Edição especial – VI Workshop de Inovações Tecnológicas na Agricultura - WINOTEC

ISSN 2359-6562 (ONLINE) 2359-6562 (CD-ROM)

EFICIÊNCIA NO USO DA ÁGUA E FLUXO DE CARBONO NA SUB-BACIA DO RIO SALGADO

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RESUMO: Regiões Áridas e Semiáridas são caracterizadas pelo déficit hídrico, condicionando diretamente as características das vegetações ao longo do ano. Todavia, perturbações ambientais podem ocorrer por ações antrópicas, onde são provocadas modificações das vegetações naturais por outras para fins agropecuários. Esse comportamento afeta a disponibilidade hídrica e a Eficiência no Uso da Água (EUA). A EUA é uma variável que possibilita mensurar o rendimento da água em um ecossistema. O presente trabalho objetivou compreender o fluxo da água e carbono ao longo dos anos na sub-bacia do rio Salgado, proporcionando uma visão de como o uso e ocupação do solo influencia na eficiência no uso da água. A área de estudo foi a sub-bacia do rio Salgado, composta por 23 municípios, estando localizada na região sul do estado do Ceará. O trabalho foi realizado, através da análise de imagens de satélite dos projetos MapBiomas e MOD16A3GF v061, para obter EUA média de cada ano no período de 2002 à 2022. Com isso, constatou-se que o maior e menor EUA da sub-bacia são as legendas Formação Campestre e Lavouras Perenes, respectivamente. Com base nesse estudo, pode-se concluir que o fluxo da água e carbono está diretamente relacionado com a exposição da cobertura do solo e o conteúdo de biomassa verde.

Palavras-chave: Uso e Ocupação do Solo, QGIS, Geoprocessamento.

WATER USE EFFICIENCY AND CARBON FLUX IN THE SALGADO RIVER SUB-BASIN

ABSTRACT: Arid and semiarid regions are characterized by water deficit, which directly affects the characteristics of vegetation throughout the year. However, environmental disturbances can occur due to human actions, where modifications of natural vegetation are caused by others for agricultural purposes. This behavior affects water availability and water use efficiency (WUE). WUE is a variable that makes it possible to measure the water yield in an ecosystem. This study aimed to understand the flow of water and carbon over the years in the Salgado River subbasin, providing insight into how land use and occupation influence water use efficiency. The study area was the Salgado River subbasin, which is composed of 23 municipalities located in the southern region of the state of Ceará. The work was carried out through the analysis of satellite images from the MapBiomas and MOD16A3GF v061 projects to obtain the average US for each year in the period from 2002--2022. The largest and smallest USs of the subbasin are the Campestre Formation and Perennial Crops legends, respectively. On the basis of this study, the flow of water and carbon is directly related to the exposure of the soil cover and the green biomass content.

Keywords: Land Use and Occupation, QGIS, Geoprocessing.

Recebido em 03/12/2024 e aprovado para publicação em 12/12/2024
DOI: http://dx.doi.org/10.17224/EnergAgric.2024v39p100-105

1 INTRODUCTION

Environments with high water deficits, which are common in arid and semiarid regions, are characterized by low rainfall and high evapotraspirometric demand resulting from climate change and accelerated by human actions. These conditions create a situation conducive to drought events and plant and soil degradation, directly interfering with the resilience capacity of the ecosystem. In addition to climate change, changes in land use and cover can lead to losses in biodiversity and natural resources (Jardim *et al.*, 2022).

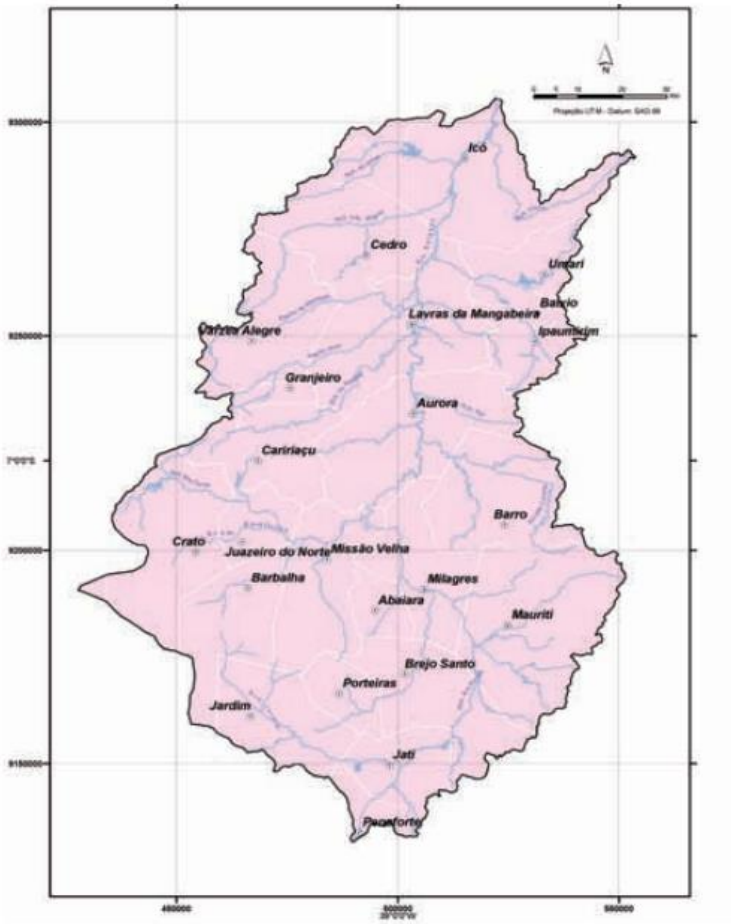
To better understand and comprehend the behavior of environments under unfavorable climatic conditions, investigating water and carbon flows is essential. This study allows us to identify vegetation patterns and the impacts of human activities (Oliveira *et al.*, 2022).

In this sense, water use efficiency (WUE) makes it possible to measure the water yield in an ecosystem, which, in arid and semiarid regions, is a factor of great importance, as water is a limited resource in this environment, thus making it crucial to carry out studies in this area of research (Zhao, 2021). The present study aimed to understand the flow of water and carbon over the years in the Salgado River subbasin, providing insight into how land use and occupation influence water use efficiency.

2 MATERIALS AND METHODS

The study was carried out in the Salgado River subbasin, a tributary of the Jaguaribe River Basin, located southeast of the state of Ceará (Figure 1).

Figure 1. Location of the Salgado River subbasin, highlighting the monitored reservoirs



Source: Santana (2018).

This basin contains a drainage area of 12,865 km², which corresponds to 8.25% of the territory of the state of Cerará. This subbasin occupies a large part of the southern region of the state, which is formed by 23 municipalities: Abaiara, Aurora, Baixio, Barbalha, Barro, Brejo Santo, Caririaçu, Cedro, Crato, Granjeiro, Icó, Ipaumirim, Jardim, Jati, Juazeiro do Norte, Lavras da Mangabeira, Mauriti, Milagres, Missão Velha, Penaforte, Porteiras Umari and Várzea Alegre (Santana, 2018).

Water use efficiency (WUE) can be defined simply as "the amount of water evaporated for each g of carbon m $^{-2}$ for NPP" (Kuglitsch *et al.*, 2008); this definition is very efficient in analyzing the water use pattern for a given area, enabling an understanding of the water cycle and assisting in the water management of a given ecosystem (Kumar *et al.*, 2023). To calculate the EUA, equation (1) is used.

$$EUA = \frac{NPP}{AET} \quad (1)$$

where USA is the water use efficiency, NPP is the net primary production, and AET is the actual evapotranspiration.

The NPP and AET data were obtained free of charge through the MOD16A3GF v061 product, which was downloaded from the website https://appeears.earthdatacloud.nasa.gov, for the period from 2002--2022. Both the NPP and AET are present in the TIFF image format and EPSG:4326 - WGS 84 latitude and longitude projection system, with composite organization, gross and net primary production, and actual and potential evapotranspiration.

To perform the US calculation, the TIFF images must undergo a prior conversion, transforming the values that are scaled to real values, using a scale factor, as represented in equation 2.

$$Valor\ real = Dados\ válidos\ x\ Fator\ de\ escala \quad (2)$$

The scale factor is different for NPP and AET, with values of 0.0001 and 0.1, respectively.

All calculations with images were performed with the free software QGIS v 3.30.3. The conversion of the images and the calculation of the EUA were performed with the raster calculator tool present in QGIS.

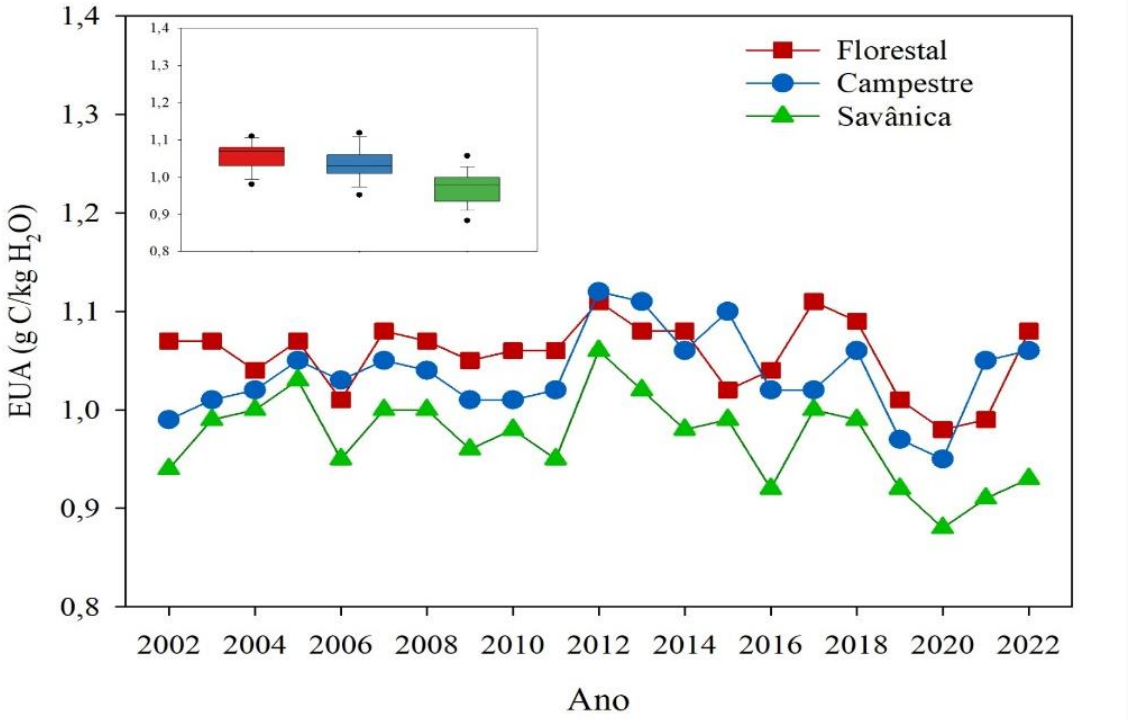
The use and occupation of the study area was obtained through images in TIFF format, available in the MapBiomas program (2024), present on the website https://brasil.mapbiomas.org/, downloaded from 2002--2022. These images come with their pixels classified into classes by the MapBiomas program, where each class represents a type of use.

The analysis of the EUA in relation to land use and occupation was carried out via QGIS software with the Zonal Statistics tool of the raster layer, which uses the mean EUA for each use shown in the images of land use and occupation as the main data for this research. With this process, data from 21 years were obtained for each land use and occupation in the study area. The data were organized via Microsoft Excel software, and the graphs were created via SigmaPlot 14 software.

3 RESULTS AND DISCUSSION

To better understand the data obtained, the data were grouped and divided into two headings: vegetation and agricultural activity. Figure 2 shows the captions related to plant formation.

Figure 2. Representation of the EUA (water use efficiency) for the period 2002--2022 in relation to the following land uses: forest formations, grassland formations and savanna formations.

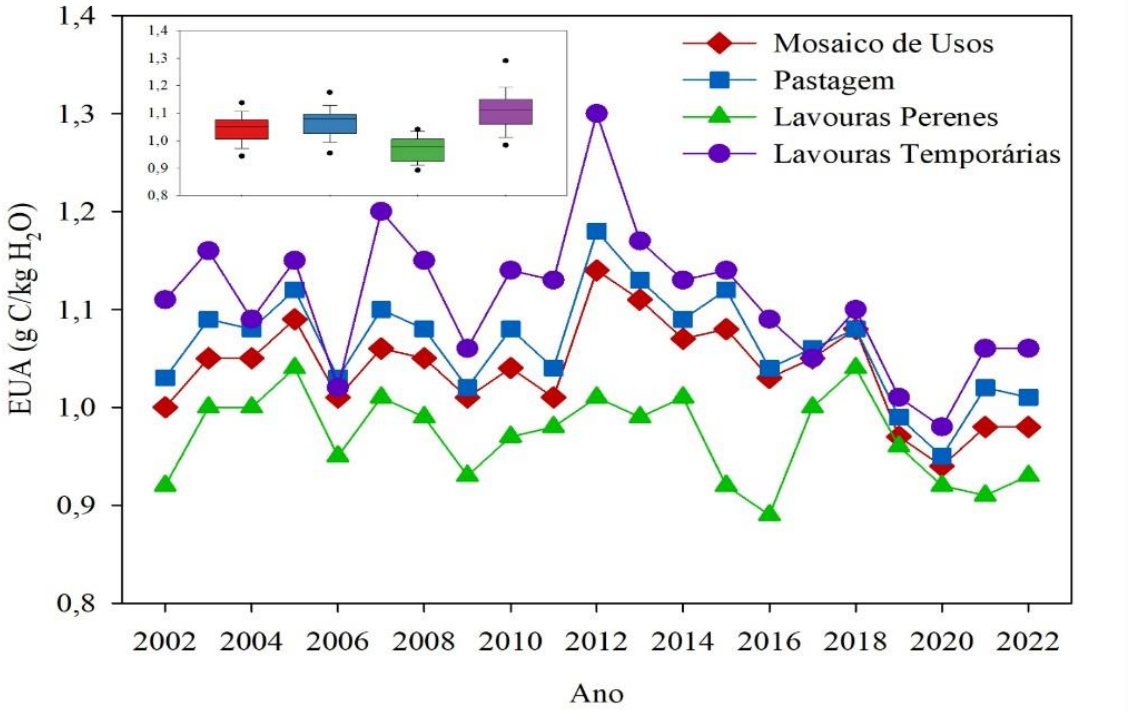


Source: Author

Figure 2 shows that the Campestre Formation had the highest UE in nearly the entire period analyzed, with an average of 1.03 g C/kg H2O and a standard deviation of 0.006. The Savânica Formation presented the lowest UE values, with a variation between the maximum value of 1.01 g C/kg H2O and the minimum value of 0.87 g C/kg H2O, with an average of 0.97 and a standard deviation equivalent to 0.004. Wang, Wang and Li (2024) emphasized that UE is directly associated with the photosynthesis and stomatal conductance of plants. However, the Florestal Formation retained a median character, presenting UE values among the other plant formations.

Figure 3 represents the EUA of agricultural activities. From the above, it was possible to observe that the legend with temporary crops stood out in relation to the others, presenting the most efficient use of water, with an average of approximately 1.10 g C/kg H2O. With an intermediate and similar character between them, the legends Pastures and Mosaic of Uses always remained between the legends with the highest and lowest values, in addition to having EUA values very close throughout almost the entire period. Among the different conditions analyzed, the legend with perennial crops had the lowest EUA values in all the periods, with an average of 0.97 g C/kg H_2O.

Figure 3. Representation of the EUA (Water Use Efficiency) for the period 2002--2022 in relation to the following land uses: Mosaic of uses, Pasture, Perennial Crops and Temporary Crops.



Source: Author

The Temporary Crops legend presented the highest UE values throughout the period, with a maximum value in 2012 (1.29 g C/kg H_2O). This behavior occurs because temporary crops consist of crops such as corn and beans, which are produced with greater intensification, always seeking high yields. Temperature is the main determining factor for shrub UE, whereas precipitation mainly influences the UE of pastures, agricultural lands and forests (Zhang *et al*., 2016).

Regarding the legend that had the lowest EUA, the Perennial Crops legend had the lowest values among all the conditions studied, with the probable explanation being the lower production, where the production of perennial crops (*e.g.*, lemon and banana) always seeks the highest production focused on the fruits and not on the production of biomass, and another factor is the issue that orchards have greater spacing between plants than temporary crops do, thus presenting a lower biomass. This behavior is similar to that reported by Nandy, Saranya and Srinet (2022), who reported the lowest EUA values for pasture conditions.

4 CONCLUSIONS

The flow of water and carbon occurs with greater intensity in areas with grassland formation, where there is greater soil coverage by herbaceous and shrubby vegetation. Conditions with greater soil exposure resulted in lower water use efficiencies.

5 ACKNOWLEDGMENTS

The authors would like to thank the Center for Agricultural and Biodiversity Sciences (CCAB) of the Federal University of Cariri (UFCA) for the logistics needed to carry out the work, the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) for its financial support to the scholarship holders participating in this research and the PROJECT: Notice No. 162022, PDPG - Strategic Postdoctorate.

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