

The binomial of fodder potential versus invasion risk of *Opuntia ficus-indica* and *Leucaena leucocephala*: resilience strategies for livestock farming in the municipality of Gambos, Angola

Abstract

The Municipality of Gambos, in the province of Huíla, faces extreme socio-ecological vulnerabilities due to cyclic droughts and high-water variability factors that jeopardize extensive livestock farming, the backbone of the local economy. This study analyzes the technical-scientific paradox of the invasive exotic species *Opuntia ficus-indica* and *Leucaena leucocephala*, assessing their fodder potential and the risks of native biodiversity degradation. A mixed qualitative and quantitative methodology was adopted, conducted between October 2025 and July 2026, with a purposive sample of 30 participants across five rural communities. The results reveal a strategic functional complementarity: *Opuntia* ensures hydration and energy via CAM metabolism, sustaining critical rainfall levels (< 400 mm), while *Leucaena* provides protein density (20-25% CP) and biological nitrogen fixation. Additional socioeconomic benefits were identified, such as fruit commercialization and charcoal production, alongside significant risks, including mimosine toxicity and the obstruction of transhumance routes by dense stands. It is concluded that these species are fundamental resilience tools, provided they are integrated into controlled management systems and rigorous technical monitoring.

Keywords: semi-arid, fodder, invasive species, Gambos, resilience, livestock farming

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Introduction

Invasive alien species represent one of the primary drivers of ecosystem degradation on a global scale, inducing often irreversible biotic and abiotic changes.¹ The dispersal of these organisms outside their natural habitat generates complex socio-ecological impacts.² However, in various regions of Africa, a paradox emerges: the vital dependence of rural communities on these species for subsistence, using them as strategic sources of fodder, firewood, and charcoal.³ While fundamental to livelihoods and the local economy, their high invasion potential can compromise native biodiversity and ecosystem balance.⁴

The Municipality of Gambos, located in southwestern Angola, is characterized by a semi-arid edaphoclimatic reality, with average annual rainfall often below 400 mm. The regional economy relies on extensive livestock farming and transhumance, systems that suffer directly from the scarcity of natural pastures during prolonged droughts. In this context, the introduction of resilient exotic species emerges as a necessary mitigation strategy to ensure livestock productivity and the food security of rural communities in the face of climate variability. The objective of this study is to analyze the potential of *Opuntia ficus-indica* and *Leucaena leucocephala* as strategic resources used in animal feed, as well as to evaluate the risks associated with their invasive nature. It further aims to understand their contribution to agro-livestock systems and the ecological

impacts resulting from their expansion. Thus, the study seeks to provide evidence for management strategies that maximize productive benefits and minimize environmental damage.

To achieve these objectives, the research adopted a mixed methodological approach, descriptive and analytical in nature, combining a literature review with fieldwork conducted between October 2025 and July 2026. Through direct observation and semi-structured interviews applied to a purposive sample of 30 participants, the main uses of the species and the communities' perceptions regarding their benefits and impacts were identified. Qualitative data were processed through content analysis,⁵ while quantitative information was processed using descriptive statistics.

Origin, distribution, and botanical characteristics

Opuntia ficus-indica, belonging to the Cactaceae family, is a species native to Mexico, later spread to Europe, Africa, Asia, and Oceania following Spanish colonial expansion.⁶ Currently, it is widely distributed across the world's arid and semi-arid regions, being cultivated for fruit production, animal feed, and soil conservation.⁷ Morphologically, it features succulent cladodes responsible for photosynthesis and water storage, a shallow and highly branched root system, and fruits rich in sugars, fibers, vitamins, and antioxidant compounds.⁸ In turn, *Leucaena leucocephala*, belonging to the Fabaceae family, originates from Latin America and Mexico and is widely distributed in tropical and subtropical regions due to its high

fodder potential, rapid growth rate, and biological nitrogen fixation capacity.⁹ The species exhibits high ecological plasticity, adapting to degraded, low-fertility soils subject to prolonged periods of drought characteristics that favor its use in resilient agro-livestock systems.¹⁰ Morphologically, it is a small to medium-sized tree, 5 to 20 m in height, with an open canopy, bipinnate leaves, and abundant production of pods with seeds of high germinative viability, which promotes its rapid dissemination.¹¹ These characteristics make both species particularly promising for semi-arid regions, such as the Municipality of Gambos, where water scarcity and pasture degradation demand sustainable alternatives for agro-livestock production.

Methodology

Characterization of the study area (Gambos, Huila)

The Municipality of Gambos is located in the south of Huila province. The region is dominated by wooded savannas and extensive plains, which are fundamental for transhumance and extensive livestock farming.¹² It is characterized by a semi-arid climate, with average annual rainfall often below 400 mm and high variability that causes frequent droughts, limiting agriculture and the availability of water and fodder.¹³ The local economy predominantly depends on the raising of cattle, goats, and sheep; therefore, the availability of fodder during the dry season is vital for the sustainability of production systems (Figure 1).¹⁴

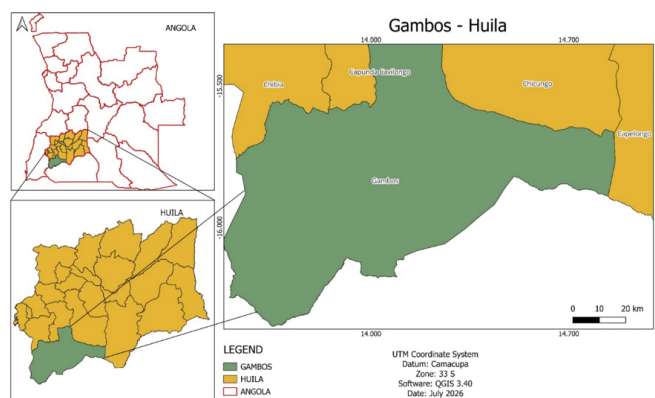


Figure 1 Location map of the study area.

Methodological procedure

The study followed a mixed methodological approach, descriptive and analytical in nature, combining a literature review and fieldwork

to evaluate the fodder and socioeconomic potential of the species *Opuntia ficus-indica* and *Leucaena leucocephala* in the Municipality of Gambos, Huila Province, as well as the ecological risks associated with their expansion. The investigation was conducted between October 2025 and July 2026, covering five rural communities with a purposive sample of 30 participants, including livestock breeders, farmers, community leaders, and technicians from the agriculture, livestock, and environment sectors, as shown in Table 1. Data collection was based on direct observation and semi-structured interviews, aimed at identifying the main uses of the species and the communities' perception of their benefits and environmental impacts. Qualitative data were analyzed through content analysis,⁵ while quantitative information was processed using descriptive statistics in Microsoft Excel. The triangulation between the literature review and empirical data allowed for an integrated assessment of the importance of these species for extensive livestock farming and their influence on local biodiversity (Figure 2).



Figure 2 Cattle consuming *Opuntia ficus-indica*.

Results

Nutritional value and ecological functionality

Leucaena leucocephala exhibits high fodder value due to its crude protein content exceeding 20-25%, high digestibility, and good regrowth capacity, constituting an important food source for cattle, goats, and sheep during the dry season and contributing to increased weight gain, milk production, and the efficiency of silvopastoral systems,¹¹ as shown in Table 2. In turn, *Opuntia ficus-indica* stands out for the high nutritional value of its fruits and cladodes, which are rich in water, carbohydrates, fibers, vitamins, minerals, and antioxidant compounds, being used for both human and animal consumption.¹⁵ The versatility of these species reinforces their potential to improve food security, diversify the income sources of rural communities, and increase the resilience of agro-livestock systems in semi-arid regions such as the Municipality of Gambos.^{14,16}

Table 1 Distribution of interviewed participants by community and professional category in Gambos Municipality, Huila Province, Angola

Community	Livestockbreeders	Farmers	Community leaders	Agricultural/Livestock/Environmentaltechnicians	Total per community
Tunda Of Gambos	4	1	1	0	6
Tchibemba	4	1	1	0	6
Kalepete	4	0	1	1	6
Kamuxixi	3	1	1	1	6
Munthiahulo	3	1	1	1	6
Total	18	4	5	3	30

Table 2 Primary Ecological Functions and Nutritional Value of *Opuntia ficus-indica* and *Leucaena leucocephala*

Species	Primary ecological function	Crude Protein Content (CP)	Main componentand benefits
<i>Opuntia ficus-indica</i>	Water retention and erosion control	Low (3%–5%)	Source of energy (soluble carbohydrates), water, vitamins, and antioxidants
<i>Leucaena leucocephala</i>	Nitrogen fixation and soil restoration	High (20%- 25%)	High protein density, digestibility, and provision of essential minerals

Potential for Use in the Municipality of Gambos: The ecological conditions of the Municipality of Gambos, characterized by a semi-arid climate, low soil fertility, and a strong dependence on extensive livestock farming, are favorable for the use of *Leucaena leucocephala* and *Opuntia ficus-indica* as strategic fodder resources.

Socioeconomic Benefits for Local Communities From a socioeconomic perspective, the introduction of these species can generate multiple benefits for the Gambos municipality, where the economy relies primarily on the raising of cattle, goats, and sheep. The adoption of agroforestry and silvopastoral systems increase the resilience of rural communities by diversifying food and income sources.¹⁷ In the case of *Opuntia ficus-indica*, the fruits can be commercialized, creating opportunities for extra income. In turn, *Leucaena leucocephala* can be used as a source of firewood, charcoal, and protein fodder, which reduces livestock production costs, especially during the dry season when natural fodder is scarce.

Invasive Potential and Ecological Behavior Despite the recognized benefits as a fodder resource, *Opuntia ficus-indica* and *Leucaena leucocephala* exhibit a high invasive potential, which may compromise biodiversity and ecosystem functioning if introduced without proper management (CABI, 2023). *Opuntia ficus-indica* spreads through seeds and cladode fragments, while *Leucaena leucocephala* is noted for its high seed production and rapid growth, forming dense stands that compete with native vegetation and reduce pasture availability.^{18,19} Therefore, the use of these species in Gambos must be accompanied by integrated management strategies, including continuous monitoring, dispersal control, and community awareness, to reconcile the benefits for animal feed with the conservation of local biodiversity and ecosystems.²⁰

Anti-nutritional Factors and Limitations Despite its high nutritional value, *Leucaena leucocephala* contains mimosine, a non-protein amino acid that can cause toxic effects in animals when consumed in large quantities, especially in exclusive feeding regimes.²¹ However, studies show that animals gradually exposed to diets containing this legume develop specific ruminal microorganisms capable of degrading mimosine, significantly reducing its adverse effects.²² In the Municipality of Gambos, where extensive livestock farming is the foundation of productive sustainability and faces worsening droughts, the use of this species must be carefully integrated. For this reason, its application in mixed feeding systems is recommended, combining forage cactus or grasses with *L. leucocephala* to avoid exclusive consumption, thereby ensuring the resilience of agro-livestock systems in the face of the high climate variability observed in southern Huíla.

Interview results and species utilization

The 30 participants interviewed were distributed across five communities in the Municipality of Gambos, including livestock breeders, farmers, community leaders, and technicians from the agriculture and livestock sectors. The predominance of livestock breeders in the sample highlights the region's strong dependence on

livestock farming. Regarding animal feed utilization, results indicate that *Opuntia ficus-indica* is widely adopted as a complementary fodder resource during dry periods, valued for its high water availability and its capacity to ensure livestock survival in adverse climatic conditions. In turn, *Leucaena leucocephala* is used as a source of animal protein, standing out as a strategic food supplement and an alternative to natural pastures during times of scarcity. Interviewees recognized that both species play a strategic role in the local rural economy, contributing not only to animal feed but also to income generation through the production of firewood, charcoal, and the commercialization of fruits (in the case of *Opuntia ficus-indica*). This contribution was linked to increased resilience of rural families in the face of recurrent droughts, as diversifying livelihood sources helps mitigate the economic vulnerability imposed by the scarcity of natural pastures and climate variability in Gambos.

Originally, these species were introduced through planting programs and the establishment of cultivated areas; however, their expansion beyond initial introduction sites is currently observed. Natural dispersal has significantly contributed to this process, occurring mainly through the passage of seeds through the animals' digestive tracts and subsequent deposition in manure which acts as a transport and fertilization agent as well as zoochorous dispersal by fruit-eating birds, favoring the colonization of new areas.

Ecological risks associated with invasive character

Despite the identified benefits, many participants are still unaware of the magnitude of these species' invasive potential. This lack of awareness regarding potential invasions and the risk of uncontrolled expansion are critical factors, as they can result in the reduction of native pastures, direct competition with local flora, and changes in vegetation structure.

In the context of Gambos, this knowledge gap reinforces the need for awareness strategies and technical training for breeders, aiming to reconcile fodder production with the preservation of ecological balance.

Discussion

The integration of these species in Gambos should not be random but based on nutritional synergy: these species exhibit high functional complementarity. *Opuntia ficus-indica* provides water and energy in the form of soluble carbohydrates, while *Leucaena leucocephala* contributes a high protein content, exceeding 20%, which allows for improved productive performance of ruminants when used in conjunction.²³ This physiological and chemical differentiation makes the two species highly complementary in ruminant feeding systems, as the combination of an energy and water source with a protein legume significantly improves the weight gain and feed efficiency of livestock.^{11,24} In the Municipality of Gambos, this synergy takes on strategic importance, given that the local economy predominantly depends on the raising of cattle, goats, and sheep, and the availability of fodder during the dry season is vital for the maintenance of

production systems. Faced with the scenario of climate change, which has intensified the severity of droughts and limited the availability of water and natural pastures in the region, the integration of these species emerges as a resilient scientific solution. Thus, in contexts such as Gambos, where pasture scarcity is critical for long periods of the year due to high rainfall variability, this combination serves as an effective strategy to mitigate animal food insecurity and reduce pressure on natural resources.

Invasive risk assessment

Although they represent an adaptive solution in the face of climate change and the degradation of natural pastures, both species possess a high invasive potential, potentially affecting biodiversity and altering the structure of local ecosystems if not properly controlled.¹ *Opuntia* can form dense and impenetrable thickets of accumulated biomass that physically block livestock access to natural grazing areas, while *Leucaena leucocephala* possesses a high germination rate, dominating disturbed ecosystems and competing with the native flora of the wooded savanna. Thus, their use must be framed within sustainable management strategies based on agroforestry and silvopastoral systems, with the delimitation of cultivation areas, dispersal control, continuous monitoring, and producer training. In this way, it is possible to balance the socioeconomic benefits associated with animal food security with the mitigation of ecological risks, ensuring a more resilient and sustainable management of natural resources in Gambos.²⁵

Imperative management recommendations

The integration of *Opuntia ficus-indica* and *Leucaena leucocephala* in the Municipality of Gambos must be mandatorily linked to sustainable pasture management policies, ensuring that the transition toward resilient agro-livestock systems does not compromise local ecological integrity. To this end, intervention strategies should include:

- i) The strict delimitation of cultivation areas, preventing spontaneous dispersal into conservation zones
- ii) The active control of natural dispersal through periodic surveillance and manual removal of extra-productive expansion foci
- iii) Implementation within planned agroforestry and silvopastoral systems that optimize land use and nutritional complementarity
- iv) Technical training for local breeders, focused on managing anti-nutritional factors and fodder processing
- v) Continuous ecological monitoring.

Conclusion

The study demonstrates that *Opuntia ficus-indica* and *Leucaena leucocephala* constitute fundamental resilience tools for the sustainability of livestock farming in the Municipality of Gambos, Huíla province, acting as strategic buffers against recurrent severe droughts. These species are essential for animal feed and rural livelihoods, ensuring water, energy, and protein reserves during critical periods. However, they present significant ecological risks associated with their uncontrolled expansion, which demands sustainable management strategies that balance productivity with environmental conservation. Given their nature as invasive alien species, it is imperative that they are managed strictly as strategic fodder supplements and never as substitutes for native vegetation. It is fundamental that public policies promote a dynamic balance between the economic productivity of the livestock sector and the preservation

of local biodiversity. To this end, technical training for breeders is recommended, focused on the management of anti-nutritional factors and fodder processing, alongside the implementation of a regulatory framework for sustainable pasture management that integrates these species in a controlled manner. Such measures are crucial to ensure that agro-livestock development does not compromise the ecological integrity and natural heritage of southwestern Angola.

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Conflicts of interest

The authors declare no conflict of interest.

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