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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Analysis of profitability of conservation tillage for a soybean monoculture associated with corn as an off-season crop

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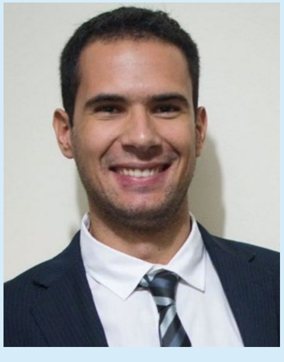
Abstract: The increasing demand for food and the need to reduce the environmental impacts of agricultural production in the face of population growth make conservation practices a valuable alternative to increase the sustainability of agriculture. The adoption of these practices, important for food production in emerging economies, increases the feasibility of production on small and intermediate farms in ways that improve social equity. The purpose of this study was to compare the economic feasibility of a no-till soybean monoculture and a no-till soybean/corn (on/off-season) rotation in Brazil. Unlike other studies, a discounted cash flow was combined with a direct cost system, in order to compare the results for farms of different sizes. The results indicate that the larger the farm is, the greater the optimization of production and fixed cost reduction for a set of investments in fixed assets. Although the net present value and internal rate of return were found to be negative for all treatments due to the need for high investment, areas of 60 and 90 hectares generated positive operational cash flow, representing positive profitability for small and intermediate-sized farms. The break-even point was over 100 ha, and the return on investment for 90 ha farms was 11.9% per year.



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PUBLIC INTEREST STATEMENT

Giving the notorious production of soybean and corn in Brazil, and its importance in economic and social components, contributing for the world's food supply, this paper explores the economic profitability of conservation tillage for a soybean monoculture associated with corn as an off-season crop. Considering a set of regular and required investment, we found that the profitability of the mentioned system is achieved above 102 hectares. However, farms of 60 hectares generate enough income to pay operational expenses, although it is not necessary to pay all the costs of investment, which presented itself elevated. In that sense, the initial investment should be minimized to allow small farmers to generate cash. Also, we concluded that the system considered promoted higher economic returns as the farms size increased.

Subjects: Agriculture and Food; Agronomy; Corporate Finance

Keywords: net present value; internal rate of return; break-even point; return on investment; discounted cash flow; investment analysis; no-tillage; direct-seeding; mulch; small-scale

1. Introduction

Malthus was the first to describe how exponential population growth and finite natural resources threaten population stability and food security (Gustafson et al., 2013). Thus, there is a need for methods that will increase agricultural production while reducing the negative externalities imposed on natural and social systems (Stagnari, Maggio, Galieni, & Pisante, 2017).

Feder, Just, and Zilberman (1985) stated that the incorporation of new technologies into agricultural production systems allows incomes to increase, especially in developing countries. As a result, there has been a worldwide movement toward the adoption of conservation agriculture (CA), particularly on the American continent (Madarász et al., 2016). CA grows at a rate of 10 M hectares (ha) per year and reached 157 M ha globally in 2013, 31.8 M ha of which occurred in Brazil (Kassam, Friedrich, Derpsch, & Kienzle, 2015).

Areas with steep slopes and intensive soil tillage are more susceptible to runoff (Tamene et al., 2017). Twenty-two years ago, Pimentel et al. (1995) reported that monetary losses in the United States of America due to erosion reached US$ 44 billion per year.

CA was introduced as a feasible method for reducing erosion, offering many additional benefits, among which are improvements in water quality and carbon sequestering (Lu & Lu, 2017; Pennington et al., 2017; Stagnari et al., 2017).

The need to amplify agricultural production while improving sustainability is a major challenge for Brazil. Brazil is the second largest soybean producer and third largest corn producer in the world, responsible for 32 and 9%, respectively, of the global supply of these commodities (United States Department of Agriculture [USDA], 2016).

This study was motivated by economic difficulties experienced by rural farmers in Brazil, whose operational margins and profitability determine the economic feasibility of their production activities, ultimately resulting in the concentration of production to fewer farms. The country contains 5.2 M rural farms, with 1.9 M of them used specifically for temporary cropping. Of the farms with temporary crops, 100 thousand of them are more than 100 ha in size and represent 5.2% of the total number of farms but are responsible for 72.7% of the agricultural production (Brazilian Institute of Geography and Statistics [IBGE, in Portuguese], 2006).

According to Sims and Kienzle (2017), mechanization is an important component of sustainable agricultural systems—conferring economic, social and environmental advantages. For this reason, they recommend that greater effort is made to provide small farmers with access to mechanization, given that, in general, they possess limited resources, especially for fixed capital investments.

The integration of the overall society becomes crucial for the success of sustainable agriculture, seeking to promote local development and thus becoming effective for reducing poverty, especially in developing countries (Schindler, Graef, & König, 2015).

The question that motivated this study was can profitability be attained on a small-scale farm in a no-tillage system where soybeans are grown as the main crop and corn is sown as an off-season crop?

The central objective of this study was to determine the conditions that promote economic feasibility in a field experiment wherein soybean was planted in summer, with corn as an off-season crop, using the practice of CA. Also, we aimed to verify the equilibrium point, or the minimum farmland area required to make the described system profitable in order to explore the economies of scale.

2. Conservation agriculture

Tittonell (2014) described the conflict between concepts of sustainable intensification and ecological intensification of agriculture. Ecological intensification relies on practices that vary according to local management approaches, aimed at using the influences of the surrounding natural ecosystem as components of the agricultural system. This can include organic, agroforestry and agroecological management practices and some CA (Tittonell, 2014). In contrast to ecological intensification, sustainable intensification consists only of intensive management practices and does not adjust to the heterogeneity of the local environment.

Practices of CA, classified as alternative, are incorporated into ecological intensification, in accordance with landscape conditions in ways that are beneficial to soil conservation (Scopel et al., 2013).

Intensive conventional soil tillage promotes soil erosion and nutrient leaching, accelerating the degradation of soils and decreasing the efficiency of fertilization while reducing the soil carbon stock (Buah et al., 2017; Ghosh et al., 2016).

On the other hand, the advantages of CA are numerous, including reducing the cost of necessary nitrogen fertilizers, increasing soil carbon sequestration, increasing soil water infiltration, and reducing soil erosion and nutrient leaching (Kassam et al., 2015; Madarász et al., 2016; Palm, Blanco-Canqui, DeClerck, Gatere, & Grace, 2014).

The three principles that guide the adoption of CA have been widely described in the literature:

(1) Minimum soil disturbance:

Sowing in soil that contains residues of the previous crop, with no primary or secondary soil tillage, favors soil aggregation, intensifies soil fauna and increases or maintains soil organic matter content (Alvarez, Steinbach, & De Paepe, 2017; Congreves, Hayes, Verhallen, & Van Eerd, 2015; Kassam et al., 2015; Palm et al., 2014; Scopel et al., 2013).

(2) Cover soil with plant residue (mulching) year-round:

Permanently covering over 30% of the soil with crop residues, live plants or decomposing material increases plant water availability, maintains high soil moisture and suppresses weed growth (Alvarez et al., 2017; Buah et al., 2017; Colbach, Granger, Guyot, & Mézière, 2014; Madarász et al., 2016; Palm et al., 2014; Scopel et al., 2013).

(3) Diversified crop rotation:

Growing different crops on the same farm allows for portfolio diversification, increases the efficiency of natural resource allocation and exploits different soil depths by means of variable root systems, thus reducing soil compaction (Alvarez et al., 2017; Palm et al., 2014; Scopel et al., 2013).

Colbach et al. (2014) found that long-term crop rotation reduces the establishment and diversification of weeds, with consequent decreases in necessary herbicide application. However, the authors state that the effects of long-term crop rotation can be reversed on commercial plantations that use living cover crops, due to the impossibility of soil tillage to suppress weeds.

According to Anderson (2017), suppressing weeds using mowers instead of tillage is more effective, mainly due to decreases in weed growth and number, and increases in yield of the main crop.

Despite presenting economic and agronomic benefits, adopting a no-tillage approach without complementing practices does not promote increases in crop yield; its practice must be implemented along with year-round soil cover (Buah et al., 2017; Pannell, Llewellyn, & Corbeels, 2014).

3. Investment analysis

The appropriate cost analysis for an investment helps farmers with decision-making, especially when evaluating a discounted cash flow (DCF), which considers the value of money over time (Regan et al., 2015).

The net present value (NPV), which consists of the sum of the cash flow for the years considered in the project, is an indicator of profitability and indicates that an investment is feasible only when its value is greater than zero (Regan et al., 2015).

Another metric used for the evaluation of investments is the internal rate of return (IRR), which represents the attractiveness rate of the project (Hurley, Rao, & Pardey, 2017). However, the authors caution that IRR estimates do not represent reality, given that they are elevated. Thus, it would be more convenient to adopt the modified internal rate of return (MIRR), which represents the annual return rate for a given project with pre-defined useful life.

Discounted cash flow analysis along with NPV and MIRR are widely used in the agricultural sciences to describe different agricultural scenarios (Lienhard et al., 2013; Regan et al., 2015; Rezende & Richardson, 2015; Ruviaro et al., 2016).

Feder (1980) recommends quantifying return per unit of area, as well as studying its relation to the size of the farm, since the contrary would only be a representation of the amount of area.

Pannell et al. (2014) discuss aspects related to the adoption of CA, especially profitability, investment, demand, labor, time, risk and uncertainty. These authors also caution that economic analysis must be carried out in addition to calculating instantaneous return, in order to account for long-term context, diversity of production, and decisions about the need for implementing management practices preferred by farmers.

Farmers have at their disposal several management practices, making it difficult to define the system of production that is best able to minimize risks and maximize expected returns (Feder, 1980). The value of an enterprise is determined by its capacity for generating cash (Regan et al., 2015).

4. Material and methods

4.1. Description of the study area

This work was conducted as an experiment to allow for the evaluation of relationships between crop yields and production practices.

The experimental site was located at Jaboticabal (SP), Brazil (21°15′8.75′′S and 48°16′21.50′W, 590 m above sea level). The climate according to Köppen (1936) is Aw, with dry winter and humid summer. The average annual temperature is 22 °C, with average annual rainfall of 1,425 mm, concentrated between October and March. The soil is classified as Oxisol, according to Soil Taxonomy (USDA, 1999).

This experiment established a no-tillage system (NT) in September of 2002, with 3 replicates of the same treatment, arranged in lines. The treatment consisted of soybean [*Glycine max* (L.) Merr.]

sowed in October/November as the main crop (summer crop), and corn (*Zea mays* L.) sowed in February/March as an off-season crop. Although the experiment was established in 2002, the time frame adopted in this study was for 10 crop seasons, initiated in July and completed in June of the next year, according to the availability of data.

Fertilizations were based on chemical soil analyses and expected crop yield (considering elevated yield), resulting in the application of 300 kg ha^{-1} of 2-20-20 NPK to the soybean plantation. In order to manage crop pests and diseases, four applications of pesticides were carried out during soybean cultivation, according to technical recommendations made by the manufacturer. It is important to emphasize that no fertilization or agrochemical applications were added to the off-season crop, in order to explore the potential of conservation practices.

During soybean sowing, between 60 and 80 kg of transgenic, certified and high yield and value seeds were planted per hectare. The spacing was 0.45 m between sowing lines, with an estimated density of 480 thousand plants.ha^{-1}. The seeds were previously inoculated with *Bradyrhizobium japonicum.* Hybrids were used for corn sowing, at a rate of 55 thousand seeds per hectare (1 bag of 20 kg of seeds), with spacing of 0.9 m between sowing lines. The harvest of both crops (soybean and corn) was conducted in a completely mechanized manner.

We performed a statistical bicaudal *T*-test using Microsoft Excel® to compare the yields of the soybean crops and off-season corn crops of this experiment, produced in a no-tillage system, with the average yields of Sao Paulo State produced in a conventional system, collected at CONAB (2017), for the 10 years of the study. For that purpose, we assigned the bicaudal *t*-test to each crop, assuming as the null hypothesis the equivalency of yields from no-tillage and conventional systems, with 95% confidence.

4.2. Estimated costs and operational expenses

Information on the number of machine-hours spent during the experiment, the machinery used, the inputs required by crops, and the yield for each crop were recorded for the 10 crop seasons under study. Costs of inputs—namely, seeds, fertilizers and agrochemicals—were obtained from authorized agricultural product stores that sell inputs from various companies.

Microsoft Office Excel® was used for data organization and processing. Additionally, costs were clustered into two categories, as follows:

(1) Fixed costs: expenses associated with machinery and tools; labor hired for indefinite periods of time and family labor; and administrative expenses.
(2) Variable costs: seeds, fertilizers and lime; agrochemicals; operations with owned or leased agricultural machinery; post-harvest; taxes; and land leasing.

The need for investments based on required machinery was defined for 90 ha as a set of one tractor with 55 kW wheels (US$ 27,298.85), one planter of 8 lines at 0.45-m spacing or 4 lines at 0.9-m spacing (US$ 21,551.72), one straw disintegrator (US$ 6,609.20) and one bar sprayer (US$ 3,709.77). The construction of a masonry shed (roof and metallic structure) of 120 m^2 was also defined as required shelter for the machinery and implements (US$ 41,379.31).

The maintenance, fuel and lubricant costs, as well as the tractor and planter insurance were included as machinery costs (National Supply Company [CONAB, in Portuguese], 2010).

Due to the difficulty of quantifying the work hours for each piece of machinery, the costs for repairs and maintenance were estimated as outlined in CONAB (2010) and described as a percentage of the price of the new equipment.

Labor costs were not included in the machine-hours costs, assuming the hiring of a tractor driver for an indefinite period of time. This procedure generated a fixed cost, regardless of the total number of working hours recorded. The family labor was estimated based on an average manager's wage.

The linear method was used to estimate the depreciation of machinery, tools and upgrades. The lifetime of all machinery was obtained from the Federal Revenue of Brazil [RFB, in Portuguese] (1999), and the useful lifetime used to determine the timing of replacement for all machinery was obtained from CONAB (2010).

Estimated depreciation was not included in the operational costs of production in the investment analysis because it did not affect the cash flow, since it was subtracted only for computing taxes and then added to the cost structure.

At the end of the period under study, that is, in the tenth year after establishment, residual estimates of 20% were assigned to the tractor and planter and 5% to the straw disintegrator and bar sprayer (CONAB, 2010).

The reason for the elevated purchase price of the grain harvester was an added cost associated with the hiring of specialized service providers. A similar approach was adopted for the conventional soil preparation operations (subsoiling, one tilling and one harrowing) conducted a single time before the establishment of CA and for lime distribution, which was conducted only twice in 10 years.

For cost analysis, two mandatory taxes, regulated by the RFB (2017), were considered:

(1) Income tax of legal entity: 15% over income. In cases where annual income was over US$ 86,206.90, before calculating the income tax, an additional 10% was taken from the profit surplus.
(2) Social contribution: over net profit of 9% before provision of income tax.

The cost of land was defined as the cost of leasing land, in order to avoid having the price of a land purchase distort the analysis.

The harvested grains were cleaned, dried and stored in a regional cooperative. Transportation costs were disregarded due to proximity. A fixed amount was also applied to cover administrative expenses.

The working capital was allocated into reinvestments, and the necessary capital for operations resulting from planting, crop management and harvest was provided by farmers via their own capital because monetary inputs are usually procured only after grains are sold.

4.3. Investment analysis

Because the objective of this study was to analyze the economic feasibility of investments in conservation agriculture, it was important that the agricultural results of the experiment be extrapolated to a typical farm, given that costs and expenses are not only variable but also fixed. The assessment of fixed costs per cropping hectare can distort the analysis and prevent the evaluation of various contributors to profitability. Thus, secondary information and real data for the studied region were used in order to demonstrate the effective economic contributions of the investments. Therefore, analysis was conducted for three hypothetical scenarios: farms of 30, 60 and 90 ha.

To calculate revenue, we used future prices of soybean and corn, assigned in August of 2016, for February and March of 2017. These were US$ 12.27 for corn and US$ 22.63 for soybean, expressed in bags of 60 kg. The crop yield, used in the present analysis, was obtained from the data reports during the conduction of the research.

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The discount rate for soybeans was 6.75%, obtained from the Capital Assets Pricing Model (CAPM) (Sharpe, 1964), and used to estimate the cost of owned capital. For calculations, the DCF was used.

Finally, the NPV of the investment was calculated, aiming at evaluating current investments, while considering cash flows obtained during the project lifetime, brought to the present value, as well as the required initial investment.

MIRR was calculated from NPV in order to obtain the attractiveness rate over a period of time. The time necessary for the initial investment to be re-payed to the investor, that is, the payback period, was also calculated.

Finally, the return on investment (ROI) was calculated by dividing annual operational cash flow by the total investment, considering the annual operational cash flow corrected with the discount rate of 6.75%.

5. Results and discussion

5.1. NT system yield and its influence on revenue

Variation in crop yield was observed over time, particularly due to climate variation during the study period. This was reflected in proffered revenue (Table 1). In our first analysis, we presented the treatment yields from one hectare and used simple multiplication to extrapolate to 30, 60 and 90 hectares.

According to a *t*-test performed with 95% confidence, the average yields of soybeans in this experiment, in a no-tillage system, were statistically higher than yields from the conventional system used by Sao Paulo State. The average yield of soybeans in the no-tillage system was 3,059 kg ha^{-1}, in contrast with 2,687 kg ha^{-1} for the conventional system, attesting to the advantage of the no-tillage system. No difference was found between systems for the off-season corn crop, although the average yield was 3,169 kg ha^{-1} for the off-season corn in the no-tillage system and 3,207 kg ha^{-1} for the conventional system. Additional information about the statistical analysis is presented in Appendices A1 and A2.

According to CONAB (2017), the average crop yield for Brazil over the last 5 years was 2,988 kg ha^{-1} for soybeans and 5,030 kg ha^{-1} for the off-season corn crop.

Table 1. Yield, revenue and their percentage in relation to the total, for soybean and corn crops, over the lifetime of a 10-year project

Crop Season	Soybean Yield (kg ha^{-1})	Soybean Revenue (US$ ha^{-1})	% of total revenue	Maize Yield (kg ha^{-1})	Maize Revenue (US$ ha^{-1})	% of total revenue	Total revenue
1	2,900	1,094	78.79	1,440	294	21.21	4,340
2	3,284	1,238	96.86	196	40	3.14	3,480
3	3,118	1,176	69.81	2,487	508	30.19	5,605
4	2,754	1,038	56.57	3,900	797	43.43	6,654
5	3,187	1,202	53.07	5,200	1,063	46.93	8,388
6	2,599	980	59.98	3,199	654	40.02	5,799
7	3,400	1,282	88.94	780	159	11.06	4,180
8	2,940	1,108	54.32	4,560	932	45.68	7,500
9	3,648	1,376	57.77	4,920	1,006	42.23	8,568
10	2,754	1,038	50.38	5,004	1,023	49.62	7,758

Source: Research data.

In the current study, soybean yields were higher than the national average in half of the years studied, with yields remaining similar during the other years.

The yield of corn cultivated as an off-season crop remained lower than the national average in 90% of the considered years. This was due to rainfall water deficits, as the area does not have an irrigation system, and not due to lack of fertilization, given that the levels of soil fertility were adequate throughout the experiment. This emphasizes that, besides the observations made by Trlica, Walia, Krausz, Secchi, and Cook (2017) and Wasaya et al. (2017) attesting to the importance of fertilization on crop yield, climate also has a major impact on yield variability (Santos et al., 2015).

Other studies conducted in no-tillage and crop rotation systems, with different edaphoclimatic patterns, found higher crop yields in contrast to conventional tillage (Buah et al., 2017; Lu & Lu, 2017; Munkholm, Heck, & Deen, 2013). Santos et al. (2015) states that soil conservation practices increase crop yield by up to 3.2% in Brazil, when compared to conventional tillage.

In 6 of the 10 years of our experiment, a considerable portion of revenue—more than 40%—derived from the sale of corn (Table 1), due to its favorable yield and price. In order to take advantage of the possibility of producing two agricultural grain harvests per year in Brazil, certain rules must be observed. The planting of the off-season crop must be done at the end of summer in order to take advantage of the final rainfall before the winter season, according to the agro-climatic zoning described by Sentelhas et al. (2015). When practiced the right way, planting corn varieties with deep root systems in areas with sufficient residue on the surface of the soil is an important strategy to mitigate risks from water stress—a common concern in the region of study (Magalhães et al., 2016).

In this study, soybean crops were harvested as early as possible, as allowed by the sowing of short-cycle cultivars. According to a report by Rio, Sentelhas, Farias, Sibaldelli, and Ferreira (2016), the shortest cycle for soybean cultivars, in combination with other factors, such as elevated temperatures, water deficit and planting period, reduces potential crop yield in certain regions. In contrast, improvements in soil quality, increases in water retention and reduction of soil compaction contribute to the increases in crop yield associated with the adoption of crop rotation (Sentelhas et al., 2015).

The crop yields presented in Table 1 confirm the agronomic viability of the adopted management practices, given the similarities of soybean yield to the national average, and the yields obtained of the off-season corn crop, given climatic adversities and the lack of fertilization.

5.2. Representativeness of the cash flow costs

Table 2 shows the total and unitary operational costs for areas of 30, 60 and 90 ha. These costs are composed of the payable fixed costs, variable costs and taxes for soybean and corn crops.

Reductions in the total operational costs were observed for larger areas, indicating an increase in gains with an increased scale of production. Studies from other authors suggest that the gains generated by an increase in scale exceed associated increases in variable costs (Sheng, Zhao, Nossal, & Zhang, 2014).

In this study, we assumed that variable costs grew in proportion to the increase in area size, that is, via a multiplicative function. The doubling of area generated a doubling of variable costs, and the tripling of the area tripled the variable costs. However, an increase in area did not increase total operational costs by the same proportion. The increase from 30 to 60 ha elevated total operational costs by approximately 65 to 78%, while the increase from 60 to 90 ha elevated costs by approximately 39 to 49% (Table 2).

The advantage of larger-scale production was obtained as a function of the stability of fixed costs, notably labor costs. This indicates that the optimization of available resources allows increases in

Table 2. Total operational costs and unitary costs (per hectare), expressed in American dollars, averaged over 10 years, for 30, 60 and 90 hectare farms

Crop season	30 ha		60 ha		90 ha	
	Total	Unitary (ha)	Total	Unitary (ha)	Total	Unitary (ha)
1	57,791	1,926	96,130	1,602	134,468	1,494
2	55,110	1,837	90,767	1,512	126,424	1,404
3	53,782	1,792	88,871	1,481	127,093	1,412
4	57,358	1,911	96,487	1,608	138,517	1,539
5	57,966	1,932	102,953	1,715	147,941	1,643
6	57,573	1,919	95,694	1,594	135,969	1,510
7	56,833	1,894	94,214	1,570	131,594	1,462
8	54,746	1,824	95,754	1,595	136,762	1,519
9	60,470	2,015	107,202	1,786	153,934	1,710
10	34,866	1,162	62,204	1,036	92,984	1,033

Source: Research data.

the scale of production. However, it is important to highlight that the existence of only one tractor on the farm, despite lowering costs, can also threaten crop yields in an emergency situation such as when mechanical malfunction prevents a needed pest or disease control operation and requires the enlistment of outsourced specialized services. Cases like these would cause increases in variable costs.

Variable and fixed costs changed differently with farm size (Table 3). For variable costs, the curve was ascendant and for the fixed costs, descendent, demonstrating the use of idle capacity of the entrepreneurship.

Hired and family labor costs in the 30 ha area represented 32.5% of total expenses. In contrast, labor represented 13.4% of costs when managing 90 ha, which is close to the costs associated with agrochemicals (14.5%) and seeds (13.8%).

Table 3. Relative percentages of each component of the total operational cost, averaged over 10 years, for 30, 60 and 90 hectare farms

Components	30 ha	60 ha	90 ha
Seeds (soybean and corn)	11.12	13.08	13.78
Fertilizers and lime	9.38	11.02	11.61
Agrochemicals	11.62	13.67	14.40
Field operations (owned machinery)	1.95	2.29	2.41
Field operations (rented machiney)	7.84	9.21	9.70
Post-harvest	4.27	5.01	5.28
Taxes	1.71	4.22	6.01
Leasing (land)	18.47	21.73	22.90
Variable costs	66.36	80.22	86.10
Machinery (general) expenses	0.13	0.08	0.05
Hired and family labor	32.47	19.10	13.42
Administratives expenses	1.04	0.61	0.43
Payable fixed costs	33.64	19.78	13.90

Source: Research data.

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The second highest cost for the 30 ha farm was for land leasing (18.5%). Lease prices in the region are relatively high due to competition with sugarcane crop, high soil fertility, logistics, and other factors. The cost of leasing land was the highest cost for the 90 ha farm (22.9%).

5.3. Net present value, modified internal rate of return, and return on investment

The NPV is shown in Table 4 as the average of the 10 years considered, for farms of 30, 60 and 90 ha, in American dollars. The values were adjusted to the current value using a rate of discount defined as 6.75% per year. Table 4 also shows the economic payback, MIRR, break-even point, and ROI. Appendices A3, A4 and A5 present detailed cash flows for farms of 30, 60 and 90 ha.

From an economic perspective, the NPV was negative for the three situations considered (30, 60 and 90 ha areas), with lower losses (US$ −55,526) observed for the 90 ha area. Factors such as labor and need for initial capital can limit the gains obtained by farming, causing it to be non-profitable in certain cases (Pannell et al., 2014).

Depreciation represented an advantage only for the 60 and 90 ha areas in the third and fourth years, due to the depreciation of the tractor. Notwithstanding, the fiscal advantage was not used in its entirety.

Table 4. Cash flow expressed in American dollars, (US$) followed by economic indicators, averaged over 10 years, for 30, 60 and 90 hectare farms

Components	30 ha	60 ha	90 ha
Revenue	374,453	748,907	1,123,361
Variable costs	251,954	503,909	755,864
Contribution margin	122,498	244,997	367,496
Payable fixed costs	133,974	133,974	133,974
EBITDA[1]	(11,475)	111,023	233,522
Depreciation	46,524	46,524	46,524
Operational results	−58,000	64,498	186,997
Income tax	3,656	16,535	33,330
CSLL[2]	2,194	9,921	19,998
Surplus taxes	0	0	1,791
Operational results	−63,851	38,041	131,877
Depreciation	46,524	46,524	46,524
Operational cash flow	−17,326	84,565	178,401
Investment	163,277	187,045	210,812
Reinvestment	19,757	21,436	23,115
NPV[3]	−200,361	−123,915	−55,526
Economic payback	–	–	–
MIRR[4]	−36.24%	−12.92%	−2.15%
Break-even point	102 ha	110 ha	119 ha
ROI[5]	−1.49%	6.36%	11.91%

Source: Research data.

[1]Earnings before interest, taxes, depreciation and amortization.

[2]Social contribution over net profit (CSLL, in Portuguese).

[3]Net present value.

[4]Modified internal rate of return.

[5]Return on investment.

The analysis of operational cash flow showed a capacity to generate income by the end of 10 years on farms of 60 ha (US$ 84,565) and 90 ha (US$ 178,401). However, this income was insufficient to cover the high expenses associated with investment and reinvestment.

In a situation with infinite time, that is, when conducting profit analysis for perpetuity, the 30, 60 and 90 ha farms generated discounted cash flows of US$ −404,005, US$ −249,861 and US$ −111,962, respectively. Given the break-even points, it appears that profits would become positive on farms that were larger than 102 ha.

MIRR was negative and lower than the established discount rate for the three considered areas, indicating that the costs of the farmers' capital was high, which makes investment in fixed assets unfeasible because of the long waiting time until the gains can be realized (Pannell et al., 2014).

The ROI was negative for the 30 ha farm and positive by 11.9% for the 90 ha farm. This shows a ROI greater than the discount rate, observed after 10 years of study. These financial results confirm the feasibility of investment in CA, given the positive operational cash flow for the 60 and 90 ha areas. On the other hand, the results suggest that CA production is unfeasible for 30, 60 and 90 ha farms and requires areas larger than 100 ha. These results highlight the economic and financial difficulties faced by small farmers and confirm the fact that crops such as soybean and corn, while commodities, require large-scale production to become competitive.

6. Conclusions

In a no-tillage system, planting soybeans in the summer season and corn as an off-season crop resulted in a positive net present value (NPV) for farms larger than 102 ha. However, 60 ha farms can generate positive operational cash flows, presenting revenue that exceeds total operational cost, despite being unable to meet the costs of investment and reinvestment.

Regional price variation and the duration of the study are factors that can alter the results by influencing cash flow and decision-making. Additionally, in the present study, the possible advantages of in-scale purchases of input and other financial options available in the market, which could reduce the discount rate, were not considered. The outsourcing of agricultural operations deserves future research because it changes economic dynamics. A reduced need for investment in machinery and implements may provide positive NPV.

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Competing interest
The authors declare no competing interest.

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Appendix A1

Data used to perform the *t*-test for the soybean crops, and the results of the statistical test performed

Year	No-tillage system yield (kg ha^{-1})	Conventional system yield (kg ha^{-1})
1	2,901	2,385
2	3,284	2,240
3	3,118	2,520
4	2,754	2,670
5	3,188	2,750
6	2,600	2,459
7	3,400	2,772
8	2,940	2,788
9	3,648	2,970
10	2,754	3,316
Statistical *T*-test		
Average	3,059	2,687
Variance	107,871	96,478
Degrees of freedom	18	
Stat *t*	2.60034	
Bicaudal *p*-value	0.01809	
Bicaudal critical value	2.10092	

Source: Research data and CONAB (2017).

Appendix A2

Data used to perform the *t*-test for the off-season corn crop, and the results of the statistical test performed

Year	No-tillage system yield (kg ha^{-1})	Conventional system yield (kg ha^{-1})
1	5,004	3,150
2	1,440	2,320
3	196	2,100
4	2,488	2,600
5	3,900	3,550
6	5,200	3,345
7	3,200	3,800
8	780	2,900
9	4,560	5,010
10	4,920	3,297
Statistical *T*-test		
Average	3,169	3,207
Variance	3,447,319	691,713
Degrees of freedom	12	
Stat *t*	−0.05972	
Bicaudal *p*-value	0.95336	
Bicaudal critical value	2.17881	

Source: Research data and CONAB (2017).

Appendix A3

Discounted cash flow for the 30 hectares farm

		Years					
		2016/17	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**
Components	Op.	0	1	2	3	4	5
Revenue	(+)	–	41,658	38,369	50,548	55,091	67,976
Variable costs	(−)	–	38,338	35,657	34,329	37,905	37,727
Contribution margin	(=)	–	3,320	2,712	16,219	17,185	30,248
Payable fixed costs	(−)	–	19,453	19,453	19,453	19,453	19,453
EBITDA[1]	(=)	–	(16,132)	(16,741)	(3,234)	(2,267)	10,795
Depreciation	(−)	–	4,124	9,819	9,819	9,819	7,526
Operacional results	(=)	–	(20,257)	(26,560)	(13,053)	(12,087)	3,269
Income tax	(−)	–	–	–	–	–	490
CSLL[2]	(−)	–	–	–	–	–	294
Surplus taxes	(−)	–	–	–	–	–	–
Net results	(=)	–	(20,257)	(26,560)	(13,053)	(12,087)	2,484
Depreciation	(+)	–	4,124	9,819	9,819	9,819	7,526
Operational cash flow	(=)	–	(16,132)	(16,741)	(3,234)	(2,267)	10,010
Investment	(−)	132,486	–	–	–	–	–
Reinvestment	(−)	–	27,508	(1,026)	327	5,231	1,477
Net cash flow	(=)	(132,486)	(43,641)	(15,715)	(3,562)	(7,498)	8,533
Accumulated cash flow	(=)	(132,486)	(176,128)	(191,843)	(195,406)	(202,904)	(194,371)
Discounted cash flow	(=)	(132,486)	(40,882)	(13,790)	(2,928)	(5,774)	6,155
Accumulated discounted cash flow	(=)	(132,486)	(173,369)	(187,159)	(190,088)	(195,862)	(189,707)

Source: Research data.

[1]Earnings before interest, taxes, depreciation and amortization.

[2]Social contribution over net profit (CSLL, in Portuguese). Numbers inside brackets indicate negative values. American dollar monetary units (US$).

		Years				
		2022/23	**2023/24**	**2024/25**	**2025/26**	**2026/27**
Components	Op.	6	7	8	9	10
Revenue	(+)	49,050	43,262	61,245	71,470	61,860
Variable costs	(−)	38,120	37,380	34,617	38,919	16,435
Contribution margin	(=)	10,930	5,881	26,627	32,550	45,425
Payable fixed costs	(−)	19,453	19,453	19,453	19,453	11,283
EBITDA[1]	(=)	(8,523)	(13,571)	7,174	13,097	34,142
Depreciation	(−)	4,359	4,359	4,359	4,359	4,359
Operacional results	(=)	(12,882)	(17,931)	2,814	8,737	29,782
Income tax	(−)	–	–	422	1,310	4,467
CSLL[2]	(−)	–	–	253	786	2,680
Surplus taxes	(−)	–	–	–	–	–
Net results	(=)	(12,882)	(17,931)	2,139	6,640	22,634
Depreciation	(+)	4,359	4,359	4,359	4,359	4,359
Operational cash flow	(=)	(8,523)	(13,571.57)	6,498	11,000	26,994
Investment	(−)	–	–	–	–	59,169
Reinvestment	(−)	2,047	915	(1,107)	5,957	(28,999)
Net cash flow	(=)	(10,570)	(14,486)	7,606	5,042	(3,176)
Accumulated cash flow	(=)	(204,942)	(219,429)	(211,823)	(206,780)	(209,956)
Discounted cash flow	(=)	(7,143)	(9,170)	4,510	2,801	(1,652)
Accumulated discounted cash flow	(=)	(196,850)	(206,021)	(201,510)	(198,709)	(200,361)

Source: Research data.

[1]Earnings before interest, taxes, depreciation and amortization.

[2]Social contribution over net profit (CSLL, in Portuguese). Numbers inside brackets indicate negative values. American dollar monetary units (US$).

Appendix A4

Discounted cash flow for the 60 hectares area

		Years					
		2016/17	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**
Compo-nents	Op.	0	1	2	3	4	5
Revenue	(+)	–	83,317	76,738	101,096	110,182	135,953
Variable costs	(−)	–	76,676	71,313	68,658	75,810	75,455
Contribution margin	(=)	–	6,641	5,424	32,438	34,371	60,497
Payable fixed costs	(−)	–	19,453	19,453	19,453	19,453	19,453

		Years					
		2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
EBITDA [1]	(=)	–	(12,812)	(14,029)	12,984	14,918	41,044
Deprecia-tion	(−)	–	4,124	9,819	9,819	9,819	7,526
Operacional results	(=)	–	(16,936)	(23,848)	3,165	5,098	33,518
Income tax	(−)	–	–	–	474	764	5,027
CSLL[2]	(−)	–	–	–	284	458	3,016
Surplus taxes	(−)	–	–	–	–	–	–
Net results	(=)	–	(16,936)	(23,848)	2,405	3,875	25,473
Deprecia-tion	(+)	–	4,124	9,819	9,819	9,819	7,526
Operational cash flow	(=)	–	(12,812)	(14,029)	12,224	13,694	33,000
Investment	(−)	156,254	–	–	–	–	–
Reinvest-ment	(−)	–	42,079	(3,707)	(1,000)	8,807	1,300
Net cash flow	(=)	(156,254)	(54,892)	(10,321)	13,224	4,887	31,699
Accumu-lated cash flow	(=)	(156,254)	(211,146)	(221,468)	(208,243)	(203,355)	(171,656)
Discounted cash flow	(=)	(156,254)	(51,421)	(9,057)	10,871	3,763	22,867
Accumu-lated discounted cash flow	(=)	(156,254)	(207,675)	(216,733)	(205,861)	(202,098)	(179,230)

Source: Research data.

[1]Earnings before interest, taxes, depreciation and amortization.

[2]Social contribution over net profit (CSLL, in Portuguese). Numbers inside brackets indicate negative values. American dollar monetary units (US$).

		Years				
		2022/23	2023/24	2024/25	2025/26	2026/27
Components	Op.	6	7	8	9	10
Revenue	(+)	98,101	86,524	122,490	142,940	123,721
Variable costs	(−)	76,240	74,760	69,234	77,839	32,871
Contribution margin	(=)	21,860	11,763	53,255	65,101	90,850
Payable fixed costs	(−)	19,453	19,453	19,453	19,453	11,283
EBITDA[1]	(=)	2,406	(7,689)	33,801	45,647	79,567
Depreciation	(−)	4,359	4,359	4,359	4,359	4,359
Operacional results	(=)	(1,952)	(12,049)	29,442	41,288	75,207
Income tax	(−)	–	–	4,416	6,193	11,281
CSLL[2]	(−)	–	–	2,649	3,715	6,768
Surplus taxes	(−)	–	–	–	–	–
Net results	(=)	(1,952)	(12,049)	22,376	31,379	57,157
Depreciation	(+)	4,359	4,359.	4,359	4,359	4,359

		Years				
		2022/23	2023/24	2024/25	2025/26	2026/27
Operational cash flow	(=)	2,406	(7,689)	26,735	35,738	61,517
Investment	(−)	–	–	–	–	59,169
Reinvestment	(−)	2,439	175	(3,870)	10,259	(51,483)
Net cash flow	(=)	(33)	(7,864)	30,606	25,478	53,831
Accumulated cash flow	(=)	(171,689)	(179,554)	(148,947)	(123,468)	(69,637)
Discounted cash flow	(=)	(22)	(4,978)	18,149	14,153	28,012
Accumulated discounted cash flow	(=)	(179,253)	(184,231)	(166,082)	(151,928)	(123,915)

Source: Elaborated by the own authors.
[1]Earnings before interest, taxes, depreciation and amortization.
[2]Social contribution over net profit (CSLL, in Portuguese). Numbers inside brackets indicate negative values. American dollar monetary units (US$).

Appendix A5

Discounted cash flow for the 90 hectares area

		Years					
		2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
Compo-nents	Op.	0	1	2	3	4	5
Revenue	(+)	–	124,976	115,107	151,645	165,273	203,930
Variable costs	(−)	–	115,015	106,970	102,988	113,716	113,183
Contribution margin	(=)	–	9,961	8,136	48,657	51,557	90,746
Payable fixed costs	(−)	–	19,453	19,453	19,453	19,453	19,453
EBITDA[1]	(=)	–	(9,491)	(11,316)	29,203	32,104	71,293
Deprecia-tion	(−)	–	4,124	9,819	9,819	9,819	7,526
Operacional results	(=)	–	(13,615)	(21,136)	19,384	22,284	63,767
Income tax	(−)	–	–	–	2,907	3,342	9,565
CSLL[2]	(−)	–	–	–	1,744	2,005	5,739
Surplus taxes	(−)	–	–	–	–	–	–
Net results	(=)	–	(13,615)	(21,136)	14,731	16,936	48,463
Deprecia-tion	(+)	–	4,124	9,819	9,819	9,819	7,526
Operational cash flow	(=)	–	(9,491)	(11,316)	24,551	26,755	55,989
Investment	(−)	180,022	–	–	–	–	–
Reinvest-ment	(−)	–	56,650	(6,388)	(2,327)	12,383	1,123

		Years					
		2016/17	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**
Net cash flow	(=)	(180,022)	(66,142)	(4,927)	26,878	14,372	54,866
Accumulated cash flow	(=)	(180,022)	(246,164)	(251,092)	(224,213)	(209,840)	(154,974)
Discounted cash flow	(=)	(180,022)	(61,959)	(4,324)	22,095	11,067	39,579
Accumulated discounted cash flow	(=)	(180,022)	(241,982)	(246,306)	(224,210)	(213,142)	(173,563)

Source: research data.

[1]Earnings before interest, taxes, depreciation and amortization.

[2]Social contribution over net profit (CSLL, in Portuguese). Numbers inside brackets indicate negative values. American dollar monetary units (US$).

		Years				
		2022/23	**2023/24**	**2024/25**	**2025/26**	**2026/27**
Components	Op.	6	7	8	9	10
Revenue	(+)	147,151	129,786	183,735	214,411	185,582
Variable costs	(−)	114,360	112,141	103,852	116,759	49,307
Contribution margin	(=)	32,790	17,645	79,883	97,651	136,275
Payable fixed costs	(−)	19,453	19,453	19,453	19,453	11,283
EBITDA[1]	(=)	13,337	(1,807)	60,429	78,198	124,992
Depreciation	(−)	4,359	4,359	4,359	4,359	4,359
Operacional results	(=)	8,977	(6,167)	56,069	73,838	120,632
Income tax	(−)	1,346	–	8,410	11,075	18,094
CSLL[2]	(−)	807	–	5,046	6,645	10,856
Surplus taxes	(−)	–	–	–	–	3,442
Net results	(=)	6,822	(6,167)	42,613	56,117	88,238
Depreciation	(+)	4,359	4,359	4,359	4,359	4,359
Operational cash flow	(=)	11,182	(1,807)	46,972	60,477	92,597
Investment	(−)	–	–	–	–	59,169
Reinvestment	(−)	2,832	(564)	(6,633)	14,561	(73,967)
Net cash flow	(=)	8,350	(1,242)	53,606	45,915	107,395
Accumulated cash flow	(=)	(146,624)	(147,867)	(94,260)	(48,345)	59,049
Discounted cash flow	(=)	5,642	(786)	31,788	25,506	55,886
Accumulated discounted cash flow	(=)	(167,920)	(168,707)	(136,919)	(111,412)	(55,526)

Source: Research data.

[1]Earnings before interest, taxes, depreciation and amortization.

[2]Social contribution over net profit (CSLL, in Portuguese). Numbers inside brackets indicate negative values. American dollar monetary units (US$).