http://dx.doi.org/10.18623/rvd.v23.5958

ECONOMIC VIABILITY OF IRRIGATED SUGARCANE CROPS IN NORTHERN GOIÁS, IN THE BRAZILIAN CERRADO

VIABILIDADE ECONÔMICA DA IRRIGAÇÃO DE CANA-DE-AÇÚCAR NO NORTE DE GOIÁS, NO CERRADO BRASILEIRO

Article received on: 12/11/2025
Article accepted on: 3/12/2026

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The authors declare that there is no conflict of interest

Abstract
Analyses of the economic viability of irrigated sugarcane crops in northern Goiás, Brazil, based on current agricultural and economic factors, are increasingly important, facilitating and promoting the expansion of irrigated crops. The objective of this study was to evaluate the economic viability of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil. Economic viability was analyzed using survey data collected at the Uruaçu Plant in Uruaçu, Goiás, Brazil, in a 100-hectare area, planted with irrigated sugarcane. Irrigation was carried out using a central pivot system, covering a total irrigated area of 100 ha. Costs were structured according to the adjusted operational cost methodology, using the Effective Operational Cost approach. The economic indicators evaluated included the Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), Benefit-Cost Ratio (B/C). The economic viability analysis was based on data from two harvests of the sugarcane cultivar CTC4 (plant crop and ratoon crop), including stalk yield and total recoverable sugar from the irrigated crops. The irrigation in sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás are economically viable, as all evaluated economic indicators were favorable.

Keywords: Saccharum Officinarum. Profitability. Operational Cost. Yield.

Resumo
Analisar viabilidade econômica da irrigação de cana-de-açúcar no norte goiano, diante da atual conjuntura agrícola e econômica brasileira, passa a ser cada vez mais importante, por viabilizar e difundir a exploração da cultura irrigada na região Norte de Goiás. Objetivou-se avaliar a viabilidade econômica da cana-de-açúcar irrigada no primeiro e segundo ano de cultivo (cana planta e cana soca) na região Norte de Goiás. A análise de viabilidade econômica foi realizada, junto à usina de Uruaçu, no município de Uruaçu - GO. Os levantamentos dos dados necessários foram obtidos a partir da usina de Uruaçu, no município de Uruaçu – GO. A área de 100 ha utilizada para o plantio da cana-de-açúcar irrigada é pertencente a usina de Uruaçu. A irrigação foi realizada por um Pivô central, com área total irrigada de 100 ha. A organização dos custos seguiu a metodologia de custo operacional ajustada, em que o COE (Custo Operacional Efetivo). Os indicadores econômicos avaliados foram o Valor Presente Líquido (VPL), Taxa Interna de Retorno (TIR), Payback, relação Benefício/Custo (B/C). Para a análise de viabilidade econômica, foram considerados dois cortes da cultivar de cana-de-açúcar CTC4 (cana-planta e cana-soca), dessa maneira, foram obtidas as produtividades de colmo e açúcares totais recuperáveis (ATR). A irrigação da cana-de-açúcar no primeiro e segundo ano de cultivo (cana planta e cana soca) na região norte de Goiás apresentara viabilidade econômica, uma vez que os indicadores econômicos empregados são positivos em todas as situações.

Palavras-chave: *Saccharum Officinarum. Lucratividade. Custo Operacional. Rendimento.*

1 INTRODUCTION

Sugarcane is one of the most significant crops globally, with social, economic, and environmental importance. It provides raw material for industries to produce ethanol, sugar, liquor, biodiesel, and animal feed. Additionally, its byproducts (bagasse and straw) are used for electricity generation (SOUZA; BERNARDO; CARVALHO, 1999; NOGUEIRA, 2016). Water deficit caused by irregular rainfall is one of the main factors affecting sugarcane crop yield and industrial productivity. This issue is particularly common in certain regions of Goiás, Brazil, including the northern region (SOBRINHO *et al*., 2019).

In this context, irrigation is one of the most influential factors affecting industrial quality, crop yield, and sugarcane production costs. However, the use of this agricultural technique in sugarcane cultivation requires significant investments and careful management to prevent water waste. In this context, irrigation has become an increasingly adopted technique, combining yield gains with water and electricity efficiency in Brazil and worldwide (FERNANDES, 2003; TEODORO *et al*., 2013).

Despite being an important tool for farmers cope with climatic variations such as El Niño, La Niña, and global warming, irrigation is a high-cost technique that, when poorly managed, can significantly reduce profitability, making its use unviable. This highlights the importance of optimizing resources invested in irrigation (PEREIRA *et al*., 2015; ALVES JÚNIOR *et al*., 2018).

The pursuit of economic efficiency, focused on optimizing invested resources, is usually not considered in traditional management of existing irrigation systems, which primarily focus on maximizing crop yield. This occurs because irrigation aimed at maximizing profits is a complex and challenging process, even though its economic viability can be analyzed based on physical yield and water resource efficiency, particularly in regions with scarce rainfall, such as northern Goiás (FIGUEIREDO *et al*., 2008; MARTINS *et al*., 2016).

Analyses of the economic viability of irrigated sugarcane crops in northern Goiás, Brazil, considering current agricultural and economic factors, are increasingly important. Understanding the economic efficiency of yield increases due to irrigation is essential to enable and promote the expansion of irrigated crops in northern Goiás (FRIZZONE, 1993). In addition, the need for economic improvements is linked to competition for water use and socio-environmental impacts of irrigation. These factors may drive a paradigm shift in irrigation, prioritizing economic efficiency over the exclusive focus on water supply to plants (FRIZZONE, 2004; CASTRO JÚNIOR *et al*., 2015).

In this context, the hypothesis proposed was that irrigation in sugarcane crops, whether for plant crop or ratoon crop, is economically viable in northern Goiás, Brazil. Therefore, the objective of this study was to evaluate the economic viability of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.

2 METHODOLOGY

Economic viability was analyzed using survey data collected at the Uruaçu Plant in Uruaçu, Goiás, Brazil (14°31'29"S, 49°08'27"W, and average altitude of 520 m). The region has a tropical Aw climate, characterized by lower rainfall in the winter than in the summer, according to the classification of Köppen and Geiger (1928) classification, with a pronounced seasonal variation in mean monthly rainfall depth, ranging from 265 mm in January to 2 mm in July. Although the mean annual rainfall depth reaches 1,638 mm, its distributed throughout the year is irregular. The mean daily minimum and maximum temperatures are 17 °C and 35 °C, respectively.

A 100-ha area of the Uruaçu Plant was used for growing irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years. The soil was prepared using a conventional system, including plowing, harrowing, and furrowing. The crops were planted in May, using a mechanical planting system, as commercially practiced, adhering to the recommended number of buds per meter for the sugarcane cultivar CTC4. The plants were irrigated using a center pivot system, covering a total irrigated area of 100 ha and applying a total water depth of 500 mm.

Survey data were obtained from the Uruaçu Plant in Uruaçu, Goiás, Brazil, and from the periodically published table of estimated sugarcane production cost by FAEG (2024). The costs were structured according to the adjusted operational cost methodology, in which the Effective Operational Cost approach consists of the sum of all expenses with mechanized operations, labor, and inputs used during the sugarcane crop implementation and production (MATSUNAGA *et al*., 1976; MARTIN *et al*., 1998; RODRIGUES *et al*., 2018); and the Total Operational Cost consists of the Effective Operational Cost plus other operational costs (RAMBO *et al*., 2015).

Financial parameters were estimated to assess the viability of investments in irrigation. The percentage value of Minimum Attractiveness Rate of Return (MARR) adopted was 4%, as typically recommended for agricultural production (BNDES, 2014). Gross income (in Brazilian real – R$) was estimated according to Equation 1:

$$GI = P \times PPM \qquad (1)$$

where

GI = gross income (R$ ha^{-1})
P = sugarcane production (Mg ha^{-1})
PPM = product price in the market (R$ Mg^{-1})

Net Present Value (NPV) and Internal Rate of Return (IRR) are the most used indicators in economic-financial analyses. NPV at t = 0 is calculated as the sum of all cash flows, discounted back to the initial period at a certain MARR, according to Equation 2 (ROSS *et al*., 2007):

$$NPV = -C_0 + \sum_{i=0}^{T} \frac{C_i}{(1+r)^i} \qquad (2)$$

where

C_0 = cash flow at time 0
C_i = cash flow at period *i*

r = discount rate

When a NPV is greater than zero, the initial investment is covered, meeting the minimum required return and generating a cash surplus (OLIVEIRA *et al*., 2020).

The IRR was determined by setting Equation 1 to zero, and solving for the roots of the polynomial equation, according to Equation 3 (ROSS *et al*., 2007):

$$NPV = -C_0 + \sum_{i=0}^{T} \frac{C_i}{(1+r)^i} = 0 \qquad (3)$$

where

$i > K$ = economically viable project

An investment is considered viable when IRR is greater than the MARR, and it is rejected when it is lower (COELHO *et al*., 2016).

The Payback Period (PBP) was determined based on the definition of T and calculated using Equation 4 (VERGARA *et al*., 2017):

$$I = \sum_{t=1}^{T} \frac{CF_t}{(1+K)^t} \qquad (4)$$

where

I = initial investment
CF_t = cash flow at period t
K = capital cost

The Benefit-Cost Ratio (B/C) was calculated according to Equation 5 (RASOTO *et al*., 2012):

$$\frac{B}{C} = \frac{\sum_{k=0}^{n} B_k(1+j)^{-k}}{\sum_{k=0}^{n} C_k(1+j)^{-k}} \quad (5)$$

where

B = benefit (R$)
C = cost (R$)
j = annual interest rate
k = useful life (years)

The investment is considered viable when the B/C ratio is greater than 1; a higher B/C ratio indicates greater profitability (OLIVEIRA *et al*., 2020).

The economic viability analysis was based on data from two harvests of the sugarcane cultivar CTC4 (plant crop and ratoon crop), including stalk yield and total recoverable sugar from the irrigated crops. These conditions reflect the advanced technological level adopted for the crop. The price of total recoverable sugars, in Brazilian real, was R$ 0.7783 kg^{-1} and the received price was R$ 160.44 Mg^{-1}.

3 RESULTS

Figure 1 illustrates the costs of soil preparation and sugarcane planting in the first growing year (plant crop). The costs of inputs, mechanized planting, and services and machinery were approximately R$ 1,161.10, R$ 4,306.62, and R$ 4,181.39 per hectare, respectively, accounting for 12.03%, 44.63%, and 43.33% of total costs of soil preparation and planting.

Figure 1

Costs of soil preparation and sugarcane planting, and percentage contributions in the first growing year (plant crop) in northern Goiás, Brazil.

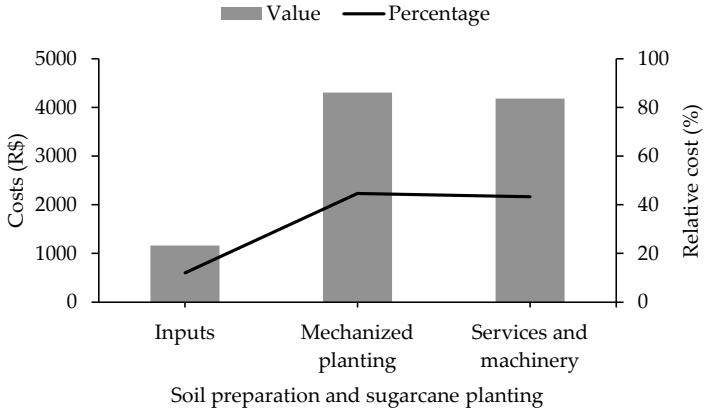
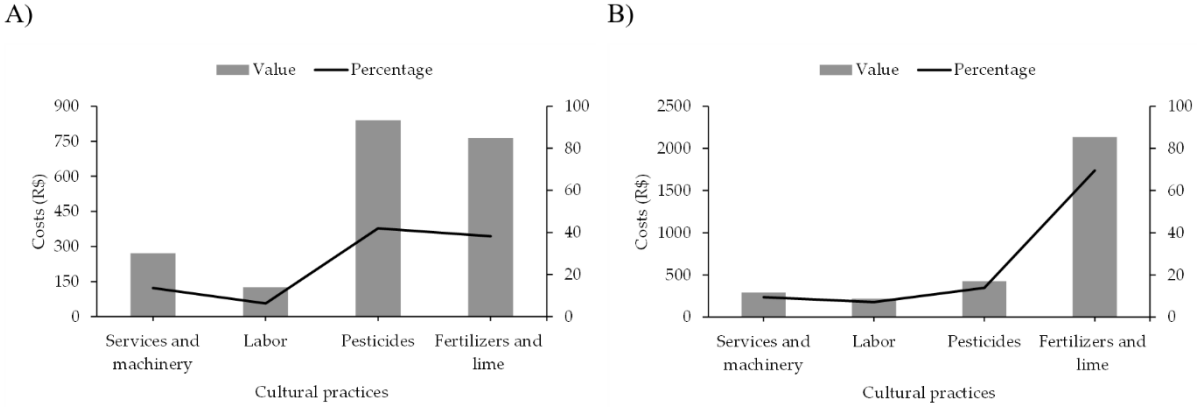


Figure 2 illustrates the costs of cultural practices in the first and second growing years. The costs of services and machinery, labor, pesticides, and fertilizers and lime in the first growing year were R$ 271.37, R$ 125.33, R$ 839.95, and R$ 763.33 per hectare, respectively, accounting for 13.57%, 6.27%, 42.00%, and 38.17% of total cultural practice costs.

Figure 2

Costs of cultural practices and percentage contributions of irrigated sugarcane crops in the first (plant crop) (A) and second (ratoon crop) (B) growing years in northern Goiás, Brazil.



In the second growing year (ratoon crop), the costs of services and machinery, labor, pesticides, and fertilizers and lime were R$ 291.37, R$ 218.60, R$ 426.35, and R$

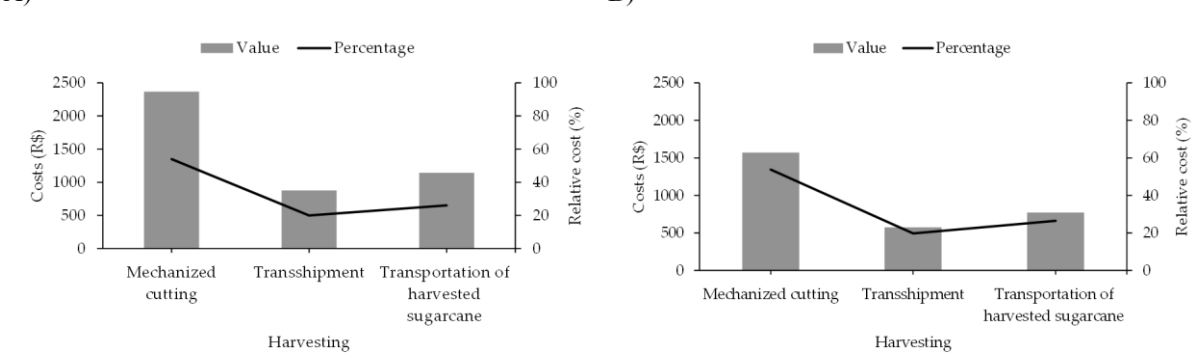
2,136.33 per hectare, respectively, accounting for 9.48%, 7.11%, 13.88%, and 69.53% of the total cultural practice costs.

In the first growing year, the cultural practices incurring the greatest costs were those related to applications of pesticides, fertilizers, and lime. In contrast, in the second growing year, cultural practice costs were primarily associated with application of fertilizers and lime.

Figure 3 illustrates the costs of sugarcane harvesting in the first and second growing years. The costs of mechanized cutting, transshipment, and transportation of harvested sugarcane in the first growing year were R$ 2,366.67, R$ 876.00, and R$ 1,143.50 per hectare, respectively, accounting for 53.96%, 19.97%, and 26.07% of total harvesting costs.

Figure 3

Costs of harvesting and percentage contributions of irrigated sugarcane crops in the first (plant crop) (A) and second (ratoon crop) (B) growing years in northern Goiás, Brazil.



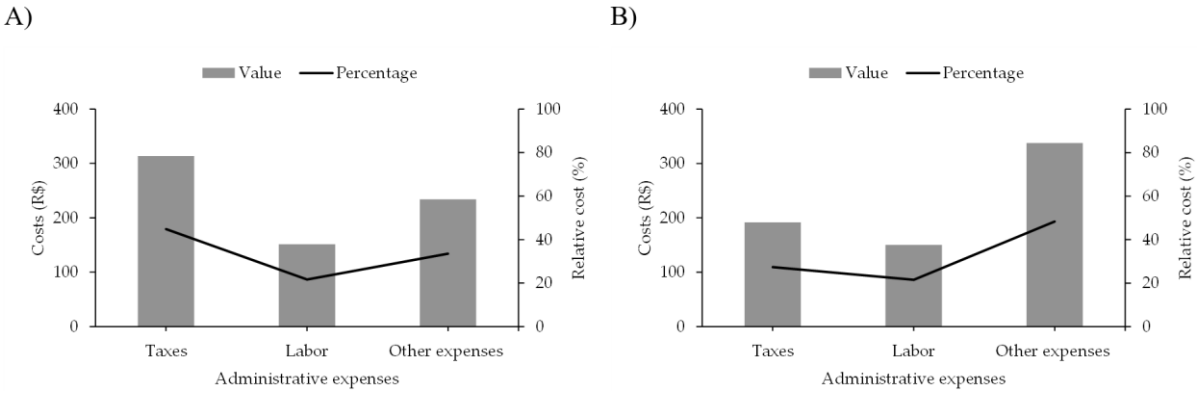
The cost of mechanized cutting was R$ 1,300.00 in the second, and R$ 2,500.00 in the first growing year. In the second growing year, the costs of mechanized cutting, transshipment, and transportation of harvested sugarcane were R$ 1,570.33, R$ 575.00, and R$ 771.00 per hectare, respectively, accounting for 53.85%, 19.72%, and 26.44% of total harvesting costs. Although these percentage contributions were similar to those in the first growing year, the actual costs were, on average, 33.53% higher in the first growing year.

Figure 4 illustrates the administrative expenses of sugarcane cultivation in the first and second growing years. In the first growing year, the costs of taxes, labor, and other

expenses were R$ 313.54, R$ 151.40, and R$ 234.08 per hectare, respectively, accounting for 44.85%, 21.66%, and 33.49% of total administrative expenses.

Figure 4

Administrative expenses and percentage contributions of irrigated sugarcane crops in the first (plant crop) (A) and second (ratoon crop) (B) growing years in northern Goiás, Brazil.



In the second growing year, the costs of taxes, labor, and other expenses were R$ 191.49, R$ 150.40, and R$ 337.82 per hectare, respectively, accounting for 27.39%, 21.52%, and 48.33% of total administrative expenses.

Figure 5 illustrates the total costs of cultural practices in the first and second growing years, which were approximately R$ 2,000.00 and R$ 3,072.66 per hectare, respectively, accounting for 39.43% of the total costs in the first, and 60.57% in the second growing year.

Figure 5

Total costs of cultural practices and percentage contributions of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.

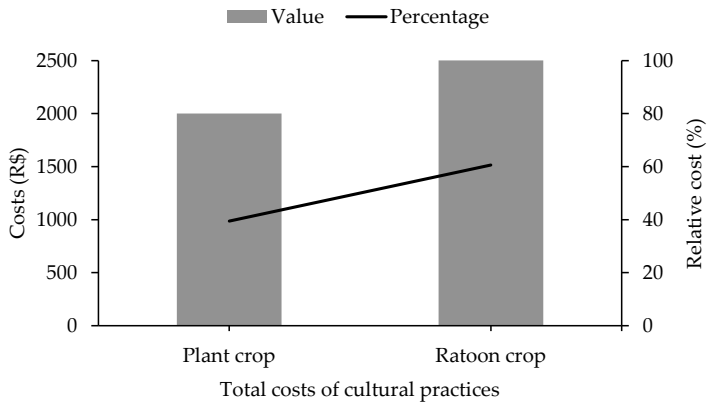


Figure 6 illustrates the total cost of sugarcane harvesting in the first and second growing years, which amounted to R$ 4.386.17 and R$ 2.916.33 per hectare, respectively, accounting for 60.06% and 39.94% of the total costs.

Figure 6

Total costs of harvesting and percentage contributions of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.

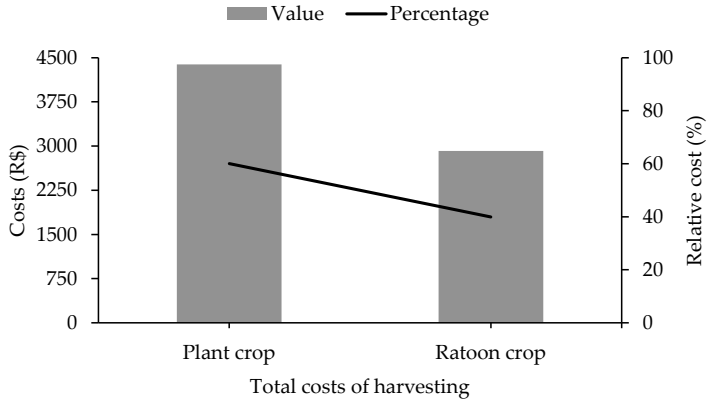
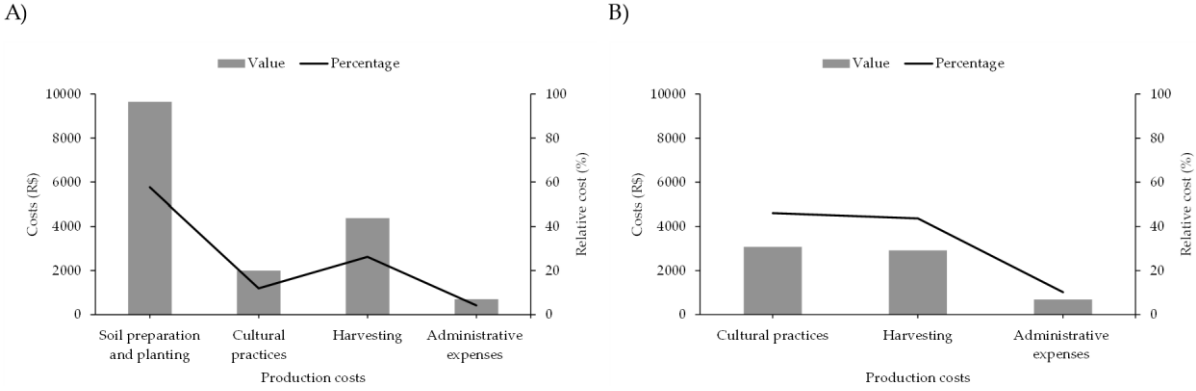


Figure 7 illustrates the production costs of sugarcane in the first and second growing years. In the first growing year, the costs of soil preparation and planting, cultural practices, harvesting, and administrative expenses were approximately R$ 9,649.11, R$

2,000.00, R$ 4,386.17, and R$ 699.02 per hectare, respectively, accounting for 57.66%, 11.95%, 26.21%, and 4.18% of the total costs.

Figure 7

Production costs and percentage contributions of irrigated sugarcane crops in the first (plant crop) (A) and second (ratoon crop) (B) growing years in northern Goiás, Brazil.



In the second growing year, the costs of cultural practices, harvesting, and administrative expenses were R$ 3,072.66, R$ 2,916.33, and R$ 679.71 per hectare, respectively, accounting for 46.08%, 43.73%, and 10.19% of the total costs.

Figure 8 illustrates the effective operational costs of sugarcane production in the first and second growing years, which were approximately R$ 16,734.28 and R$ 6,668.70 per hectare, respectively, accounting for 71.50% and 28.50% of the total cost.

Figure 8

Effective operational costs and percentage contributions of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.

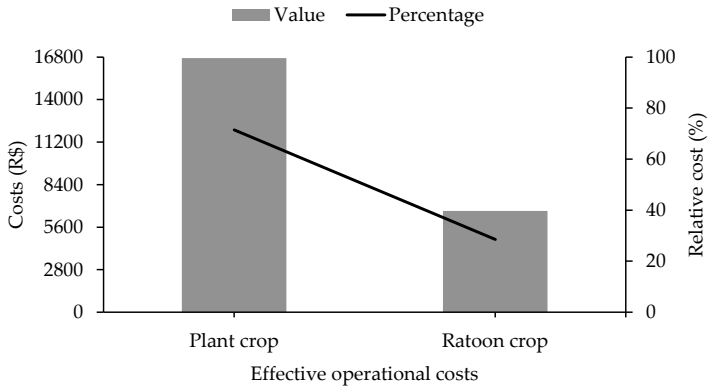


Figure 9 illustrates the irrigation operational costs for sugarcane production in the first and second growing years, which were R$ 5,869.11 and R$ 985.91 per hectare, respectively, accounting for 85.62% and 14.38% of the total costs. Irrigation operational costs were higher in the first growing year due to expenses associated with assembling and implementing the irrigation system. In contrast, costs were lower in the second growing year, as they were limited to electricity and system maintenance.

Figure 9

Irrigation operational cost and percentage contributions of sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.

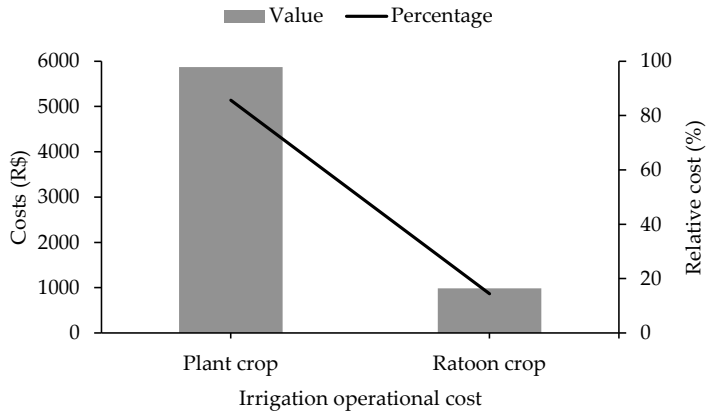


Figure 10 illustrates the percentage cost contribution of irrigated sugarcane production in the first growing year, with the highest costs attributed to services and machinery, planting, and irrigation, accounting for 18.50%, 19.05%, and 25.97% of the total costs, respectively, totaling 63.52% of total production costs.

Figure 10

Percentage cost contribution of irrigated sugarcane production in the first (plant crop) growing years in northern Goiás, Brazil.

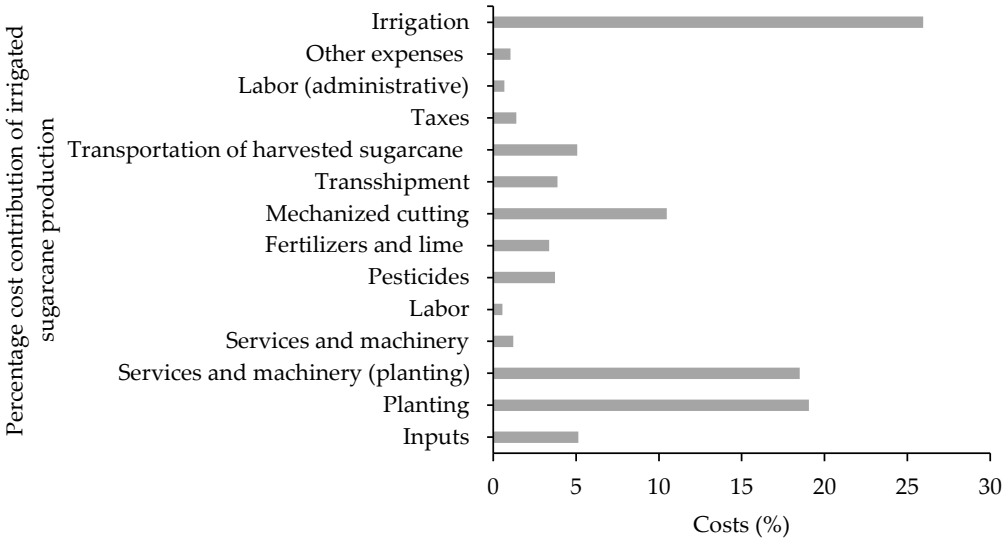


Figure 11 illustrates the percentage cost contribution of irrigated sugarcane production in the second growing year, with the highest costs attributed to irrigation, mechanized cutting, and fertilizers and lime, accounting for approximately 12.88%, 20.51%, and 27.91% of total costs, respectively, totaling 61.30% of total production costs.

Figure 11

Percentage cost contribution of irrigated sugarcane crops in the second (ratoon crop) growing year in northern Goiás, Brazil.

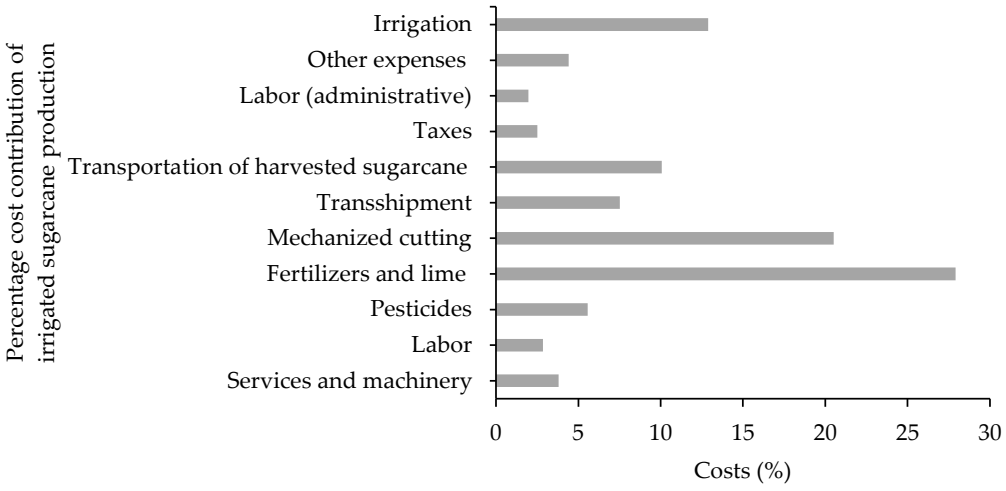


Figure 12 illustrates the total operational cost (sum of operational effective cost and irrigation operational cost) of sugarcane production in the first and second growing years, which were R$ 22,603.39 and R$ 7,654.61 per hectare, respectively, accounting for 74.70% and 25.30% of the total operational cost.

Figure 12

Total operational cost and percentage contributions of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.

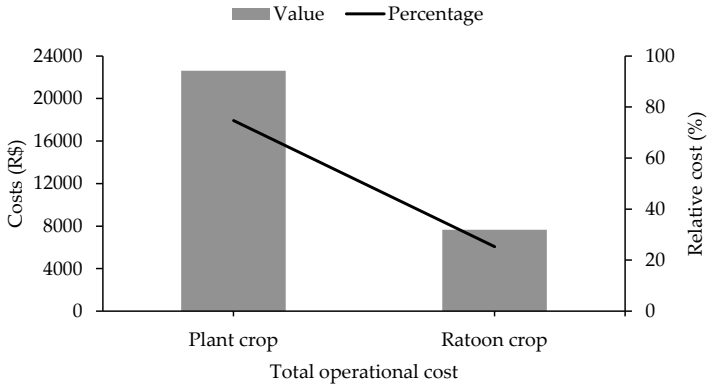
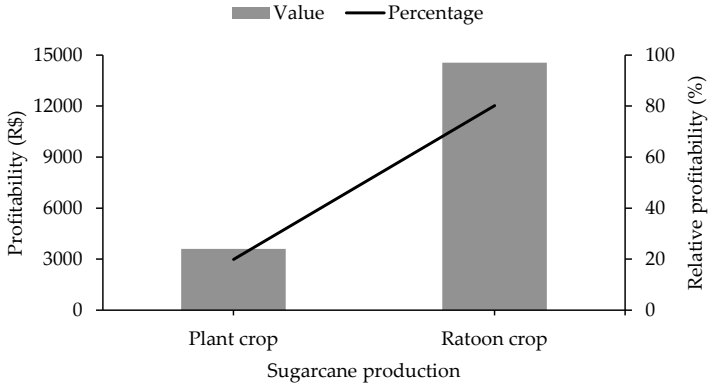


Figure 13 illustrates the profitability of irrigated sugarcane crops in the first and second growing years, which were R$ 3,608.09 and R$ 14,556.87 per hectare, respectively, representing a percentage profit contribution of 19.86% and 80.14% of the total profit across both growing years.

Figure 13

Profitability and percentage profit contribution of irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil.



The Benefit-Cost Ratio (B/C) of irrigated sugarcane crops in northern Goiás exceeded 1.0, indicating economic viability, with a return of R$ 0.80 for each Real (R$) invested (Table 1). The Payback Period (PBP), which represents the time required to recover the invested capital, was three years at an interest rate of 4%, yielding a profitability of R$ 2,693.85 per hectare per year for irrigated sugarcane crops.

Table 1

Economic indicators used for evaluating irrigated sugarcane crops in the first (plant crop) and second (ratoon crop) growing years in northern Goiás, Brazil

Economic indicators				
MARR	**IRR**	**Payback**	**NPV**	**B/C**
%	%	years	R$ ha^{-1} $year^{-1}$	R$
4	58.23	3	2,693.85	1.80

Minimum attractive rate of return (MARR); internal rate of return (IRR); payback period (PBP); Net Present Value (NPV); benefit-cost ratio (B/C). Brazilian real: R$ (BRL).

The Internal Rate of Return far exceeded 4%, a threshold based on the interest rate for irrigated projects financed by the Brazilian Development Bank (BNDES), confirming the strong economic viability of irrigation in sugarcane crops in northern Goiás.

Irrigation of sugarcane crops in northern Goiás results in a high NPV. This substantial profitability is attributed to increases in stalk yield and improved industrial quality of sugarcane, as irrigation significantly enhances plant growth and development.

4 DISCUSSION

Most agricultural operations, from soil preparation to harvest, can be mechanized when properly scaled and planned, enabling a satisfactory financial return (Duarte Júnior *et al*., 2008; Silva *et al*., 2021). Properly conducted economic viability studies can generate reliable indicators for de-cision-making in crops implementations, such as sugarcane, by providing growers with results in monetary terms. Additionally, these studies often highlight that the highest percentage cost contributions to cultural practices are associated with pesticides, and fertilizers and lime (Casarotto Filho, 2009; Carvalho *et al*., 2020).

Considering economic aspects when recommending more suitable agricultural practices has become increasingly important in recent years, as the prices of produc-tion inputs have tended to rise faster than the product prices. Thus, a more efficient use of

these inputs is necessary to minimize variable costs per unit of production (Paulino *et al*., 1994; Gonçales Filho *et al*., 2020).

Studies highlight that harvest mechanization is driven by environmental considerations, guiding the sector toward a new operational structure that integrates economic, social, and environmental viability (Sousa, 2015; Batista; Mendonça, 2019).

Economic viability studies for sugarcane cultivation require knowledge and understanding of the origin and composition of production costs, including administrative expenses (Garcia; Silva; Denadai, 2021).

The variation in cultural practice costs for sugarcane ratoon crops and transportation expenses generally do not significantly affect the net income generated from irrigation (Frizzone *et al*., 2001; Girardi, 2019).

In recent years, costs of sugarcane harvesting in the second growing year have typically been around R$ 3.000.00 per hectare, with a percentage cost contribution of 40% (Cunha, 2021).

During the planning and decision-making processes, farmers should assess the strengths and weaknesses of sugarcane cultivation in the first and second growing years and manage their total relative costs, as production costs are crucial in the management of rural enterprises (Andrade *et al*., 2017).

Economic analyses provide a rational understanding of potential actions and their consequences in agricultural planning based on pre-established criteria. They also determine the economic success of the activity depending on decision-making informed by effective cost data (Rezende *et al*., 1999; Banchi *et al*., 2019).

Irrigation can mitigate the economic risks of sugarcane cultivation, particularly in agricultural years of climatic instability, when reduced rainfall can lead to water restrictions, decreasing crop yield (Santos *et al*., 2016).

A reliable and efficient investment analysis for financial decision-making in the implementation of an irrigation system for sugarcane cultivation requires a detailed characterization of irrigation investments, as they often have a significant impact on profitability (Rebelatto 2004; Pereira, 2017).

Conducting a thorough agricultural survey and effective management requires a detailed analysis of the efficiency of each operational procedure from the beginning of the crop season to the final delivery of the product (Souza; Fernandes, 2020).

In the first year, irrigation represents the largest share of irrigated sugarcane production costs, accounting for a significant portion of the total expenditure (Cunha; Pasqualetto, 2020). Assessing the total operational cost of irrigated sugarcane production provides valuable short-term projections, aiding decision-making for investments in the sugarcane sector. Additionally, it facilitates the analysis of price dynamics and their correlation with production costs (Oliveira *et al*., 2022).

The irrigation is a viable agricultural investment, offering a relatively fast return on investment and a satisfactory income, representing an efficient and safe investment strategy for rural properties (Dal'sotto 2013; Verma; Solanki, 2020). Therefore, irrigation generally presents a Net Pre-sent Value (NPV) greater than zero indicates a viable project, as it signifies that the present value of the investment's returns exceeds the initial investment, considering the farmer's investment costs (Rezende; Oliveira, 2001; Oliveira *et al*., 2022). It is important to note that high tax rates are among the most critical financial challenges in the agricultural sector, as they disrupt production capacity, reduce the investments and competitiveness of rural properties in Brazil (Momm, 2020).

5 CONCLUSION

The production cost of irrigated sugarcane crops in northern Goiás was higher in the first growing year (plant crop), with the highest expenses attributed to services and machinery (related to planting), planting, and irrigation, which together accounted for 63.52% of the total production costs. In the second growing year (ratoon crop), the major cost components were irrigation, mechanical harvesting, and application of fertilizers and lime, representing 61.30% of the total production costs.

The Net Present Value was positive (R$ 2693.85 ha^{-1} $year^{-1}$), confirming the investment's viability, promising profitability, and efficient allocation of resources. The Internal Rate of Return weas 58.23%, exceeding the discount rate, while the Benefit-Cost Ratio was R$ 1.80, reinforcing the economic feasibility of irrigation. Additionally, the Payback Period for the invested capital was 3 years, indicating a relatively fast return on investment.

Overall, the adoption of irrigation in sugarcane production during both the first (plant crop) and second (ratoon crop) growing years in northern Goiás proved to be economically viable, as all evaluated economic indicators were favorable.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

The data will be available on demand to authors.

How to cite this article (APA)

Cunha, G. N., & Moura, J. B. de. (2026). ECONOMIC VIABILITY OF IRRIGATED SUGARCANE CROPS IN NORTHERN GOIÁS, IN THE BRAZILIAN CERRADO. Veredas Do Direito, 23(6), e235958. https://doi.org/10.18623/rvd.v23.5958