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Análise da eficiência das ações de controle e combate às queimadas na Amazônia Legal Brasileira: o caso do Estado do Tocantins

Efficiency analysis of control actions and fighting fires in the Brazilian Legal Amazon: the case of the State of Tocantins

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Resumo

A queimada constitui uma das principais ameaças à conservação da biodiversidade em diferentes escalas. Assim, o presente estudo analisou a eficiência dos municípios do Estado do Tocantins em ações de controle e combate às queimadas. Para tanto, foi aplicado o modelo Data Envelopment Analysis (DEA), retornos constantes, orientação a input e output. Dentre os municípios analisados (101) apenas 5 obtiveram 100% de eficiência (Benchmarking), ou seja, utilizaram os insumos de forma otimizada em relação aos produtos. O modelo demonstrou um padrão de gastos per capita por performance em ações de controle e combate às queimadas e gestão ambiental. Assim, os municípios ineficientes devem melhorar a qualidade dos gastos per capita por unidade de performance, contribuindo para a redução do número de focos de queimadas.

Palavras-chave: controle e combate às queimadas; Gestão Ambiental; Data Envelopment Analysis (DEA)

Abstract

The present study aims at analyzing the efficiency of control actions and firefighting in the municipalities of the State of Tocantins. For this, the Data Envelopment Analysis (DEA) model was applied, constant returns, orientation to input and output. Among the municipalities analyzed (101), only 5 showed 100% efficiency (Benchmarking), that is, that they used the inputs in an optimized way. The model showed a pattern of per capita expenditure per performance. Thus, inefficient municipalities should improve the quality of expenditures per capita per unit of performance, contributing to reduce the number of outbreaks of fires.

Keywords: Control and firefighting; Data Envelopment Analysis (DEA); Environmental management

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INTRODUCTION

The clearing of areas for opening of pastureland is one of the main reasons for the appearance of burnings, increasing the vulnerability of vegetation (Brazil, 2004). Burning is a very common activity in the management of agricultural areas and rural areas (Vieira et al., 2016). In forest areas fire spreads in a linear manner and slow in sub-forest, eliminating mainly species of smaller size (Fearnside, 2005). In the Brazilian Savanna burning, in times of drought, can change the floristic composition of the vegetation, resulting in the extermination of species, vulnerable to burning (Miranda and Sato, 2005).

Brazil has the third highest number of fire outbreaks in Latin America over the past seven years, following only Venezuela and Colombia. Approximately 40% of the outbreaks occur in the Brazilian Savanna biome and 31% in the Amazon Biome (INPE, 2017a).

Among the states with the largest number of fires are Pará (29,323), Mato Grosso (25.079), Maranhão (23,346), Tocantins (14,415), Amazonas (8,922), Rondônia (8,101), and Acre (4,110). Of these, three are in the region of the Legal Amazon (INPE, 2017b).

Diaz et al. (2002) conducted studies in the Brazilian Amazon and found that the costs caused by burning can occur: (i) at the level of ownership (12 and 97 million dollars) and forestry (1 and 13 million), etc.; and (ii) at the level of society (1 to 11 million dollars per year) with the number of hospitalizations varying between 4,000 to 13,000 in the region. In relation to the loss of biodiversity, these values are more difficult to be accounted for, but it is known that there is a commitment to climate change and soil erosion, among others.

The Burnings dilapidate Brazilian biodiversity, considered "of importance to meet the needs of food, health and other nature of a growing world population" (Brazil, 2000), In addition to placing at risk the achievement and the provision of goods and ecosystem services (Ricklefs, 2009; Adenle, 2015; Petersen et al., 2016). It can also cause the elimination of habitats, species and the fragmentation of environments, affecting the conditions and survival of ecosystems (White and White, 2016).

Agriculture is one of the main economic activities in Brazil, which modifies the conditions of the environment. In this sense, the country has been building the Initiative Natural Capital of Brazil or Economics of Ecosystems and Biodiversity (BSE) that, among its objectives, highlights "to influence the implementation of policies and management tools, as well as behavior change to ensure the supply of natural resources in the long term" (Brazil, 2016).

The state of Tocantins occupies fourth place in the ranking of the states that burn most in the region. According to INPE (2017b) the numbers of outbreaks ranged from 5,750 in 2009, 25,077 in 2010. Among the major activities associated with large numbers of outbreaks of fires are agriculture and livestock (SEPLAN, 2016).

In this regard, the Ecological ICMS was created in the state, an environmental policy instrument that seeks to compensate municipalities for the environmental protection of protected areas, encouraging the strengthening of environmental management actions. Thus, the present study evaluates the efficiency of control actions and fighting fires in the framework of environmental policy through the implementation of the model Data Envelopment Analysis (DEA).

MATERIALS AND METHODS

The study was developed by the state of Tocantins, with an area of 277,620.91 m2, located between the coordinates 46º 00' and 51º 00' longitude west of Greenwich and 05º 00' and 13º 00' south latitude. It has 139 municipalities included in the Legal Amazon (SEPLAN, 2013a). Features three phyto-ecological regions and three regions of tension (an ecotone and two embedded): Brazilian Savanna, 60.90%; Seasonal Forest, 16.60%; tropical rain forest, 7.70%; Eco Voltage (Ecotone Semideciduous/Tropical Rain Forest), 1.80%; Eco Voltage (Binding Brazilian Savanna/Seasonal Forest), 11.50% and Pioneer Formations, 0.30% (SEPLAN, 2013b).

In this context, the study efficiency was applied two criteria of the Ecological ICMS: control and combating fires and environmental management.

The Ecological ICMS represents a set of environmental criteria used to define the value of transfers of financial resources that the state gives to municipalities. The legal reasoning can be found in article 158 of the Federal Constitution of 1988, Section IV, and Complementary Law no. 63, 11/01/90. The resources are derived principally from the inflow of the Tax on Movement of Goods and Services (ICMS).

The first experiment with Ecological ICMS in Brazil was implemented in the state of Paraná, in 1995, when the entered criteria protected areas in the index of participation of municipalities (IPM) (Loureiro, 2002). In Tocantins, the Ecological ICMS was created in 2002, by Law no. 1.323/02, regulated by Decree no. 1.666/02. It is currently active in 16 states in the United States and addresses issues that involve both protected areas, conservation units and indigenous lands, as well as local environmental management actions, as shown in the experiments reported by the research of Avelino et al. (2014), Lovatto and Rocha (2016), Aydos and Figueiredo (2016), Merlin and Oliveira (2016), Ferreira et al. (2016), e Matos and Almeida (2016), among others.

The Federal Constitution of 1988 establishes that 25% of taxes from ICMS must be passed on to municipalities, whereas three quarters (75%) in the proportion of value added tax and 1/4 (25%) following criteria pre-established by the states. In this aspect, the percentage relating to environmental criteria in Tocantins is 13%, distributed into five criteria: municipal policy of environment (2.0%), conservation units and indigenous lands (3.5%), control and combating burning (2.0%), basic sanitation and water conservation (3.5%) and soil conservation (2.0%) (Tocantins, 2002).

The performance of the criteria Municipal Policy of Environment (PMMA), here referred to as environmental management, and control and combating burning (CCQ) were calculated from data collected in the Ecological ICMS Management System (SIGIE), At the Instituto Natureza do Tocantins (NATURATINS), the body responsible for the implementation of the environmental policy of the State. The data refers to the results of the questionnaires applied in the year 2012, based on information from the year 2011.

The questionnaire relating to environmental policy, composed of 28 questions, addressed: (a) institutional structure of the municipality in environmental management; (b) Implementation of Municipal Policy Environment, and (c) of Local Agenda 21; (d) achievement of environmental planning participatory approach; and (e) participation in training events and training. The questionnaire related to fires, composed of 18 questions, considered: (a) whether there is an association of civilian brigades to fight the fires; (b) development of partnerships with the private sector and civil society entities with a focus to preventive actions in the control of fires; and c) promotion of actions of prevention and combat of burning (Tocantins, 2002; Tocantins, 2005).

The performance of the municipalities were obtained from the multiplication of the values of the questions by their answers. The maximum score for environmental management was 165 points and for the actions to control and combat burned 155 points.

The expenditures by municipalities in the area of environmental management were obtained from Naturatins, according to information from the Court of Auditors of the state of Tocantins (ECA) and the number of inhabitants per municipality was obtained on the website of IBGE, from the 2010 census. The historical series of outbreaks of fires in the period from 2008 to 2012 was obtained from the site of the National Institute for Space Research (INPE, 2017).

The data relating to expenditures in environmental management by inhabitants was normalized, excluding the municipalities with outliers $z < -0.5$ and $z > 2.5$. We also excluded the municipalities with zero and added one to municipalities with zero performance. The municipalities were divided into two groups: group A (greater than or equal to 10 thousand inhabitants) and group B (less than 10 thousand inhabitants). The processing of data is indicated in order to avoid possible distortions in the association of input and output (virtual) to its relative importance in each DMU (Decision Making Unit), represented here by the 101 municipalities qualified (Alves and Mello, 2015). The other municipalities were excluded due to some type of variable void, which represents a restriction of the model.

The results of the efficiency were grouped into four classes of efficiency: very low - 0% to 25%; low - 26% to 50%; average - 51% to 75%; and high - 76% to 100%, visualized on maps drawn up on the platform/ESRI ArcGis/ArcMap version 10.3.

The analysis used the model Data Envelopment Analysis (DEA), constant returns (CCR) with broad inputs and output in software R (R Core Team, 2011), Benchmarking package (Otto and Boge-

toff, 2011; Wilson, 2008). The model is applied for efficiency evaluation in different areas of study and of public policy, as shown in the experiments reported by the research of: Ferreira e Gomes (2009), Gomes et al. (2009), Vieira (2014), Naciff Andrade et al. (2014), Sabbag (2015), Camioto et al. (2015), Alonso et al. (2015), Quintanilha, Ho Lee (2016), Galariotis et al. (2016), Bittelbrunn et al. (2016) e among other areas.

The interest of the study was to evaluate the lower expense in the city for a smaller number of outbreaks of fire in relation to the area. In this analysis, two inputs were considered: (i) x1 - spending on environmental management per capita divided by the performance in environmental management; (ii) x2 - spending on environmental management per capita divided by the performance of control actions and fighting fires. As output (y) is considered the opposite of the average of outbreaks of fires over the last five years, divided by the area of the municipality.

For the analysis of the data, the projection of the virtual DMUs was performed by multiplying the efficiency by inputs, conducting a radial movement toward the border of efficiency. The calculation (Equation 1) of the value to be reduced (VR) in spending was performed, considering the gap in the inputs:

$$VR = \left| input - projection + clearance \right| / input \quad (1)$$

The value of an input x1 to be reduced was obtained by multiplying the projection, the value to be reduced considering the gap and input. The result was divided by the input x1. The same procedure was performed for x1 and x2. Finally, we calculated the expected expenditure as in Equation (2).

$$\sum_{i=1}^{101} \left| x_1 + x_2 \right. \quad (2)$$

From the actual and expected expenditures, the budget expenditures were obtained, thus representing the value to be optimized, if the municipalities adopt an efficient posture, considering the benchmarks.

In order to clarify the inefficiency of the municipalities, an analysis of the model with output orientation was performed. The projection of y 'was given by y's product by efficiency. Once projected at the efficiency frontier, the number of foci per area was calculated from the product of the multiplication of y 'and the mean of foci by the input (y). Finally, the result of the equation was divided by the area of the municipality, producing the number of foci per area, in case of efficiency.

RESULTS

In relation to the performance of municipalities in control and combating of burning (CCQ), the average value for the performance was of 66.59 points, being that 50% of the municipalities have reduced lower than the mean values. In environmental management, the average performance was of 77.27 points, with 64.40% of the cities above the average. Figures 1(a) and 1(b) show the performance of municipalities in group A (with more than 10 thousand inhabitants).

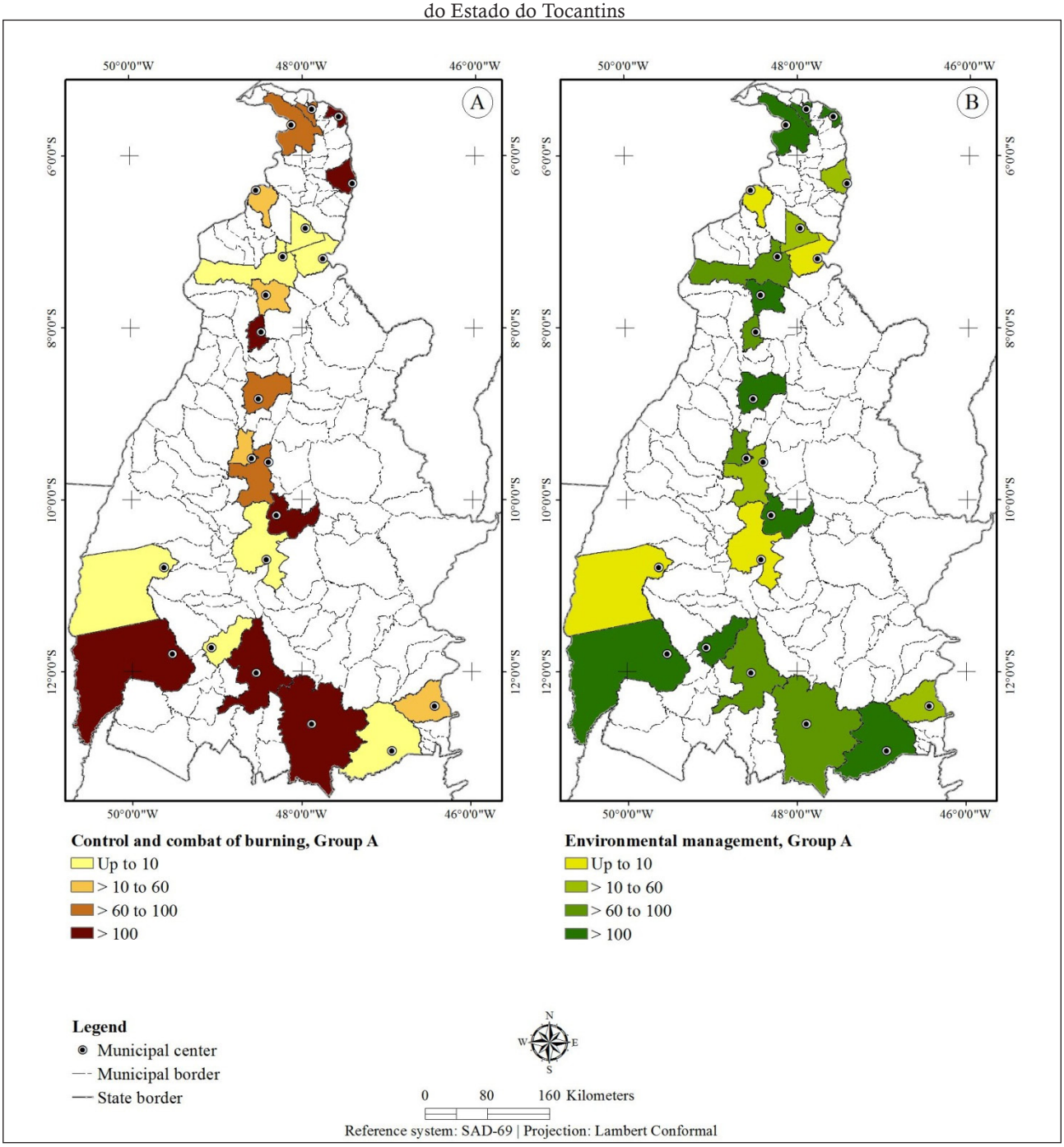

Figure 1 - Performance of the municipalities of Tocantins (Group A) in the ambit of the Ecological ICMS.
Source: Research data.

In the municipalities of group B (with less than 10,000 inhabitants) the average performance in CCQ was 43.16 points, being that 52% showed lower values than the average observed. In relation to the performance in environmental management, the average was 69.56 points, with 50% of municipalities, approximately, with values above the average (Figures 2a and 2b).

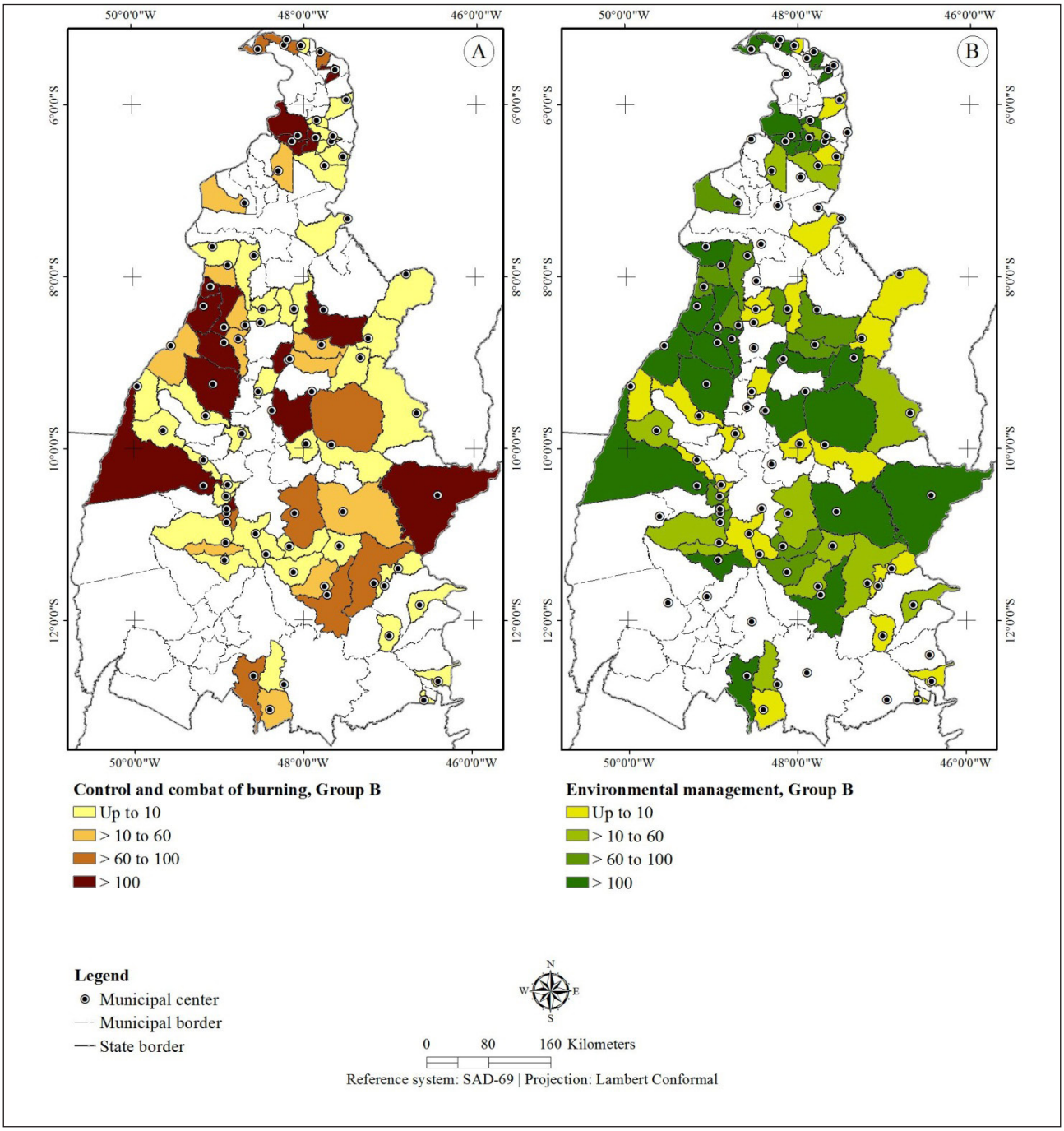

Figure 2 - Performance of the municipalities of Tocantins (Group B) in the ambit of the Ecological ICMS.
Source: Research data.

In relation to expenditures made by Municipalities of Tocantins in environmental management, the Group acquired the annual average cost of R$786,869, 76, and 55% of Municipalities are below average. This distance in most localities, in relation to the mean, can be exemplified by the municipalities of São Miguel do Tocantins, Miranorte, Miracema do Tocantins, Porto Nacional, Lagoa da Confusão, Formoso do Araguaia, Guaraí, Xambioá and Palmas, who had spent above average in the year of 2012 (Figure 3a).

The municipalities of group B executed on average R$153,791.94 in the area of environmental gement, representing 52% of municipalities with expenditures below the average (Figure 3b).

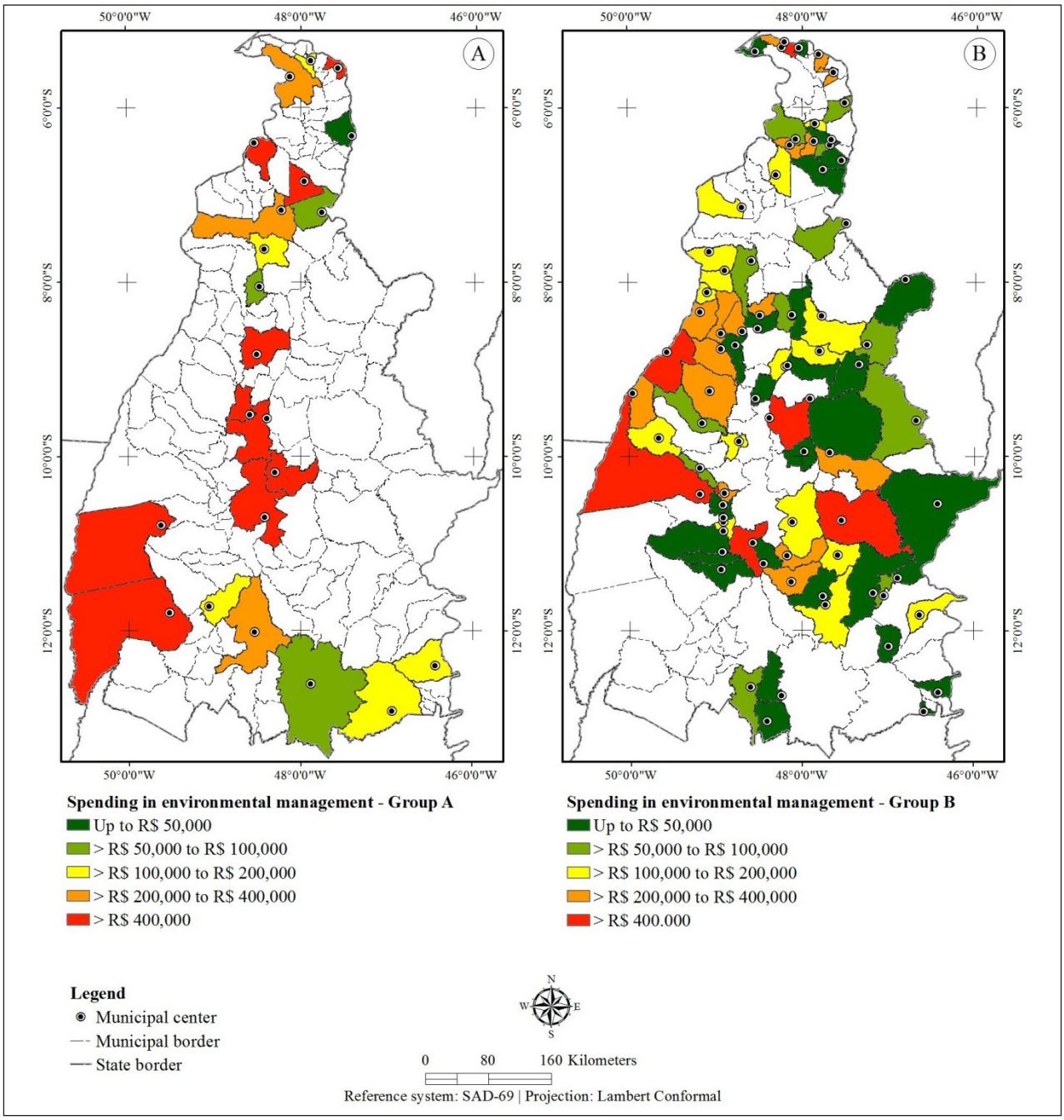

Figure 3 - Expenditures in the area of environmental management to the municipalities of Tocantins.

The efficiency of the municipalities of the group in relation to actions to control and fight against fires and environmental management is shown in Table 1. Source: Research data.

Table 1 - Efficiency of municipals with more than 10,000 inhabitants – Tocantins – 2016

Municipalities (DMUs)	Efficiency	Municipalities (DMUs)	Efficiency
1. Araguaína	15%	12. Miranorte	6%
2. Araguatins	100%	13. Nova Olinda	12%
3. Arraias	7%	14. Palmas	4%
4. Augustinópolis	22%	15. Paranã	14%
5. Babaçulândia	0%	16. Peixe	7%
6. Colinas do Tocantins	100%	17. Porto Nacional	0%
7. Formoso do Araguaia	2%	18. São Miguel do Tocantins	9%
8. Guaraí	3%	19. Taguatinga	10%
9. Gurupi	100%	20. Tocantinópolis	37%
10. Lagoa da Confusão	0%	21. Wanderlândia	1%
11. Miracema do Tocantins	4%	22. Xambioá	0%

Table 2 shows the number of municipalities by efficiency, distributed as follows: 14 municipalities between 0% and 10% efficiency, 3 between 11 and 20%, 2 between 21 and 60% and 3 between 61 and 100%.

The results of the efficiency of the municipalities in group B are shown in Table 2. The data show that 64 municipalities have achieved efficiency between 0 to 10%, 7 cities with efficiency between 11 and 20%, 5 with efficiency between 21 and 60% and only 3 with efficiency between 90 and 100%.

Table 2 - Efficiency of municipals with up to 10,000 inhabitants – Tocantins – 2016

Municipalities (DMUs)	Efficiency	Municipalities (DMUs)	Efficiency
1. Abreulândia	0%	41. Mateiros	13%
2. Aliança do Tocantins	96%	42. Maurilândia do Tocantins	0%
3. Almas	18%	43. Monte do Carmo	4%
4. Ananás	36%	44. Natividade	3%
5. Angico	3%	45. Nazaré	53%
6. Aparecida do Rio Negro	1%	46. Nova Rosalândia	8%
7. Araguacema	1%	47. Novo Acordo	0%
8. Arapoema	18%	48. Novo Alegre	2%
9. Aurora do Tocantins	0%	49. Novo Jardim	0%
10. Bandeirantes do Tocantins	24%	50. Oliveira de Fátima	9%
11. Barrolândia	0%	51. Palmeiras do Tocantins	1%

Table 2 - continuation..

Municipalities (DMUs)	Efficiency	Municipalities (DMUs)	Efficiency
12. Bernardo Sayão	10%	52. Palmeirópolis	100%
13. Bom Jesus do Tocantins	57%	53. Pequizeiro	11%
14. Brasilândia do Tocantins	0%	54. Pindorama do Tocantins	1%
15. Brejinho de Nazaré	0%	55. Piraquê	1%
16. Buriti do Tocantins	6%	56. Pium	1%
17. Campos Lindos	0%	57. Ponte Alta do Tocantins	1%
18. Carrasco Bonito	0%	58. Porto Alegre do Tocantins	0%
19. Caseara	0%	59. Praia Norte	4%
20. Centenário	6%	60. Presidente Kennedy	0%
21. Chapada da Natividade	5%	61. Pugmil	0%
22. Chapada de Areia	0%	62. Recursolândia	0%
23. Colmeia do Tocantins	100%	63. Riachinho	5%
24. Couto de Magalhães	6%	64. Rio da Conceição	1%
25. Crixás do Tocantins	2%	65. Rio dos Bois	1%
26. Darcinópolis	8%	66. Rio Sono	11%
27. Dois Irmãos do Tocantins	8%	67. Santa Fé do Araguaia	9%
28. Esperantina	15%	68. Santa Maria do Tocantins	1%
29. Fátima	4%	69. Santa Rita do Tocantins	2%
30. Filadélfia	0%	70. Santa Rosa do Tocantins	1%
31. Goianorte	3%	71. Santa Terezinha do Tocantins	5%
32. Ipueiras	0%	72. São Salvador do Tocantins	7%
33. Itacajá	3%	73. São Sebastião do Tocantins	1%
34. Itapiratins	0%	74. Silvanópolis	1%
35. Itaporã do Tocantins	4%	75. Sítio Novo do Tocantins	43%
36. Jaú do Tocantins	5%	76. Taipas do Tocantins	0%
37. Juarina	16%	77. Tocantínia	1%
38. Lizarda	1%	78. Tupirama	2%
39. Luzinópolis	1%	79. Tupiratins	2%
40. Marianópolis do Tocantins	1%		

Source: Research Data

Figure 4(a) shows the cities efficient in groups A (≥ a 10 thousand inhabitants) and B (< that 10 thousand inhabitants), grouped according to the classes of efficiency defined. Figure 4(b) outlines the average number of outbreaks of fires in municipalities, in the period 2008 to 2012.Figures 5(a) and 5(b) show, respectively, the number of outbreaks of effective in two situations: inefficiency and efficiency.

The states of the legal Amazon region, with the highest averages of fires in the period 2005 to 2016 (INPE, 2017), follow the logic of the spatial distribution of the deforestation arc. Fires in these regions are used after shallow cutting of vegetation and removal of "secondary vegetation in extensive areas of poorly managed pastures" and may also be associated with intensive logging and grazing of

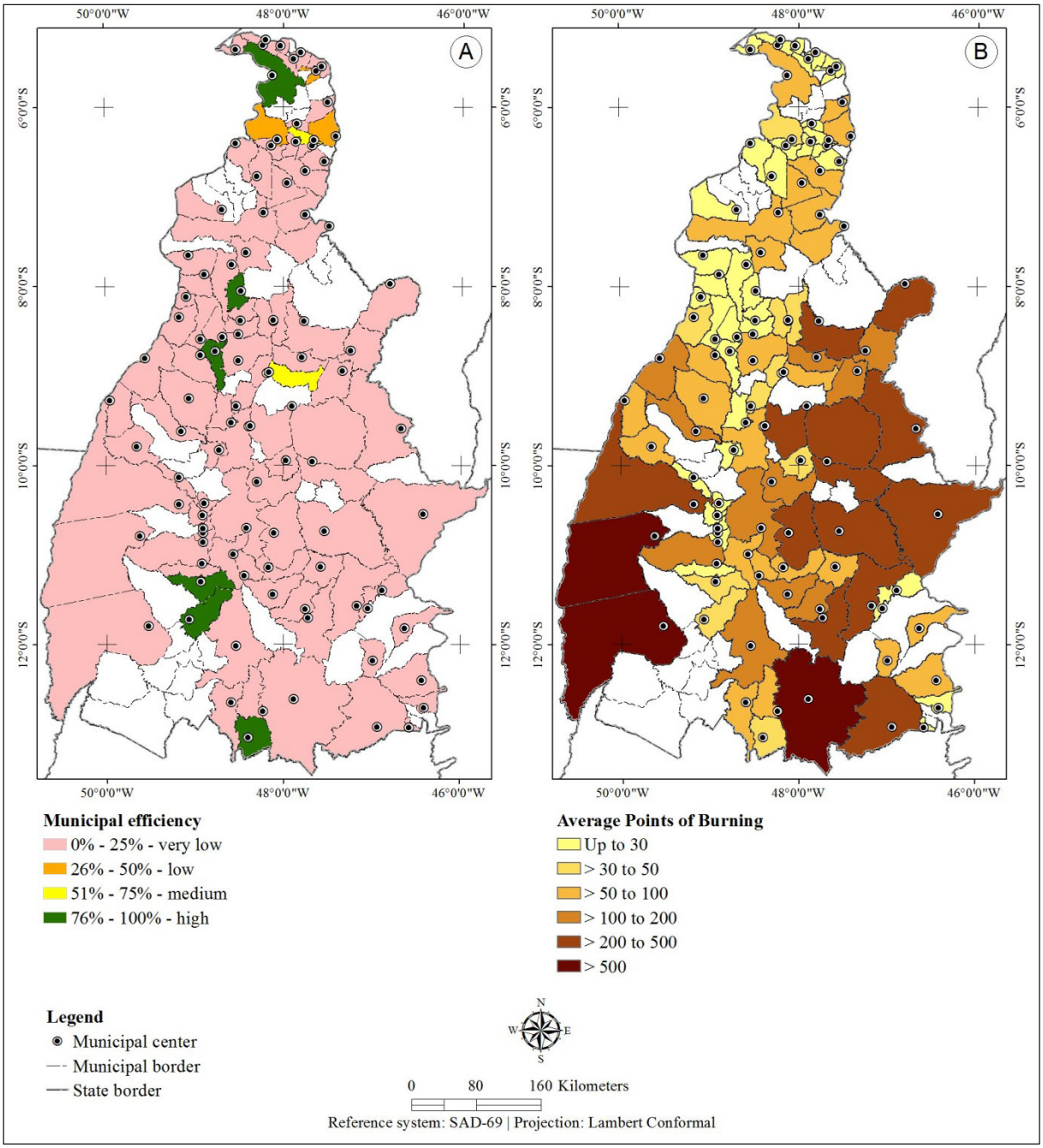

Figure 4 - Efficiency of the municipalities of Tocantins in relation to outbreaks of fires.
Source: Research data.

public lands (BRASIL, 2004). The region is marked by logging, agricultural expansion and the opening of highways (Domingues, 2012).

In the State of Tocantins, the highest number of outbreaks of fires was recorded in the year 2010 (25,077), followed by the years of 2012 (19,173) and 2015 (17,400). Burning is often used due to the low cost of soil preparation (SEPLAN, 2016a) and can occur in a controlled manner when using fire, natural or anthropic techniques. The fact is that, due to the accumulation of biomass from one year to the next, added to the water stress, the cases of burnings increase or even the lack of control of the same, resulting in large areas decimated by fire (Diaz 2002, Pivello 2005).

The period with the highest incidence of slash-and-burn occurs between the months of July and September (SEPLAN, 2016b). The municipalities that burned the most were those that have intense

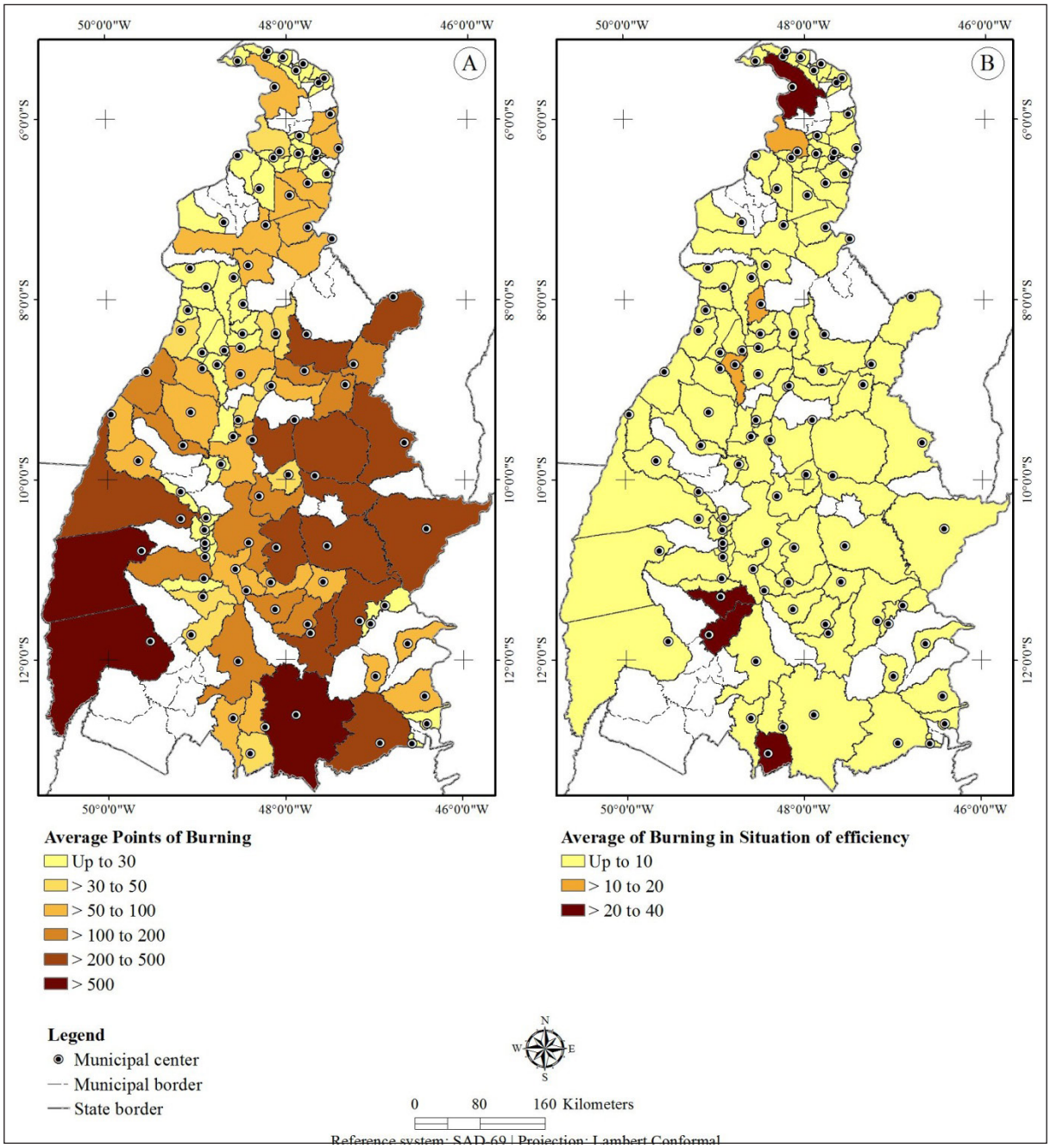

Figure 5 - Municipalities of Tocantins and the number of outbreaks of fires in a situation of inefficiency and efficiency.
Source: Research data.

management areas for agriculture, livestock and consolidation of production of grain, especially soybeans: Formoso do Araguaia, Lagoa da Confusão, Paranã and Pium.

The municipalities of Formoso do Araguaia River and Lagoa da Confusão (southwest region) occupy the second largest territorial area and lowest population density (1.39 inhabitants/km^2). They are responsible for 15.45% of the planted area of the State and have the worst data of the Human Development Index (HDI). In Paranã (Southeast region), one of the lowest HDI in the region, and Pium (central west region) dominated the activities of agriculture, livestock, forestry, fisheries and aquaculture. In the municipality of Pium is one of the largest areas of grain production (10,740 ha), in the vicinity of the Bananal Island (SEPLAN, 2016c).

The performance of the municipalities in control and fighting fires and environmental mana-

gement represents the effort that the municipality gives to achieve the goals of the proposed policy (Souza, 2006; Secchi, 2013) and in the collective demands. In this respect, the data show that the actions to consolidate the environmental policy were more effective than the actions in control and firefighting in both group A and group B. However, it should be pointed out that fires can be caused by exogenous factors Anthropic process, among them environmental conditions such as, for example, abundance of biomass and water stress.

The technical capacity and the regulation of environmental policy of cities with more than 10 thousand inhabitants have influenced in the consolidation of the institutional framework in the area of environmental management, elevating performance. In relation to the actions of control and combating fires, the municipalities of two groups are virtually equivalent, i.e., in the initial stage, which is worrying for the conservation of biodiversity.

The average per capita expenditures made by the municipalities of Tocantins in environmental management were, respectively, R$27.95, for the group, and R$35.50 for Group B. The municipalities that presented the highest per capita expenditures, in group A, were: Formoso do Araguaia (R$56.88), Lagoa da Confusão (R$87.23) and Xambioá (R$106.24). In group B stood out, with the higher expenses, the municipalities: Tocantínia (R$108.12), Brasilândia do Tocantins (R$121.81), Brejinho de Nazaré (R$120.88), Pugmil (R$126.56) and Pium (R$154.12).

The expenditures in environmental management by MI2, in group A, were, on average, of R$399.46. The municipalities with higher expenses were Guaraí (R$504.00), Miranorte (R$525.90), Palmas (R$3,648,50), São Miguel do Tocantins (R$1,087,14) and Xambioá (R$1,028,32). In the municipalities with less than 10,000 inhabitants, the average spending per km2 was R$176.65. The municipalities with the highest values are: Buriti do Tocantins (R$1,744,83), Praia Norte (R$1,302,77), Sítio Novo do Tocantins (R$987.59) and São Sebastião do Tocantins (R$833.56).

By projecting inefficient municipalities at the limit of efficiency, a new scenario was created, demonstrating that with the cost per capita practiced and the respective performances, the focused numbers are reduced, efficiently allocating inputs to products. The results demonstrate that due to the high inefficiency of some municipalities, as in Lagoa da Confusão e Formoso do Araguaia, the focus numbers of burnings are near zero.

The DEA model can provide more than one benchmark to the inefficient municipalities, as shown in the data: (i) Gurupi: Miracema do Tocantins, Paranã, Tocantinópolis e Xambioá; (ii) Colinas do Tocantins: Araguaína, Arraias e Wanderlândia; (iii) Araguatins e Gurupi: Babaçulandia, Formoso do Araguaia, Lagoa da Confusão, Palmas, Peixe, Porto Nacional, São Miguel do Tocantins, e Taguatinga; (iv) Araguatins and Colinas do Tocantins: Augustinópolis, Guaraí, Miranorte, and Nova Olinda. The municipalities referred to are those that present the best combination of spending per capita, performance in control and action against burning, and environmental management for the focus number of burnings presented. The municipalities became inefficient due to satisfactory performance of the benchmarks.

In the case of smaller municipalities, Colmeia do Tocantins is the reference for the whole group (79) and Palmeirópolis is the reference for 55 municipalities. Both are reference for 54 municipalities.

In relation to the budget expenditures, considering the inefficient situation of the municipalities, note that beginning from the line of the projection of efficiency it is possible to evaluate the resultant budget expenditures of the actions. Figure 6(a) presents budget expenditures of group A in two situations: inefficiency and efficiency, demonstrating that the difference between the costs would be R$15,595,510.53. These resources could be avoided, being allocated to other areas of public administration.

Figure 6(b) presents budget expenditures for municipalities with fewer than ten thousand inhabitants. The difference between the costs represents a savings of R$11,126,531.20. The municipalities of Bom Jesus do Tocantins and Nazaré present the lowest spending per capita (R$0.81). However, the elevated number of focus of burnings, and low performances impaired the results, principally in Bom Jesus do Tocantins, making it inefficient. The amount economized in the situation of efficiency was representative, considering the socioeconomic conditions of the municipalities of the state of Tocantins.

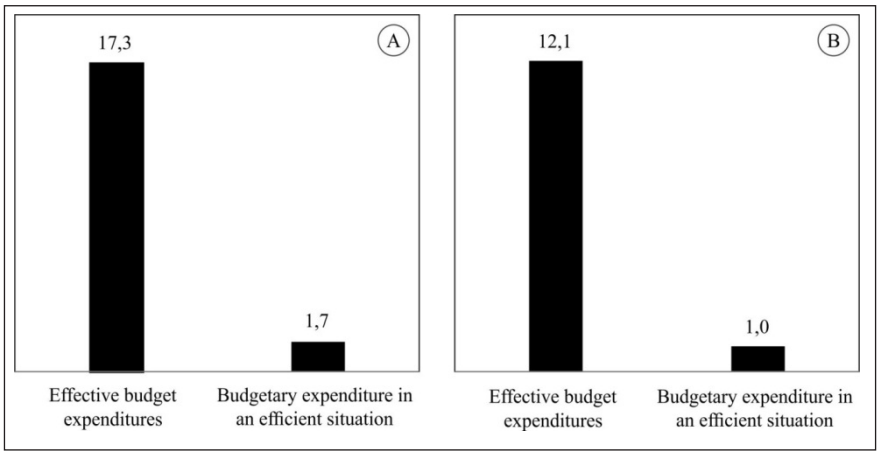

Figure 6 - Budget expenditures for the municipalities of the state of Tocantins in situations of inefficiency and efficiency (millions of reais).
Source: Research data.

CONCLUSION

The analysis of efficiency for the area of the environment is not trivial, which causes the application of the model to be complex. The model demonstrated that there is a pattern of per capita expenditure per performance, pointed out the inefficient DMU's and the value of the inputs to be altered in order to become efficient. The DEA model showed to be applicable in the analysis of the environmental policy, evaluating the performance of the municipalities in the efficient use of resources in relation to the implementation of public policy goals. Among the municipalities analyzed (101) only five (5) demonstrated 100% efficiency, utilizing inputs optimally.

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