Article

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ECONOMIC INJURY LEVEL OF CANJIQUEIRA IN NATIVE PASTURES IN PANTANAL OF NHECOLÂNDIA

Nível de Dano Econômico de Canjiqueira em Pastagens Nativas no Pantanal da Nhecolândia

ABSTRACT - Pantanal plain has large extensions of land formed by many types of landscapes suitable to extensive livestock system. Open grasslands and lowlands are formed by forage such as grasses and forbs widely consumed by cattle. However, climatic and human factors can promote the dissemination of invasive shrub species such as canjiqueira (*Byrsonima cydoniifolia* A. Juss) making it necessary, in many cases, the human intervention to control the invasion. The present work had as objective to determine the economic threshold level to control canjiqueira through two methods: tractor driven blade and link chains pulled by tractor in different invasion levels plants per hectare. Economic Threshold proved to be a tool for efficient and effective management for making decisions of when and how to do the control of canjiqueira in natural pastures of Pantanal of Nhecolândia.

Keywords: *Byrsonim cydoniifolia* A. Juss**, cost control, beef cattle, economic threshold.

RESUMO - *A planície pantaneira é composta por extensas áreas formadas por diversos tipos de paisagens utilizadas para a pecuária de corte, onde o nível tecnológico utilizado é baixo. O uso do solo é basicamente com forrageiras como gramíneas e herbáceas nativas para o consumo bovino. A invasão de espécies arbustivas nas pastagens é um dos problemas na redução da produtividade em bezerros dos produtores. Na região do pantanal da Nhecolândia, a disseminação da canjiqueira (**Byrsonima cydoniifolia** A. Juss) diminui a capacidade de suporte das forrageiras, fazendo-se necessária, em muitos casos, a intervenção do homem no controle dessa espécie. Este trabalho teve como objetivo encontrar o nível de dano econômico para o controle de canjiqueira no Pantanal da Nhecolândia, por meio de dois métodos: lâmina acoplada ao trator e corrente link tracionada por tratores. O nível de dano econômico para a decisão da limpeza com o link foi de 8% da cobertura da superfície do solo com a invasora; independentemente da infestação, o controle com a lâmina variou de 9% a 30%, de acordo com a densidade de invasão. O método com lâmina apresentou eficiência média de 83%, e o link de 70%.*

Palavras-chave: *Byrsonima cydoniifolia* A. Juss, custo de controle, pecuária de corte, limiar econômico.

INTRODUCTION

Livestock is considered the main economic activity developed in Pantanal, and the feeding of the cattle herd consists primarily of the grazing of native grasses, often intercropped with exotic species (Santos et al., 2011).

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Pantanal has a great diversity of vegetation types, of which the clean fields and wet areas around the water bodies are those which present a greater richness in native forage for beef cattle rearing. However, these areas present variable floristic composition as a function of anthropogenic and climatic factors. Such variation makes these types of vegetation have different states, many of which are undesirable, such as the state of dirty field or field invaded by shrub species (Santos et al., 2014).

A species is considered invasive when it colonizes areas outside its natural domain. The invasion of tree and shrub species in areas of clean fields has declined, in large part, the farms productive capacity in Pantanal, impairing the zootechnical indexes of the livestock sector in the region. These variations may be caused as a result of natural disturbances (multiannual cycles of flood and drought) and management (fire, animal stocking rate, method of control/cleaning). Among the shrub species in the swampland plains, where sandy soils prevail, canjiqueira stands out (*Byrsonima cydoniifolia* A. Juss.), which has been spreading in the fields and low areas, especially during the driest years (Santos et al., 2006).

Dantas and Rodrigues (1980), in studies carried out in the northeastern region of Pará, estimated that the cost of weeds control in pastures by mowing method are responsible for 10% to 20% of the farms operating costs, without taking into account the damage caused by toxic plants, that result in illnesses and deaths of cattle.

The inefficiency in controlling weeds in pastures is related to non-compliance with the specific characteristics of each invasive species (Dias Filho, 1990), as well as aspects of the ecosystem that facilitate or enhance the invasion process (Ditomaso and Barney, 2012). Thus, it is necessary to develop a modern concept of management and control of invasive plants in harmony with a critical study of biology and ecology of these plants, reaching their most vulnerable stage with a method or a set of more appropriate control methods for each invasive species.

One of the main strategies to prevent the invasion of herbaceous and shrubby species in native pastures is based on early detection of the problem. However, the main challenge refers to the decision of where, when and how to make the control of invasive species economically and environmentally correct (Sheley et al., 1996). The identification of the threshold or economic damage level allows to evaluate in which density of invasive species or what percentage of damage the cost of control is equal to the benefit of control (Auld and Tisdell, 1987; Vidal et al., 2010).

This study aimed to evaluate the level of economic damage in two control methods, *link* and blade, of canjiqueira (*Byrsonima cydoniifolia* A. Juss.) in areas of clean field in Pantanal of Nhecolândia region.

MATERIAL AND METHODS

The development of the study comprised two areas of Pantanal in the municipality of Corumbá, Mato Grosso do Sul, which have units of landscape characteristics of Nhecolândia, sub-region of the Pantanal, as cerradão, cerrado field, clean field, lagoons and ebbs, arranged in mosaic, representing one of the most important regions of cattle ranching in Pantanal, since they are subject to small floods which, when they occur, they are usually of origin of rainfall, which enables the permanence of cattle during the whole year (Pozer and Nogueira, 2004).

The climate of the region is the Aw köppen type: megatermal tropical climate, with dry winter and rainy in summer, which occur during the period from November to April, and dry from May to October with an annual average rainfall of 1,300 mm (Pereira et al., 2012).

From the floristic survey performed in two areas of study by the pyramid method (Passos, 2000), areas of clean field were identified and evaluated with different levels of invasion of canjiqueira, with the following densities: 0.015, 0.03, 0.045, 0.06, 0.075 and 0.09 pl m^{-2}. The percentage of covered areas (hectare) with canjiqueira and pasture were performed with aerial images obtained with the use of unmanned aerial vehicle (VANT, known as *drone*, equipped with a GoPro camera). The flights were performed between 11 hours and 12 hours in totally sunny day, at 100 meters from the surface of the ground. The georeferencing of the pictures was performed by means of AutoCAD program. In this program, the separation and quantification of

invaded areas and pastures were also carried out. In Figure 1, one of the evaluated areas is displayed, with high density of canjiqueira and its processing in AutoCAD.
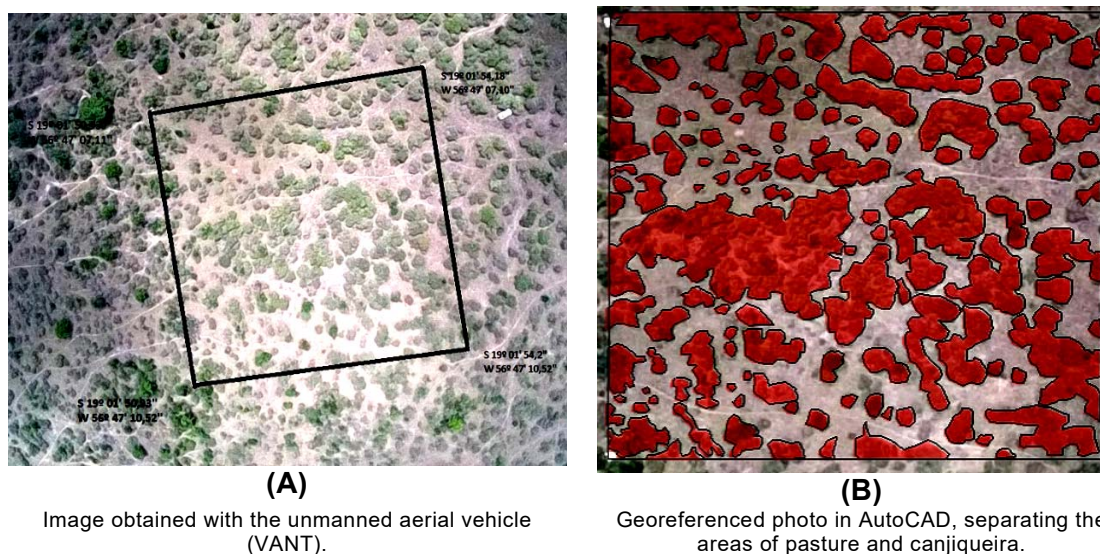

| **(A)** | **(B)** |
| Image obtained with the unmanned aerial vehicle (VANT). | Georeferenced photo in AutoCAD, separating the areas of pasture and canjiqueira. |

Figure 1 - Picture obtained with the use of VANT in an area of 10,644 m² (A) and (B) georeferenced with demarcation of the infestation of canjiqueira, in November 2014, on Alegria farm, located in Pantanal of Nhecolândia, Corumbá, Mato Grosso do Sul. The pasture area is 5,338 m² (50.15%), and the area of canjiqueira, 5,306 m² (49.85%).

The level of economic damage (LED) of canjiqueira was determined for two control methods: one, with the use of tractor with blade, and the other with the use of link chain pulled by two tractors. To determine the NDE, the model established by Norton (1976) was used and applied in the works of Rizzardi et al. (2003) and Galon et al. (2007).

The model was expressed by Equation 1.

$$LED = \frac{Custo}{R \; xP \; x \left(\frac{I}{100}\right) x \left(\frac{H}{100}\right)}$$

(eq. 1)

where LED = level of economic damage (%); Cost = cost in US\$ ha^{-1} (C cost with blade or c cost with *link*); value of the dollar exchange rate corresponds to the average of the month of April 2014; R = yield of calves ha^{-1}; P = price of calf (US\$); I = loss of productivity of calf per advancement of invasive species (%); H = control efficiency (%).

To calculate the yield of calves (R), the study conducted by Carvalho et al was taken was a basis. (2009), which presents the profile of the farms with higher occurrence in the region of Pantanal of Nhecolândia, municipality of Corumbá, MS. Thus, it was considered, a modal farm of 10,000 ha and 2,000 ha of legal reserves (20%), with 3,096 animals, providing capacity of 0.387 cow-calf per hectare and with birth rate of 70%, thus generating 0.27 calf ha^{-1} in the annual commercialization, being 50% males and 50% females.

The calves of the farm were offered at auction Novo Horizonte, in November 2014, located in the Curvado-leque, Pantanal of Nhecolândia, municipality of Corumbá, MS. The average price obtained by animals (male and female) was US\$471.50.

In the same farm, dry matter yield of pasture (native pasture) was determined in an area without canjiqueira, using the mean value obtained from 3,000 kg ha^{-1} of dry mass, with the degree of utilization of 50% (Santos et al., 2008), with utilization per grazing by cattle of 1,500 kg ha^{-1} yr^{-1} of dry mass.

The loss of productivity (i) was obtained from the data of the levels of weeds and productivity of calves ha^{-1}, which was adjusted to non-linear regression model, with the use of computer program Sigma Plot. The model chosen was the one that presented the sum of the squares of the deviations of the observations, this in relation to the adjusted values, which had the minimal value, according to Ratkowsky (1983).

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Thus, the adjusted model was the rectangular hyperbole (Equation 2).

$$(i) = \frac{a\,X}{(1+b\,X)}$$ (eq. 2)

where (i) = loss of productivity of calves (%); X = area of the soil surface occupied with the invasive plant (%); a and b = coefficients of the fit of the model. The ratio of coefficients (a/b) expresses the loss of production of calf per percentage of area covered by canjiqueira.

The proportion of loss of pastureland was applied in the reduction of productivity of calves. The loss of productivity (i) is the loss of calves in function of the advance of competing plant (canjiqueira) obtained by reducing the dry matter content of the pasture, which, in turn, affects the stocking rate per hectare.

The cost of time-machine for the cleaning blade was calculated by the software Scot Consulting - Cost of time-machine and mileage. In view of the fact that the machine model used in the field work is no longer manufactured in the composition of the spreadsheet software, the market value of a new tractor Massey Ferguson brand, model 4283, equipped with blade, in the amount of $57,822.55 was considered.

The depreciation was calculated considering a useful life of 12,000 hours, with annual usage of 1,000 hours and scrap value of 10% of the value of the new one, according to data prearranged by the software used. The rate of interest on the invested capital considered for the calculation was 6% per year, the operator's salary of $408.91/month and labor charges of 45.59%, as consulting done at Rural Trade Union of Campo Grande, MS, in November 2014.

Regarding the costs of insurance and housing, it was considered the percentage of 1% per year and annual maintenance of 5%, according to data established by the Scot Consulting software. The price of lubricant/liter considered for the calculation was U$0.27, and the fuel price of U$1.09/liter, as values practiced in fuel stations in Corumbá in the month of November 2014. The consumption was 5 liters hour^{-1} for the service with blade, equivalent to tractor Massey Ferguson brand model 4283.

From the cost of the time-machine obtained of US$ 20.181, the cleaning cost was calculated per hectare in the infestations of 0.143, 321, 448, 607, 752 and 917 ha^{-2}. To measure the time spent on each transaction, a tractor brand Massey Ferguson MF 283 (equivalent to the Model 4283), provided with blade coupled to the hydraulic system, and cleanliness of the area was performed (logging and windrowing). It was multiplied, thus the cleaning time by the number of shrubs, resulting in the number of hours of service required to perform the service and, consequently, the amount spent per hectare in different densities, by means of Equation 3.

$$C = T \times N \times H$$ (eq. 3)

where C = cost in US$ ha^{-1} per hectare for the control method with blade; T = cleaning time per individual in hours; N = number of plants ha^{-1}; H = cost of time-machine, in US$h^{1}.

The cost of control per hectare of pasture cleaning with *link* was calculated through the demarcation and measurement of the cleaning time in three areas of 20 ha, arranged in different archaeological site of the farm nearby, in the dimensions of 100 m x 200 m. In the areas identified with the densities of plants, the measurement of cleanliness was proceeded in areas demarcated for obtaining the yield per hour of work with *link*. The *link* is a drag chain of 40 m of extension, also known as the *correntão marítimo*, pulled by two tractors. The *link* used had the chain links of 3.81 cm thick and 25 cm length. At each end of the 40 m of chain a system of swivels was placed, so that, to the extent that it was pulled by the tractors, it also turned. The yield measured under the conditions of Pantanal of Nhecolândia was 2.5 ha for each hour of use of equipment *link*. The equipment can be rented in the region to a value of US$ 85.84 per day, which provides an average value of $3.43 per hour.

With the average price of time-tractor raised in method with blade and the yield measured in the field, it was found the cost of cleaning with *link*, by Equation 4.

$$c = \frac{h}{r} + li$$ (eq. 4)

where c = cost in US$ ha^{-1} per hectare for the method with *link*; h = cost of service time (for two tractors), in US$; r = yield in ha per hour of service; li = rent for using *link*, in US$.

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After 60 days of cleaning with blade and *link*, flight was performed with VANT. The images obtained (photos) through the AutoCAD program were georeferenced, and the remnant invasive species were identified, calculating the surface of the soil covered and determining the efficiency of control. The efficiencies were between 70% and 90% for control with blade, and between 60% and 85% for control with *link*.

RESULTS AND DISCUSSION

The reduction of the availability of pasture caused by the advance of canjiqueira provided the drop in productivity of calves per ha from 0.27 to 0.135 (Table 1). The maximum coverage that the invasive species occupied was 49.85% of the surface of the soil, indicating that, for the climatic conditions of the region, this was the maximum capacity of occupation of this species.

Table 1 - Number of plants of canjiqueira and percentage of surface area of soil covered by pasture and by canjiqueira and productivity of calves in Pantanal of Nhecolândia region

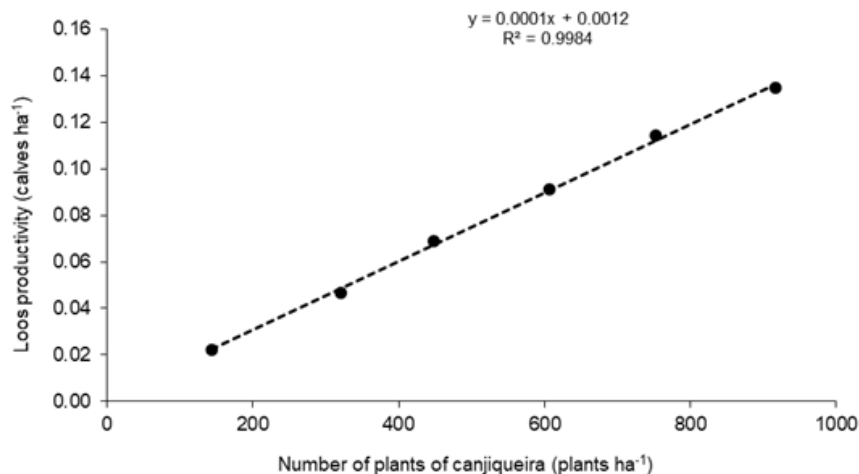| Number of plants per ha of canjiqueira	By imaging VANT*		Productivity of calves per ha
	Area of the soil surface covered by the pastures (%)	Area of the soil surface covered by canjiqueira (%)	
0	100	0	0.270
143	91.79	8.21	0.248
321	82.68	17.32	0.223
448	74.46	25.54	0.201
607	66.29	33.71	0.179
752	57.71	42.29	0.156
917	50.15	49.85	0.135

* Unmanned aerial vehicle.

The swampland plains is influenced by changes in the regime of floods, causing changes in vegetation cover (Pereira et al., 2012), attributed to the complexities of the hydrologic regime of Paraguay river, to low slope of the land and the low drainage capacity of rivers and lakes, leaving large areas with a large volume of water on a regular basis in the region (Gonçalves et al., 2011). These facts act in the control of the advancement of canjiqueira. According to Santos et al. (2006), the presence of canjiqueira is considered normal when found in edge of ridges, capão, cerrado field (floodable or not), becoming invasive species when disseminated in the clean fields and low areas, clay soils, in which the species is found sparsely. This dissemination by fields there may be in very dry years, reinforcing the idea of Alho (2011), that the change in the aquatic environment for terrestrial and vice-versa, as a result of seasonal flooding, is the most important ecological phenomenon of Pantanal, which can be, in some way, controlling this species, conditioning to maximum coverage of the soil surface, which in this work has reached 50%.

The adjusted model of rectangular hyperbole for the loss of productivity as a function of the number of plants of canjiqueira can be observed in Figure 2. This model has also been adjusted in the work of Cousens (1985), Rizzardi et al. (2003) and Galon et al. (2007). Portugal and Vidal (2009), in a review of literature, commented that the hyperbolic model is the one that best relates to the reduction of crop production with the density of infestation caused by a single species.

The relationship of the coefficients of the model (0.0002/0.0000474 = 4.21) provided the percentage of losses in productivity of calves by advancement of canjiqueira.

The studied control methods of canjiqueira showed differences in the level of economic damage (LED); the average with *link* was 8% and 20% with blade of the coverage of the soil surface with the invasive species (Figure 3). Comparing these indices and establishing a ratio, it is verified that, in the control with blade, there is need of 2.75 more in the soil covering with canjiqueira to take advantage in relation to the control with *link*.

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$$y = 0.0001x + 0.0012$$
$$R^2 = 0.9984$$

** Significant at 1% of probability and [ns] non-significant.

Figure 2 - Loss of productivity of calves by increasing the number of plants of canjiqueira in Pantanal of Nhecolândia.
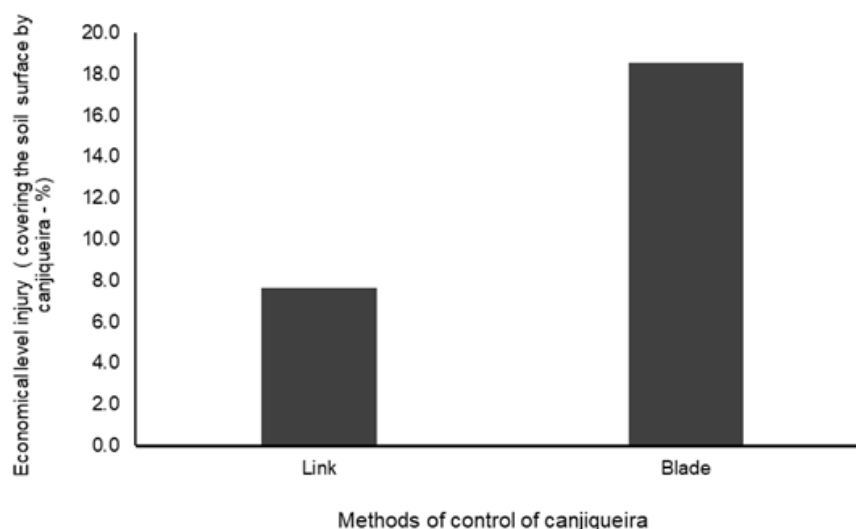

Figure 3 - Economic damage level for two methods of control of canjiqueira in Pantanal of Nhecolândia.

The link method eliminates the aerial part of the plant, while the blade method provides the removal of the aerial part and root system, requiring more execution time. In this study, the average time for cleaning with blade was 17.16 seconds per canjiqueira, which corresponds to 1.67 h ha^{-1}, while the *link* spent 0.4 h ha^{-1}, thus making the cost with blade superior than *link*, which reflected in the LED.

The efficiency of control with the use of the *link* ranged from 60% to 80% of plant density of canjiqueira, reflecting the value of LED from 6.5% to 9.2% of coverage of the soil surface of the species (Figure 4).

Andrade et al. (2015), working with various systems of chemical control of guava tree species (*Psidium guajava*) in pastures, verified control efficiency from 80% to 96%, values close to those found in this study.

Whereas Pellegrini et al. (2007), studying the mechanical and chemical control of weeds in native pastures, found 76.2% of efficiency for the chemical and 27.9% for the mechanic.

The efficiency of control method with blade was better than *link*, ranging from 70% to 90%, being, however, affected by the plants density. The increase of plant density also increased LED, which ranged from 5% to 30% of soil surface coverage by canjiqueira (Figure 5).
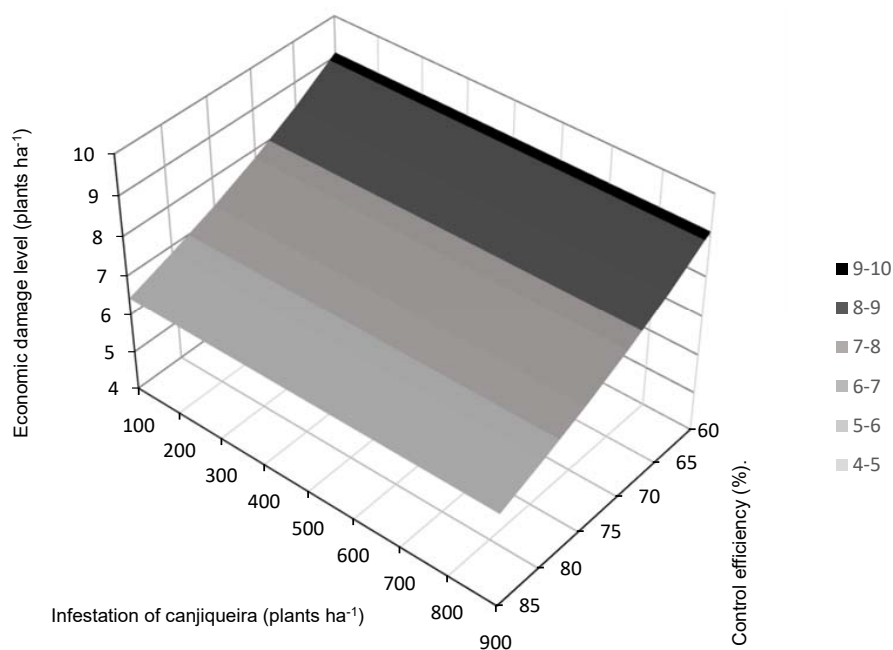
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Figure 4 - Level of economic damage to control with link of canjiqueira in Pantanal of Nhecolândia in different plant densities and control efficiency.
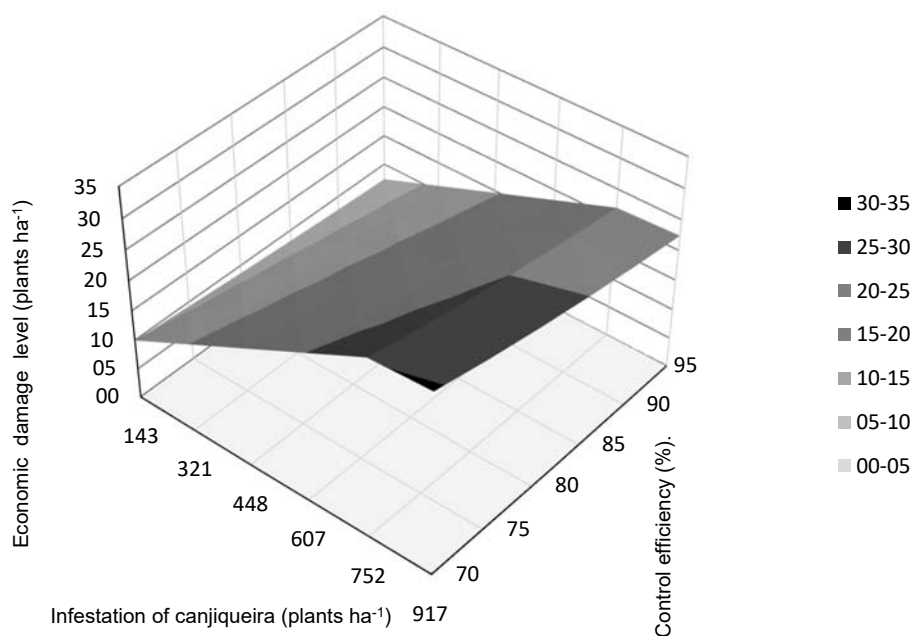

Figure 5 - Level of economic damage to control with blade of canjiqueira in Pantanal of Nhecolândia in different plant densities and control efficiency.

The best efficiency with blade can be attributed to the fact that, in this method, canjiqueira is removed with its root system, and when it is not removed, the blade cuts the plant close to the ground, hindering the regrowth. Carmona et al. (2001), working with various systems of control with the arboreal species, such as canjiqueira, the sponge (*Acacia farnesiana*) and the small-sized and large-sized joint-vetch (*Mimosa pteridofita*) and two cutting heights, 0 to 20 cm from the ground, verified that the cut flush with the soil presented efficiency of 83.3%, and 20 cm, 43%. These data corroborate that the flush cutting of tree plants provides greater efficiency in the control.

Regardless of the plants density, the link method presented LED below the blade (Figure 6).
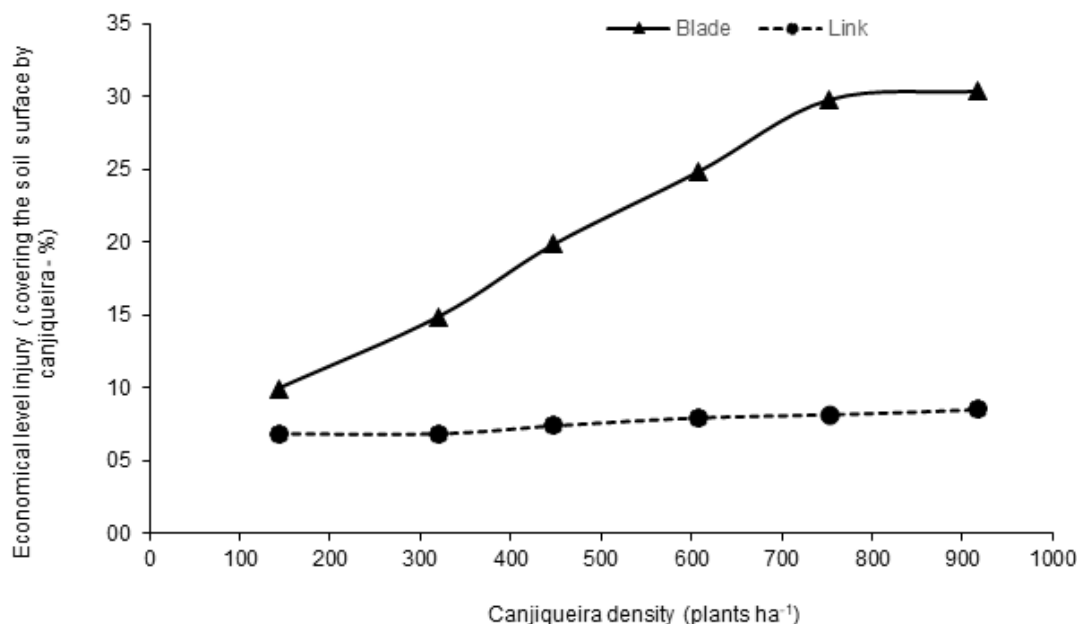
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Figure 6 - Economic damage level for control of canjiqueira, with blade and link in Pantanal of Nhecolândia.

The decision taking to choose the mechanical control method of canjiqueira depended on the percentage of coverage of the invasive species. When the coverage of canjiqueira was around 8%, the best method was *link* , and the density of 10% to 30% coverage of the soil, the most efficient method was the blade. Fleck et al. (2002), working with LDE of guanxuma (*Sida rhombifolia*), verified that the value ranged from 2 to 50 plants m^2 and that the cost of control resulted in an increase of the LED, corroborating the data of this work when the control was performed by the blade.

The control method of canjiqueira with blade was more efficient than the control by *link.* However, its use is recommended when the coverage by canjiqueira is between 10% and 30% of the area. In the case of *link,* its use was recommended when the coverage of the soil surface by canjiqueira reached 8%, regardless of the plants density.

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