Engenharia Agrícola

ISSN: 1809-4430 (on-line)

www.engenhariaagricola.org.br

Scientific Paper
Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v44e20230137/2024

ECONOMIC FEASIBILITY OF CENTER PIVOT IRRIGATION WITH CORN, COWPEA, AND SOYBEAN CROPS IN SANDY SOILS

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KEYWORDS

production cost, precision irrigation, economic profitability.

ABSTRACT

The use of irrigation enhances productivity, reduces vulnerability to drought and climate variation, and boosts agricultural production. This study aimed to verify the economic viability of implementing center pivot irrigation for corn, cowpea, and soybean crops. A 50-hectare area irrigated by a center pivot system was considered, simulating rotational cultivation in the region of Paraíso das Águas, MS. The historical average ET0 of 8 mm day-1 for the region was used for project design and irrigation management. Financial indicators were calculated based on regional technical cultivation coefficients. Overall, 62.1% of the total production costs for the corn, cowpea, and soybean agricultural system were allocated to preparation, planting, cultural practices, and harvesting, while 34.8% were allocated to irrigation (investment in hydraulic equipment and infrastructure, energy, depreciation, and maintenance). The net present value (NPV) for corn, cowpea, and soybean crops were $72.07, $359.68, and $410.59 per hectare, respectively, averaging $842.34 per hectare per year. This profitability provides gains for producers, generating employment and regional development. The implementation of a 50-hectare center pivot irrigation system is economically feasible for cultivating corn, cowpea, and soybeans, considering a 4-year and 9-month return on capital investment under the study conditions.

INTRODUCTION

Center pivot irrigation is a technique used in agriculture to ensure crop production in low water availability regions. Allied to this, economic viability is a critical factor when making investment decisions in irrigated agriculture. Therefore, assessing costs and benefits of implementing and operating these systems provides valuable information for farmers.

Moreover, the choice of crops is also essential when analyzing the economic viability of center pivot irrigation. In this sense, economic analyses comparing irrigated corn with rainfed corn have shown that irrigated plants result in greater net profitability due to increased yields and reduced risks associated with water scarcity (Oliveira et al., 2020).

Cowpea (*Vigna unguiculata*), also known as black-eyed pea or macassar bean, is a staple crop in the North and Northeast regions of Brazil, particularly in the Northeastern Semiarid region. This crop offers product diversification and has been a profitable option for farmers (Costa & Souza, 2019). Azevedo et al. (2023) highlighted that *V. unguiculata* attracts significant global interest as a protein source for human and animal consumption. Furthermore, it has high production capacity in environments with high temperatures, water deficit, and low soil fertility (Obala et al., 2020).

Soybean productivity in the 2022/2023 harvest followed recent trends, estimated at 3,537 kg ha^{-1}, 24% higher than the 2021/22 harvest, with record productivity across several Brazilian states, totaling 44.03 million hectares planted (Conab, 2023).

Irrigation increases productivity, reduces vulnerability to drought and climate variation, and boosts agricultural production. Among irrigation techniques, center pivot irrigation is widely used in large, irrigated areas

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Area Editor: Fernando António Leal Pacheco
Received in: 10-9-2023
Accepted in: 5-8-2024

worldwide. Evaluating the economic viability of center pivot irrigation is crucial for farmers considering this technique (Gava et al., 2023).

Based on the above, this study aims to analyze the economic viability of implementing center pivot irrigation for corn, cowpea, and soybean crops in sandy soils.

MATERIAL AND METHODS

To study the economic viability of center pivot irrigation for cultivation of corn, cowpeas, and soybeans, successive production costs, phytosanitary treatments, and agricultural operations were evaluated on farms of the Indaiá group in the municipality of Paraíso das Águas, MS - Brazil. The area designated for the feasibility study is located in the mid-north region of Mato Grosso do Sul State, at an altitude of 650 meters. The soil has a sandy texture (Tables 1 and 2). According to the Köppen classification system, the climate is humid tropical (Aw), with a rainy season from October to April and a dry season between May and September. The average annual temperature ranges from 20 to 25 ºC.

TABLE 1. Physical properties of the soil and its water content in the experimental area.

Depth layer (cm)	Particle size distribution (%)			Water content (g g^{-1})		Density (g cm^{-3})
	Clay	Silt	Sand	FC	SPW	
0-20	12	5	83	0.088	0.053	1.300

FC - Field Capacity; SPW - Soil permanent wilting point.
Source: The author (2023).

TABLE 2. Chemical properties of the soil in the experimental area.

Depth layer (cm)	pH	P	K	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	t	T	V	P-rem	OM
	H_2O	mg dm^{-3}		cmol$_c$ dm^{-3}							%	mg L^{-1}	dag kg^{-1}
0-20	5.02	10.19	0.06	1.54	0.71	0.00	3.18	1.65	1.79	7.72	43.02	10.18	5.71

Source: The author (2023).

Corn, cowpea, and soybean crops were planted, with each harvest occupying the soil for four months. For corn cultivation, the cultivar P3454 PWU was used, sown on March 5th, with the cycle closing on July 5th. Cowpea was sown immediately after and harvested on November 5th. Soybeans, using the cultivar Neo 750 with a 110-day cycle, were sown on November 5th and harvested on March 5th of the following year.

This study aimed to explore sandy areas due to their lower acquisition cost, considered to be $4,000.00 per hectare. The lower cost is attributed to the high sand content in these areas. Given the more affordable land value, a feasibility study on implementing a center pivot irrigation system was planned. This approach is seen as economically viable because it allows for three irrigated crops to be cultivated simultaneously with good productivity and profitability.

The feasibility calculations were based on a 50-hectare area with a terrain slope of 2.0%. Costs for implementing the irrigation project and energy infrastructure, including transformers, were obtained from local commercial establishments specializing in irrigation. Additional data necessary for crop implementation were sourced from the national reference book of production costs (Agrianual, 2022).

An economic viability analysis was conducted using the amazonSaf spreadsheet (Arco-Verde & Amaro, 2011). Production costs were estimated in US dollars ($), considering a cultivated area of 50 hectares and simulating the cultivation of three crops in a 50-hectare center pivot system, designed with an irrigation depth of 8 mm day^{-1}. The design depth was calculated using a maximum crop coefficient of 1.1, representing the highest water demand period for corn crops (Allen et al., 1998), which has the highest demand in the adopted cultivation system (corn, cowpea, and soybeans). The application efficiency for the center pivot was set at 85% (Bernardo et al., 2019).

For irrigation management calculations from March to July (second crop corn cultivation period), an average Kc of 1.10 was used for corn crops. The study considered 200 days of irrigation per year: 30 days for summer crops (grain corn), 60 days for winter crops (cowpea), and 15 days for winter/spring crops (soybeans). Each crop had an average cycle of 120 days, including sowing, farming, and harvesting.

For feasibility calculations, we used the method presented by Alves Sales et al. (2018). Indicators used to evaluate the investment viability included the profitability indicator, which refers to gross revenue (GRE, $), determined by [eq. (1)]:

$$GRE = PRO \times PRI \quad (1)$$

Where:

PRO is the production in the 50-ha study area (in kg), and

PRI is the sales price (in US dollar - U$).

The net present value (NPV), defined as the difference between the present value of benefits and the present value of costs (Frizzone & Andrade Júnior, 2005), was determined by [eq. (2)]:

$$NPV = \sum_{j=0}^{n} \frac{CF_j}{(1+i)^j} \quad (2)$$

Where:

n is the project longevity;

j is the period of cash flow;

CF is the cash flow balance, and

i is the yearly interest rate of 12%.

The internal rate of return (IRR) measures the project's potential to generate returns (Frizzone & Andrade Júnior, 2005) and is determined as in [eq. (3)]:

$$IRR = \sum_{j=0}^{n} \frac{FC_j}{(1+i)^j} = 0 \quad (3)$$

Payback period is the time it takes for the project to return the invested capital (Puccini, 2016). The benefit/cost ratio (B/C) is used to verify whether the benefits outweigh the costs and is determined according to [eq. (4)] (Frizzone & Andrade Júnior, 2005):

$$B/C = \frac{\sum_{k=o}^{n} B_k (1+i)^{-j}}{\sum_{k=o}^{n} C_k (1+i)^{-j}} \quad (4)$$

Where:

B is the benefit (U$);

C is the cost (in US dollar);

i is the yearly interest rate of 12%, and

j is the period of cash flow.

Sales prices of corn, cowpea, and soybeans, as well as their productivity, are based on values accepted and used by AEB (2023) in projections and financing, as follows: 1) Corn: productivity = 6,500 kg.ha^{-1}; price = \$10.20 per bag; 2) Cowpea: productivity = 2,250 kg.ha^{-1}; price = \$42.00 per bag; and 3) Soybeans: productivity = 4,000 kg.ha^{-1}; price = \$25.00 per bag.

The project recommended cultivating corn, cowpea, and later soybeans. In the subsequent agricultural year, the same crops were chosen, repeating the cycle. These rotations aim to improve system profitability, as irrigated soybeans are notably profitable in the Paraíso das Águas MS region, where November marks the onset of regular rainfall.

Irrigation has become a crucial pillar in agricultural production worldwide. In the Paraíso das Águas region, the average annual rainfall is 1,580 mm. The use of center pivot irrigation in this area allows for three harvests within a year, enhancing productivity and profitability. Additionally, the sandy soil in these areas has a lower added value, which further justifies the economic feasibility study for implementing a center pivot irrigation system.

RESULTS AND DISCUSSION

The results of the economic analyses revealed the total production costs for corn, cowpea, and soybean crops in Paraíso das Águas – MS, which were \$1253.93, \$1530.32, and \$1589.41, respectively (Table 3). The production cost of soybeans is 1.26 times higher than that of corn and 1.04 times higher than that of cowpea, mainly due to the high costs associated with preparing and planting cowpea, which together represented 16.30% of the total costs. Carvalho et al. (2023) found that the cost of producing irrigated cowpea increases by around 17 bags per hectare, yet it remains viable to implement the crop in an area with full irrigation.

TABLE 3. Production cost (including investments, activities, and inputs) for corn, cowpeas, and soybeans grown under central pivot irrigation on a 50-hectare area in Paraíso das Águas, MS - Brazil

Investments / activities / inputs	Corn		Cowpea		Soy	
	U$ ha^{-1}	%	U$ ha^{-1}	%	U$ ha^{-1}	%
Total production cost	1,253.93	100.0	1,530.32	100.0	1,589.41	100.0
Opportunity cost	324.10	25.8	317.76	20.8	373.82	23.5
Depreciation	24.69	2.0	24.69	1.6	24.69	1.6
Electricity	92.74	7.4	185.47	12.1	46.37	2.9
Maintenance	32.00	2.6	32.00	2.1	32.00	2.0
Administrative costs	6.67	0.5	6.67	0.4	6.67	0.4
FUNRURAL taxes	29.17	2.3	41.58	2.7	44.00	2.8
Tillage and planting	72.18	5.8	249.76	16.3	159.22	10.0
Cultivation	517.70	41.3	517.70	33.8	795.28	50.0
Harvest	154.70	12.3	154.70	10.1	107.37	6.8
Total	1,253.93	100.0	1,530.32	100.0	1,589.41	100.0

Source: The author (2023).

Fernandes (2012) found that expenses related to tillage and planting, cultural treatments, and harvesting of bean crops irrigated by center pivot accounted for 65.39% of total production costs. This percentage is slightly higher than the present study, where these expenses represent around 62.10%. This data indicates a slight decrease in the costs of sowing, farming, and harvesting beans over the past 10 years.

In evaluating the production costs of corn irrigated by center pivot in the Montes Claros-MG region, Rabelo et al. (2017) reported a production cost of \$769.80 ha^{-1}, which is lower than the cost presented in Table 3, suggesting that the cost of corn production increased by approximately 63% over six years.

Table 3 shows that, on average, 62.1% of the total production costs for the corn, cowpea, and soybean agricultural system are allocated to preparation, planting, cultural treatments, and harvesting, while 34.8% are allocated to irrigation (investment in hydraulic equipment and infrastructure, energy, depreciation, and maintenance). Irrigation costs are indirectly related to fertilizer and pesticide costs, as excessive water can cause nutrient leaching (e.g., nitrate and potassium) and the emergence of diseases and pests (Oliveira et al., 2020).

An average energy cost of \$0.08 KWh^{-1} was considered. The study assumed 360 days of land use per year, with irrigation depth calculations made individually for each crop per cycle. Increased water supply to the crops presumably leads to higher electricity costs due to longer irrigation times, thereby increasing total production costs (Kahramanoğlu et al., 2020).

The project recommended cultivating corn, followed by cowpeas and soybeans. In the study region, summer soybeans are particularly profitable due to favorable climatic conditions and long photoperiods. Sensitivity to photoperiod varies among soybean cultivars, with each having a critical photoperiod above which flowering is delayed, making soybeans short-day plants. Corn and cowpeas require hotter days and high light, conditions prevalent in this region. Cowpea, in particular, has several advantageous characteristics, such as good adaptation to low fertility soils, drought tolerance, and high atmospheric nitrogen fixation capacity (Farias et al., 2021). Additionally, cowpea has a short growth cycle, making it an attractive option for crop rotation in the region.

Table 4 presents the economic indicators of the agricultural production system.

TABLE 4. Economic impact of central pivot irrigation systems on corn, cowpea, and soybean production over 30 years in Paraíso das Águas, MS - Brazil, considering a 50-hectare area.

Activity	Revenue	Profit			Financial evaluation
		Accumulated	Net	Operational cost	
	U\$ ha^{-1}	U\$ ha^{-1}	U\$ ha^{-1}	U\$ ha^{-1}	
Year 1	260,800.00	92,901.06	42,117.16	42,117.16	
Year 2	260,800.00	92,901.06	42,117.16	84,234.32	
Year 3	260,800.00	92,901.06	42,117.16	126,351.47	
Year 4	260,800.00	92,901.06	42,117.16	168,468.63	*Payback*
Year 5	260,800.00	92,901.06	42,117.16	210,585.79	*4 years e 9 months*
Year 6	260,800.00	92,901.06	42,117.16	252,702.95	
Year 7	260,800.00	92,901.06	42,117.16	294,820.11	
Year 8	260,800.00	92,901.06	42,117.16	336,937.26	

Source: Prepared by the author (2023).

Table 4 shows that the net profit accumulated with 50 hectares of conventional center pivot equipment took five years to bring the cash flow to zero, indicating that this would be the time needed to recoup the initial investment, considering the harvest cycle proposed in this assessment. This finding reveals the project's viability within a 5-year horizon. The net present value (NPV) for corn, cowpea, and soybean crops were \$72.07, \$359.68, and \$410.59 per hectare, respectively, totaling \$842.34 per hectare per year. This profitability provides significant gains for farmers, generating employment and development for the region.

Table 5 provides the detailed economic indicators of the study, illustrating the financial metrics used to evaluate the feasibility and profitability of implementing center pivot irrigation for these crops.

TABLE 5. Economic performance of a 50-hectare central pivot irrigation system for corn, cowpea, and soybean production in Paraíso das Águas, MS - Brazil

Harvest year	Crop	Return (%)	Profitability (%)	Contribution margin (U$)	Return rate (%)	B/C
1	Corn	5.75	5.43	U$ 5,171.21	42.61	1.43
	Cowpea	23.50	19.03	U$ 19,552.03	55.87	1.56
	Soybeans	25.83	20.53	U$ 22,097.62	64.53	1.65
2	Corn	5.75	5.43	U$ 5,171.21	42.61	1.43
	Cowpea	23.50	19.03	U$ 19,552.03	55.87	1.56
	Soybeans	25.83	20.53	U$ 22,097.62	64.53	1.65
3	Corn	5.75	5.43	U$ 5,171.21	42.61	1.43
	Cowpea	23.50	19.03	U$ 19,552.03	55.87	1.56
	Soybeans	25.83	20.53	U$ 22,097.62	64.53	1.65
4	Corn	5.75	5.43	U$ 5,171.21	42.61	1.43
	Cowpea	23.50	19.03	U$ 19,552.03	55.87	1.56
	Soybeans	25.83	20.53	U$ 22,097.62	64.53	1.65
5	Corn	5.75	5.43	U$ 5,171.21	42.61	1.43
	Cowpea	23.50	19.03	U$ 19,552.03	55.87	1.56
	Soybeans	25.83	20.53	U$ 22,097.62	64.53	1.65

Source: The author (2023).

For the three crops evaluated (Table 5), there was a profit indicated by a B/C ratio greater than 1.0 (Puccini, 2016), as well as for each year of cultivation. This indicator shows that for every $1.00 invested, there is a return with a profit of $1.43 for corn, $1.56 for cowpea, and $1.65 for soybeans.

Additionally, the internal rate of return (IRR) varied among the crops, with corn showing a lower IRR of 42.61% and soybeans showing a higher IRR of 64.53%. Considering that a well-managed 50-hectare center pivot system typically has a longevity of more than 30 years (Oliveira et al., 2020) and that the producer can recoup the pivot's implementation costs after five years, it can be concluded that from the fifth year onwards, the system reaches maximum profitability.

CONCLUSIONS

The implementation of a 50-hectare center pivot irrigation system is viable for cultivation of corn, cowpeas, and soybeans, considering a horizon of four years and nine months for the return on invested capital under the conditions of this study.

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