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# IMPACT OF LAND USE ON WATER QUALITY IN THE ALAGADO RIVER BASIN: A TEMPORAL AND REGIONAL ANALYSIS

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**Abstract:** The aim of this work was to estimate and compare the diffuse loads of pollutants in the Alagado River basin over time (1985, 2005 and 2022), using geoprocessing and export coefficients, and to evaluate temporal variations and by federal unit (DF and GO). Land use and occupation maps from the MapBiomas Platform and export coefficients from Moruzzi et al. (2012) were used. The MQUAL 1.5 model was applied to calculate the daily contribution of pollutants based on the area of each type of land use. In 2022, the DF had total loads of phosphorus (30.41 $Kg/Km^2$.day), nitrogen (375.54 Kg/day), BOD (1084.70 Kg/day), suspended solids (22451.62 Kg/day) and total coliforms (6.64 x $10^{12}$ Kg/day). GO showed loads of phosphorus (45.40 Kg/day), nitrogen (488.31 Kg/day), BOD (1211.35 Kg/day), suspended solids (30970.42 Kg/day) and total coliforms (1.01 x $10^{13}$ Kg/day). Agricultural activities, urban expansion and pastures are the main sources of diffuse pollution, requiring environmental management strategies to ensure the quality of the region's water resources. Environmental management strategies include soil conservation practices, recovery of degraded areas, conservation of natural areas, environmental education, monitoring and enforcement, as well as the expansion of rainwater drainage and sewage treatment infrastructure, ensuring the quality of the region's water resources. It is essential to carry out research to develop specific and calibrated export coefficients for the region, improving the accuracy of the analyses.

**Keywords:** Water pollution; Diffuse loads; Environmental management; Environmental sanitation; Land use and occupation.

## INTRODUCTION

The Alagado River basin is an important tributary of the Corumbá IV dam reservoir, extending through the territories of the Federal District (DF) and Goiás (GO), and on a national scale is part of the Paranaíba Hydrographic Basin. The Alagado River basin is essential for the collection and supply of water for the public supply of these states, and it is home to the Corumbá Water Producer System operated in consortium by the SANEAGO and CAESB concessionaires. This system has a potential capacity to treat and supply 2.8 cubic meters per second ($m^3/s$) of water.

Knowledge of land use and occupation, integrated with an understanding of diffuse loads, is essential for protecting the quality of water in springs. By pinpointing the origins of diffuse pollution, it is possible to develop targeted strategies aimed at minimizing the input of nutrients and contaminants into water resources.

The analysis of diffuse loads uses geoprocessing techniques and the diffuse load equation, applying tools in a GIS environment such as joining, clipping and separating land uses by color, based on official geographic data.

In this study, the daily amounts of phosphorus, nitrogen, Biochemical Oxygen Demand (BOD), suspended solids and total coliforms from different classes of land use and occupation were estimated.

Phosphorus and nitrogen have been identified as elements responsible for eutrophication, with both natural and anthropogenic origins. Both are essential for the growth of algae, and high concentrations can have negative impacts on water resources. BOD is considered an indicator of the potential consumption of dissolved oxygen in bodies of water, associated with organic matter. Suspended solids and the presence of total coliforms are also addressed, relating to impurities in aquatic ecosystems and the possibility of containing pathogenic microorganisms (Von SPERLING 2007).

The purpose of this study was to carry out an indirect estimate and comparison of diffuse loads over time in the basin of the Alagado River branch of the Corumbá IV dam lake, improving discussions on pollution control of water resources, which tend to focus exclusively on standards for the treatment of effluents discharged punctually.

## OBJECTIVE OF THE WORK

The aim of this study was to indirectly estimate (secondary data) and compare the diffuse loads deposited over time, for the years 1985, 2005 and 2022, using geoprocessing and export coefficients published by Moruzzi et al. (2012), in addition to assessing whether there are temporal variations and by federative unit (DF and GO) that make up this basin.

## MATERIALS AND METHODS

The land use and occupation maps used in this study come from the MapBiomas Platform (MAPBIOMAS 2009). The year 1985 was chosen because it is the oldest available from MapBiomas. The year 2005 was selected because it was the closest before the Corumbá IV dam was inaugurated and the year 2022 because it was the most recent, with the dam lake already consolidated. The dates of the 1985, 2005 and 2012 maps were selected to maximize the contrast in land use over the period, taking advantage of the extended intervals to highlight significant changes. Maps were then drawn up by the federal unit that makes up the river basin in question.

To estimate the diffuse loads of pollutants such as total phosphorus, total nitrogen, biochemical oxygen demand (BOD), suspended solids and coliforms, this study applied export coefficients (EC) that correlate the type of land use to the amount of pollutants generated. These coefficients were taken from the work by Moruzzi et al. (2012). The MQUAL 1.5 model was adopted, which relates land use and occu-

| Land Use and Occupation | Total phosphorus | Total nitrogen | BOD | Suspended solids | Total coliforms |
|---|---|---|---|---|---|
| | Kg/Km².day | | | | |
| Agricultural activity | 0,346 | 2,95 | 7,32 | 230 | $1x10^{11}$ |
| Cerrado Campestre | 0,028 | 0,50 | 1,06 | 30 | $1x10^{8}$ |
| Cerrado Forest | 0,039 | 0,60 | 1,20 | 20 | $1x10^{8}$ |
| Pasture | 0,050 | 0,90 | 2,25 | 40 | $1x10^{9}$ |
| Exposed Soil | 0,034 | 1,27 | 5,54 | 50 | $1x10^{9}$ |
| Urban Area | 0,034 | 1,27 | 5,54 | 50 | $1x10^{9}$ |

Table 01: Export coefficients (EC) for each type of land use and occupation area in the Alagado River basin, adapted (MORUZZI, 2012).

| Land Use and Occupation | State | 1985 | | 2005 | | 2022 | |
|---|---|---|---|---|---|---|---|
| | | Km² | % | Km² | % | Km² | % |
| Agricultural activity | DF<br>GO | 72,64<br>109,54 | 11,21<br>16,9 | 60,84<br>84,26 | 9,39<br>13,00 | 65,09<br>99,90 | 10,04<br>15,42 |
| Cerrado Campestre | DF<br>GO | 29,36<br>53,70 | 4,53<br>8,29 | 18,91<br>42,40 | 2,92<br>6,54 | 20,49<br>41,73 | 3,16<br>6,44 |
| Cerrado Forest | DF<br>GO | 73,56<br>143,26 | 11,35<br>22,11 | 56,03<br>126,52 | 8,65<br>19,52 | 55,74<br>126,64 | 8,6<br>19,08 |
| Pasture | DF<br>GO | 36,37<br>45,97 | 5,61<br>7,09 | 65,96<br>102,56 | 10,18<br>15,83 | 53,91<br>84,99 | 8,32<br>13,11 |
| Exposed Soil | DF<br>GO | 40,85<br>27,76 | 6,30<br>4,28 | 12,81<br>7,00 | 1,98<br>1,08 | 12,03<br>5,81 | 1,86<br>0,90 |
| Urban Area | DF<br>GO | 14,27<br>0,39 | 2,20<br>0,06 | 52,50<br>9,33 | 8,10<br>1,44 | 59,87<br>11,56 | 9,24<br>1,78 |
| Body of water | DF<br>GO | 0,23<br>0,15 | 0,04<br>0,02 | 0,22<br>8,70 | 0,03<br>1,34 | 0,15<br>13,16 | 0,02<br>2,03 |
| Total | DF/GO | 648,01 | 100 | 648,04 | 100 | 648,06 | 100 |

Table 02: Annual percentage of land use and cover in the BH of the Alagado river branch (DF/GO).

pation to water quality, thus making it possible to calculate the daily contribution of pollutants based on the area of each type of land use and occupation class. The formula used was CD = A×CE, where CD represents the daily diffuse load, A is the total area of each land use, and CE is the specific export coefficient.

Table 1 below shows the export coefficients (EC) presented in the study by Moruzzi et al. (2012), but with some adaptations to the reality of the uses of the basin under analysis.

## RESULTS

Table 2 and Figure 1 show the areas (A) corresponding to each land use class for the respective states of DF and GO.

The maps generated for each state (DF and GO) are shown in Figures 1 and 2:

Table 3 shows the estimates of the diffuse loads generated in the basin under study.

The results of the total diffuse loads in the context of land use and occupation in the states of DF and GO (Table 3) show different patterns. In the Federal District, there is a predominance of urban areas and agricultural activity, accounting for 19.28% of the territory in 2022, which reflects the greater contribution of these categories to total diffuse loads. Specifically, in 2022 the DF had a total P load of 30.41 Kg/day, total N of 375.54 Kg/day, BOD of 1084.70 Kg/day, suspended solids of 22451.62 Kg/day and total coliforms reaching $6.64 \times 10^{12}$ Kg/day.

In contrast, GO stands out for its greater area of pastures and agricultural activities, which together occupy 28.53% of the state, which leads to a different configuration of diffuse loads, with the state presenting a total phosphorus load of 45.40 Kg/day, total nitrogen of 488.31 Kg/day, BOD of 1211.35 Kg/day, suspended solids of 30970.42 Kg/day and total coliforms reaching $1.01 \times 10^{13}$ Kg/day in 2022.

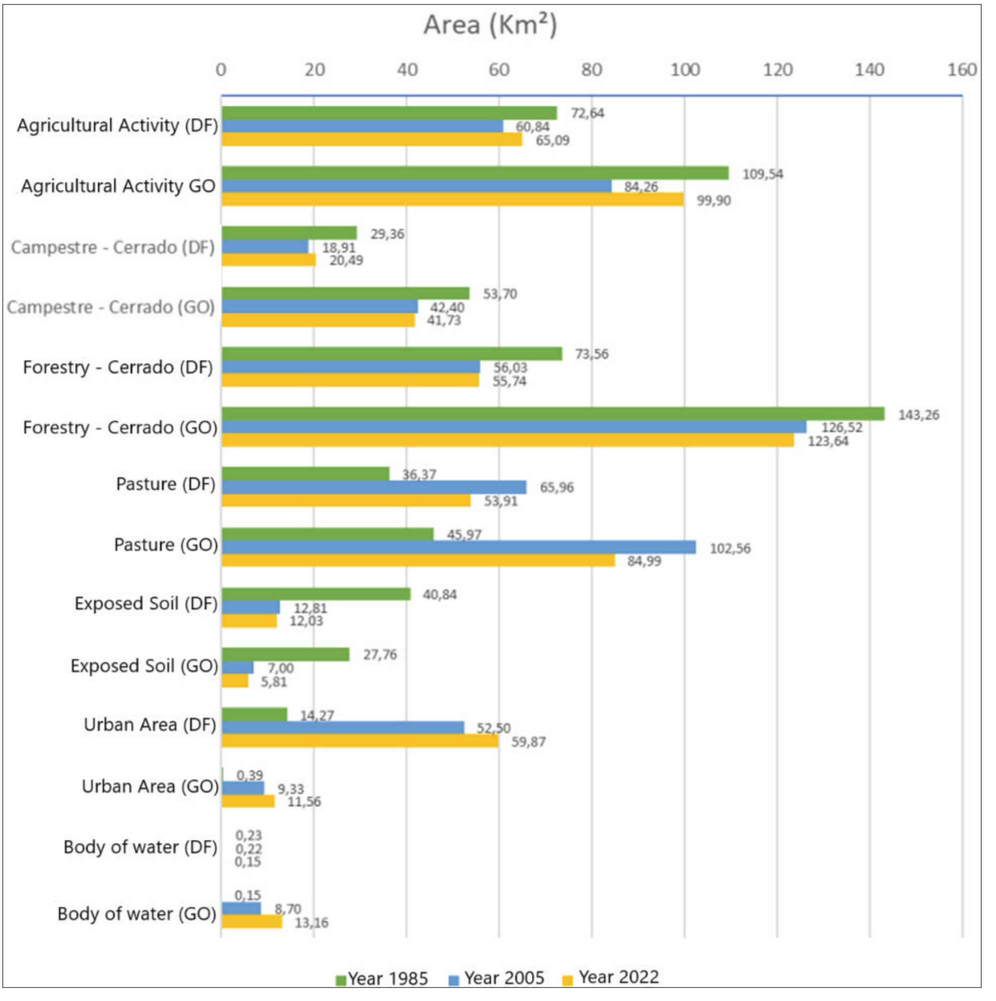


Figure 1: Area (Km²) occupied by each land use in 1985, 2005 and 2022.

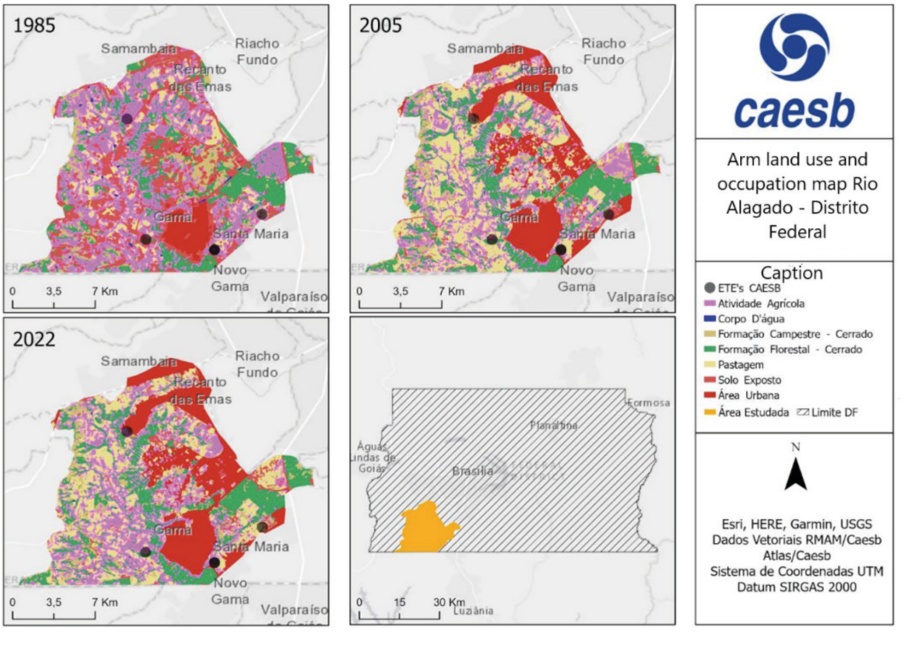


Figure 02: Land Use and Occupation Map of the Alagado River arm watershed within the Federal District in 1985, 2005 and 2022.

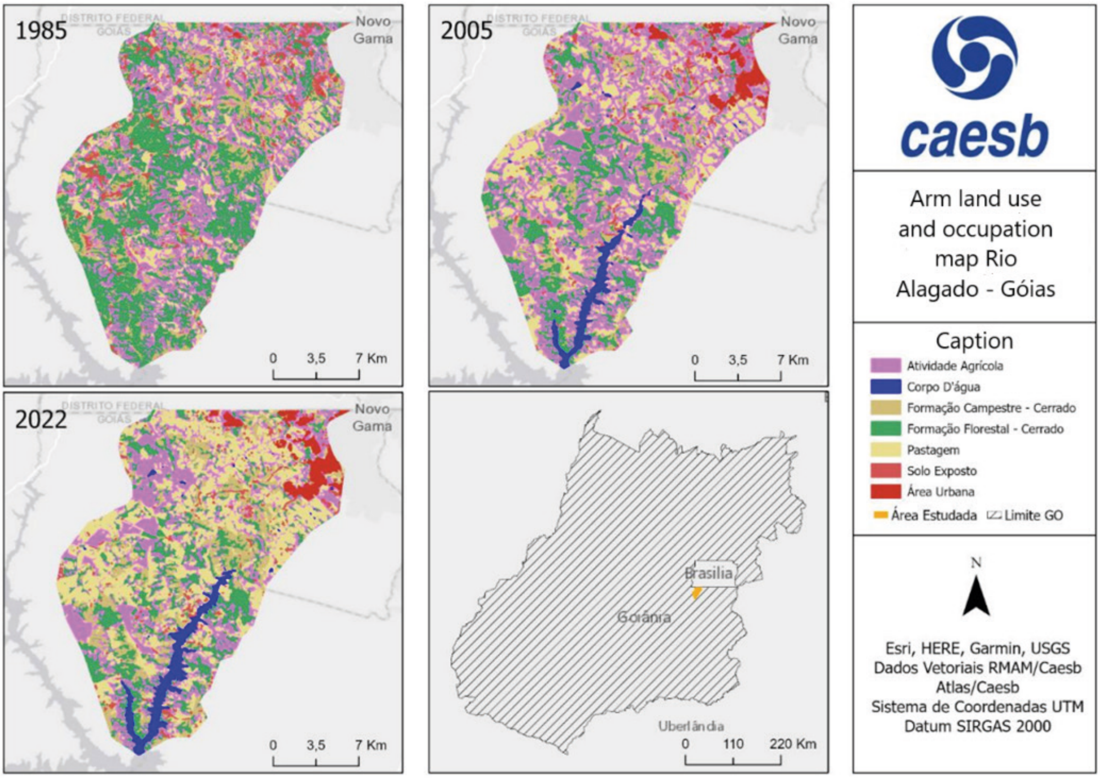


Figure 03: Land Use and Occupation Map of the Alagado River basin in GO in 1985, 2005 and 2022.

| Diffuse loads | Year | Federation Unit | Agricultural activity | Cerrado Campestre | Cerrado Forest | Pasture | Exposed Soil | Urban Area | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | Kg/day | | | | | | |
| Total Phosphorus | 1985 | DF | 25,1 | 0,8 | 2,9 | 1,8 | 1,4 | 0,5 | 32,5 |
| | | GO | 37,9 | 1,5 | 5,6 | 2,3 | 0,9 | 0,0 | 48,3 |
| | 2005 | DF | 21,1 | 0,5 | 2,2 | 3,3 | 0,4 | 1,8 | 29,3 |
| | | GO | 29,2 | 1,2 | 4,9 | 5,1 | 0,2 | 0,3 | 41,0 |
| | 2022 | DF | 22,5 | 0,6 | 2,2 | 2,7 | 0,4 | 2,0 | 30,4 |
| | | GO | 34,6 | 1,2 | 4,8 | 4,3 | 0,2 | 0,4 | 45,4 |
| Total Nitrogen | 1985 | DF | 214,3 | 14,7 | 44,1 | 32,7 | 51,9 | 18,1 | 375,8 |
| | | GO | 323,2 | 26,9 | 86,0 | 41,4 | 35,3 | 0,5 | 513,1 |
| | 2005 | DF | 179,5 | 9,5 | 33,6 | 59,4 | 16,3 | 66,7 | 364,9 |
| | | GO | 248,6 | 21,2 | 75,9 | 92,3 | 8,9 | 11,9 | 458,7 |
| | 2022 | DF | 192,0 | 10,3 | 33,4 | 48,5 | 15,3 | 76,0 | 375,5 |
| | | GO | 294,7 | 20,9 | 74,2 | 76,5 | 7,4 | 14,7 | 488,3 |
| BOD | 1985 | DF | 531,7 | 31,1 | 88,3 | 81,8 | 226,3 | 79,0 | 1.038,2 |
| | | GO | 801,9 | 56,9 | 171,9 | 103,4 | 153,8 | 2,2 | 1.290,0 |
| | 2005 | DF | 445,3 | 20,0 | 67,2 | 148,4 | 71,0 | 290,9 | 1.042,9 |
| | | GO | 616,8 | 44,9 | 151,8 | 230,8 | 38,8 | 51,7 | 1.134,8 |
| | 2022 | DF | 476,5 | 21,7 | 66,9 | 121,3 | 66,7 | 331,7 | 1.084,7 |
| | | GO | 731,3 | 44,2 | 148,4 | 191,2 | 32,2 | 64,0 | 1.211,4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sus-pended Solids** | 1985 | DF | 16.706,1 | 880,7 | 1.471,1 | 1.454,8 | 2.042,0 | 713,4 | 23.267,9 |
| | | GO | 25.194,8 | 1.610,9 | 2.865,1 | 1.838,8 | 1.387,8 | 19,5 | 32.916,9 |
| | 2005 | DF | 13.992,9 | 567,3 | 1.120,6 | 2.638,5 | 640,4 | 2.625,2 | 21.584,9 |
| | | GO | 19.380,0 | 1.272,0 | 2.530,5 | 4.102,3 | 350,0 | 466,4 | 28.101,1 |
| | 2022 | DF | 14.970,7 | 614,7 | 1.114,7 | 2.156,3 | 601,6 | 2.993,6 | 22.451,6 |
| | | GO | 22.977,8 | 1.251,8 | 2.472,8 | 3.399,4 | 290,5 | 578,0 | 30.970,4 |
| **Total Co-liforms** | 1985 | DF | $7,26x10^{12}$ | $2,94x10^{9}$ | $7,36x10^{9}$ | $3,64x10^{10}$ | $4,08x10^{10}$ | $1,43x10^{10}$ | $7,37x10^{12}$ |
| | | GO | $1,10x10^{13}$ | $5,37x10^{9}$ | $1,43x10^{10}$ | $4,60x10^{10}$ | $27,8x10^{9}$ | $0,39x10^{9}$ | $1,10x10^{13}$ |
| | 2005 | DF | $6,08x10^{12}$ | $1,89x10^{9}$ | $5,60x10^{09}$ | $6,60x10^{10}$ | $1,28x10^{10}$ | $5,25x10^{10}$ | $6,22x10^{12}$ |
| | | GO | $8,43x10^{12}$ | $4,24x10^{9}$ | $1,27x10^{10}$ | $10,3x10^{10}$ | $7,00x10^{9}$ | $9,33x10^{9}$ | $8,56x10^{12}$ |
| | 2022 | DF | $6,51x10^{12}$ | $2,05x10^{9}$ | $5,57x10^{9}$ | $5,39x10^{10}$ | $1,20x10^{10}$ | $5,99x10^{10}$ | $6,64x10^{12}$ |
| | | GO | $9,99x10^{12}$ | $4,17x10^{9}$ | $1,24x10^{10}$ | $8,50x10^{10}$ | $5,81x10^{9}$ | $11,6x10^{9}$ | $1,01x10^{13}$ |

Table 03: Diffuse loads in the Alagado River basin (DF/GO).

## ANALYSIS OF RESULTS

Table 02 shows a trend towards changes in natural areas, with a loss of 19.43% (58.28 Km²) throughout the basin over the 37 years. There is a tendency for these areas to be converted into spaces occupied by agricultural activities, pastures and urban areas, highlighting a shift towards environments with a greater potential impact on water quality, an aspect that will be analyzed later in the text.

The analysis of diffuse loads by soil class, Table 03, shows that agricultural activity in the Basin under study has the highest coefficients for almost all the pollutants, suggesting that this use has a greater impact and can contribute to the deterioration of the water from Lake Corumbá IV captured for public supply.

The reduction in P load in both states can be directly linked to the filling of reservoirs, which expanded the area of water bodies and consequently reduced the pollutant contribution of pasture and agricultural areas.

On the other hand, the Campestre and Cerrado Forest classes show lower loads for all pollutants, indicating that natural areas are essential for watershed management, as they help preserve water quality through filtration and retention.

On the other hand, the loads generated by pastures are moderate when compared to the Agricultural Activities class, but still represent a high source of pollution, especially for N and P. This shows that grazing practices also have an impact on water quality. In the Federal District, for example, Total N from pastures increased from 32.73 Kg/day (1985) to 48.52 Kg/day (2022), showing the growing contribution of this class to N pollution.

For the Exposed Soil class, there are loads that indicate a moderate impact on the export of pollutants. Exposed soil, in particular, is a concern due to its susceptibility to erosion, which acts to load sediment with a direct impact on suspended solids in the water.

Finally, the results for the Urban Area class highlight pollution in terms of BOD and suspended solids. This highlights the need for adequate infrastructure for rainwater drainage and sewage collection and treatment in these regions.

Checking the results for each state, the DF has a greater impact on urban areas and agricultural activity, as it has the largest area in these classes, occupying 19.28% of the state in 2022. GO, on the other hand, has a greater influence on pasture and agricultural activity, occupying 28.53% of the state's area.

## CONCLUSIONS / RECOMMENDATIONS

The assessment of diffuse loads in the Alagado River basin, using secondary data, provided an estimate of the amount of pollutants discharged into the basin.

Agricultural activities, urban expansion and pastures are identified in this study as the main sources of diffuse pollution, since these three categories together occupy 57.91% of the entire basin in 2022, requiring the implementation of environmental management strategies for the watershed in question.

These strategies include a set of actions aimed at adopting soil conservation practices, recovering degraded areas, conserving natural areas, environmental education, monitoring and inspecting potentially polluting activities, as well as expanding rainwater drainage infrastructure and sewage collection and treatment, thus ensuring that the region's water resources meet the standards set out in the framework.

Finally, it is essential to carry out research aimed at developing export coefficients that are specific and calibrated for the region, in order to improve the accuracy of this type of analysis.

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