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TECHNICAL PAPER

FINANCIAL ANALYSIS OF THE INVESTMENT IN PRECISION AGRICULTURE TECHNIQUES ON COTTON CROP

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ABSTRACT: The aim of this study was to evaluate a financial analysis by the use of precision agriculture (PA) techniques on cotton crop. The experiment was carried out in a cotton field of 91 ha and its result compared to another field with similar area, cultivated with the conventional agricultural techniques. The financial analysis was extrapolated to the total farm area of 3,500 ha. All agricultural inputs applied, during the 2013/14 cotton crop season were analyzed, as well as their costs. The use of precision agriculture techniques over the cotton crop reduces production costs in 6.6%, increases the profitability index and operating profit in 3.3% and 7.9% respectively, when compared to conventional agriculture. The fertilizer application in variable rate, using precision agriculture, provides 41% of costs reduction with these inputs. Profitability and investment analysis indicators demonstrate economic feasibility and return over investment to both production systems (precision agriculture and conventional) over the cotton crop production, however, the use of precision agriculture techniques shows higher economic viability and smaller return over investment time, even having higher initial costs with machines, sensors and maps production.

KEYWORDS: economic viability, crop cost production, profitability.

INTRODUCTION

Among the management systems used in the Brazilian agriculture, precision agriculture (PA) techniques stand out as modern alternatives that aim at optimizing resources in agricultural areas. In addition, it is a system that can result in effects such as greater competitiveness in the market, due to the optimization of production costs and higher productivities, allowing the producer to offer the product in the market for a more competitive price. The cotton crop in the Brazilian cerrado has received investments in the PA sector, aiming at the acquisition of embedded electronics equipment (Baio & Antuniassi, 2015).These investments aim to reduce production costs, which can reach US$ 2,600 ha^{-1} (IMEA, 2017). According to Bernardi & Inamasu (2017), PA applied to the cotton crop represents only 4.4% of the total area. In addition, the main activities in which this technique is present are in the application of soil correctives and in the harvesting process.

The use of the PA contributes to making agricultural techniques more sustainable, due to the rational use of resources (Amaral et al., 2015). According to Baio et al. (2015), the PA involves three critical elements: collection of information; application of technology; and management. According to these authors, investing in sensors, GPS and mapping only increase the cost of production if nothing is done with the detailed information obtained in the field. Silva et al. (2011) highlight that the PA technique is a management system based on the spatial variability of the factors inherent to the productivities obtained in the areas, aiming at optimizing profit, sustainability and environmental protection. This system uses strategies to solve the problems of crop variability, taking advantage of this variability when possible.

The use of remote sensing helps to map the spatial variability of the species in the field and extends to a series of applications directed to agriculture. Silva et al. (2014) cite that the use of

multispectral sensors to determine vegetation indexes shows a focus on the spectral characterization of soils and plants, as well as the estimation of crop productivity. Amaral et al. (2015) advocate the use of active optical sensors in the optimization of the inputs use, mainly nitrogen fertilizers, based on PA techniques as a tool to aid in the diagnosis and recommendation of fertilization of this element. There are several types of multispectral sensors aimed at the application of inputs at differentiated rates, also called Variable Rate Technology (VRT) applications. The N-Sensor multispectral sensor, developed by Yara International (Duelmen, Germany), has two photodiode receptors that determine the vegetation index, based on the reflectance ratio of the spectral waves of the target in the electromagnetic spectrum lengths of 730 and 760 nm. According to Raper & Varco (2015), this index is called the red edge vegetation index and is obtained by the mathematical subtraction ratio of the natural logarithm of reflectance in these bands of the spectrum, multiplied by one hundred.

However, the adoption or investments in these new technologies makes it necessary to carry out financial analyzes to judge the feasibility of its application. According to Guiducci et al. (2012), the economic feasibility analysis allows the producer to plan the activities to be developed. The use of production costs aims to allow the verification of the resources value used per unit produced and the comparison of it to the product price. From this evaluation between the two values, it is possible to infer about the activity profitability and, consequently, about its economic viability (Guiducci et al., 2012). For Sanvicente (1987), the sensitivity analysis measures when some element of the analysis differs from the expected value, modifying the decision parameter. From variations in the total revenue, caused by changes in the level of prices (or changes in crop productivity), the results related to the remuneration of the entrepreneur and the capitalist will be affected, since changes in revenues affect the economic efficiency indicators and the cash flow (Guiducci et al., 2012).

Little is known about the profitability of the PA techniques application in the cotton crop. In this sense, the aim of this study was to evaluate financially the use of PA techniques in this crop.

SUBJECT DESCRIPTION

The study was carried out in an area cultivated with cotton (*Gossypium hirsutum* L), on the Amambaí farm (52°37'17.79"W and 18°21'21.40"S), located in the municipality of Chapadão do Céu - GO, Brazil, in the 2013/2014 harvest. The results were obtained in a field of 91 ha of this crop, called precision agriculture, and sown in the second harvest period. These results were compared to those of another field with similar area, named conventional agriculture. The costs were extrapolated to the total area of 3,500 ha of the farm. The variety cultivated was FiberMax 975 WS, which shows resistance by transgenic to some species of caterpillars, such as *Heliothis virescens*, *Pectinophora gossypiella*, *Spodoptera frugiperda* and *Alabama argilacea*. The sowing was carried out on 01/02/2013 using a John Deere 8430 tractor (Montenegro, Brazil) together with a 15-row John Deere CCS 2115 seeder (Horizontina, Brazil), with row spacing of 0.80 m and a population of 100,000 plants per hectare.

The recommendations of the fertilizers were carried out according to the soil analyzes from samples collected before planting and with the cotton requirements. The applications of these inputs at differentiated rates occurred according to the division of the area into three application zones or three classes, following the variability of the average input need in these zones. The chemical characterization of the soil in the field under PA techniques was carried out by a georeferenced sample in a quadratic grid with a point sample composed by ten subsamples every 5 ha (Baio & Leal, 2012; Demattê et al., 2014).The manipulation and interpolation of the data by the inverse of the distance in the elaboration of the maps were carried out with the aid of the SSToolbox Geographical Information Systems software, developed by SST Software (Stillwater, USA). The prescription maps have been inserted into field machines in applications at differentiated rates.

The applications of potassium chloride, simple superphosphate and calcium nitrate were carried out by the self-propelled Hercules 5.0 from Stara Company (Não-Me-Toque, Brazil). In the application of plaster and limestone, the self-propelled distributor Stara Hercules 24000 C was used (Não-Me-Toque, Brasil). In the three zones of plaster application in the field under PA regime, the

zero, 527 kg ha^{-1} and 1,330 kg ha^{-1} doses were applied. In the three zones of limestone application, the 436 kg ha^{-1}, 684 kg ha^{-1} and 842 kg ha^{-1} doses were used. The single superphosphate doses were 120 kg ha^{-1}, 198 kg ha^{-1} and 283 kg ha^{-1} were applied. The potassium chloride was applied at zero, 32 kg ha^{-1} and 36 kg ha^{-1} doses. Finally, nitrogen fertilization with calcium nitrate was carried out by doses of 100 kg ha^{-1}, 130 kg ha^{-1} and 160 kg ha^{-1}.

The correctors comparative values of the fixed rate used in the field under conventional agriculture were 1,000 kg ha^{-1} of limestone, 300 kg ha^{-1} of plaster, 300 kg ha^{-1} of single superphosphate, 150 kg ha^{-1} of potassium chloride and 120 kg ha^{-1} of nitrogen (Urea and Calcium Nitrate), according to the need of this comparative field and to the results of the soil analysis. The growth regulator doses used were 50, 75 and 80 mL ha^{-1} of Pix® in the first, second and third applications, respectively, and the dose of 2,000 mL ha^{-1} of the Finish® ripener.

Using the methodology proposed by Baio et al. (2015), six measurements of the Red Edge vegetation index in the cotton crop were carried out at 23, 49, 70, 91, 130 and 168 days after emergence (DAE). In these measurements, the N-Sensor multispectral sensor (Yara International, Duelmen, Germany) was coupled onto the John Deere 4730 spray booth (Catalão, Brazil). The vegetation index maps served as a basis for the creation of prescription maps with differentiated rates in the three application areas of the Basf Pix® (Mepiquat Chloride 250 g L^{-1}) and Bayer Finish® (Etefon 480 g L^{-1} + Cyclaniline 60 g L^{-1}). The vegetation index maps were also used in the recommendation of differentiated rates of nitrogen fertilizer (Calcium Nitrate). Three growth regulator applications were necessary. The electronic controller of the self-propelled sprayer carried out the variation of the pulverized inputs application rate. The pesticides used during the harvest had their doses recommended according to Rosolem et al. (2013). The maximum variation adopted was 20% of the average rate, as a function of the tolerable variation on the pulverized droplet size (Baio & Antuniassi, 2015). The Finish® pesticide was used as a ripener in the cotton plant, in order to standardize the opening of the maces, being used at doses 40, 50 and 60 L ha^{-1}. The harvest was carried out by John Deere 7760 harvester (Des Moines, USA), equipped with a John Deere AMS harvest monitoring system, GreenStar Harvest Doc.

It was considered the time available (TA) in the accomplishment of each agricultural operation in the calculation of the operational rhythm (OR), according to the methodology presented by Baio et al. (2013), extrapolating the number of mechanized sets from the reference field in PA (91 ha) to the total area of the property in 3,500 ha. The technical specifications of the machines have been obtained from the manufacturers' prospectuses. The acquisition prices of these machines were obtained in consultation on the local market. The operational field capacity (OFC) was calculated from the specifications of each equipment and the selected operational efficiency estimates selected from ASAE (2000) and Hanna (2017).

A risk analysis was carried out using a sensitivity analysis, varying the area (1,500 and 2,000 ha) and varying the average productivity of 1,800 kg ha^{-1} (120 ha^{-1}) of cotton in fiber (1,680 kg ha^{-1} and 1,920 kg ha^{-1}). The sensitivity analysis is carried out aiming at the evaluation of a range of variation associated with each element of the cash flow (Souza Junior et al., 2011).

The methodology of the calculation of cost production used was that of the IEA (*Instituto de Economia Agrícola*), described in Barbosa et al. (2014). The factors considered in the production system were: effective operational cost (EOC), which are the expenses incurred with labor, machinery/equipment operations and materials consumed throughout the production process; and total operational cost (TOC), which is the actual operating cost plus expenses with direct social charges, rural social security contribution, financial charges, technical assistance and machine depreciation. The TOC is the margin in relation to the operational cost, that is, the result obtained after the producer has to bear the operating cost, considering a certain unit price of sale and the productivity of the production system for the activity. Thus, this margin indicates the availability to cover the risk and the entrepreneurial ability of the owner.

The economic viability of cotton production in the PA system and the conventional system was analyzed using profitability indicators. The indicators used were those defined in Rosini et al. (2016),

of which: gross revenue (GR) is the expected revenue for a given production per hectare, defined as GR = (Op x Pu), where Op is the output and Pu is the unit price actually received; and operating income (OI) or net revenue, OI = (GR - TOC), where GR is the gross revenue and TOC is the total operating cost. The gross margin (GM), defined as GM = [(GR - TOC) / (TOC) x 100], where GR is the gross revenue, was also calculated.

Two other important indicators calculated in the economic profitability analysis are: the profitability index (PI), where PI = [(OI/GR) x 100]; and the leveling point (LP), where LP = (TOC/Pu). A cash flow was elaborated for the PA systems and the conventional system, evidencing the values of the inflows and outflows of financial resources, by calculating the net present value (NPV) and the period of capital return (PCR). Souza Junior et al. (2011) reports that NPV is the monetary return of the investment, reducing the value of money in time at a discount rate, calculated by $NPV = \{CF_1 + \Sigma [CF_n/(1+i)^t]\}$, where CF is the cash flow of each period and i is the discount rate in relation to time (t). The annualized net present value (NPVa) was also calculated by $NPVa = \{NPV \times [i \times (1+i)^n]/ (1+ i)^n – 1\}$. The capital recovery period (CRP) or payback is the indicator that determines the term of recovery of an investment, also called a payout. This indicator is used to evaluate the attractiveness of the investment (Marquezan & Brondani, 2006). According to Souza Junior et al. (2011), the CRP is the number of periods necessary for the sum of future net nominal revenues to equal the value of the initial investment. It is easier to decide to rationalize in terms of earnings per period (analogous to the accounting concept of profit per period) than in terms of accumulated gain over several periods. The minimum attractiveness rate (MAR) used in this analysis was 8% per year (return rate of the investment to the producer), corresponding to the Selic rate (Special Clearance and Escrow System), verified on September 10, 2013. Silva et al. (2012) emphasize that the use of MAR can be defined with the policy of each company, however, its determination or choice is of fundamental importance in the decision to allocate resources in investment projects. The MAR is functionally used to discount the cash flow (to bring to the present value), thus, helping to calculate the NPV of a project (Casarotto Filho & Kopittke, 2015).

Table 1 shows the total operating costs of comparative production for both systems used (PA and conventional agriculture) and extrapolated for the cultivation scenario of 3,500 ha. Effective operating costs in relation to inputs show that fertilizers with limestone and single superphosphate applied at differentiated rates in PA reduced costs by 47% and 29%, respectively. This reduction was a consequence of the greater percentage of the total area, which required lower dosage by the PA system, based on the information showed by the soil fertility maps, which served as the basis for the recommendation. The reduction of fertilizers applied, according to PA techniques, does not always occur, as shown by Demattê et al. (2014). These authors demonstrate that the cost with the PA system varies according to the size of the grid during sampling in the soil fertility mapping.

TABLE 1. Agricultural inputs participants of the cotton production cost by the use of precision agriculture techniques and conventional agriculture.

Cost factors	Precision agriculture		Conventional agriculture	
	Production costs (US$)	% of total costs	Production costs (US$)	% of total costs
Micronutrients subtotal[1]	**71.029.48**	**0.93**	**71.029.48**	**0.87**
Fertilizer 44.6-00-00	83,163.80	1.09	319,349.24	3.90
Fertilizer MAP	415,895.94	5.43	415,895.94	5.07
Fertilizer nitrate YaraBela	241,489.07	3.15	358,265.33	4.37
KCl - Potassium Chloride	18,327.22	0.24	314,467.01	3.84
Single superphosphate	276,636.86	3.61	389,086.29	4.75
Dolomitic limestone	103,627.28	1.35	195,431.47	2.38
Plaster	77,478.37	1.01	69,289.34	0.85
Fertilizer subtotal	**1,216,618.53**	**15.89**	**2,061,784.62**	**25.15**
Seed subtotal	**845,857.87**	**11.05**	**845,857.87**	**10.32**
Herbicides subtotal[2]	**616,270.79**	**8.05**	**616,270.79**	**7.52**
Insecticides subtotal[3]	**2,814,586.49**	**36.76**	**2,814,586.49**	**34.34**
Fungicide subtotal[4]	**678,129.83**	**8.86**	**678,129.83**	**8.27**
Growth regulators				
Legend in fix Tx	27,585.12	0.36	27,585.12	0.34
Pix HC	18,417.75	0.24	16,226.40	0.20
Finish	143,823.81	1.88	168,994.92	2.06
Tuval in fix Tx	27,493.95	0.36	27,493.95	0.34
Regulators subtotal	**208,812.22**	**2.84**	**240,300.40**	**2.93**
SAG adjuvant subtotal	**23.008.98**	**0.3**	**23.008.98**	**0.28**
Maps elaboration				
Soil fertility map	53,299.49	0.70	0.00	0.00
Growth regulator map	44,416.24	0.58	0.00	0.00
Ripener and defoliant map	44,416.24	0.58	0.00	0.00
Productivity map	44,416.24	0.58	0.00	0.00
Maps elaboration subtotal	**186,548.22**	**2.44**	**0.00**	**0.00**
Machines and Implements				
Tractor 8430 + Seeder CCS	167,352.07	2.19	167,352.07	2.04
4730 Convenc. Sprayer	0.00	0.00	135,271.01	1.65
4730 VRT +Sensor N-Sensor Sprayer	262,285.10	3.43	0.00	0.00
Hércules 24000 Truck	26,758.03	0.35	26,758.03	0.33
Hércules 5.0 self-propelled	47,239.66	0.62	47,239.66	0.58
JD 7760 harvester	437,035.40	5.71	437,035.40	5.33
Aerial spraying	31,979.70	0.42	31,979.70	0.39
Machines subtotal	**972,649.96**	**12.7**	**845,635.87**	**10.32**
Soil analyses subtotal	**14,057.01**	**0.18**	**780.94**	**0.01**
Total Operacional cost (TOC)	**7,656,077.81**	**100**	**8,197,385.28**	**100**

[1]**Micronutrients**: Profol N 30 BB, Profol Produtivity, Solupotasse Sulfate K, Triunfu Flex; [2]**Herbicides**: Aramo 200, Dropp Ultra SC, Dual Gold, Finsh, Flumizyn 500, Liberty BCS, Podium EW 110, Select 240 EC, Verdict R and Zapp; [3]**Inseticides**: Ampligo, Avaunt, Bamako, Belt, Bulldock 125 SC, Cefanol, Chess 500 WG, Connect, Counter 150G, Danimen 300 CE, Dimilin, Engeo Pleno, Fipronil, Fury 200 EW, Grimectin, Mospilan, Oberon SC 240, Pirate, Pirephos EC, Polo, Premio, Primo, Sponsor, Tiger 100 EC, Turbine 500 WG, Urge 750 SP and Vertimec 18 EC; [4]**Fungicides**: Bion 500 WG, Emerald, Fox, Frowncide 500 SC, Mertin 400, Priori 250, Score and Trichodermil GL.

The applications in differentiated rates of urea, nitrate and potassium chloride also reduced costs in the PA system by 74.0%, 32.6% and 94.0%, respectively, in agreement with the reduction showed by Amado et al. (2006). There was an average reduction in fertilizer costs of 41.0% for the

use of PA techniques. Silva et al. (2011) reported that 71.0% of the consulted sugarcane mills stated that they achieved reduction in production costs through the use of these techniques. The use of the Pix® growth regulator at differentiated rates resulted in a higher cost of 13.5% for the PA, since there was a higher dosage of this input in function of the maps than the recommendation by the average of the field in the conventional system. However, the percentage participation of this input in the total cost was small, representing 0.24% by the PA and 0.20% by the conventional one. On the other hand, the costs with the Finish® maturity were 14.9% lower in the PA system. Rosolem et al. (2013) report that the correct dose adjustment of the phytoregulators in the cotton crop improves production quality indicators, such as fiber length and *micronaire* index (indicative of fiber maturity).

The soil analysis costs are 94.4% higher by the application of PA techniques compared to the conventional system, since it was necessary to increase the number of soil samples in the area, raising the cost of collection and analysis, in agreement with the results showed by Cherubin et al. (2011) and Demattê et al. (2014). However, the increase in this cost represents 0.18% of total costs, and is little significant when compared to the 41.0% of fertilizer savings obtained by reducing this input in the applications at differentiated rates, which need the fertility maps.

The acquisition of N-sensor multispectral sensor, used in the elaboration of prescription maps of growth regulator and ripener at differentiated rates, resulted in a 13.06% increase in costs for agricultural machinery, or 2.38% over total cost, when compared to the conventional agricultural system. Also, the application of the PA system raised the partial costs by the need to hire a service provider for the preparation of the maps, which represented 2.44% of the total costs, whose application by the other system is not necessary.

Feasibility indicators were better when the cotton was grown under the PA system (Table 2). The gross margin calculated in relation to the total operating cost for both systems shows that the gross revenue remained the same, assuming the scenario of the same productivity, according to field evaluation. However, total-operating costs changed, resulting in an 8.41% higher gross margin in the PA when compared to the conventional system. This difference is related to the lower costs of production of this system, which resulted in a higher profit margin, showing that even after paying the TCO (total operating cost) the agricultural company still has part of the gross revenue to remunerate the producer or to cover other possible risks that may occur in the cotton cultivation. The leveling points, which refer to the fiber production required to pay the total operating costs of production by the two systems, were 3,770.62 t (251,374.55 @ - PA) and 3,970.59 t (264,706.09 @ - conventional system) of fiber in the area of 3,500 ha, evidencing a smaller production in the PA system in relation to the conventional one, thus obtaining greater profitability for the producer.

TABLE 2. Profitability indicators of the cotton crop by application of precision agriculture and conventional agriculture over the crop season 2013/2014 in the Brazilian Cerrado.

Feasibility indexes	Precision agriculture	Conventional agriculture
Gross revenue (US$)	12,791,878.17	12,791,878.17
Gross margin (%)	67.08	58.67
Leveling point (t ha^{-1})	3,770.62	3,970.59
Equilibrium price (US$)	18.23	19.20
Operating profit (US$)	5,135,800.36	4,59,492.89
Profitability Index (%)	40.22	36.97

We identified that the cost per arroba of fiber (equilibrium price) was 5.15% lower by the PA system. Soares & Alves (2013) found similar results in the soybean crop, obtaining cost with inputs and operations for conventional agriculture 5.56% higher than the cost found for the PA. This cost was directly influenced by the optimization in the use of agricultural inputs in the PA technique, which provided lower total costs.

The operating income (OI) in the conventional system was US$ 4,729,763.91 and in the PA system it was US$ 5,135,800.36, showing a higher financial return when compared to the

conventional system. The profitability indexes were 40.22% and 36.97%, respectively, in the analysis of PA and conventional systems. The values of operating profit and profitability indexes show that cotton production is profitable and that although both systems are profitable, the PA system gives the producer greater profitability.

According to the cash flows of the productive systems by conventional agriculture and PA, NPV (Net Present Value) and APV (annualized present value) were estimated at a certain minimum attractiveness rate (MAR) of 8% per year, also defining the time of the investment return or capital recovery period (PRC) within the analysis horizon of 10 years (Table 3). In this scenario presented for the cash flow planning horizon, there was no variation of the TOC, as well as of GR over the 10 years.

TABLE 3. Viability indicators by the net present value annualized present value and payback, in each one of the productive systems analyzed.

Feasibility indexes	Precision agriculture	Conventional agriculture
NPV (US$)	34,461,638.49	31,737,100.80
Payback (US$)	5,135,800.36	4,729,763.91
Capital recovery period	10 months	11 months

The feasibility indicators of the investments of the PA and conventional systems showed a return on the investment made, since the NPV was positive, meaning that all investment was recovered and there was an increase to the value of the producer's estate of R$ 34,461,638.49 and R$ 31,737,100.80 for the PA and conventional systems, respectively. The capital recovery period was 10 months for the investment using the PA system and 11 months for the conventional system. Although both systems return the investment in a short time, the system by the use of PA techniques recovers the investment in less time.

The sensitivity analysis evaluated the estimates of areas and productivities in the different production techniques, to indicate which scenario shows the best return on investment. In this sense, areas of 1,500; 2,500 and 3,500 ha were applied, besides the productivities of 112, 120 and 128 @ ha^{-1} of cotton fiber. This analysis determines in which of these estimates there would be better financial results in applying PA techniques and conventional agriculture.

The adequacy of the machinery stock or number of mechanized sets required for each operation was optimized according to the total OFC of each operation, taking into account the need imposed by the OR in the different scenarios and adjusted the total cost values. In the 1,500 ha cultivation scenario, we estimated that only one self-propelled sprayer (with a multispectral sensor installed in the PA and without that sensor in conventional agriculture), a tractor, a seeder, a harvester and two fertilizer distributors would be required. However, for the 2,500 ha area, two self-propelled sprayers, two tractors, two seeders, two harvesters and two fertilizer distributors were used. And for the 3,500 ha scenario, three self-propelled sprayers, five tractors, five seeders, five harvesters and two fertilizer distributors were estimated. Table 4 shows the sensitivity analysis of the financial indicators from the initial area of 3,500 ha and cotton in fiber yield of 1,800 kg ha^{-1}.

TABLE 4. Sensitivity analysis for the factors of area and productivity variation.

Area (ha)	Technique	Prod. (kg ha^{-1})	PI (%)	CRP (months)	NPV (US$)	NPVa (US$)	Net revenue (US$ ha^{-1} year^{-1})
1,500	AP	1,680	36.52	11	12,539,506.86	1,868,756.30	1,245.84
1,500	AP	1,800	40.75	9	14,991,922.39	2,234,238.53	1,489.49
1,500	AP	1,920	44.46	8	17,444,337.93	2,599,720.76	1,733.15
1,500	CV	1,680	31.11	13	10,680,472.50	1,591,705.36	1,061.14
1,500	CV	1,800	35.70	10	13,132,888.04	1,957,187.59	1,304.79
1,500	CV	1,920	39.72	9	15,585,303.57	2,322,669.82	1,548.45
2,500	AP	1,680	36.37	12	20,812,662.27	3,101,700.42	1,240.68
2,500	AP	1,800	40.61	10	24,900,021.50	3,710,837.47	1,484.33
2,500	AP	1,920	44.32	9	28,987,380.73	4,319,974.53	1,727.99
2,500	CV	1,680	30.97	14	17,721,481.37	2,641,023.31	1,056.41
2,500	CV	1,800	35.57	11	21,808,840.59	3,250,160.36	1,300.06
2,500	CV	1,920	39.60	9	25,896,199.82	3,859,297.42	1,543.72
3,500	AP	1,680	35.87	12	28,739,335.55	4,283,008.48	1,223.72
3,500	AP	1,800	40.15	10	34,461,638.49	5,135,800.36	1,467.37
3,500	AP	1,920	43.89	9	40,183,941.42	5,988,592.24	1,711.03
3,500	CV	1,680	31.34	14	26,014,797.87	3,876,972.03	1,107.71
3,500	CV	1,800	35.92	11	31,737,100.80	4,729,763.91	1,351.36
3,500	CV	1,920	39.92	9	37,459,403.73	5,582,555.79	1,595.02

PA - Precision Agriculture; CV - Conventional Agriculture; Prod. - Productivity; PI - Profitability Index; and, CRP - Capital recovery period.

The most attractive profitability index (44.46%) was demonstrated by the cultivation in the area of 1,500 ha, obtaining a productivity of 1,920 kg ha^{-1} (128 @ ha^{-1}) of cotton fiber, according to the PA techniques. Still, the cultivation area in 1,500 ha resulted in a shorter capital recovery period. Most likely due to the optimization of the operational field capacity of the mechanized sets to the operational rhythm of the necessary mechanized activities. The higher yields of cotton in fiber were responsible for the better profitability indexes and shorter periods of capital return. The application of PA techniques in the largest cultivated areas and in concomitance with the higher yields resulted in higher NPV and NPVa. According to Lowenberg-Deboer (2015), PA techniques should gain range of use only when applied simply, as happened with the adoption of autonomous satellite guidance systems, such as autopilot, which simply operate by the press of a button. Thus, PA techniques for the use of variable rate inputs will only be applied on a large scale after the arrival of the day on which the producer only presses a button to use.

The applications of PA techniques were superior to conventional agricultural techniques in all respects. This result demonstrates the efficiency of the PA, regardless of the productive area and estimated productivity. As expected, higher yields resulted in higher profitability and shorter time of investment return, intensifying the need to search for high productivity in the agricultural sector.

CONCLUSIONS

The uses of precision agriculture techniques in cotton crops reduced production costs by 6.6%, increased profitability and operating profit by 3.3% and 7.9%, respectively, when compared to conventional agriculture.

The application of fertilizers at differentiated rates using precision agriculture techniques provided a 41% reduction in the costs of these inputs.

Profitability indicators and economic viability indicators demonstrate economic viability and investment return of both production systems (PA and conventional) in cotton cultivation, however,

the use of precision agriculture techniques evidences greater economic viability and less time of investment return, even with higher start-up costs for machines, sensors and map production.

The scenario with lower area of work and higher productivity showed the best profitability index and lower investment return period.

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