REGET/UFSM
Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental
ISSN 2236-1170
Acesso aberto
REGET, v. 28, e85297, 2024 • https://doi.org/10.5902/2236117085297
Submitted: 03/10/2023 • Accepted: 21/11/2024 • Published: 30/12/2024

Environmental Management

Evaluation of the impact on dams in the previous and current scenario in affected areas

Avaliação do impacto em barragens no cenário prévio e atual em áreas afetadas

Gabriela de Vargas Heinen[I], José Cardoso Sobrinho[I]

[I] Universidade Federal de Santa Maria, Santa Maria, RS, Brazil

ABSTRACT

Precision agriculture and irrigation improve yields and efficiency in agricultural activity. It is important to consider the impact of irrigation on the environment and adopt mitigation solutions. In this work, a regression equation model for remote prediction of environmental impact caused by the construction of irrigation dams in the micro watersheds of the Ijuizinho River/RS was developed through quantitative data. For this, 20 dams were selected in the study area, where a history of construction and maintenance was informed. Two buffers were drawn around the dams, considering the minimum PPA required for dams following current environmental legislation, Law Number 12.651/2012 and CONSEMA Resolution nº 323/2016. To carry out the spatial analysis of land use and occupation, images from the Sentinel-2A sensor were selected. The pre-processing of images was carried out following supervised classification to determine the land use classification. The information was used to obtain the proportion of each type of habitat present in the study area, namely: water, tillage, arboreal vegetation, damp areas, and undergrowth. For the analysis of environmental impact, equations of modeling were realized using multiple linear regression and Pearson's correlation. Currently, there are no forms of prior analysis to define the environmental impact caused by the construction of an irrigation dam. Prior analysis of the environmental impact would be an important tool for decision-making on environmental licensing. The proposed methodology does not replace the other licensing steps but may justify their starts. Based on the present data set and statistical analyses applied, developing models to predict the environmental impact was not possible. Therefore, it is important to consider the peculiarities and importance of each habitat in the watershed. The suppression of a stable habitat for the construction of a dam, even with PPA recovery, will cause an environmental impact.

Keywords: Irrigation; Dam; Permanent preservation area; Habitats; Environmental impact

RESUMO

A agricultura de precisão e a irrigação melhoram a eficiência e produtividade agrícola. É importante considerar o impacto da irrigação no meio ambiente e tomar medidas de mitigação. Neste trabalho buscou-se avaliar com equações de regressões algum modelo capaz de prever remotamente o impacto ambiental causado pela construção de barragens utilizadas para abastecer um sistema de irrigação por pivôs de irrigação na Microbacia Hidrográfica do Rio Ijuizinho/RS, através de dados quantitativos. Para isso, foram selecionadas 20 barragens da área de estudo onde o histórico já era conhecido. Foram traçados dois buffers entorno das barragens, considerando a APP mínima exigida para barragens de acordo com a legislação ambiental vigente, de acordo com a Lei nº 12.651/2012 e a Resolução do CONSEMA nº 323/2016. Para fazer a análise espacial do uso e ocupação de solo foram selecionadas imagens do sensor Sentinel-2A. Foi realizado o pré-processamento das imagens e para o processamento da imagem foi utilizado a classificação supervisionada para determinar a classificação do uso do solo. As informações foram utilizadas para obter a proporção de cada tipo de habitat presente na área de estudo, sendo eles, água, lavoura, vegetação arbórea, área úmida e vegetação rasteira. Para a análise do impacto ambiental foi realizado equações de modelagem utilizando regressão linear múltipla e a correlação de Pearson. Atualmente, não existem formas de análise prévia para definir o impacto ambiental causado na construção de uma barragem de irrigação. A análise prévia do impacto ambiental seria uma ferramenta importante para a tomada de decisão do licenciamento ambiental. A metodologia proposta não substitui as outras etapas do licenciamento, mas pode justificar seu início. Com base nos dados e análises estatísticas, não foi possível desenvolver modelos para prever o impacto ambiental. É importante considerar a peculiaridade e importância de cada habitat na microbacia. A supressão de um habitat estável para a construção de uma barragem, mesmo com recuperação de APP, acarretará algum nível de impacto ambiental.

Palavras-chave: Irrigação; Barragem; Área de preservação permanente; Habitats; Impacto ambiental

1 INTRODUCTION

Precision agriculture arose from the constant need to improve the efficiency of agricultural production processes and the interest in conserving natural resources. Precision agriculture and irrigation dams play an important role in improving agricultural efficiency and productivity. While precision agriculture focuses on using advanced technologies to maximize benefits in the field, irrigation dams provide a reliable source of water for crops.

Considering the importance of vegetation in permanent preservation areas (PPAs) and the need to use water for irrigation purposes, it is important to consider that the local interventions carried out with different levels of detail and range of environmental quality parameters. In this way, it is possible to characterize the impact of irrigated agriculture on the environment and list the monitoring systems and mitigation measures necessary to prevent negative impacts, as well as to enhance positive impacts.

However, with the current legislation (CONSEMA Resolution nº 372/2018) for environmental licensing purposes, temporary impacts caused by actions to install low-impact catchments in PPAs are prioritized. In this way, the water regime of the microbasin in which the irrigation project is located remains in the background. For this, it is necessary to express, quantitatively, the factors that must be analyzed when implementing an irrigation project and their interrelationships.

In this context, the objective of this study was to evaluate, using regression equations, a model capable of remotely predicting the environmental impact caused by the construction of dams used to supply an irrigation system using irrigation pivots in the Ijuizinho River watershed/RS, through quantitative data.

1.1 Agriculture irrigation

Irrigation is an ancient technique designed to provide water to plants so that they can produce adequately without suffering from a water deficit. Over the centuries, technology has been improved and developed, today having irrigation systems with adequate time, place, and quantity control to promote plant growth (Levien; Figueirêdo; Arruda, 2021).

The objective of irrigation is to correct the natural distribution of rainfall, so that irrigated crops can reach their development potential even in times of limited water resources (Lima *et al.*, 2007). Irrigation is a strategy to increase the profitability of agricultural land, increasing production and productivity in a sustainable way, unlike in the past, when it was just a technology to combat drought (Leão, 2012).

Expanding the irrigated area has the potential to reduce pressure on the agricultural frontier. Data related to productivity gains with irrigation applications reinforce the need for the agricultural sector to develop and effectively adopt new technologies aimed at water sustainability (Santos, 2010).

To take advantage of the potential of irrigated agriculture in Brazil, it is necessary to consider the availability of favorable water, soil, and climate. Furthermore, it is important to understand that sustainable irrigated agriculture includes its own practices, activities, interactions, and concepts, inherent to intensive regimes and relatively higher production costs, but with proportionally greater benefits (FAO, 2017).

In particular, in Brazil, the irrigated area corresponds to 18% of the cultivated area and contributes to 42% of total production. Among the Brazilian states, Rio Grande do Sul has the largest irrigated area, with 19.5% and is one of the main centers of recent expansion of the central axis of irrigation, mainly for grain producers, located in the northwest of the state. (ANA, 2017).

1.1.1 Intervention in permanent preservation area according to Brazilian legislation

As it is a territorially protected space, interventions in PPAs can only be carried out, in accordance with art. 8th of Federal Law No. 12,651/2012, if considered to be of public utility or social interest or of low environmental impact. Furthermore, interventions in PPAs are subject to administrative procedures that are duly characterized and substantiated when approved by the competent environmental authority.

Federal Law No. 12,651/2012, in its art. 3rd, section IX, sub-section “e,” considers social interest to be an enterprise in which the capture and conduction of water for projects where water resources are an integral and essential part of the activity. As a result, the construction of irrigation dams has become an activity of social interest, and, therefore, it is possible to obtain authorization for intervention in PPAs.

Environmental impact is defined by CONAMA Resolution No. 01/1986, as any change in the physical, chemical, and biological properties of the environment. These changes can be caused by any type of material or energy resulting from human activities, which directly or indirectly affect the health, safety and well-being of the population. Furthermore, the effects can affect socioeconomic activities, biota, the aesthetic and sanitary condition of the environment and the quality of environmental resources.

Loss of habitats are the main factors that generate a decrease in biodiversity (Loyn *et al.,* 2007; Groom, Vynne, 2006). These factors are related to human activities (Gardner *et al.,* 2009). Changes in land use affect ecological processes that are important for maintaining the integrity of ecosystems, which can no longer support the species originally present (Lambeck, 1997).

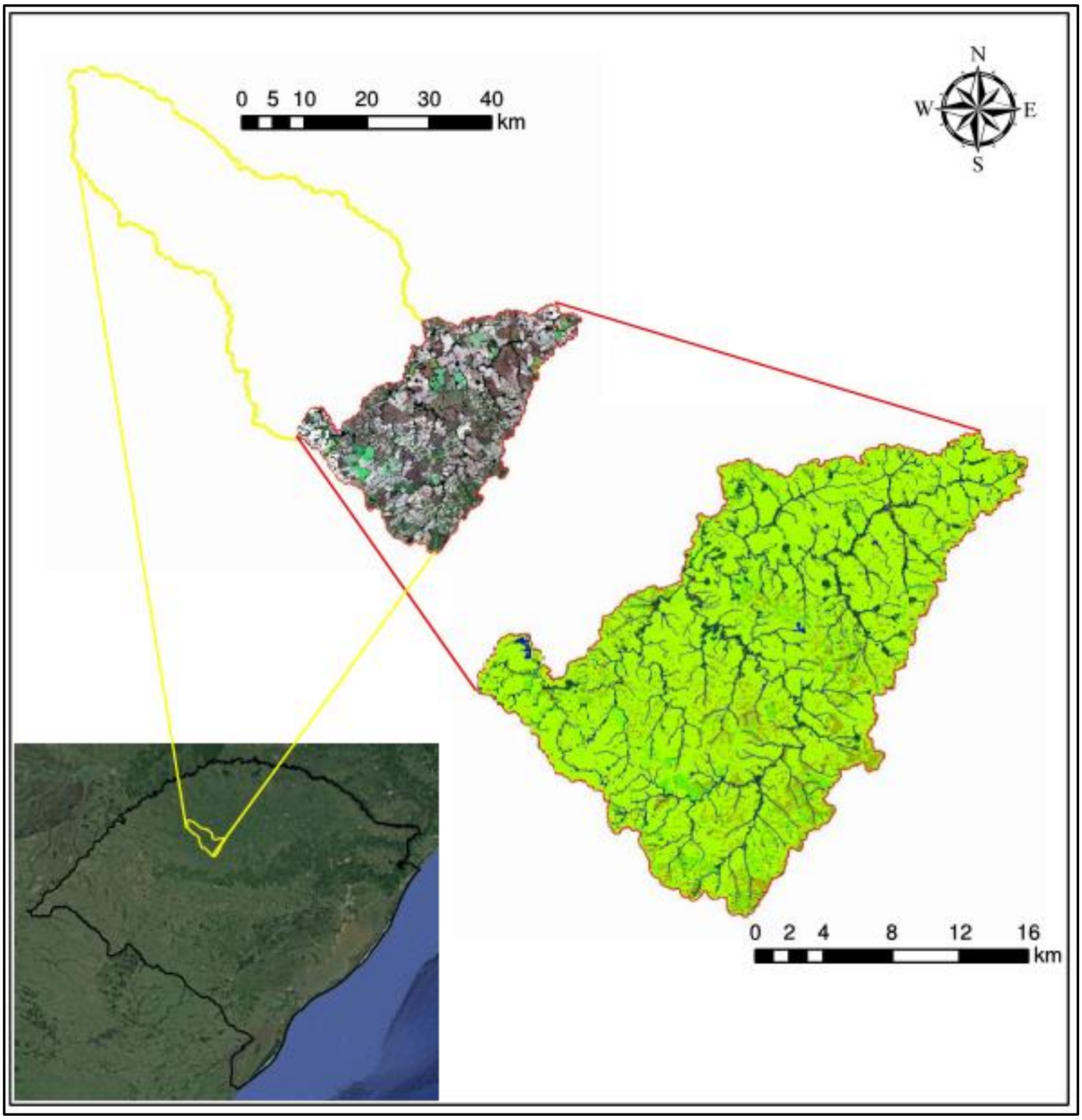
The conversion of native vegetation leads to habitat loss, which is one of the main causes of the decline in the conservation status of terrestrial species (Ceballos *et al.*,2015). Habitats in many areas are undergoing changes due to local anthropogenic factors (Schulze *et al.,* 2018), such as dam construction.

To carry out an environmental impact assessment, it is necessary to follow a methodology made up of a set of standards varying with the environmental factor to be assessed. The evaluation methods are flexible and can be applied at any stage of the process and are constantly reviewed. It is important to highlight that current environmental assessment methods reported in the literature are subjective in their approach to the physical environment, so they have specific applications and defined criteria for use (Cremonez *et al.,* 2014).

2 MATERIALS AND METHODS

The present study was carried out in the southern region of the Ijuizinho River/RS Hydrographic Microbasin, as shown in Figure 1. This microbasin is located in the Planalto Meridional geomorphological province, including 4 cities (Cruz Alta, Tupanciretã, Boa Vista do Cadeado and Jóia). The main watercourses are Arroio Santa Maria, Arroio Urupu, Arroio São Bernardo and Rio Ijuizinho (upper part).

Figure 1 – Location of the Ijuizinho River/RS in Hydrographic Microbasin



Source: Authors (2023)

The Ijuizinho River is located northwest of the state of Rio Grande do Sul and has its source located in the city of Tupanciretã. The course of the Ijuizinho River, which is a tributary of the Ijuí River, runs from southeast to northwest, crossing the cities of Entre-Ijuís and Tupanciretã, being responsible for part of the border of the cities of Cruz Alta, Boa Vista do Cadeado, Jóia, Augusto Pestana, Eugenio de Castro and Entre-Ijuís.

To define the study area, the basin coding proposed by Pfafstatter (1989) was used, where the methodology for classifying river basins is based on the natural configuration of the drainage system. The division of ottobasins available in the Ottocoded Multiscale Hydrographic Base 2017 (ANA, 2020) was used.

The study area is represented by 4 level 6 ottobasins upstream of the Ijuizinho River, with the central geographic coordinates of the study area at Latitude -28.892341° and Longitude -53.851562°. The area of the 4 ottobasins that represents the tributaries of the Ijuizinho River corresponds to 85932.73 ha.

Within the study area there are 95 dams used for irrigation, according to the SIOUT database (SIOUT, 2023). For this study, 20 dams were selected, with historical knowledge of the scenario before their construction. The irrigation system implemented in these dams was between 2011 and 2021. These 20 dams were used as a sample, in order to develop an environmental impact methodology, with only quantitative and remote analysis data, from the study area.

2.1 Remote Sensing

For the spatial analysis of land use and occupation, four images from the Sentinel-2A sensor were selected, which were imaged on December 31, 2022, on the European Space Agency's online platform (ESA, 2023). To carry out this analysis, a database was created using the QGIS 3.10.4 software, where bands 2, 3, 4, and 8 were selected with a spatial resolution of 10 m.

After georeferencing the images, mosaic operations (grouping the two images into a single one) and cropping (to work only with the area of the basin under study) were carried out for each band. Furthermore, in image pre-processing operations, the contrast of each band was performed (histogram manipulation that automatically reduces contrast in very light or very dark areas). Subsequently, the same QGIS software database was used, and the RGB (843) color composition of the image was performed, that is, in band 8 with the color red, in band 4 the color green and in band 3 the color blue, which provides a good characterization and differentiation of land uses and coverage, and facilitates visual analysis of the landscape.

After completing the pre-processing of the database, the habitats were defined for the realization of land use and occupation classes, namely: (1) water (surface water depth); (2) tillage (area of annual crops); (3) arboreal vegetation (tree-shrub cover, as a characteristic of the biome, this type of formation is normally found along watercourses); (4) damp area (lowland areas or valleys, featuring water accumulation) and (5) undergrowth (predominance of grasses and some subshrub species).

For image processing, supervised classification with the minimum distance algorithm was used. This method calculates the spectral distance of the pixels and the average for each class signature. In this way, according to the average values of the pixels defined by the samples, each pixel will be incorporated into a cluster through the analysis of the distance similarity measure.

From the classification of land use of the entire area under study, information was obtained on the areas that each habitat makes up in the Ijuizinho River/RS Hydrographic Microbasin. These data were used to obtain the proportion of each habitat type present in the study area.

2.2 Projection of future habitat change

To evaluate the future scenario of the 20 sample dams, the flood perimeter of each of the dams was manually drawn, using QGIS software. After defining the perimeter of each dam, two buffers of 30 and 60 m were drawn.

These buffers were defined considering the minimum PPA in accordance with current environmental legislation, in accordance with Law No. 12,651/2012 and COSEMA Resolution No. 323/2016, for each dam.

Subsequently, from the QGIS software database referring to the classification of land use of the entire area under study, new sections were made within the PPA area for each dam. With this, it was quantified for each dam which habitats are present in each PPA, according to the classes previously defined in the previous stage of image processing.

2.3 Impact analysis in the habitats

Data from the 20 sample dams were analyzed, in the scenario prior to the dams being built or used for irrigation. These information were obtained through a database of each irrigation dam projects. Also, the data on the current scenario of the 20 samples were obtained through remote sensing analysis, in order to prospect the scenario after the regularization of the PPAs. At this stage of the work, the habitats were analyzed separately.

Data modeling was evaluated using multiple linear regression. Pearson's r correlation analysis was carried out, in this analysis it is possible to verify the intensity of the linear relationship between the quantitative values of two variables in a sample (TRIOLA, 2005). All data was analyzed using the R software.

2.3.1 Evaluation of habitat modeling with the dam flood area

Firstly, a multiple linear regression was carried out, in which the variable "Y" was considered as the perimeter of the flood area (current scenario of the dam), and variable "X" was considered as the area of each habitat to be evaluated (scenario prior to the construction of the dam). The equation that represents the regression is shown below (Equation 1).

$$Y = \alpha + \beta1.X1 + \beta2.X2 + \beta3.X3 + \beta4.X4 + \beta5.X5 + e \qquad (1)$$

α = is the expected value of Y when all independent variables are zero;
$\beta1$ = is the expected variation in Y given a unit increase in X1, with X1 being water (this happens when there is already a reservoir and there is a desire to expand it) keeping all other independent variables constant;
$\beta2$ = is the expected variation in Y given a unit increase in X2, with X2 being tillage, keeping all other independent variables constant;
$\beta3$ = is the expected variation in Y given a unit increase in X3, with X3 being arboreal vegetation, keeping all other independent variables constant;
$\beta4$ = is the expected variation in Y given a unit increase in X4, with X4 being a damp area, keeping all other independent variables constant;

$\beta5$ = is the expected variation in Y given a unit increase in X5, with X5 being undergrowth, keeping all other independent variables constant;
e = is the error not explained by the model

2.3.2 Evaluation of habitat modeling with the PPA area of each dam

To evaluate the habitats with the PPA area, a multiple linear regression was also carried out, in which the variable “Y” was considered as the perimeter of the PPA of each dam, and the variable “X” was considered as the area of each habitat to be evaluated, together with the flood area of the dam itself. It is worth noting that for both variables, data from the current scenario were considered. The equation that represents the regression is shown below (Equation 2).

$$Y = \alpha + \beta 1.X1 + \beta 2.X2 + \beta 3.X3 + \beta 4.X4 + \beta 5.X5 + \beta 6.X6 + e \quad (2)$$

Where:
α = is the expected value of Y when all independent variables are zero;
$\beta 1$ = is the expected variation in Y given a unit increase in X1, with X1 being the flood area of the dam itself, keeping all other independent variables constant;
$\beta 2$ = is the expected variation in Y given a unit increase in X2, with X2 being water, (this happens when there is another near reservoir), keeping all other independent variables constant;
$\beta 3$ = is the expected variation in Y given a unit increase in X3, with X3 tillage, keeping all other independent variables constant;
$\beta 4$ = is the expected variation in Y given a unit increase in X4, with X4 being arboreal vegetation, keeping all other independent variables constant;
$\beta 5$ = is the expected variation in Y given a unit increase in X5, with X5 being a damp area, keeping all other independent variables constant;
$\beta 6$ = is the expected variation in Y given a unit increase in X6, with X6 being undergrowth, keeping all other independent variables constant;
e = is the error not explained by the model

2.4 Impact analysis in the remaining of native vegetation and consolidated area

In order to understand whether the sample data (both in the scenarios before the construction of the dam and in the current PPAs status) are correlated, an additional study was carried out by combining the habitat areas. For this purpose, the sum of the areas of arboreal vegetation, damp area and undergrowth was considered to be a remaining of native vegetation (RNV), and the sum of water and tillage areas was considered as a consolidated area (CA). This analysis was performed again in both scenarios.

2.4.1 Evaluation of the modeling of data obtained in the dam flood area

For this stage of the evaluation, a multiple linear regression was also carried out, in which the variable "Y" was considered as the perimeter of each dam, and the variables X1 being the consolidated area and X2 remaining native vegetation. The equation that represents the regression is shown below (Equation 3).

$$Y = \alpha + \beta 1.X1 + \beta 2.X2 + e \tag{3}$$

Where:
α = is the expected value of Y when all independent variables are zero;
$\beta 1$ = is the expected variation in Y given a unit increase in X1, with X1 being a consolidated area, keeping all other independent variables constant;
$\beta 2$ = is the expected variation in Y given a unit increase in X2, with X2 remaining native vegetation, keeping all other independent variables constant; and is the error not explained by the model;
e = is the error not explained by the model

2.4.2 Evaluation of the modeling of data obtained from the PPA

The multiple linear regression in this evaluation stage has as variable "Y" the perimeter of each PPA surrounding the dam, and variable X1 being the consolidated area and X2 remaining native vegetation (Equation 4).

$$Y = \alpha + \beta 1.X1 + \beta 2.X2 + e \tag{4}$$

Where:
α = is the expected value of Y when all independent variables are zero;
$\beta 1$ = is the expected variation in Y given a unit increase in X1, with X1 being a consolidated area, keeping all other independent variables constant;
$\beta 2$ = is the expected variation in Y given a unit increase in X2, with X2 remaining native vegetation, keeping all other independent variables constant; and is the error not explained by the model;
e = is the error not explained by the model

3 RESULTS AND DISCUSSIONS

3.1 Pre analysis on environmental impact on the dams

Initially, an analysis of the areas of the 20 dams was carried out considering the scenario prior to the irrigation project. The size of these areas existing before the construction of the dams are shown in the Table 1.

Table 1 – Characterization of the habitats and floot areas

Dam	Habitat area (ha)					Total dam flood area (ha)
	Water	Tillage	Arboreal vegetation	Damp areas	Undergrowth	
B1	0.0	5.4	0.3	2.7	0.0	8.4
B2	4.3	0.0	0.0	32.4	0.0	36.8
B3	0.0	9.5	0.0	0.0	0.0	9,5
B4	2.1	0.0	0.0	0.0	0.0	2.1
B5	0.0	0.8	0.2	4.8	0.0	5.9
B6	0.0	6.3	2.2	0.4	0.0	8.9
B7	0.0	1.1	0.7	0.0	0.0	1.8
B8	4.8	0.0	0.0	0.0	0.0	4.8
B9	0.0	1.3	0.0	0.0	0.0	1.3
B10	4.5	0.0	0.0	0.0	0.0	4.5
B11	12.7	0.0	0.0	0.0	0.0	12.7
B12	0.0	5.4	1.9	5.2	0.0	12.6
B13	0.3	0.0	0.0	0.0	0.0	0.3
B14	0.0	1.9	1.4	0.0	0.0	3.3
B15	0.0	0.0	0.0	0.0	43.4	43.4
B16	3.1	6.5	1.1	6.4	0.0	17.1
B17	0.0	0.0	0.0	0.0	29.6	29.6
B18	0.1	0.0	0.0	1.2	0.6	1.8
B19	0.3	0.0	0.1	0.7	1.6	2.8
B20	0.0	1.8	0.8	0.4	0.0	3.0

Source: Authors (2023)

As can be seen in Table 1, dams (B4, B8, B10, B11 and B13) already existed before the installation of the safety project, being considered consolidated reservoirs, that is, built previously on July 22, 2008, data defined in Law no. 12,651/2012. These 5 samples present 100% water as habitat.

It is worth noting that in the study region where the dams were built, it is common for wet areas to be eliminated, with drainage, in order to expand the work area. Flight from these areas occurred with greater intensity in the 1980s, due to government incentives financed through the PROVÁRZEAS program. As a reflection of this, it is observed that two samples (B3 and B9) were built in an area that covered 100% work as habitat. Likewise, samples B1, B6, B7, B14 and B20 are also examples of the great impact of this return process, since more than 50% of their flooded area was in an area that was used for farming.

When analyzing the remaining native vegetation, samples B2, B5, B16 and B18 stand out, where there was already a smaller reservoir prior to the irrigation project. In these samples there was a dam expansion project, which had a major impact on the wetland habitat.

Considering that the study area is inserted in the Pampa biome, which is the only Brazilian biome whose occurrence is restricted to just one state and which still retains a total of 41.13% of the native (original) vegetation cover ─ 23, 03% correspond to rural formations, 5.38% to forest formations and 12.91% to transition formations — field-forest mosaic (PROBIO, 2007). However, only 39% of its rural vegetation and characteristic marshes remain (Picolli, Schnadelbach, 2007).

3.2 Analysis of the current sample scenario

The current scenario was obtained through the classification and quantification of the habitats of each PPA, as shown in Table 2. According to the data obtained, it was observed that most areas were never recovered, with only samples B11 and B13 being in good condition, in accordance with Law 12651/2012 and CONSEMA Resolution 323/2016. In this case, sample B13 complies with the legislation as it has a flood area of less than 1 ha, and therefore does not require an PPA in its surroundings.

Table 2 – Analysis of the current scenario of dam PPA areas. Data were obtained after image processing using QGis software

	Habitat area (ha)					
Dam	**Water**	**Tillage**	**Arboreal vegetation**	**Damp area**	**Undergrowth**	**Total PPA area (ha)**
B1	0.0	6.9	0.1	1.5	0.7	9.3
B2	0.1	12.0	0.6	0.0	0.0	12.8
B3	1.2	8.7	0.0	0.0	0.0	10.0
B4	0.0	2.7	0.0	0.3	1.5	4.5
B5	0.8	2.1	0.6	0.2	3.1	6.7
B6	0.3	6.8	1.2	0.0	0.0	8.2
B7	0.1	1.4	0.1	0.3	0.0	1.9
B8	0.5	2.0	0.0	0.5	2.9	5.9
B9	0.1	0.2	0.0	0.0	1.6	1.9
B10	0.9	1.5	0.2	0.2	2.6	5.4
B11	0.5	0.0	0.2	0.5	3.4	4.6
B12	0.3	0.2	0.0	1.1	3.4	5.0
B13	0.0	0.0	0.0	0.0	0.0	0.0
B14	0.0	4.6	0.8	0.2	0.0	5.6
B15	0.1	12.5	0.1	1.8	0.0	14.4
B16	0.0	5.8	0.4	0.0	0.0	6.2
B17	0.0	5.7	1.9	1.7	1.3	10.5
B18	0.0	0.5	0.0	0.6	1.1	2.2
B19	0.1	1.0	1.1	0.7	2.7	5.6
B20	0.0	4.5	0.3	0.5	0.0	5.3

Source: Authors (2023)

It is important to mention the PPA of the 20 analyzed samples, there are currently a total of 79 ha of crops to be recovered, so that all dams can be regularized. These information shows that irrigation is one of the human activities with great potential to directly affect PPAs and, in particular, damp areas and riparian forests. In general, irrigation activities involve the damming of watercourses through the construction of dams, destroying the original PPA areas. Therefore, in the state of Rio Grande do Sul, the Conselho Estadual do Meio Ambiente (CONSEMA), through Resolution No.

323/2016, in article 11, determines the reconstitution of PPAs surrounding dams, with characteristics equivalent to the suppressed vegetation areas. However this is not observed so far for the dams analyzed.

3.3 Analysis of the environmental impact in habitats

It should be noted that currently, there are no forms of prior analysis to define the environmental impact caused by the construction of an irrigation dam. To begin environmental licensing for the construction of an irrigation dam, is necessary to check if there is a 20% of Legal Reserve on the property, as defined by Law No. 12651/2012. This being the quantitative factor of the Legal Reserve, the main data for defining the beginning of a licensing process, if you do not have the required Legal Reserve there is no justification for starting the analysis process.

Therefore, this study comes together with a project of Law No. 1282/2019. This project of Law proposes to amend Law No. 12651/2012, to allow the construction of water reservoirs for irrigation projects and associated physical infrastructure in areas of permanent preservation of rural properties. In this way, a methodology for prior analysis of the environmental impact caused by the construction of dams would facilitate decision-making regarding environmental licensing.

For this evaluation, historical data from the 20 samples were used. From this, the development of a statistical model for environmental impact was evaluated, in order to predict the correlation of each separate habitat that was suppressed to give rise to a dam. The current scenario was also evaluated, which was previously described, there are a total of 79 ha of crops inserted in PPA to be recovered. In this wat, it was also considered to develop a statistical model to determine the possible habitats to be established for the recovery and regularization of PPAs.

3.3.1 Evaluation of habitat modeling with the dam flood area

As described in the section 2.3.1 (Evaluation of habitat modeling with the dam flood area), data processing was carried out, without the perimeter of the dam's flood area and the areas of the habitats under study (water, tillage, arboreal vegetation, damp areas and undergrowth) in the R software. The results of this assessment, which were processed according to Equation 1, are shown in Table 3.

Table 3 – Estimated parameters of the adjusted multiple linear regression model

	Coefficients	**Standard error**	**t-value**	**p-value**
Intersection (Y)	475.2 (α)	50.51	9.409	1.98e-07
Water (X1)	0.007670 (β1)	0.001046	7.333	3.71e-06
Tillage (X2)	0.01143 (β2)	0.001253	9.125	2.87e-07
Arboreal vegetation (X3)	0.004907 (β3)	0.005174	0.948	0.359
Damp area (X4)	0.008815 (β4)	0.0004185	21.060	5.33e-12
Undergrowth (X5)	0.009381 (β5)	0.0002831	33.139	1.05e-14

Source: Authors (2023)

As indicated in Table 3, X3 (habitat referring to arboreal vegetation) should not be part of the regression ($p>0.05$).

3.3.2 Evaluation of habitat modeling with the dam flood area

Table 4 shows the results of the evaluation of Equation 2 after processing the data with the R software, as determined in the section 2.3.2 (Evaluation of habitat modeling with the PPA area of each dam).

Table 4 – Estimated parameters of the adjusted multiple linear regression model

	Coefficient	**Standard error**	**t-value**	**p-value**
Intersection (Y)	293.3 (α)	79.96	3.669	0.002835
Dam flood area (X1)	0.006265 (β1)	0.0005006	12.516	1.26E-08
Water (X2)	-0.0002944 (β2)	0.01246	-0.024	0.981506
Tillage (X3)	0.01107 (β3)	0.002045	5.413	0.000119
Arboreal vegetation (X4)	0.003070 (β4)	0.006279	0.489	0.632993
Damp area (X5)	0.01655 (β5)	0.006952	2.380	0.033307
Undergrowth (X6)	0.01378 (β6)	0.004490	3.069	0.008971

Source: Authors (2023)

As can be seen in Table 4, arboreal vegetation (X4) should not be included in the regression, along with the water area (X2). This is because, the p-value for both predictor variables is greater than the common alpha level of 0.05, which indicates that it is not statistically significant.

These results obtained in the correlations evaluated show that it is not statistically possible work with habitats separately. According to the analyzes carried out with the scenarios before the construction of the dam and the current PPAs, it was not possible to obtain a correlation of the data.

3.4 Impact analysis – remaining native vegetation and consolidated area

An additional study was carried out, as discussed in the section 2.4 (Impact analysis in the remaining of native vegetation and consolidated area). Correlation analysis is an important tool for understanding the relationships between different variables. It allows you to check whether there is a relationship between two variables and the intensity of this relationship. In this analysis, correlation analysis was applied, joining the areas of previously analyzed habitats, now being remnants of native vegetation and a consolidated area, in order to analyze whether joining the habitats is possible to obtain a regression.

3.4.1 Evaluation of modeling of data obtained in the dam flood area

For this stage of the evaluation, Table 5 shows the results of the evaluation of Equation 3, which considers evaluating the correlation of the dam's flood perimeter with the consolidated areas (CA) and remaining native vegetation (RNV), after processing the data with the R software.

Table 5 – Estimated parameters of the adjusted multiple linear regression model

	Coefficient	**Standard error**	**t-value**	**p-value**
Intersection (Y)	485.7 (α)	55.34	8.777	1.01e-07
Ca (X1)	0.008897 (β1)	0.0009672	9.199	5.19e-08
RNV (X2)	0.009171 (β2)	0.0002827	32.438	< 2e-16

Source: Authors (2023)

Considering the values as consolidated area and remaining native vegetation, the statistical significance for the variables was observed by the p value ($p < 0.05$).

3.4.2 Evaluation of modeling of data obtained from the PPA

As described in the section 2.4.2 (Evaluation of the modeling of data obtained from the PPS), after processing the data in the R software, Table 6 shows the results of the evaluation of Equation 4.

Table 6 – Estimated parameters of the adjusted multiple linear regression model

	Coefficients	**Standard error**	**t-value**	**p-value**
Intersection (Y)	340.3 (α)	66.21	5.140	8.19e-05
CA (X1)	0.006484 (β1)	0.0004767	13.603	1.45e-10
RNV (X2)	0.01013 (β2)	0.001597	6.346	7.31e-06

Source: Authors (2023)

Considering the values as consolidated area and remaining native vegetation, the statistical significance for the variables was observed by the p value ($p < 0.05$).

4 CONCLUSIONS

The use of data as a RNV and CA area provide a correlation of the data, being able to develop a regression and more detailed statistical analyses. However, it is not coherent to analyze only the areas to be suppressed with the areas to be preserved, since each habitat has its peculiarity and importance in the watershed. Therefore, the suppression of a stable habitat for the construction of an irrigation dam, even if there is recovery of PPA around the dam that was built, will have an environmental impact, even if the PPA is larger than the flooded area.

It is possible that in the study region, as it is in the Pampa Biome, the areas of arboreal vegetation were not representative, due to local phytosociology. However, this habitat (arboreal vegetation) cannot be disregarded, because when dealing with environmental impact, the State of Rio Grande do Sul published a CONSEMA Normative Instruction No. 01/2018 that establishes procedures to be observed for Mandatory Forest Replacement (MFR).

The analysis of the data with the remaining native vegetation habitats and consolidated area only served to check whether there was a correlation with the proposed theme (flooding to recover the surrounding flood area). However, it was not possible to continue with this assessment as this could simply be an index of PPA to be recovered divided by the flood area.

In this way, if the value is greater than 1, the environmental impact would be more than compensated, and it can be said that if the PPA to be restored is larger than the flood area already characterized by a future increase in natural habitats. However, analyzing only the remaining areas of native vegetation to be flooded with the PPAs to be recovered is incoherent, as each habitat has specificity and importance in its microbasin.

ACKNOWLEDGEMENTS

Authors thank to Federal University of Santa Maria.

REFERENCES

AGÊNCIA NACIONAL DE ÁGUAS - ANA. **Atlas Irrigação:** Uso da Água na Agricultura Irrigada. Brasília: ANA, 2017.

AGÊNCIA NACIONAL DE ÁGUAS - ANA. **Base Hidrográfica Ottocodificada Multiescalas 2017**. . Disponível em https://metadados.snirh.gov.br/geonetwork/srv/api/records/0c698205-6b59-48dc-8b5e-a58a5dfcc989. Acesso em em 22 de setembro de 2020

BRASIL. Lei nº 12.615, de 25 de maio de 2012**.** Dispõe sobre a proteção da vegetação nativa, altera as Leis 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006, revoga as Leis nos 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória no 2.166-67, de 24 de agosto de 2001, e dá outras providências. Diário Oficial da União: seção 1, Brasília, DF, ano 149, n. 85, p. 1-16, 28 mai. 2012. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm. Acesso em: 18 mai. 2023.

BRASIL. **Projeto de Lei n° 1282, 28 de fevereiro de 2019**. Altera a Lei 12.651/12, de 25 de maio de 2012. Altera o Código Florestal para permitir nas áreas de preservação permanente dos imóveis rurais, a construção de reservatórios d’água para projetos de irrigação e a infraestrutura física a ele associado. Brasília: Senado Federal, [2019]. Disponível em: https://www25.senado.leg.br/web/atividade/materias/-/materia/135567. Acesso em: 23 jun. 2023.

CEBALLOS, G.; EHRLICH, P.R.; BARNOSKY, A.D.; GARCÍA, A.; PRINGLE, R.M.; PALMER, T.M. Accelerated modern human-induced species losses: Entering the sixth mass extinction. **Environmental Sciences Adv,** *[S.l]*, v.1, e1400253, 2015.

CONSELHO NACIONAL DO MEIO AMBIENTE - CONAMA. Resolução nº 1, de 23 de janeiro de 1986. Dispõe sobre critérios básicos e diretrizes gerais para a avaliação de impacto ambiental. **Diário Oficial da União**: seção 1, Brasília, DF, ano 124, n. 35, p.2548-2549. Disponível em: https://www.ibama.gov.br/sophia/cnia/legislacao/MMA/RE0001-230186.PDF. Acesso em: 19 mai. 2023.

CONSELHO ESTADUAL DO MEIO AMBIENTE - CONSEMA. Resolução nº 323, 08 de setembro de 2016. Dispõe sobre os procedimentos de Licenciamento Ambiental dos empreendimentos de irrigação. Alterada pelas Resoluções CONSEMA 336/2017, 340/2017 e 372/2018. **Diário Oficial do Estado**: seção 1, Porto Alegre, RS, 21 set. 2016. Disponível em: https://sema.rs.gov.br/upload/arquivos/201803/01170951-323-2016-licenciamento-de-irrigacao-compilada.pdf. Acesso em: 19 mai. 2023.

CONSELHO ESTADUAL DO MEIO AMBIENTE - CONSEMA**.** Resolução nº 372, 22 de fevereiro de 2018. Dispõe sobre os empreendimentos e atividades utilizadores de recursos ambientais, efetiva ou potencialmente poluidores ou capazes, sob qualquer forma, de causar degradação ambiental, passíveis de licenciamento ambiental no Estado do Rio Grande do Sul, destacando os de impacto de âmbito local para o exercício da competência municipal no licenciamento ambiental. Alterada pelas Resoluções 375/2018, 377/2018, 379/2018, 381/2018, 383/2018, 389/2018, 395/2019, 403/2019, 408/2019, 415/2019, 424/2020, 429/2020, 432/2020, 437/2021, 441/2021, 445/2021, 446/2021, 448/2021 ,452/2021, 464/2022 e 467/2022. **Diário Oficial do Estado**: seção 1, Porto Alegre, RS, 01 mar. 2018. Disponível em: https://www.sema.rs.gov.br/upload/arquivos/201803/15120855-372-2018-atividades-licenciavies-revisao-288.pdf. Acesso em: 19 mai. 2023.

CREMONEZ, F.E.; CREMONEZ, P. A.; FEROLDI, M.; DE CAMARGO, M. P.; KLAJN, F. F.; FEIDEN, A. Avaliação de impacto ambiental: metodologias aplicadas no Brasil. **Revista Monografias Ambientais,** *[S.l],* v. 13, n. 5, 2014.

DOS SANTOS, R. R. Irrigação como alternativa de sustentabilidade agrícola e ambiental. **Saber Acadêmico,** *[S.l],* v. 10, 2010.

EUROPEAN SPACE AGENCY - ESA. **Copernicus Open Access Hub.** 2023. Disponível em: https://scihub.copernicus.eu/dhus/#/home. Acesso em 22 de janeiro de 2023.

FOOD AND AGRICULTURE ORGANIZATION - FAO. **O futuro do alimento e da agricultura**. Roma: FAO, 2017. Disponível em: http://www.fao.org/3/a-i6583e.pdf. Acesso em: 19 mai. 2023.

GARDNER, T. A.; BARLOW J.; CHAZDON, R.; EWERS, R. M.; HARVEY, C. A.; PERES, C. A., SODHI.; N. S. Prospects for tropical forest biodiversity in a human-modifield word. **Ecology Letters,** *[S.l]*, v. 12, n. 6, p. 561 – 582, 2009.

GROOM, M. J., VYNNE, C. H. Habitat degradation and loss. *In*: Groom, M. J.; Meffe, G. K. & Carroll, C. R. (Eds.). **Principles of Conservation Biology**. Sunderland: Sinauer Associates, 2006. p.173 – 212.

LAMBECK, R. J. Focal Species: A Multi-Species Umbrella for Nature Conservation. **Conservation Biology,** [*S.l*]: v. 11, p. 849 – 856, 1997.

LEVIEN, S. L. A.; FIGUEIRÊDO, V. B.; DE ARRUDA, L. E. V. **Panorama da atual área de agricultura irrigada no Brasil**. Nova Xavantina: Pantanal, 2021.

LEÃO, F.R. **Dimensionamento de uma pequena barragem de terra para produção de energia hidrelétrica e irrigação em uma propriedade rural.** Monografia (Bacharelado em Engenharia Agrícola) - Unidade Universitária de Ciências Exatas e Agrícolas, Universidade Estadual de Goiás, Anápolis, GO, 2012.

LOYN, R. H.; MCNABB, E. G.; MACAK, P. & NOBLE, P. Eucalypt plantations as habitat for birds on previously cleared farmland in south-eastern Australia. **Biological conservation,** [*S.l*]: v. 137, p. 533 – 548, 2007.

PFAFSTETTER, O. **Classificação de Bacias Hidrográficas** – Metodologia de Codificação. Rio de Janeiro: DNOS, 1989.

PICOLLI, L.R.; SCHNADELBACH, C. V. **O Pampa em Disputa:** A biodiversidade ameaçada pela expansão das monoculturas de árvores. Porto Alegre: Amigos da Terra Brasil, 2007.

SECRETÁRIA DE ESTADO DO AMBIENTE E DESENVOLVIMENTO SUSTENTÁVEL – SEMA. **Instrução Normativa SEMA N º 01/2018**. Estabelece procedimentos a serem observados para a Reposição Florestal Obrigatória no Estado do Rio Grande do Sul. Porto Alegre: SEMA, [2018]. Disponível em: https://www.sema.rs.gov.br/reposicao-florestal-obrigatoria. Acesso em: 25 jun. 2023.

SISTEMA DE OUTORGA DE ÁGUA - SIOUT. **Consulta SIOUT**. Disponível em http://www.siout.rs.gov.br/consulta/#/. Acesso em 22 de junho de 2023.

SCHULZE, K.; KNIGHTS, K.; COAD, L.; GELDMANN, J.; LEVERINGTON, F.; EASSOM, A.; MARR, M.; ... BURGESS, N.D.; 2018. An assessment of threats to terrestrial protected areas. **Conservation Letters**, [*S.l*], v. 10, p. e12435, 2018.

TRIOLA, M. F. **Introdução à estatística.** 9. ed. Rio de Janeiro: LTC, 2005.

Authorship contributions

1 – Gabriela de Vargas Heinen

Graduação em Engenharia Florestal pela Universidade Federal de Santa Maria
https://orcid.org/0009-0003-6866-5332 • gabrieladvheinen@gmail.com
Contribuition: Writing – original draft | Writing – review & editing

2 – José Cardoso Sobrinho

Doutorado em Engenharia Agrícola pela Universidade Federal de Viçosa
https://orcid.org/0000-0001-7765-4916 • jcardoso@politecnico.ufsm.br
Contribuition: Writing – original draft | Writing – review & editing

How to quote this article

HEINEN, G. DE V.,; CARDOSO SOBRINHO, J. Evaluation of the impact on dams in the previous and current scenario in affected areas. **Revista de Gestão, Educação e Tecnologia ambiental**. Santa Maria, v.28, e85297, 2024. DOI 10.5902/2236117085297. Disponível em: https://doi.org/10.5902/2236117085297. Acesso em: dia, mês abreviado, ano.