Economic and Socio-environmental impact assessment of a silvopastoral system in Mato Grosso do Sul state, Brazil

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Abstract

Silvopastoral systems, also known in Brazil as Integrated Livestock-Forestry Systems (ILFS), are a promising alternative for marginal agricultural areas in Mato Grosso do Sul state. This paper analysed the economic viability of a representative ILFS in the state Central-East region and, using Ambitec-Agro model, assessed the associated socio-environmental impacts. We used panel data with experts to build an eight-year cash flow used in follow-up investment analysis and found ILFS was more economically attractive then extensive beef systems (BF), typical in poor soil regions. However, implementation costs and uneven distribution of income over the years can be detrimental to adoption by some farmer groups. Results showed an improvement of several socio-environmental indicators by replacing BF for ILFS. Policymakers should account for those economic barriers when developing supporting strategies for farmers and should also promote specific initiatives to stimulate the forestry sector, in general, and Silvopastoral systems specifically, in other marginal areas of Mato Grosso do Sul state.

Key-words: Ambitec-Agro; Beef farming; Integrated farming system; Sustainable livestock; Technological impact analysis.

Introduction and purpose

An additional demand for meat, of 200 million tonnes, is estimated to feed the global population, which is expected to reach 9.8 billion people by 2050 (FAO, 2017). Much of this demand will be met by developing countries, particularly Brazil. One alternative is through integrated farming systems (IFS), such as integrated crop-livestock-forestry (ICLF) and their combinations (Pereira et al., 2018). In addition to promoting sustainability, the diversification of production using IFS can result in rapid and sustained increase in the supply of meat, milk, grains, wood and energy-based products. The Brazilian Government has been fostering these systems through public policies, like the Plan for Low Carbon Agriculture (ABC) and its newest version, the ABC+ (BRAZIL, 2021), by facilitating access to low-interest credit for farmers. Locally, state policies for mitigating carbon emissions are also supportive of such production systems (SEGOV, 2019; SEMAGRO, 2021a).

Mato Grosso do Sul (MS) has the potential to widely implement and benefit from IFS. The state is the third major beef producer in Brazil, with a herd of over 20 million head, now facing the challenge of increasing productivity, reducing environmental impact, while still remaining competitive. Beef farming is of paramount importance to MS culture and economy, being responsible for 56% of the formal jobs in the state agriculture. Along with cash crops, responded for 17% of the state Gross Domestic Product (GDP), generating US$ 800 million in exports, in 2021 (SEMAGRO, 2021b). Additionally, there has been increasing demand for paper, celluloses and laminated timber over the last ten years in the state Eastern region driven by major wood processing factories established there (Laura et al., 2021). MS has over 3,2 million ha already under IFS (Rede ILPF, 2021). According to Kleffman consultancy, in 2015-2016, 83% were integrated as crop-livestock (ICL), and only 7% estimated as livestock-forestry integration (ILF), usually established in marginal agricultural areas. Among the advantages of adopting integrated livestock-forestry systems (ILFS), or silvopastoral, are the production diversification, risk reduction, animal welfare assurance (Pereira et al., 2018), added value production and, more recently, payment for ecosystem services (Malafaia et al., 2019), among others.

The low adoption of ILFS in MS raises questions about possible limitations of such systems. Arango et al. (2020) call attention to main factors limiting the adoption of sustainable technologies, including silvopastoral systems: access to credit, resources and information. This article aims to gain insights about the economic, social and environmental aspects related to silvopastoral systems, possibly influential on farmers' adoption behaviour.

Objectives

We aim to contribute to knowledge gap, by analysing the economic viability of a representative hypothetical silvopastoral system in Mato Grosso do Sul and by assessing its associated socio-environmental impact. In particular, our objectives are to:

1. Compare the economic performance of a representative ILFS in Central-East region of Mato Grosso do Sul and traditional beef farming (BF);
2. Assess the socio-environmental impacts of changing from traditional beef farming to ILFS.

Methods

A panel with ten experts was carried out in 2018, involving extension professionals, researchers and farmers, to raise the technical coefficients of a typical silvopastoral system, in the Central-East region of Mato Grosso do Sul state, Brazil, which is described in the next section. We considered all operational costs (inputs and services) and income generated by the system as a whole (i.e. ILFS) per hectare to build an eight-year cash flow, using 2020/2021 prices. With the data at hand, we run investment analysis and calculated the net present value (NPV), annualized NPV (NPVa), benefit-cost ratio and payback period.

The economic impacts were based on the “Economic Surplus Method”, described in Ávila et al. (2015). This framework has been used at the Brazilian Agricultural Research Corporation – Embrapa - for over 20 years and poses that the economic benefits and costs of new technology uptake must be estimated by comparing to the previous technology (baseline), that had been replaced. Thus, benefits and costs are relative, when using the method. According to Avila et al. (2015), the four main types of economic benefits are: productivity increase, cost reduction, expansion into new areas and/or added value products. In our study, we considered the benefits of a silvopastoral system (ILFS), expanding to new marginal areas in the state of MS, previously established with low-productivity beef farming.

To estimate the area of adoption, secondary data was used from Rede ILPF. In 2020-2021, there were 3,16 million ha with integrated farming systems (IFS) in MS, of which 2% was ILFS (about 63,000 ha).

The socio-environmental impacts were assessed using the Ambitec-Agro method, developed by Embrapa Environment (Ávila et al., 2015). Ambitec is an easy-to-use multi-criteria spreadsheet-based method that encompasses the following aspects: 1. Use of Inputs and Resources; 2. Environmental Quality; 3. Respect for the Consumer; 4. Employment; 5.
Income, 6. Health; and 7. Management” (further details in Ávila et al., 2015). Each aspect involves various weighted indicators, each of them scored by the technology users (-3 to +3), who also indicate the scale of occurrence (on the field/paddock, within the farm or the surrounding). In order to equalize for different numbers of indicators within the aspects, the weighting process is normalized (Figure 1). The positive and negative scores for the aspects and their constituents’ indicators show whether the adoption of the novel technology (in our study, ILFS) has improved or worsened them by replacing the former technology (i.e., BF).

Table of change coefficients for variable

Water Quality		Water quality variable: Biochemical Oxygen Demand	Turbidity	Floating materials / Oil / Scum	Siltation	weighing factor check
Weighing factors k		-0,5	-0,25	-0,25	0	-1
Scale of occurence = Non-applicable	Mark with X				X	
Near	1	-1	-3			
Proximate	2			-3		
Surrounding	5					
Impact Coefficient = (change coefficients * weighing factors)		**0,5**	**0,75**	**1,5**	**0**	**2,75**

Figure 1. Example of the water quality indicator, a component of the Environment Quality aspect (Source: Ávila et al., 2015).

Once the scoring phase is complete, a Technological Innovation Impact Index is calculated, ranging from -15 to 15, “by averaging all the normalized impact indices for the aspects considered” (Ávila et al., 2015).

Results and discussion

Silvopastoral system description

According to panel data, a typical silvopastoral system is generally established in 20% of a 2,000-ha farm in Central-East of Mato Grosso do Sul state, replacing former degraded pasture. This Savanna region has poor sandy soils (Quatzarenic Neossol), marginal for cash crops, being more suitable for beef farming and forestry. In this study, we compare the integrated livestock-forestry system (ILFS) against beef farming alone (BF). The typical production system consisted of tree arrangements of *Eucalyptus urograndis* for pulp production (clone I144) with four rows (3 m x 2 m) and 20 meters between rows (441 trees/ha), where pasture of *Urochloa brizantha* cv. BRS Piatã is cultivated. At the establishment of ILFS and BF, the soil is prepared and has applications of 2 t/ha of limestone and 0.5 t/ha of gypsum. Additionally, ILFS has applications of preplant herbicides, 93 kg/ha of Natural Reactive Phosphate (NRP), 121 kg/ha of 10-27-10 (Nitrogen-PhosphorousPotassium (NPP)) fertilizer and a cover fertilization with 66 kg/ha of 20-00-20. BF has applications of 300 kg/ha of NRP and 200 kg/ha of 20-00-20 (NPP). Cover fertilization with 70 kg/ha is carried out on IFLS until year four, then raised to 250 kg/ha on year five, and discontinued afterwards. BF only has a cover fertilization of 250 kg/ha on year five. Crossbred feeders are raised with low-intake supplements during the dry season (May-October).

The yields and average prices for beef and timber are presented in Figure 2.

Agricultural outputs	*Yield (unit/ha)* *ILFS*	*BF*	*Prices (USD/unit)*[2]
Beef	kg of live weight (kg LWT)		
Total production (8-yr period)	1,452	1,946	1.80
Annual average	182	243	1.80
Wood for pulp	m^3		
Production (year 8)	230	-	12.14

[1] Average exchange rate (2020/2021): 0.189 BRL:USD (www.xe.com/pt/currencytables/). [2] The unit is shown on the yield columns (e.g. USD 12.14/m^3 for timber).

Figure 2. Estimated agricultural outputs and associated prices[1] (2020/2021).

Economic Performance

The implementation costs were estimated at USD 682.3 and USD 455.8 ha^{-1} for IFLS and BF, respectively. Considering the systems yields, output prices (Figure 2) and costs, the annual net benefits were calculated (Figure 3).

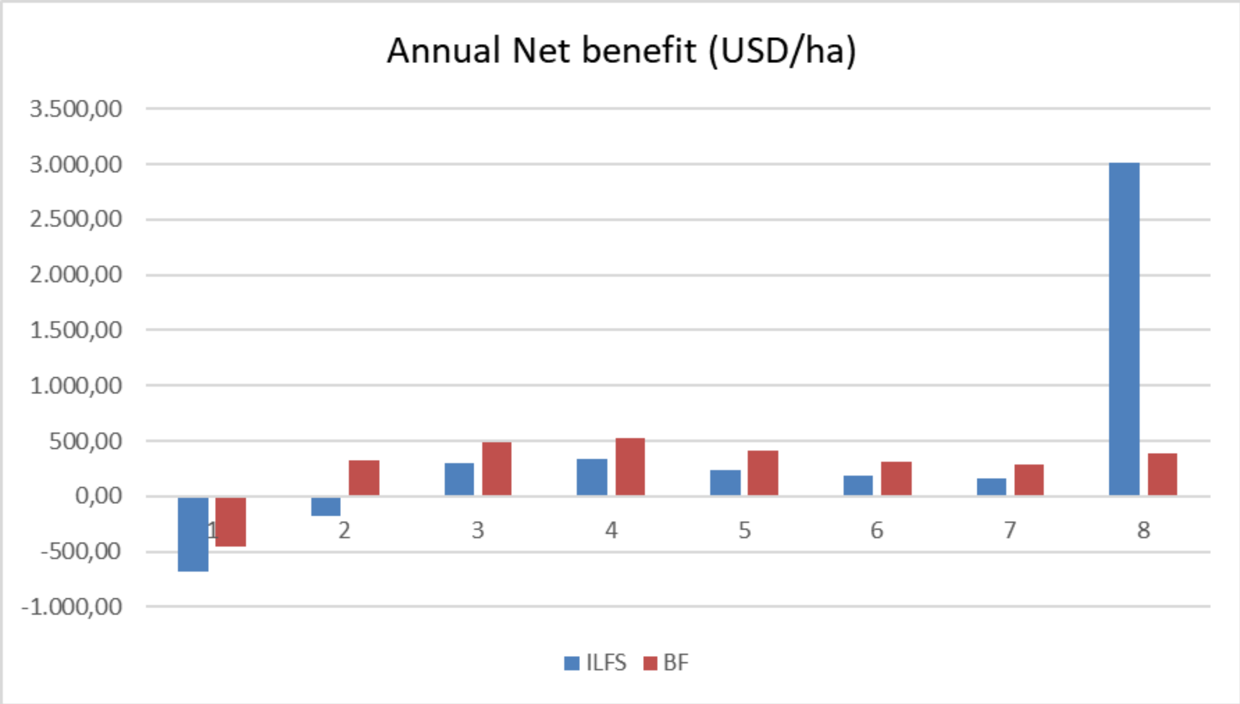

Figure 3. Annual net benefit from ILFS and BF, at 2020/2021 prices.

As shown in Figure 3, the distribution of income is uneven for ILFS, with implementation costs concentrated at the beginning and a major benefit (USD 3,210 ha^{-1}) at the end of the production cycle. This is in sharp contrast with BF, whose income was more or less stable.

Estimated beef production was higher for BF than for ILFS, given the reduced net pasture area available for cattle and delayed grazing for up to one year post-planting the trees in ILFS. In BF, grazing is allowed few months after pasture establishment. Nonetheless, in mixed farming, the combined result is more important than the result of the parts individually, since trade-offs amongst the system components are expected (Pereira et al., 2018).

The investment analysis contributes in this regard, offering a holistic long-term analysis of the systems as a whole. Table 1 shows that the Net Present Value (NPV), and consequently NPVa, was higher for ILFS than BF, suggesting better returns for the former, at 6% discounted rate. The additional annual income from ILFS was USD 64.36 ha^{-1}. Pereira et al. (2019), studying two silvopastoral systems in the same region, with 178 and 441 trees ha^{-1}, found NPVs of USD 1,062 and USD 1,126, respectively, and only USD 632 for beef farming, corroborating our findings.

It is worth noting that, in 2021, beef prices peaked in Brazil (Portal do Agronegócio, 2021) and fertilizers prices also increased significantly, while timber prices are still recovering from the economic crisis resulting from the pandemic. BF benefitted from this situation for producing more meat than ILFS, with less applications of fertilizers in the system, but remained less economically attractive than ILFS.

Table 1. Investment parameters for ILFS and BF, in Mato Grosso do Sul state, Brazil (2021).

Parameters	ILFS	BF

[1] The payback here does not include investment capital, such as machinery purchase. Since we are using operational costs, the internal rate of return would be overestimated and was disregarded.

NPV (USD/ha)	2,141.53	1,741.83
NPVa (USD/ha)	344.86	280.50
B/C	3.52	4.82
PBK (yr)	2.83	2.34

The payback period[1] was slightly longer and the benefit-cost ratio was lower for ILFS than for BF because the discount rate has higher impact in future results, where most ILFS net benefit occurs, leading to a reduced net benefit at present for this production system. Given the economic results above, and considering the estimation of 63,000 ha under silvopastoral systems in MS state, the estimated wood production for pulp is 14,5 million m^3 while the annual beef production is 11.4 thousand tonnes (about 91 thousand tonnes in eight years) under ILFS. At 2021 prices, the total gross production value would reach almost 200 million dollars.

Socio-environmental assessment

From a socio-environmental standpoint, the use of ILFS is fully justified. According to the system users and other specialists, ILFS improved the majority of indicators considered in the Ambitec-Agro model, resulting in positive scores for all seven aspects, compared to BF (Figure 4).

Criteria for impact assessment	Importance weighing factor	Criteria impact index	Integrated Index
Direct land use change	0.05	3.8	Use of inputs
Indirect land use change	0.05	7.7	
Water consumption	0.05	5.0	
Use of agricultural inputs	0.05	0.2	
Use of vet inputs and raw materials	0.05	3.5	
Energy consumption	0.05	-0.3	
Self-generated energy, reuse and autonomy	0.025	0.9	0.71
Atmosphere emissions	0.02	5.9	Environmental quality
Soil quality	0.05	12.5	
Water quality	0.05	1.8	
Biodiversity conservation and environmental restoration	0.05	-0.4	4.95
Product quality	0.05	0.3	Customer respect
Social capital	0.02	6.8	
Animal welfare and health	0.02	10.3	5.83
Training	0.02	8.3	Employment
Opportunity and qualification for local employment	0.02	3.2	
Employment & occupation quality	0.05	5.0	
Gender , generation and ethnical equity	0.02	0.9	4.33
Net income generation	0.05	6.7	Income
Land value	0.02	9.0	7.83
Occupational safety & health	0.025	-0.1	Health
Food safety	0.05	4.8	2.34
Farmer capability and dedication	0.05	10.4	Management
Trade arrangements	0.05	4.3	
Waste disposal	0.02	0.8	
Chemical inputs management	0.02	0.0	
Institutional relationship	0.02	7.9	4.70
Weighing factor check	1	Integrated performance index	4.34

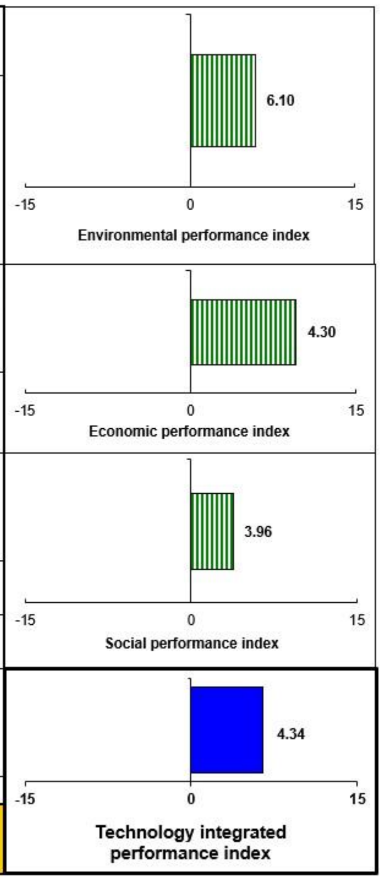

Figure 4. Socio-environmental impact assessment of ILFS in Central-East of MS state, using the Ambitec-Agro method.

The follow-up interviews to justify the users' perceptions throw light at relevant aspects of the mixed farming approach. Some of them are explored below.

With respect to the use of inputs, the most outstanding impact occurs on the indirect land use change (score 7.7). Given the possibility of producing both wood and beef on the same area, the land-saving effect is very evident in their opinion, reducing pressures for further deforestation, as Martha Jr. et al (2012) also discuss. However, energy consumption, i.e., fossil fuel, increased slightly because of machinery operations required (planting, trimming, fertilizing and cutting trees). The direct use is also improved since ILFS increases the overall production level, the carbon storage and biodiversity, when compared to pasture solely. Water availability increases due to the trees, which hold humidity within the system, as they argued, in line with Bosi et al. (2020). The trees also provide shade to cattle, which has implications for animal welfare, noted by interviewees, as the high score for this indicator suggests (Figure 4, Customer respect Aspect). Karvatte Jr. et al. (2016) explain that shade reduce water consumption for body temperature regulation.

Regarding the environmental quality, the soil quality is the most benefitted by ILFS, as panel data shows. Trees and pasture operate in synergy: fertilizations benefit both activities; different growth patterns of tree and grass roots play complementary work (i.e., tree roots recycle nutrients from deep soil whereas grass roots improve the physical and biological conditions of superficial layers) (Chará et al., 2019). GHG emissions are mitigated by the presence of the trees, which capture carbon in their trunks, and by good management practices required by such systems. This is in accordance with research results (Almeida et al., 2016; Arango et al., 2020).

On social aspects, panel data demonstrate a recognition for the complexity of mixed farming and scored high several associated indicators, such as: social capital (including the increase in technology transfer and extension work); training (all sorts and levels); employment and occupation quality (the offer of permanent positions on the farms and demand for more specialized workforce) as well as training and dedication of farm owners to manage ILFS. The latter, in particular, are required since the introduction of trees in traditional beef farming leads farmers to operate in a different market with different rules and players, as they pointed out. A consequence is the increase in institutional relationships, specially, technical assistance and consultancy, as indicated by the 7.9 score of this indicator.

Finally, their perceptions on the economic impacts of changing from BF to ILFS corroborates the economic analysis presented previously. The high score for net income generation and land value is evidence.

The combined results of all aspects, within the three dimensions, generated a weighed integrated performance index of 4.34 for ILFS, which is relatively high for farming systems, given their complexity, multiple iterations and tradeoffs. In part, this positive result is also explained by the low number (and magnitudes) of indicators with negative scores.

Integrated analysis and discussion of the findings

Our findings corroborate previous results that demonstrated ILFS presented greater economic responses compared to BF solely (Pereira et al. 2018; 2019). In general, diversification of beef farming with the introduction of trees for pulp or timber production has been economically attractive for farmers, showing higher NPV than extensive pasture-based systems, typical in marginal areas, such as Central-East of Mato Grosso do Sul. There are opportunities for farmers to convert areas, given the pulp and paper cluster established in this region, and other processing plants available. In a decade, Mato Grosso do Sul changed from the 14th to the 3rd largest producer of pulp and paper in Brazil (Gamarra, 2021). However, outside this cluster there may be logistic problems for wood trade due to freight costs.

Alternative use of timber should be considered, therefore.

Our findings also confirmed previous studies (Pereira et al., 2018; 2019) which found higher implementation costs for ILFS than for BF, which can be an entry barrier for farmers willing to convert areas. This may be softened by their level of (and willingness to) access to credit through the ABC+ Plan, that promotes the adoption of all IFS. Additionally, the uneven nature of net benefits distribution through the production cycle may pose another challenge for farmers managing tight budgets. Eventually, they need to be aware and make an informed decision whether to pursue better profitability (i.e., ILFS) or better income stability (i.e., BF) strategies, since both farming systems were economically viable.

Malafaia et al. (2019) call attention to additional opportunities for ILFS like payments for environmental services and carbon credits, or the addition of value to products (e.g., Carbon Neutral Brazilian Beef (CNBB), Certified Wood etc.). According to Almeida et al. (2016; 2019) and Alves & Almeida (2017), silvopastoral systems are eligible for CNBB as long as there are enough trees to offset cattle GHG emissions and timber is used only or in part in sawmills.

At state level, other marginal areas, like the South-Eastern, have potential to develop further, but would require government investments and tax incentives to attract large companies. Further developments of the forestry sector, thus, can bring new business opportunities for local farmers and contribute twofold to the state 2020-2023 Multiannual Plan guidelines (SEGOV, 2019): (i) Economic development, by inducing beef farming sustainable intensification; and, (ii) Environment, by promoting GHG mitigating strategies.

From a social and environmental perspective, our findings suggest, and other studies confirm, the adoption of ILFS improve both aspects. Whether our panellists' perceptions can be widely extrapolated is open to discussion, as their experience and level of training may be much higher than the average beef farmer – the potential adopter of ILFS. Nonetheless, data indicated consensus on the role ILFS play in improving the soil and the microclimatic conditions with positive effect on animal welfare, and in promoting shelter for various animal species, compared to monoculture pasture. In addition, the need for trained and permanent workers improves employment relations, but also introduces the risk of increasing the dependency on external workforce. Amongst the ten "megatrends" anticipated for beef farming in Brazil, one of them is a shortage of qualified rural workers (Malafaia et al., 2019).

Conclusion

Combined beef and wood production for pulp, under a silvopastoral system, is economically more attractive than extensive pasture-based systems in marginal areas of Mato Grosso do Sul. The socio-environmental impact of ILFS improve significantly several sustainability indicators, reinforcing the benefits of this strategy. Overcoming entry costs and uneven cash flow remain barriers for willing farmers, however. Policymakers should consider these barriers, both at farm and state levels, when developing supporting strategies for farmers and also promote specific initiatives to stimulate the forestry sector in other marginal areas.

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