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Abstract

The objective of this study was to evaluate the potential of improve economic value of integrated crop-livestock systems in comparison to conventional systems specialized in monoculture. Empirical studies have demonstrated the environmental benefits of integrated crop-livestock systems, however the potential for creating economic value these systems are controversial, especially in emerging countries, where the necessity to expand the food supply needs be associated with better land use. This research evaluated six models of integrated systems and two conventional systems (corn grain production and pasture beef cattle production) in the south-eastern region of Brazil for two years. The models were conducted in an experiment to replicate the main management possibilities in the integrated systems. We show for the first time the economic impact analysis combined the risk optimization and discounted cash flow techniques based on Monte Carlo simulation, considering the price and productivity uncertainties of each system. Results indicated that, for the indicators of added value and return on investment, integrated crop-livestock systems had an economic advantage when compared to conventional systems. It was also found that integrated crop-livestock systems needed a smaller operational area for the economic break-even point to be reached.

Keywords: beef cattle, feasibility financial, integrated systems, maize, pasture

Author contributions

All authors contributed to the study conception and design. FFS, GGM, JGA, JGO and LSM conducted experiments. FFS, GGM, AHG and DFLS elaborated and analysed data. The first draft of the manuscript was written by FFS, GGM and DFLS and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

1. Introduction

Systems that integrated animal and plant cultures were the basis of food production for ancient civilizations. However, when facing the challenges of a growing demand for food post-World War II, a search began for means of improving productivity. This resulted in a trend towards specialization of plant and animal systems, and the implementation of monocultures (FAO, 1955; Dumont *et al.*, 2013; Gameiro *et al.*, 2016; Mendonça *et al.*, 2020).

A Conventional System (CS) is based on the intense use of agricultural machines and implements, chemicals for applying nutrients and fighting pests, and non-renewable energy sources, with the aim of high crop productivity (Mendonça *et al.*, 2020).

Although CS have provided gains in crop productivity and food security (Foley *et al.*, 2011; Reis *et al.*, 2020), the use of this type of system have been linked to declining biodiversity and negative environmental impacts on ecosystems around the world, leading the feasibility of other, alternative, agricultural production models being mooted (Branca *et al.*, 2021; Moraine *et al.*, 2016; Hunt *et al.*, 2016).

Over the past decade, research has addressed possibilities for measuring environmental problems, as well as different configurations for agricultural systems that make it possible to minimize impacts on ecosystems and their natural resources, while still producing viable economic returns and sufficient food (Herrero *et al.,* 2015; Reis *et al.,* 2020). It is in the context of depletion of natural resources, that the systems that integrate plant and animal cultures are once again approached by science, as an alternative means of producing economically and environmentally viable food (Branca *et al.,* 2021; Gil *et al.,* 2015; Florindo *et al.,* 2020; Lazicki *et al.,* 2016; King and Hofmockel, 2017).

Research has already shown benefits of ICLS, when compared to conventional systems, in relation to physical, chemical and biological soil properties (Ryschawy *et al.,* 2017; Olson *et al.,* 2017), nutrient cycling, natural control of invasive plants and, consequently, the decrease the use of chemical products (Tully and Ryals, 2017; Schuster *et al*., 2019). Thus, is good evidence for the potential of ICLS to be help meet environmental challenges, with results demonstrating the sustainability and resilience of this type of system (Ryschawy *et al.,* 2013; Lemaire *et al.,* 2014). However, there is a gap in information - proof of the economic efficiency of ICLSs (Wilkins, 2008; Rego *et al.,* 2017; Rosa-Schleich *et al.,* 2019; Sneessens *et al.,* 2019; Reis *et al.,* 2020).

Accordingly, the current study investigated the economic viability of Integrated Crop-Livestock System and Conventional System, based on the Discounted Cash Flow (DCF) method in which the productive and market volatilities were controlled via a Monte Carlo Simulation. With the DCF it was possible to analyze the indicators of Net Present Value, Added Value, Return on Investment and the Break-even-Point (Nordblom *et al.*, 2021). This is the first to analyze the effects of diversifying the production of the Integrated Crop-Livestock System on production risk compared to the Conventional System.

This methodological approach expands on recent results obtained in other studies (Reis *et al.*, 2020; Mendonça *et al.*, 2020), indicating not only the economic benefits, but in which conditions of production systems are viable.

2. Material and methods

2.1. Site description

The experiment was conducted between November 2015 and January 2018 at the Centro de Pesquisa de Bovinos de Corte, Instituto de Zootecnia/APTA/SAA, Sertãozinho, São Paulo, Brazil (21°8'16" S and 47°59'25" W). The average local altitude is 548 m. The regional climate, according to the Köppen classification, is Aw, characterized as humid tropical, with a rainy season in summer and dry season in winter. The soil of the experimental area is classified as very clayey dystrophic Red Latosol (Santos *et al.,* 2018), equivalent to the Oxisol under the USDA Soil classification (Soil Survey Staff, 2014).

2.2 Production systems models

The experiment was carried out in a 16.02 ha area, divided into 18 paddocks of 0.89 ha. Each was organized in a randomized block design, with three replications and six Models of production systems: Crop System (corn grain production); Livestock System (beef cattle in pasture) and four Integrated Crop-Livestock System (ICLS) (ICLS-1, ICLS-2, ICLS-3, ICLS-4). The Integrated Crop-Livestock System variants were as follows: ICLS-1 maize plus Marandu grass sown simultaneously without herbicide; ICLS-2 maize plus Marandu grass sown simultaneously with herbicide; ICLS-3: maize plus Marandu grass with lagged sowing; ICLS-4: maize plus Marandu grass sown simultaneously in maize rows and between-rows with herbicide. All production systems were sown in December 2015 under no-tillage systems.

In the crop system, Pioneer P2830H maize (*Zea mays*) was sown at 75 cm in-row spacing, a seeding density of 70,000 plants ha^{-1}. At the time of sowing, 32 kg ha^{-1} of nitrogen (urea), 112 kg ha^{-1} of P_2O_5 (simple superphosphate), and 64 kg ha^{-1} of K_2Cl (potassium chloride) were applied. In addition, 80 kg ha^{-1} of nitrogen (urea) and 80 kg ha^{-1} of K_2Cl (potassium chloride) were applied to the maize twenty days after sowing (second fertilization). Maize was planted for two consecutive years (December 2015 and December 2016), providing two harvests of maize grains (May 2016 and 2017). The field was left fallow between one harvest and the next.

For the livestock system, *Urochloa brizantha* (Hoechst. ex A. Rich.) R.D. Webster cv. Marandu (syn. *Brachiaria brizantha* cv. Marandu) pasture was sown at 37.5 cm row spacing, a seeding density of 5 kg ha^{-1} (76% of cultural value). The Marandu grass seeds were mixed with the sowing fertilizer: 32 kg ha^{-1} of nitrogen (urea), 112 kg ha^{-1} of P_2O_5 (simple superphosphate), and 64 kg ha^{-1} of K_2Cl (potassium chloride). In addition, 40 kg ha^{-1} of nitrogen (urea), 10 kg ha^{-1} of P_2O_5 (simple superphosphate), and 40 kg ha^{-1} of K_2Cl (potassium chloride) were applied to the pasture in October 2016 and March 2017. Ninety days after sowing, the pasture was ready for grazing (March 2016). Three continuous stocking cycles were performed: the first cycle between March and April 2016 (30 days), the second between August and October 2016 (78 days), and the third between November 2016 and December 2017 (370 days).

For the ICLS, four types of Marandu grass and maize intercropping were studied. The same cultivar, row spacing, seeding density, and fertilizers as described for the crop system and the same seeding density, fertilizers as described for the livestock system were used for all integrated systems. For ICLS-1, Marandu grass was sown simultaneously with maize in the sowing row. For ICLS-2, simultaneous sowing was also performed, but 20 days after maize germination 200 ml ha^{-1} of the herbicide nicosulfuron (8 g ha^{-1} of active ingredient) was applied. For ICLS-3, Marandu grass was sown 20 days after maize had been sown (lagged sowing), for this purpose, the grass seed was mixed in the fertilizer for the second fertilization and between-row sowing was performed using a cultivator. For ICLS-4, Marandu grass and maize was sown simultaneously, but with the grass seed sown within and between the maize rows, resulting in a spacing of 37.5 cm. Exclusively for this system, the sowing fertilizer and the amount of grass seeds were divided between and within the maize rows to guarantee an equal mixture of grass seed and fertilizer. In addition, 200 ml ha^{-1} of the herbicide nicosulfuron (8 g ha^{-1} of active ingredient) was applied 20 days after maize germination. In all integrated systems, the maize was harvested in May 2016. Ninety days after harvest, the pastures were ready for grazing. Two continuous stocking cycles were performed: the first cycle between August and October 2016 (78 days) and the second cycle between November 2016 and December 2017 (370 days).

For economic analyses, two years of the project were used, in which the results of the first corn harvest (2016) and the weight of the animals and stocking rate for the first grazing cycle (August to October 2016) and the second grazing cycle (November 2016 to December 2017) were considered.

2.3 - Animals

The stocking method was continuous with a variable stocking rate (put and take), according to Mott (1960) to Livestock system and ICLS. The Caracu beef cattle used were 14 months of age at the beginning of the experiment, with an average body weight of 335 kg. For the economic analysis of Livestock systems ICLS-1 to ICLS-4, animals in the growing phase until fattening (finishing) were considered, using 50% of the carcass yield.

2.4. Economic analysis

The economic analysis was carried out using the DCF, which is the most traditional and robust method for analysing investments, including the agricultural context (Rezende and Richardson, 2015; Faleiros *et al.,* 2018, Montoro *et al.,* 2019). Equation 1 shows the DCF calculation:

$$DCF = \sum_{j=1}^{n} \frac{ACF_j}{(1+i)^t} \tag{01}$$

Where, ACF = Annualized Cash Flow; i = interest; t = time.

To calculate FCL, the following flow structure adapted to the Brazilian tax context was used Faleiros *et al.* (2018) and Farinelli *et al.* (2018):

(+) Gross Revenue
(-) Taxes on income (FUNRURAL)
(=) Net Revenue
(-) Variable Costs
(=) Contribution Margin
(-) Fixed Costs
(=) Earn Before Taxes, Interest, Depreciation and Amortization (EBTIDA)
(-) Depreciation
(=) LAIR
(-) Tax
(+) Depreciation

(=) Operational Cash Flow

(-) Investment Flow

(=) Free Cash Flow

To construct Cash Flow variables, the operational and productive parameters of the experiment and market information were used, so that the results of economic viability could be comparable to the real conditions of the rural properties in the experimental region. Monte Carlo Simulation was used in the results of the experiment to model cash flow (Table 1). Using this, it was found that the modal size for a rural property in the region was 75 hectares; a profile compatible with other studies in the region (Faleiros *et al.,* 2018; Farinelli *et al.,* 2018).

Table 1. First and second year production results for the empirical study system field-trials.

System	Year 1					Year 2				
	Maize (t/ha)			Beef cattle(@)		Maize (t/ha)			Beef cattle (@)	
	Mean	Min	Max	Mean	CV	Mean	Min	Max	Mean	CV
Crop	12.02	9.93	14.53	n.a.	n.a.	9.02	7.45	10.90	n.a.	n.a.
Livestock	n.a.	n.a.	n.a.	46.02	5.33%	n.a.	n.a.	n.a.	98	29%
ICLS-1	11.01	9.52	12.49	33.13	7.15%	n.a.	n.a.	n.a.	100	5.67%
ICLS-2	12.46	10.88	14.04	29.07	9.40%	n.a.	n.a.	n.a.	100	4.40%
ICLS-3	11.10	8.80	13.54	30.50	8.27%	n.a.	n.a.	n.a.	103	8.43%
ICLS-4	12.16	9.68	14.68	30.12	6.31%	n.a.	n.a.	n.a.	100	6.22%

Crop system (maize grain production); livestock system (beef cattle on pasture); ICLS-1: maize and Marandu grass sown simultaneously, without herbicide; ICLS-2 maize and Marandu grass sown simultaneously, with herbicide; ICLS-3: maize and Marandu grass in lagged sowing; ICLS-4: maize and Marandu grass sown simultaneously in maize rows and between-rows, with herbicide.

The prices and movement of maize and beef were based from Brazilian Mercantile and Futures Exchange (BM&F) values from January 2004 to December 2016, with the recorded values were combined to give an average value of R $ 38.14 for the 60 kg sac of maize and R$ 152.31 for the @ beef cattle (@ = 15 kg), with 17.32% and 9.33% being the respective variation coefficients. Price variability is shown Table 1, and this was used to perform a Monte Carlo Simulation, effectively combining the uncertainties inherent in productivity and the market.

The cost structure was segregated into variables. Fixed and non-remunerable expenses, such as depreciation, were not included, since the aim was to determine the economic break-even point of each activity. The variable costs of maize production include spending on soil preparation, planting, crop management and harvesting activities. Variable costs for meat production included expenses for the purchase of animals, veterinary care and medicines. Fixed costs values included labour, administration, insurance, maintenance of machines and taxes were included (a guide to the breakdown of these costs can be found in Mendonça *et al.,* 2020). For all analytical economic criteria, it was necessary to determine the annual cash flow (ACF) of each production system, allowing for the DCF determined by the two years of experiment results. Equation 2, shows the annual cash flow calculation based on a current value.

$$ACF = \frac{DCF \times i}{1 - (1 + i)^{-t}} \qquad (02)$$

Because cash flow structure represented estimated values, the two main uncertainties in the construction of this dynamic were the prices and productivity of maize and soybeans. To include the uncertainty inherent in the volatility of these variables, a Monte Carlo Simulation was used in which 10,000 simulations of possible results were generated for each treatment, in order to obtain greater precision in the probability distribution of the viability of each production system (Oliveira and Medeiros Neto, 2012).

It should be noted that the volatilities used were considered as independent, since the correlation between price variations of maize and beef was 0.27 and without statistical significance. To generate simulations, the possibilities of maize and beef prices and beef productivity were generated using a normal distribution pattern, following identification of normality via a Jarque-Bera test. For corn productivity, a discrete distribution pattern was used using the average, minimum and maximum values from the Crop System, ICLS-1, ICLS-2, ICLS-3 and ICLS-4 systems.

NPV determination used investment profiles specific to each production alternative. Thus, land values were not considered, since an investment already made (sunk costs) is configured for this type of analysis and does not have a future impact on the cash flow of any of the investments. As any investment required for each production system will have a time-limited life, this equipment use utility for the was used to calculate NPV. The calculation is given in Equation 3 (Farinelli *et al.,* 2018):

$$NPV = \sum_{j=1}^{n} \frac{OCF_j}{(1+i)^t} - I_0 \qquad (03)$$

To quantify each production system as a rural property production strategy, the calculation of valuation in perpetuity was used and, to provide a conservative approach, a real growth rate was not assumed (Faleiros *et al.,* 2018). The calculation is shown in Equation 4:

$$Valuation = \frac{ACF}{i} \qquad (04)$$

Added value represents the surplus obtained by a rural producer who decides to invest in one of the studied production systems. It considers all the necessary investment, including land. For the calculation of the added value of each production system, Equation 5 was used:

$$Added\ Value = Valuation - Total\ Investment \qquad (05)$$

As investment decisions in productive assets in agriculture do not have the same requirements as for assets traded in strongly efficient markets, such as: liquidity, information symmetry, dispersion between agents with supply and demand for capital, it was considered appropriate to analyse not only the added value, but the inclusive profitability of each investment, so allowing for comparison with other investment opportunities (Nordblom *et al.,* 2021). Therefore, Return on Investment (ROI) was used as an indicator, using Equation 6 (Farinelli et al., 2018).

$$ROI = \frac{Annual\ OCF}{Total\ Investment} \qquad (06)$$

The proposed cash flow calculation structure allows calculation of the break-even point for the operation area of each production system (Farinelli *et al.,* 2018). It is remarkable how this indicator has been generally ignored in agribusiness economic feasibility studies, despite it being highly relevant to producers, as well as having strong social relevance, since it can help indicate the viability of forms of investment that require less land use, can contribute to a reduction in the process of land concentration and, in effect, increase the sustainability of small- and medium-scale rural producers (Faleiros *et al.,* 2018). This break-even point calculation can be obtained by Equation 7.

$$BEP = \frac{\sum_{j=1}^{n} \frac{Fixed\ Costs_j}{(1+i)^t} + Total\ Investment}{\sum_{j=1}^{n} \frac{Contribution\ Margin\ per\ ha_j}{(1+i)^t}} \quad (07)$$

When determining production system discount rates, it was decided that rates should express the risk inherent in each system (as is generally modelled in the literature). Accordingly, the Capital Assets Pricing Model (CAPM) calculation structure was deployed, using Equation 8 (Montoro et al., 2019).

$$CAPM = i = R_f + \beta_s(R_m - R_f) \quad (08)$$

Where, R_f = Risk-free rate, β = systematic risk, R_m = Return on market portfolio.

For the risk-free rate, the Selic rate that backs Brazil's national treasury bills for January 2019 was used (when net remuneration was estimated at 6.4% per annum). The historical difference used by market analysts for the Brazilian market premium ($R_M - R_f$) was taken (8.9% per annum).

To determine the exact systematic risk for each production system, it would be necessary to analyse the covariance of past results for each system using the returns on the Brazilian market portfolio (Ibovespa). However, as a lack of information makes this impossible, risk of each production system were estimated considering the historical volatility of maize and beef prices on the Crop and Livestock System, respectively, while for the ICLS, risk was calculated based on the risk of a portfolio in which returns also vary together, according to Equation 9 (Farinelli *et al.,* 2018).

$$\sigma_{m,b} = \sqrt{\{[(w_m^2 \times \sigma_m^2) + (w_b^2 \times \sigma_b^2) + 2 \times w_m \times w_b \times COV_{m,b}]\}} \quad (09)$$

Where: w = weight of each asset (maize or beef) within the total system revenue; σ = risk, measured by the standard deviation in price changes for each asset.

Equation 9 allowed risk determination for each production system and for those with more than one product, allowing evaluation of the effect of diversification on the risks involved, when considering the second part of Equation 9, which aggregates the effects of covariance between maize and beef individual risks.

From this, the risk for each system was related to the Ibovespa-based risk, where β = 1, making it possible to estimate β values of each system using Equation 10:

$$\beta_s = \frac{\sigma_s}{\sigma_m} \tag{10}$$

Where, β_s = overall production system risk (s); σ_s = risk for each production system; σ_m = market portfolio risk (Ibovespa).

It should be noted that this procedure was performed as a proxy to identify the risk in each production system, which is expressed in the DCF model by the discount rate *(i)* and appears directly in the calculations of equations 1, 2, 3, 4 and 7.

In agribusiness-related literature a risk-free rate is frequently used as a discount rate for investment projects (Faleiros *et al.,* 2018; Montoro *et al.,* 2019). However, this use contradicts a theoretical assumption in the area of finance in which investments must be related to a rate that expresses its risk, considering the risk/return ratio inherent to each investment (Farinelli *et al.,* 2018; Montoro *et al.,* 2019).

Financial values were updated using the official Brazilian inflation index for January 2019 in Reais (R$). The average exchange rate between the Real and the United States dollar in January 2019 was R$ 3.74 = U$ 1.00.

3. Results

Mean present value consolidated results (Equation 2) for Cash Flow variables in each of the six analysed systems are given in Table 2. Net revenues generated by the ICLS were higher than for SC, possibly due to the better land-use.

Table 2. Averaged Current Cash Flow Values for the six analysed systems with 75 ha of production.

Cash Flow Variables	Crop	Livestock	ICLS-1	ICLS-2	ICLS-3	ICLS-4
(=) Net Revenue	803.918	1.480.380	1.848.407	1.906.637	1.916.328	1.877.192
(-) Variable Costs	428.304	1.219.894	1.315.642	1.319.218	1.368.167	1.304.326
(=) CM	375.614	260.485	532.764	587.418	548.160	572.865

(-) Fixed Costs	193.610	154.796	159.399	159.205	159.443	159.426
(=) EBITDA	182.004	105.690	373.365	428.213	388.717	413.439
(-) Depreciation	143.311	127.014	137.485	137.317	136.737	136.374
(=) PBT	38.693	-21.324	235.880	290.896	251.980	277.066
(-) Income tax	23.421	16.249	68.559	84.780	72.507	81.211
(+) Depreciation	143.311	127.014	137.485	137.317	136.737	136.374
(=) OCF	158.583	89.441	304.805	343.433	316.210	332.228
(=) OCF by year	93.491	49.130	168.034	189.560	174.274	183.354

Crop system (maize grain production); livestock system (beef cattle on pasture); ICLS-1: maize and Marandu grass sown simultaneously, without herbicide; ICLS-2 maize and Marandu grass sown simultaneously, with herbicide; ICLS-3: maize and Marandu grass in lagged sowing; ICLS-4: maize and Marandu grass sown simultaneously in maize rows and between-rows, with herbicide.

To calculate the current value of each variable, the discount rate *(i)* of each production system was used, and these were calculated using formulas 8, 9 and 10. Results appear in Table 3.

Table 3. Effect of operational diversification on the discount rate *(i)* of each treatment.

Systems	Risk Free (%)	With Crop (%)	With Beef (%)	Risk (%)	Beta	Real Discount Rate (%)
Crop	6.40	100	0	6.97	1.16	11.72
Livestock	6.40	0	100	2.98	0.50	6.51
ICLS-1	6.40	25.09	74.91	3.19	0.53	6.76
ICLS-2	6.40	27.50	72.50	3.25	0.54	6.85
ICLS-3	6.40	24.51	75.49	3.17	0.53	6.74
ICLS-4	6.40	27.29	72.71	3.25	0.54	6.84

Note: The calculated rate of inflation was 3.75% per annum. Crop system (maize grain production); livestock system (beef cattle on pasture); ICLS-1: maize and Marandu grass sown simultaneously, without herbicide; ICLS-2 maize and Marandu grass sown simultaneously, with herbicide; ICLS-3: maize and Marandu grass in lagged sowing; ICLS-4: maize and Marandu grass sown simultaneously in maize rows and between-rows, with herbicide.

The economic risk of the ICLS expressed as a discounted rate showed a high level of diversification, this was due to the weak price correlation between a sac of maize and Beef cattle (@) (0.27), which increased the natural hedge of these production systems, whose response was shown in the associated interest rates.

Annualized OCF is equivalent to a value for OCF per year, this indicates more clearly the differences between the net operating results of each production system, when risks involved are considered.

Even though the ICLS financial results are higher than those from the CS, the impact of risk diversification for each system, and the different fixed capital investment requirements must be comparatively evaluated, that is, in the differences in requirements for machinery, equipment, implements, tools, installations and utensils must be considered in such calculations.

Accordingly, Table 4 shows the main economic results, produced by the DCF Method developed in this study. It is important to note that, since the economic results were built from extrapolation of the empirical experimental results (Table 1), applied in the context of a model property in the region where the experiment was conducted, it was necessary to annualize all investment-related information using Equation 2. Additionally, current value annualized OCF was also used for the calculation of the Production System Value (Equation 5).

Table 4. Comparison of Production System Economic Result Means.

Systems	Annualized fixed capital investment (R$)	NPV (R$)	Probability of Positive NPV	ROI (%)	BEP (ha)	Production System Value / ha (R$)
Crop	71.595	154.429	65.33%	3.38	172	5.833
Livestock	94.895	-132.268	39.30%	1.71	383	-614
ICLS-1	105.598	653.611	90.91%	5.77	82	21.660
ICLS-2	105.467	771.936	93.63%	6.48	73	25.572
ICLS-3	104.787	674.415	90.31%	5.97	75	23.042
ICLS-4	104.536	733.586	92.73%	6.28	75	24.496

Note: The NPV averages were statistically different using the two-tailed t-test, with a 5% confidence level. Crop system (maize grain production); livestock system (beef cattle on pasture); ICLS-1: maize and Marandu grass sown simultaneously, without herbicide; ICLS-2 maize and Marandu grass sown simultaneously, with herbicide; ICLS-3: maize and Marandu grass in lagged sowing; ICLS-4: maize and Marandu grass sown simultaneously in maize rows and between-rows, with herbicide.

The differences in investments in fixed capital demonstrated that the ICLS required higher levels of spending on long-term resources. This comes from the need to develop more than one agricultural activity in the same area, which reinforces the need for an economic analysis of the viability of this investment. The Livestock System was not economically viable. Even with the lowest risk involved, it was the system with the lowest rate of return and, in effect, the lowest probability of having a positive NPV, across 10,000 simulations. The Crop System was the one that showed the greatest risk, as a result of greater combined volatility of prices and productivity, this was directly reflected in a higher discount rate. However, as the investment value was the lowest among all the production systems analyzed, the NPV of this system was positive.

On the other hand, when these indicators were evaluated via SC and ICLS, it was evident that greater efficiency in the use of resources allowed operating cash flow generation to be much higher than the highest investment level, so increasing the levels of profitability of the property (ROI), and resulting in positive NPV delivery having a high occurrence probability (> 90%).

For the treatments, the ICLS-related enhanced cash flow generation capacity had an impact on the area necessary to make each system viable, as can be seen in the breakeven points calculated in formula 7. All systems showed a positive contribution margin but, due to the value that each system generated across the different investment profiles, the ICLS had a lower BEP.

The per hectare production system valuation, that is, the perpetuity calculation for the capacity of each production system to generate free cash flow to the investor (Formula 4) is given in the final column of Table 4. This is the intrinsic value of the entire production structure established per hectare, according to the premises of corporate finance (Danthine and Donaldson, 2014; Farinelli *et al.,* 2018). The ICLS gave economic results that were statistically more robust than the SC.

It was clear that, in the long term, between production system differences existed in the potential for value creation, especially between ICLS treatments and the CS. However, these values were below the experimental region values for land acquisition (the mean per hectare being R $ 30,608: IEA, 2019). This difference may result both from the asymmetry between agents in the land market, as well as from the possible overvaluation of land prices.

4. Discussion

Although economic feasibility analyzes are extremely important for rural producers to make effective decisions, there is a knowledge gap in this study area for ICLS (Ryschawy *et al.,* 2012). A reason for this gap may be the difficulty of the required analyzes given the complexity of the systems management involved, as reported by Wilkins (2008). Additionally, viability analysis of livestock systems requires studies over longer time-frames than does crop production, which further complicates evaluations (Moraes *et al.,* 2014; Romazini et al., 2020). In this context, our study contributes to analysis of comparative ICLS/ CS economic viability considering, in addition to the different impacts on cash flow, the effects of diversification in terms of long-term economic evaluation. In addition, the different treatments carried out, and the possibility of including market and production uncertainties, allowed for a more robust economic analysis to be conducted.

The literature refers to two main economic benefits of ICLS. The first is scope economics, which occurs when the cost of producing two products in the same production system is lower than if the same products were produced separately (Panzar and Willig, 1981). In other words, it is the saving obtained due to the scope of the production unit (Mendonça *et al.,* 2020). This is one of the hypotheses that explains the increase in the cash-generating capacity of the ICLS systems, as shown in the results in Table 2. The second benefit is the risk reduction associated with the activity, made possible by product diversification (Russelle *et al.,* 2007; Hendrickson *et al.,* 2008; Wilkins, 2008; Ryschawy *et al.,* 2012; Gameiro *et al.,* 2016, Mendonça *et al.,* 2020).

The Crop System was found to have a higher activity risk value (6.97%) than the Livestock System (2.98%), while for ICLS risk was 50% less than the Crop System, but 6.04% greater than the Livestock System. As a result, it was possible to assert the benefits of combining livestock with an agricultural system, so supporting the findings of Wilkins (2008), Vermersch (2007) and Russelle *et al.* (2007). The greatest risk of conventional, monoculture-based agriculture is the influence of climatic factors, which vary every year, on the market values for the purchase of inputs and the sale of grains, applied technologies and natural resources. Nevertheless, the results showed that, overall, livestock is the activity with the lowest risk.

Risk reduction in agricultural activities when ICLS is adopted has also been reported by Ryschawy *et al.* (2012). A risk analysis study by Lazzarotto *et al.* (2010) found diversification of ICLS products to be beneficial. However, the system was more complex, since it required the rural producer to have a broad technical and market knowledge, based around agricultural and livestock-based activities. However, ICLS were considered less vulnerable to variations in operational and market factors, as the combination of agricultural and livestock activities reduced non-systematic risks, that is the specific risks associated with the activities making up the systems. In the study by Ryschawy *et al.* (2012) a higher gross margin was observed for ICLS compared to a Crop System, plus the participating farm had greater autonomy to reduce total cost. In addition, sensitivity analysis showed that, unlike CS, ICLS were less likely to be affected by fluctuations in the price of inputs and sales, as a result of diversification. One of the differences in this study compared to the others, regarding risk diversification, is that, via CAPM, it was possible to target this risk reduction in terms of the discount rate, a practice not generally used in agricultural systems feasibility studies (Farinelli *et al.,* 2018).

The discount rate was highest for the Crop System (11.72%), and lowest for Livestock (2.98%). For ICLS, risks cannot be calculated simply with a weighted average, as they are diversified, but rather must include the effect of the correction between them (Formula 9). Accordingly, the ICLS betas can lie very close to the Livestock System level, directly influencing the discount rate, and the lower the discount rate, the greater the added economic value. Thus, the reduction in production system risk must be reflected in the interest rate, and contribute objectively to the creation of system value.

The use of Monte Carlo Simulations allowed the inclusion in the analytic model of uncertainties related to productivity and the market value of prices. As with the ICLS, in addition to generating a higher level of cash flow, they also had no significant positive correlation. This contributed to a lower level of system cash flow volatility and, consequently, a higher level of probability of positive NPV for the ICLS (+/- 91.90%), followed by Crop (65.33%) and Livestock (39.30 %) systems. These results reinforce the economic viability of the ICLS, and indicate that the confidence level for this result is high. It should be noted that this result is based on a property of 75 hectares.

The ICLS systems performed better in all the indicators used in the study. The presence of a positive NPV means that the sum of all discounted cash inflows during the operational time of the project is greater than for discounted cash outflows, which would make the project viable. Additionally, indicator showed that the ICLS systems were financially more viable, than the CS. In the current study SC and ICLS productivity results were the same, for both for corn and livestock production (Table 1). This result shows that it is possible, by adopting ICLS systems, to obtain satisfactory productivity, and generate competitive revenues, which ends with a positive NPV using ICLS.

The Livestock System negative NPV can be explained by the higher outlays (cost of livestock: purchase of animals, mineral salt, medicines and maintenance of pasture). Summed, these costs were nearly equal to revenue, so negatively impacting the cash flow of this system. It is possible, however, that, under other operational approaches the Livestock System could show more satisfactory economic results. For example, in the case of breeders who operate complete production cycles (rearing, rearing and fattening), although the investments and costs may be higher, there is also the potential for higher revenues, so generating more promising net cash flows. Still, production of livestock of more than one phase represents a within production system diversification strategy, resulting in greater revenue generation flexibility (sale of calves, lean cattle, fat cattle, and breeding stock).

The ICLS and Livestock systems are similar in cash outflows terms. However, ICLS revenues are higher than those of the Livestock System, which is associated with the calculated discount rate (Table 3), which gave ICLS a positive NPV.

Although the Crop System has a positive NPV, its NPV was impacted by variation in the system´s crop production indicator, since in the second experimental year the of corn sacs per hectare production was lower than in year one. Grain production may have been affected by unfavorable climatic conditions during the second harvest. This factor is linked to the higher risk of agricultural activity, as shown in Table 3.

The different ICLS, vary in relation the NPV in ways related to sowing techniques and how the corn and pasture linkage was implemented. Higher corn productivity was obtained in the ICLS-2 and ICLS-4 treatments (Table 1) and, consequently, net revenues obtained by these systems were higher. For grain production this result can be attributed to the use of nicosulfuron to control Marandu grass, so as to reduce competition for water, light and nutrients. The input is a selective systemic herbicide and was used to delay the initial development of the pasture.

Our results support those of Poffenbarger *et al.* (2017) who compared the economics of grain-specialized production systems and ICLS (grains plus animal production), in the United States Corn Belt over 8 years (2008 to 2015). The authors concluded that the initial investments in the ICLS were higher, which can be explained, mainly, by animal production and labor expenses. However, in the long run, these systems showed a better economic return than CS. The authors associated increases in crop productivity with the environmental benefits which this type of system can capture.

The ROI indicator was higher (mean values 6.13%) for ICLS-1 and ICLS-4 compared to CS. Lower values were found for Crop (3.38%) and Livestock (1.71%) system. This indicator is important to show the producer the level of profitability of his investment.

But even though it provides relevant information, it cannot be considered a complete indicator, as it functions only as a comparative indicator between activities. It is important to note that in agriculture and livestock-raising activities, the requirements different from those affecting assets traded in markets such as liquidity, information symmetry, dispersion between agents with supply and demand for capital. However, it is understood that it is appropriate to analyze not only added value, but the profitability of each investment by allowing comparison with other investment opportunities.

Because of such alternative economic viability indicators, our study used the BEP indicator as a differentiated and appropriate method, based on the number of hectares required for each studied system to be viable. BEP for Crop and Livestock System were 172 ha and 383 ha, respectively, while for ICLS the mean was 76 ha. Thus, the BEP indicator showed that ICLS required a smaller area than CS in order to function viably, with this being 56% smaller in than that needed for the Crop System and 80% smaller than that required for Livestock.

The use of CM is necessary to achieve a BEP and, as all systems have positive CM, all systems can be made feasible depending on the production scale required. This reinforces the importance in the analysis of segregating costs as variable and fixed forms, which helps explain the variation in results described in the literature, which in the interest of presenting the results by hectares, ignores the effect of the size of each property in the dilution of fixed costs (Faleiros *et al.,* 2018).

In addition to the economic importance, this BEP-related result has an associated social dimension since, by extending the economic viability for medium-sized agricultural properties (> 76 ha), an economically-viable alternative for land use is demonstrated, one that allows such rural producers to have sufficient resources for the operational and economic requirements involved. As such, the environmental, social and economic benefits of ICLS can contribute to better land use.

The indicator “production system value (R$)” (Table 4), was positive in all studied systems, except for Livestock, where a negative economic value indicates that the OCF generated by the system was unable to meet investment needs over time. While a positive OCF means production is financially viable, when considering the risk involved and the investment flow required over time, the Livestock System alternative became unfeasible under our experimental conditions.

The results of our study are in agreement with Peyraud *et al.* (2014), a broad review which showed the advantages of ICLS, the possibility of high productivity, and how good agricultural yields could be guaranteed while, at the same time, conserving natural resources, producing valuable ecosystem services and providing sectorial greater resilience against climatic and economic restrictions. Other studies have also demonstrated how ICLS maximize land use (Tracy and Zhang., 2008; Carvalho *et al.,* 2018). Therond *et al.* (2017) reported that these integrated agriculture formats require the development of assessment methods at various local, regional and global levels, with analytical capacity in the areas of social and human sciences. These authors pointed out that these methods support the innovation dynamics of such new agricultural production models, but that their coexistence is likely to require the development of socio-ecological and transdisciplinary policies.

5. Conclusions

The Integrated Crop-Livestock Systems are more economically viable than the existing Conventional System. The management technique used for ICLS of intercropped sowing, between maize and Marandu grass, is important and directly affects economic viability. ICLS has lower associated risks when compared to the Crop System. However, risk with the Livestock System is the lowest among all the systems compared. The area required by the ICLS to reach break-even point is smaller than for Conventional System. Thus, our results may be an important indicator of the economic viability of agricultural production using ICLS.

It is possible that the short evaluation period of this study means that the economic gains of the ICLS are being underestimated compared to Conventional System. It is suggested using optimization tools, such as mathematical models, is important for decision making, as it allows exploration of the means of enabling economic gains, while considering the optimal size of cultivated areas to be explored, as well as the technologies used, and for the available resources and production objectives also to be considered.

Declarations

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Conflicts of interest

The authors declare that they have no conflicts of interest to this resarch.

Availability of data and material

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Financial interests

The authors declare they have no financial interests.

Ethics approval

This research was approved by Ethic Committee on Animal Used the School of Veterinary Medicine and Animal Science, University of São Paulo under protocol number CEUA 4306220617.

References

Carvalho, P.C.F., Peterson, C.A., Nunes, P.A.A., Martins, A.P., Filho, W.S., Bertolazi, V.T., Kunrath, T.R., Moraes, A., Anghinoni, I., 2018. Animal production and soil characteristics from integrated crop-livestock systems: toward sustainable intensification. Journal of Animal Science, 96, 3513--3525.

Danthine, J.P and Donaldson, J.B., 2014. Intermediate Financial Theory. (Elsevier, San Diego).

Dumont, B., Fortun-Lamothe, L., Jouven, M., Thomas, M., Tichit, M., 2013. Prospects from agroecology and industrial ecology for animal production in the 21st century. Animal, 7, 1028--1043.

Faleiros, G.D., Santos, D.F.L., Cora, J.E., 2018. Analysis of profitability of conservation tillage for a soybean monoculture associated with corn as an off-season crop. Cogent Food Agriculture. 4, 1429699.

FAO, 1955. The State of food and agriculture 1955. Review of a Decade and Outlook. (FAO, Rome).

Farinelli, J.B.M., Santos, D.F.L., Fernandes, C., Fernandes, M.M.H., Silva, M.F., 2018. Crop Diversification Strategy to Improve Economic Value in Brazilian Sugarcane Production. Agronomy Journal, 110, 1402--1411.

Florindo, T.J., Florindo, G.I.B.M., Ruviaro, C.F., Pinto, A.T., 2020. Multicriteria decision-making and probabilistic weighing applied to sustainable assessment of beef life cycle. Journal of Cleaner Production, 242, 118362.

Foley, J.A., Ramankutty, N., Brauman, K., Cassidy, E.S. et al., 2011. Solutions for a cultivated planet. Nature. 478, 337--342.

Gameiro, A.H., Rocco, C.D., Vicente, J., Filho, C., 2016. Linear Programming in the economic estimate of livestock-crop integration: application to a Brazilian dairy farm. Revista Brasileira de Zootecnia, 45, 181--189.

Gil, J., Siebold, M., Berger, T., 2015. Adoption and development of integrated crop-livestock-forestry systems in Mato Grosso, Brazil. Agriculture, Ecosystems & Environment, 199, 394--406.

Hendrickson, J.R., Hanson, J.D., Tanaka, D.L., Sassenrath, G.F., 2008. Principles of integrated agricultural systems: introduction to processes and definition. Renewable Agriculture and Food Systems, 23, 265--271.

Herrero, M., Wirsenius, S., Henderson, B., Rigolot, C., Thornton, P., Havlík, P., Boer, I., Gerber, P., 2015. Livestock and the Environment: What Have We Learned in the Past Decade? Annual Review of Environment and Resources, 40, 177--202.

Hunt, L., Bonetto, C., Resh, V.H., Buss, D.F., Fanelli, S., Marrochi, N., Lydy, M.J., 2016. Insecticide concentrations in stream sediments of soy production regions of South America. Science of The Total Environment, 547, 114--124.

IEA. 2019. Instituto de Economia Agrícola. Valor de terra nua. http://ciagri.iea.sp.gov.br/nia1/precor.aspx?cod_tipo=1&cod_sis=8 .Accessed 10 Feb 2019.

King, A.E., Hofmockel, K.S., 2017. Diversified cropping systems support greater microbial cycling and retention of carbon and nitrogen. Agriculture, Ecosystems & Environment, 240, 66--76.

Lazicki, P.A., Liebman, M., Wander, M.M., 2016. Root Parameters Show How Management Alters Resource Distribution and Soil Quality in Conventional and Low-Input Cropping Systems in Central Iowa. PLoS One. 11, e0164209.

Lazzarotto, J.J., Santos, M.L., Lima, J.E., 2010. Financial viability and risks of integrated crop-livestock systems in the state. Organizações Rurais e Agroindustriais, 12, 113--130.

Lemaire, G., Franzluebbers, A., Carvalho, P.C.F., Dedieu, B., 2014. Integrated crop–livestock systems: Strategies to achieve synergy between agricultural production and environmental quality. Agriculture, Ecosystems & Environment, 190, 4--8.

Mendonça, G.G., Simili, F.F., Augusto, J.G., Bonacim, P.M., Menegatto, L.S., Gameiro, A.H., 2020. Economic gains from crop-livestock integration in relation to conventional systems. Revista Brasileira de Zootecnia, 49, e20190029.

Montoro, S.B., Lucas Jr, J., Santos, D.F.L., Costa, M.S.S.M., 2019. Anaerobic co-digestion of sweet potato and dairy cattle manure: A technical and economic evaluation for energy and biofertilizer production. Journal of Cleaner Production, 226, 1082--1091.

Moraes, A., Carvalho, P.C.F., Lustosa, S.B.C., Lang, C.R., Deiss, L., 2014. Research on Integrated Crop-Livestock Systems in Brazil. Revista Ciência Agronômica, 45, 1024--1031.

Moraine, M., Grimaldi, J., Murgue, C., Duru, M., Therond, O., 2016. Co-design and assessment of cropping systems for developing crop-livestock integration at the territory level. Agricultural Systems, 147, 87--97.

Mott, G.O., 1960. Grazing pressure and the measurement of pasture production. In: Proceedings of the 8th International Grassland Congress, Reading.

Nordblom, T., Penfold, C., Whitelaw-Weckert, M., Norton, M., Howie, J., and Hutchings, T., 2021. Financial comparisons of under-vine management systems in four south Australian vineyard districts. Australian Journal of Agricultural and Resource Economics, 65, 246--263.

Oliveira, M.R.G., Medeiros Neto, L.B., 2012. Monte Carlo simulation and Valuation: a stochastic approach. Revista de Gestão, 19, 449--466.

Olson, K.R., AL-Kaisi, M., Lal, R., Morton, L.W., 2017. Soil ecosystem services and intensified cropping systems. Journal of Soil and Water Conservation, 72, 64--69.

Panzar, J.C, Willig, R.D., 1981. Economies of scope. American Economic Review, 71, 268--272.

Peyraud, JL, Taboada, M, Delaby, L (2014). Integrated crop and livestock systems in Western Europe and South America: a review. European Journal of Agronomy, 57, 31--42.

Poffenbarger, H., Artz, G., Dahlke, G., Edwards, W., Hanna, M., et al., 2017. An economic analysis of integrated crop-livestock systems in Iowa, U.S.A. Agricultural Systems, 157, 51--69.

Rego, C.A.R.M., Reis, V.R.R., Wander, A.E., Cantanhêde, I.S.L., Costa, J.B., et al., 2017. Cost Analysis of Corn Cultivation in the Setup of the Crop-Livestock-Forest Integration System to Recover Degraded Pastures. Journal of Agricultural Science, 9, 168--174.

Reis, J.C., Rodrigues, G.S., Barros, I., Rodrigues, R.A.R., Garrett, R.D., et al., 2020. Integrated crop-livestock systems: A sustainable land-use alternative for food production in the Brazilian Cerrado and Amazon. Journal of Cleaner Production, 226, 124580.

Rezende, M.L., Richardson, J.W., 2015. Economic feasibility of sugar and ethanol production in Brazil under alternative future prices outlook. Agricultural Systems, 138, 77--87.

Romanzini, E.P., Barbero, R.P., Reis, R.A. et al., 2020. Economic evaluation from beef cattle production industry with intensification in Brazil's tropical pastures. Tropical Animal Health Production, 52, 2659--2666.

Rosa-Schleich, J., Loos, J., Mußhoff, O., Tscharntke, T., 2019. Ecological-economic trade-offs of Diversified Farming Systems – A review. Ecological Economic, 160, 251--263.

Russelle, M.P., Entz, M.H., Franzluebbers, A.J., 2007. Reconsidering Integrated Crop-Livestock Systems in North America. Agronomy Journal, 99, 325--334.

Ryschawy, J., Choisis, N., Choisis, J.P., Gibon, A., 2013. Paths to last in mixed crop– livestock farming: lessons from an assessment of farm trajectories of change. Animal, 7, 673--681.

Ryschawy, J., Choisis, N., Choisis, J.P., Joannon, A., Gibon, A., 2012. Mixed crop– livestock systems: an economic and environmental-friendly way of farming? Animal, 6, 1722--1730.

Ryschawy, J., Liebig, M.A., Kronberg, S.L., Archer, D.W., Hendricksin, J.R., 2017. Integrated Crop-Livestock Management Effects on Soil Quality Dynamics in a Semiarid Region: A Typology of Soil Change Over Time. Applied Environmental Soil Science, 2017, art. 3597416.

Santos, H.G., Jacomine, P.K.T., Anjos, L.H.C., Oliveira, V.A., et al., 2018. Sistema Brasileiro de Classificação de Solos. (Embrapa, Brasília).

Schuster, M.Z., Lustosa, S.B.C., Pelissari, A. et al., 2019. Optimizing forage allowance for productivity and weed management in integrated crop-livestock systems. Agronomy for Sustainable Development, 39, art. 18.

Sneessens, I., Sauvée, L., Randrianasolo-Rakotobe, H., Ingrand, S., 2019. A framework to assess the economic vulnerability of farming systems: Application to mixed crop-livestock systems. Agricultural Systems, 176. art. 102658.

Soil Survey Staff, 2014. Keys to soil taxonomy. Soil Conservation Service. USDA-Natural (Resources Conservation Service, Washington, DC).

Therond, O., Duru, M., Roger-Estrade, J., Richard, G., 2017. A new analytical framework of farming system and agriculture model diversities. A review. Agronomy for Sustainable Development, 37, art. 21.

Tracy, B.F., Zhang, Y., 2008. Soil Compaction, Corn Yield Response, and Soil Nutrient Pool Dynamics within an Integrated Crop-Livestock System in Illinois. Crop Science, 48, 1211-1218.

Tully, K., Ryals, R., 2017. Nutrient cycling in agroecosystems: Balancing food and environmental objectives. Agroecology and Sustainable Food Systems, 41, 761--798.

Vermersch D, 2007. L' éthique en friche. (Librairie QUAE, Paris).

Wilkins, R.J., 2008. Eco-efficient approaches to land management: a case for increased integration of crop and animal production systems. Philosophical Transactions B, 363, 517-525.