English Version

Cost of irrigation and profit of bean in a center pivot system with water pumped by diesel engine under variation of length pressurized pipe and topographic levels

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Abstract

In this paper it was simulated the cost of irrigation by a center pivot system with water pumped by diesel engine under different pressurized pipe length and topographic levels in the brown bean growing, as well their profit. It was considered an irrigated area of 103.58 ha, that is the most economic system configuration from the considered variables. The cost of irrigation in brown bean growing ranged from 26.6 to 37.6% between the extreme conditions, in the lowest topographic level (40 m) and pressurized pipe length (2000 m) to the largest topographic level (80 m) and length (4000 m). In all irrigation system settings and with prices in August 2008 it would be viable to the brown bean growing, providing profits until US$ 2,199.80. Nevertheless with the average historic price the irrigated bean growing would be unviable, with losses reaching US$ 184.50.

Keywords: center pivot; bean; costs and profits.

Introduction

Brazil is the world's larger bean producer, accounting for 23.6% of the world production. Paraná state is the major national producer, with approximately 21% of all the internal production (National Supply Company – CONAB, 2009). Still according to the National Supply Company – CONAB (2009), the bean planted area in Brazil in the 2007/2008 crop was 3,993,000 ha, with a production of 3,520,900 t, i.e., productivity of only 822 kg ha^{-1} (14.7 bags with 60 kg net per ha). Basically, there are three bean crops in Brazil: the 1st crop (summer), which is concentrated from December to February on Midwest and from February to April on North and Northeast; 2nd crop (off-season), which happens between March and April, and 3rd crop (winter), which is concentrated on the months from July to October.

According to Caser et al. (2008), in São Paulo state the 2007/2008 crop had as results: the bean planted area of the second crop (sown in January and February) was 58,085 ha for a production of 101,940 Mg, followed by the irrigated winter bean (plantation from April to June) which was 28,340 ha to a production of 68,988 Mg and the area with beans of the dry season was 18,443 ha to a production of 19,599 Mg. Therefore, it was verified that on the winter beans the productivity with irrigation is approximately 2,434 kg ha^{-1} (41.06 bags ha^{-1}), whereas without irrigation the productivity decreases to only 1,062 kg ha^{-1} (17.70 bags ha^{-1}).

The West Region of the state of São Paulo, under the control of the Rural Development Office (EDR) of Andradina, stands out in the bean production in winter due to mild temperatures and absence of frost, reducing the occurrence of plagues and diseases, which favors grain quality and good production. The most representative municipalities of the EDR on the bean production are Ilha Solteira with 41.97%, Andradina with 19.43%, Pereira Barreto with 10.40%, Murutinga do Sul with 9.32% and Guaraçaí with 6.21% (Agriculture Economy Institute – IEA, 2008).

Barros et al. (2001) verified that the prices of the bean were those who had higher annual fluctuations in the period from 1975 to 2000. Several factors contributed to this, the main one is the fact that the product presents inelastic demand, due

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to the individual limitation of consumption. This characteristic favors the sharp drop on the prices where there is excess of the product on the market. In an opposite situation, a sharp increase happens on the case of crop failures. This occurs due to the lack of sufficient international stocks and to the loss on the product quality which prevents the formations of internal buffer stocks.

Guerra et al. (2000) report that bean is normally the annual crop with the largest economical value, and that in irrigated areas it can be cultivated with high technological level. That is because the irrigation allows the planting to be done in appropriate time and ensures the water supply for plants to demonstrate their productive potential, which can exceed 4000 kg ha^{-1}.

The production costs of the winter bean are relatively high, and for the region of Pereira Barreto (SP) their value without the cost of irrigation is around R$ 3,500.00 per ha. Considering the necessity of the production with irrigation on this region, to this value it will be added the cost of irrigation, which can be high if the conditions of the planted area are unfavorable as, for instance, a long distance to the water source, high geometric gradient of the water and even if the area is far from an extension of electricity in which the investment on high-voltage line is too costly.

The energetic aspect on the irrigation is of major importance in crop production. Although there are several different energy sources to engine power, hydropower and diesel are the most used in Brazil, and, thus, most emphasized on researches involving costs of pumping systems (ZOCOLER, 2004). According to Monteiro et al. (2007), in most of the regions of the country the electric energy appears as the most economically viable alternative on the water pumping in irrigated areas, justifying its use for approximately 70% of the irrigators.

Frizzone et al. (1994), by using data from an EPAL Engenheiros Associados S/C project, on Barreiras (BA) region, compared the costs of the bean crops irrigated by central pivot powered by electric energy and diesel energy in an 91.3 ha area, considering twelve sowing periods. Monthly data of the reference evapotranspiration (ETo) with the application of the crop coefficient (Kc) were used to estimate the crop need for water. The sum of monthly water deficits referent to the water balance corresponded to the total necessity of irrigation to each month of sowing. It was verified that the highest need of irrigation happened to August sowing (337.4 mm) and the lowest to January sowing (31.6 mm). It was admitted that the crop cycle was 82 days in all planting dates. Considering that the irrigation system is used to produce two bean crops a year (one with sowing in May and other in October) the costs are presented on Table 1.

By this research, the authors verified that the system powered by diesel resulted in an irrigation cost 72.57% higher than the system powered by electric energy. It was concluded that the variable costs of

Table 1. Cost of Bean irrigation in American commercial dollar* (US$) in two sowing dates on the pivot center system with electricity and diesel pumping

Discrimination	Sowing date		Total
	May	October	
Annual cost of the effective consumption of electric energy	1,780.30	339.10	2,119.40
Cost of the electric energy demand	973,10	973.10	1,946.20
Annual cost of electric energy (with 13% of ICMS)			4,594.10
Annual fixed cost of the electricity powered system			13,372.18
Total cost with electricity powered system			**17,966.28**
Annual cost of diesel consumption	10.011,70	4,715.10	14,726.80
Annual fixed cost of the diesel powered system			16,277.32
Total cost with diesel powered system			**31,004.12**

** In the article it was not mentioned the relation US$/R$, however the price of diesel corresponded to US$0.34 L^{-1} and the consumption of electric energy was US$0.04389 per kWh* irrigation were always higher on the system powered by diesel. Also, the cost of the millimeter of water on the electricity system decreased exponentially with the increase of irrigation hours, always inferior to the diesel system. The difference between the energetic costs increased between the systems with the increase on the water level applied and the distribution of the need of irrigation during the crop cycle affected the cost of the millimeter of water applied by the electricity system.

In some cases the total annual costs of the diesel powered engines is more attractive, as Monteiro et al. (2007) concluded in an analysis of the hourly pumping diesel engines and electric engines in the five regions of Brazil. The authors considered the composition green, blue and convention tariffs, irrigation period 2,4,6 and 8 months a year and the operation 21 h day^{-1} (3 hours at peak hours). A 50 cv engine was considered in both cases, whose input values of cost composition are shown in Table 2. The balance between diesel engine and electric engine was determined by the distance between the transmission grids and the point of consumption. In conclusion, the use of diesel engines for irrigation systems is viable under the condition that the distance from the grid ranges from 1.32 km to 8.7 km, depending on

Table 2. Values of input cost composition of total and annual costs of electric engine and diesel engine

Specification	Electric engine	Diesel engine
Cost of the engine (R$)	4,550.00	11,900.00
Engine power (cv)	50	50
Useful engine life (years)	15	10
Specific consumption (L per cv per hour)	-	0.25
Diesel price (R$)	-	1.13
Annual interest taxes (%)	12	12
ICMS (%)	20	20
Cosine of φ (Power factor)	0.86	-

Table 3. Extension of three-phase mains (75 kVA) in km for the regions of Brazil, with 2, 4, 6 and 9 months of irrigation (21 hour/day) in Blue, Green and Conventional tariffs, which enables the use of motor diesel.

Region	Annual Irrigation time (Hours – month)	Tariff		
		Blue	Green	Conventional
North	1260 – 2	1.92	1.85	1.68
	2520 – 4	3.84	3.73	3.31
	3780 – 6	5.75	5.58	4.95
	5670 – 9	8.63	8.39	7.40
Northeast	1260 – 2	1.87	1.79	1.52
	2520 – 4	3.74	3.61	3.07
	3780 – 6	5.60	5.41	4.63
	5670 – 9	8.40	8.13	6.97
Midwest	1260 – 2	1.84	1.77	1.47
	2520 – 4	3.69	3.59	2.97
	3780 – 6	5.51	5.36	4.78
	5670 – 9	8.27	8.07	6.73
Southeast	1260 – 2	1.74	1.73	1.32
	2520 – 4	3.51	3.51	2.70
	3780 – 6	5.24	5.25	4.08
	5670 – 9	7.88	7.90	6.14
South	1260 – 2	1.95	1.86	1.63
	2520 – 4	3.89	3.73	3.28
	3780 – 6	5.81	5.58	4.28
	5670 – 9	8.71	8.37	7.40

the region, fare and number of daily operation hours, as it can be seen on Table 3.

Thus, this work had as objective to simulate the cost of irrigation of a center pivot system powered by diesel engine on different lengths of pipeline and geometric gap on the brown bean production on the Ilha Solteira – SP region, as well as the revenue of the crop, in each system configuration.

Material and Methods

The cost of irrigation simulations were conducted using the program Otimização de Sistemas Elevatórios – OSE (ZOCOLER, 2003).

It was considered an irrigated area of 103.58 hectares on the climate characteristics of Ilha Solteira, with an irrigation system scaled to the application of a maximum daily level of 6,17 mm in 20 hours, providing a flow of 319,5 $m^3 h^{-1}$. The level was calculated based on the average evapotranspiration in 9 years (1999 to 2008), whose dataset was obtained from the Hydraulic and Irrigation Area of the Faculty of Engeneering – Campus of Ilha Solteira/UNESP (http://www.agr.feis.unesp.br/ilhadados.php), that was 4.1 mm during the flowering season, with a Kc of 1.28 and considering an application efficiency of 85%.

It was also considered that the irrigation during the crop cycle occurred on the period between May 1st and July 19th, with a total water level of 251 mm, calculated based on the average potential evapotranspiration of the crop. To make this water level occur, considering an application efficiency of 85%, the total level applied was 295.3 mm. The system flow is 319.5 $m^3 h^{-1}$, therefore 958 hours of system operation on the bean crop were necessary, assuming the absence of rain on the considered period. To simulate the cost of irrigation some system parameters were considered unchanged, which can be seen in Table 4.

The other parameters that suffered changes were the following ones:

- Pumping topographic gap: 40, 50, 60, 70 and 80 meters;

- Length of the pressurized pipe: 1000, 1500, 2000, 2500 and 3000 meters.

However, the system was dimensioned, in each proposed variable, in a configuration more economical than the five options inserted on OSE Program, i.e., it was used the best configuration for the presented condition. That means that if there was, for instance, an addition on the length of the pressurized pipe, the system configuration was not changed only in this item, but possibly also in the others, as hydraulic pump, consumption and combustion engine power. Therefore, it was performed 25 simulations (5 gaps versus 5 pressurized pipe length) and in each simulation 5 options on the OSE program. The equipment prices (tubes, bombs, center system pivot) and services were obtained on the market during the second semester of the year 2008.

On the present work it was considered a winter crop in which the irrigation system would operate 958 hours, i.e., 48% of the total time of the annual system operation, assumed to be 2000 hours. In doing so, the annual depreciation referent to the considered crop was equivalent to this percentage.

OSE Program considers as annual fixed cost (CAF) the sum of the annual depreciation, calculated by the fund capital formation method (FRIZZONE et al., 2005), and remuneration of the capital invested in the equipments, installation and services. The annual cost of maintenance and repairs (CAMR) considers the expenditures occurred during the year, necessary to maintain the irrigation system on normal operation conditions. Annual pumping cost (CAB) considers the spending with diesel relative to the consumption of the used engine, which varies according to the power.

The input and the services used on the bean production, as well as their costs were obtained with Rapassi (2008) and adapted to Ilha Solteira – SP (ARF[1], 2009). For an expected productivity of 3000kg ha^{-1} (50 bags per ha) the bean production cost, without the cost of irrigation that are variation sources on the work, was R$ 3,587.76 ha^{-1}.

Considering the productivity of 3000 kg ha^{-1} (50 bags per hectare), production cost of R$ 3,587.76 ha^{-1}, average price of bean bag paid to the producer on the month of August 2008 (R$ 163.44,

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Table 4. General fixed input parameters on OSE program

Suction pipe	
Length (m):	30
Material:	Galvanized steel
Absolute roughness "e" universal formula (mm):	0.2
Useful life expectation of the pipe (years):	15
Annual spending with maintenance and repairs:	1.5
Spending with hydraulic accessories:	25
Spending with pipe mounting:	5
Pressurized pipe	
Material composition of the tubes	Galvanized steel
Absolute roughness "e" universal formula (mm):	0.2
Useful life expectation of this pipe (years):	15
Annual spending with maintenance and repairs (% of a new one):	0.5
Spending with hydraulic accessories (% of a new one):	5
Spending with pipe mounting (% of a new one):	7
Extra component data	
Component nature:	Center pivot
Value of the new component(s) mounted	500,000.00
Useful life expectation (years):	20
Surrender value after the "lifetime" (% of a new one):	20
Annual spending with maintenance and repairs (% of a new one)	1
Necessary pizometric load on the pivot point (m)	50
Economic data	
Annual interest taxes (%):	6.00
Diesel value (R$/liter)	1.838*
Surrender value of the water pumping system after the "lifetime" (% of a new one):	15

**Average diesel price on Araçatuba region for the year 2008, valid for Ilha Solteira – SP region. (National Oil Agency –ANP, 2009).*

Institute of Agricultural Economics – IEA), and also the actual historical average bean price on August during the period from 2001 to 2008, it was calculated the net with the culture in different configurations of the irrigation system simulated on the work. It was also calculated the equilibrium price (or capping price) as the minimum price necessary to cover the production costs in different configurations of the irrigation system.

On the attainment of the actual average price of bean on the period from August 2001 to August 2008 it was utilized the IGP-M published by Getúlio Vargas Foundation. It was considered the nominal average price of the bean bag received by producers in August 2001 to 2008, according to Institute of Agricultural Economics – IEA. The actual average price obtained was R$ 108.31 bag^{-1}.

Results and Discussion

Table 5 shows, on topographic gaps of pumping and length of pressurized pipe, the annual cost of irrigation, the total production costs, the percentage of the irrigation participation on production cost, the equilibrium price per bean bag, the net income related to the price of winter bean received by the producer in August 2008 and historical net income to climatic conditions of Ilha Solteira (SP).

Related to Table 5, it can be verified that the annual cost of irrigation ranged from R$ 1300.87 to R$ 2159.84 ha^{-1}, between the extreme conditions, i.e., from the lower topographic level (40 m) and length of pressurized pipe (2000 m) to the higher gap (80 m) and length (3000 m). This made the participation of irrigation on the cost of production range from 26.6

to 37.6%. Between the extremes there was a drop in the net income of R$ 858.97 ha^{-1}, which represent -26.2% for the price paid to the producer in August 2008 and -163% for the historic price. Thus, the equilibrium price would have to rise from R$ 97.77% to R$ 114.95 bag^{-1} representing a variation of 17.6%, i.e., to the expected productivity of 50 bags/ha on the first case the producer would cover the production costs if the price was R$ 97.77, and, on the second case, if it was R$ 114.95.

With the prices in August 2008 all the configurations of the diesel irrigation system would be viable, and even compelling, providing net income of up to R$ 3283.37/ha. By contrast, with the average historical price (from August 2001 to 2008), on the settings of a pipeline length of 3000 m or more the bean culture irrigated would have negative income, reaching losses of R$ 332.10 ha^{-1}. Conversely, one should be warned that in all cases, even with positive incomes, the minimum price of the bean bag to cover the costs of production were higher then the official minimum price of R$ 80.00 bag^{-1}, valid for the analyzed period.

By isolating the source of variation topographic gap in Table 5 it is obtained, on average, an increase of R$ 62.56 ha^{-1} in the annual cost of irrigation (and, consequentially, in the cost of production of the crop) for each 10 m increase in topographic

Table 5. Annual cost of irrigation (CAI $hectares^{-1}$, in R$), cost of production (CP ha^{-1}, in R$), participation of the irrigation on the cost of production (irrig., in%), equilibrium price per bean bag (PE bag^{-1}, in R$), net income (RL ha^{-1}, in R$, August/2008) and historical net income (RLH ha^{-1}, in R$, August/2001 to August/2008) due to pipeline length (CA, in meters) and topographic gap (DT, in meters).

DT	CA	CAI ha^{-1}	CP ha^{-1}	Irrig	PE bag^{-1}	RL ha^{-1}	RLH ha^{-1}
40	1000	1300.87	4888.63	26.6	97.77	3283.37	526.87
40	1500	1431.31	5019.07	28.5	100.38	3152.93	396.43
40	2000	1557.15	5144.91	30.3	102.90	3027.09	270.59
40	2500	1703.87	5291.63	32.2	105.83	2880.37	123.87
40	3000	1833.72	5421.48	33.8	108.43	2750.52	-5.98
50	1000	1353.20	4940.96	27.4	98.82	3231.04	474.54
50	1500	1483.64	5071.40	29.3	101.43	3100.60	344.10
50	2000	1616.88	5204.64	31.1	104.09	2967.36	210.86
50	2500	1761.32	5349.08	32.9	106.98	2822.92	66.42
50	3000	1886.05	5473.81	34.5	109.48	2698.19	-58.31
60	1000	1413.04	5000.80	28.3	100.02	3171.20	414.70
60	1500	1547.65	5135.41	30.1	102.71	3036.59	280.09
60	2000	1677.62	5265.38	31.9	105.31	2906.62	150.12
60	2500	1813.65	5401.41	33.6	108.03	2770.59	14.09
60	3000	1945.82	5533.58	35.2	110.67	2638.42	-118.08
70	1000	1469.84	5057.60	29.1	101.15	3114.40	357.90
70	1500	1595.25	5183.01	30.8	103.66	2988.99	232.49
70	2000	1729.68	5317.44	32.5	106.35	2854.56	98.06
70	2500	1870.10	5457.86	34.3	109.16	2714.14	-42.36
70	3000	2033.78	5621.54	36.2	112.43	2550.46	-206.04
80	1000	1521.90	5109.66	29.8	102.19	3062.34	305.84
80	1500	1659.81	5247.57	31.6	104.95	2924.43	167.93
80	2000	1804.96	5392.72	33.5	107.85	2779.28	22.78
80	2500	1937.42	5525.18	35.1	110.50	2646.82	-109.68
80	3000	2159.84	5747.60	37.6	114.95	2424.40	-332.10
CA-isolada		139.61	139.61	1.80	2.79	139.61	139.61
DT-isolado		62.56	62.56	0.80	1.25	62.56	62.56

pumping. In other words, participation of irrigation in the cost of production rises 0.80% in each 10 m elevation of the land in relation to the water supply. This percentage was relatively low in this work due to the non-necessity of increase in the pumping system power on extreme situations (40 m and 80 m) together with higher participation of the fixed cost (specially the one provided by the depreciation of the center pivot system) related to the pumping cost on cost of irrigation. Thus, the impact of the elevation of the topographic gap on the equilibrium price was also low, i.e., R$ 1.25 bags^{-1} every 10 m.

By isolating the source of variation length of pressurized pipe in Table 5 it is obtained, on average, an increase of R$ 139.61 ha^{-1} in the annual cost of irrigation (and, consequentially, in the production cost of the crop) for each 500 m increase in this pipe extension, representing an increase in the participation of irrigation in the cost of production of 1.80%. Thus, the impact of the increase in the pressurized pipe length on the equilibrium price was R$ 2.79 bag^{-1} to each 500 m. Due to the higher amplitude of pressurized pipe length variation (500 m) in relation to the pumping topographic gap (10 m) which was evaluated on this work, and only to that, the effect of the pressurized pipe length was higher on the irrigation costs than the topographic gap. If it was also considered the variation of 10 meters on the pressurized pipe extension, then the effect would be, expectedly, lower on the annual cost of irrigation (and, thus, on the cost of the crop production), i.e., R$ 2.97 ha^{-1}, representing an increase of 0.036% on this cost.

Conclusion

According to propositions of the work, it can be concluded that:

The participation of the irrigation on the cost of bean production ranged from 26.6 to 37.6% on the extreme conditions, i.e., from the lower topographic gap (40 m) and pressurized pipe length (2000 m) to the higher gap (80 m) and length (3000 m);

Between the extremes there would be a loss on the net income of R$ 858.97 ha^{-1};

On average, to each 10 m increase on the pumping topographic gap the annual crop cost of irrigation/cost of production increased R$ 62.56 ha^{-1};

On average, to each 500 m increase on the pressurized pipe length the annual crop cost of irrigation/cost of production increased R$ 139.61 ha^{-1};

With the prices in August 2008 all the diesel irrigation system settings would be viable, and even compelling, providing net income up to R$ 3283.37 ha^{-1};

With the average historical price (August from 2001 to 2008), with a pipeline length of 3000 m or more, the irrigated bean crop would have a negative income, reaching losses of R$ 332.10 ha^{-1}.

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