resistance, high regeneration capacity, easy propagation, in addition to having properties that allow improving soil quality (DRUMOND, CARVALHO FILHO, 2005; MATOS et al., 2005).

GLIRICIDIA SEPIUM

Native to Mexico and Central America, Gliricidia (*Gliricidia sepium* (Jacq.) Steud.) - (Leguminosae - Papilionoideae)] was introduced in Brazil in the mid-80s, belonging to the Fabaceae family, considered a tree species that can grow between 12 to 15 m and 30 to 40 cm in stem diameter. Since then, it has become an object of significant commercial and economic interest for the region, due to its multiple uses that include its use as a forage species with high nutritional value for animal feed, as well as bees as well as its use as a medicinal plant (REIS et al., 2012).

Propagated by seeds or cuttings, it has fast growth, the fruits are flattened pods of pale green color when young and brown when ripe.

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The versatility of gliricidia in the dry regions of Brazil is an important resource used as a source of nitrogen. Its roots are associated with bacteria of the genus Rhizobium, which form symbiosis by originating a number of nodules that fix atmospheric N2 (MIRANDA, 2023).

One of the main benefits of gliricidia in the context of ICLFS is its ability to improve soil fertility through biological nitrogen fixation (BNF). This fact was evaluated by Silva et al. (2020) when studying the biological fixation and nitrogen transfer by gliricidia in an organic orchard intercropped with oranges and bananas, in which the amount of N made available supplied 55% of the nutritional requirement of the crops.

In animal feed, biomass production varies from 2 to 20 tons of DM/ha/year. With high nutritional value in its leaves, DM content 30% with CP content 20-30% (GAMA et al. 2009).

Because it is a perennial tree, easy to establish, it has a low cost of DM production. Animals that graze in SSP consume the grass as the main source of forage, and the leaves and thin branches of gliricidia as a complement to the protein levels of the diet.

According to Rangel et al. (2001), the cultivation of these legumes in rows, with grass production between the rows, increases the supply of food for animals in periods of drought, in addition to improving the physical, chemical and biological characteristics of the soil, which can increase its productivity. The cultivation of gliricidia together with grasses, in an integrated system for direct grazing, increases the sustainability of pastures because the legume improves soil fertility in addition to complementing the animals' diet.

In the rainy season, gliricidia is usually not well accepted by animals, so thin branches and leaves of the plant can be hayed or ensiled, as well as being left in the soil for decomposition. In the dry season, with the decrease in grass quality, gliricidia becomes an excellent food supplement (RANGEL et al., 2001).

In addition to its function as a source of nutrients for the soil and animals, Gliricidia has a positive impact on the microclimate and soil conservation. Its dense foliage provides shade and protects the soil from direct solar radiation, reducing the evaporation of water from the soil and, consequently, the water stress of the underlying pastures and crops (ASCENCIO-ROJAS et al., 2019). The presence of Gliricidia trees also favors biodiversity, providing habitat for beneficial species, such as pollinators and natural predators of agricultural pests.

However, gliricidia requires proper management to maximize its benefits in ICLFS. Practices such as regular pruning and tree density control are essential to avoid competition with crops or pastures and to ensure access to sunlight by the underlying plants (NETO et al., 2022). When well managed, gliricidia can be a crucial component for the sustainability and resilience of ICLF systems, promoting nutrient cycling and improving animal productivity.

Studies carried out in several tropical countries, including Brazil, Mexico and India, highlight that the use of Gliricidia in integrated systems can increase biomass production, improve nutrient use efficiency and reduce soil erosion (MURGUEITIO et al., 2011). In addition, Gliricidia has great tolerance to intense pruning and is often used as a hedge or windbreak, which makes it a versatile option in agroforestry systems.

MIMOSA TENUIFLORA

The jurema *(Mimosa tenuiflora* (Willd.) Poir.), in turn, is a native, pioneer, fast-growing and very frequent species in the Caatinga, its wood is used for firewood, charcoal and fence making in the Brazilian northeast region (CALEGARI et al., 2016). As reported by Oliveira et al. (2006) about the growing demand for firewood as woody fuel in the mesoregion of the Paraíba hinterland, requiring more and more resources from species such as the jurema-preta, which has charcoal with high calorific value.

The use of leguminous tree species that are more adapted for implantation in pastures, without the need to protect the seedlings during the grazing of animals, such as the jurema-preta, for example, may reduce the cost of afforestation, in addition to allowing the introduction of these species within the conditions of low profitability of the sector, especially for extensive cattle ranching practiced in the semi-arid northeast (DIAS; SOUTO, 2007)

When evaluating the growth of jurema-preta seedlings in soils of degraded areas of the caatinga, Azevêdo (2011) found the growth of these seedlings in degraded soils, due to their aggressive root growth, confirming the rusticity of this species and its contribution to soil health, this reinforces the need to study other species of tree legumes in degraded areas of the caatinga.

The jurema-preta is an acceptable legume for animals, it has rapid development and can compete with the grass in the pasture, such attributes are essential for the success of the introduction of the tree species to the pasture, as verified in the experiment of Dias and Souto (2007) when they recommended the jurema-preta to be introduced in pastures in

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conditions of seedlings without protection and in the presence of cattle in the State of Rio de Janeiro.

The branches of the jurema-preta participate in the feeding of sheep, goats and cattle, their palatability is similar to other tree species of the caatinga, such as mofumbo and jucá (AZEVÊDO, 2011). The leaves of this species have 9.2 to 20.2% of crude protein and 17 to 37.5% of in vitro digestibility , its presence recovers nitrogen through biological fixation, in addition to improving the conditions of pastures by protecting the soil, providing forage and shade to the animals, its flowers are melliferous and its bark has medicinal properties and tannins appropriate for leather tanning (FIGUEIREDO, 2010).

Almeida et al. (2006) found average values for MS, CP, FDN and ADF of jurema leaves harvested during the dry season of 47.62% for the dry season; 14,82%; 46,38%; 33,04%

respectively and, in the rainy season, 47.52%; 14,41%; 46,33%; 32.36% when they evaluated tree and shrub species of pastures, comparing their nutritional values in the dry season with that of the rainy season.

Ruminants consume jurema in their diet in a green or hayed form, especially grazing the younger reshoots at the beginning of the rainy season, as well as the leaves and dry pods during the dry season (FILHO, 2005). However, jurema preta is part of the group of toxic plants, there are reports in the literature about congenital defects in ruminants by ingestion of jurema preta during pregnancy, but the mechanism of action of toxicity is unknown and there is no specific treatment, so it is important to avoid the ingestion of this species by females in the first 60 days of gestation (BEZERRA, 2008)

LEUCAENA LEUCOCEPHALA

Leucaena (*Leucaena leucocephala*) is a fast-growing tree leguminous species, which has been frequently cultivated in Brazil for forest recovery, since it has symbiosis with nitrogen-fixing bacteria, improving the chemical and biological quality of soils (COSTA; DURIGAN, 2010).

Leucaena is a species that has a great diversity of uses, so it is a good option for planting in tropical regions, showing good development in regions with rainfall of more than 600 mm of rain per year, but it is also found in places with annual rainfall of 250 mm (SILVA et al., 2017).

This species is rustic and is able to resprout easily even after successive cuts, it is a plant of high acceptability and palatability to ruminants, in addition to shading them. As forage, its leaves, green or hayed branches, fruits are part of the diet of ruminants, pigs and other domestic animals, with a high nutritional content, being considered a protein food (DRUMOND; RIBASKI, 2010).

The amount of crude protein in leucaena leaves is approximately 20%, the most tender foliage and fruits have up to 35% CP. Leucaena has a bromatological composition similar to that of alfalfa. However, the higher concentration of tannins in leaves and branches tends to reduce dry matter digestibility (DRUMOND; RIBASKI, 2010).

When evaluating the effect of diets containing leucaena and yeasts on rumen fermentation and methane gas emission in ruminants, Possenti et al. (2008) found that diets with 50% leucaena and 50% grasses promote a better fermentation pattern in the ruminant rumen. The production of propionic acid increases significantly and that of methane reduces by 12.3% with this diet without the action of yeasts, with the presence of fungi in the diet, there is greater production of volatile fatty acids and greater reduction of methane production, consequently increasing the energy efficiency of the animals.

Some studies in the literature report the toxic effect of leucaena foliage when fed as the only food for a prolonged period, due to the large amount of mimosin in its composition, toxicity manifests itself in metabolic dysfunctions with hair loss, salivation and weight loss. However, in Brazil, the occurrence of leucaena poisoning is practically non-existent, due to some species of bacteria present in the rumen of animals that degrade mimosin (DRUMOND; RIBASKI, 2010).

Studies also highlight the role of Leucaena in improving the microclimate and protecting the soil. The shade provided by trees reduces evapotranspiration, maintaining soil moisture and reducing the water stress of the underlying crops and pastures (MURGUEITIO et al., 2011). The integration of Leucaena in ICLF systems also favors biodiversity, promoting nutrient cycling and the recovery of degraded areas, a crucial point for long-term agricultural sustainability (VILALTA et al., 2019).

In the context of ICLFS, Leucaena has been widely used in Brazil and other tropical countries due to its adaptability to a wide range of soils and climates, as well as its rapid ability to regrow after cutting. Shelton et al. (2005) point out that the deep root system of Leucaena allows the plant to access nutrients in deep layers of the soil, avoiding direct competition with annual crops and forage grasses.

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However, one of the challenges in the use of Leucaena in ICLFS is the need for adequate management to avoid its excessive spread and possible competition with other plant species. Regular pruning techniques and tree density control are recommended to maximize benefits without compromising the productivity of other components of the integrated system (BEHLING; WRUCK., 2023).

3.8 MORINGA OLEIFERA

The *moringa oleifera* Lam., is a plant species of the *Moringaceae* family, popularly known as moringa, has perennial growth, of arboreal size and originally from India and Africa, however, cultivated all over the world, with great economic, medicinal and industrial importance (MBIKAY, 2012; SILVA et al., 2021). In all parts of the tree, such as roots, bark, leaves, flowers, fruits, and seeds, large amounts of beneficial nutrients are found (DHAKAD et al., 2019; ZAKU et al., 2015).

Moringa is a tree that adapts both in irrigated and rainfed regimes, in addition to being undemanding in soils and fertilizers, in Brazil, this species is present throughout the territory, especially in the Northeast region, where there are the most advantageous edaphoclimatic conditions for the growth of this crop, being for the producers of this region, a low-cost and easy-to-grow crop (SILVA et al., 2021).

Moringa is characterized as a small to medium-sized tree, growing up to approximately 10m in height, multipurpose in nature, used as a spice, cosmetic, source of cooking oil, in addition to having medicinal properties (MOHANTY et al., 2021). Ademiluy et al. (2018) and Gopalakrishnan et al. (2016) in their respective studies, identified moringa leaves as an excellent source of natural antioxidants, such as flavonoids, phenolic acids, cardenolides, alkaloids, oxalate, vitamin C, tannin, saponin, phytate and cardiac glycosides, thus providing essential nutrients to animal nutrition

(SILVA et al., 2021).

Moringa seeds are dark brown in color, winged, each having 3 wings, are rich in protein (33.90%) and lipids (37.20%), and thus, classified as a protein food, in appearance and flavor, moringa resembles radish (SILVA et al., 2021). The oil extracted from this species contains high levels of unsaturated fatty acids, especially oleic (71.6%), palmitic and behenic (SILVA, 2021). The root is tuber-shaped and has the function of storing energy for the plant (MACEDO et al., 2010).

The moringa tree has great ecological importance and can be used in integrated systems, as observed by Kiill et al. (2012) when analyzing the relationships between *Moringa oleifera* Lam. and its floral visitors, in the region of Petrolina-PE, concluded that the species has potential as a beekeeping plant, among the orders of insects that visited the trees, Diptera, Coleoptera, Lepidoptera, Hymenoptera, as well as hummingbirds can be mentioned, totaling 25 species.

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Due to its rusticity in arid conditions and its rapid growth, together with the high protein content of its leaves, moringa is being studied as a supplier of forage for supplementation of animal feed, in the dry season; either as a source from monoculture (BAKKE et al., 2010) or as an integral part of integrated systems (GUALBERTO et al., 2014).

FINAL CONSIDERATIONS

In view of the current discussions on the issue of carrying out a more sustainable agriculture, due to the major problems that humanity currently faces, such as climate change, unsustainable agricultural systems, soil degradation, among others, and the greater concern of government systems with the care of the environment, ensuring income, quality of production and animal welfare, Integrated systems emerge as a possibility for small cattle ranchers in the Brazilian Northeast to ensure sustainable production, with profitability and preserving the soil of their property.

Integrated production systems are designed to create and increase synergies arising from integrated activities. Ensuring animal welfare in integrated systems results in animal health, better feed conversion and sustainability. Therefore, the present work emphasizes the need for the producer to take care of the product to choose the best forage and tree components.

The microclimatic changes induced by trees, mainly related to the transmission of solar radiation, promote greater animal thermal comfort. In addition, integrated systems can help livestock to adapt to climate change, providing lower values of greenhouse gas emissions to the environment. Therefore, it is essential that these systems are adaptable to current issues, and to the needs of the small farmer, as well as to allow better conditions for production animals.

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