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REGULATION ECOSYSTEM SERVICES IN A WATERSHED IN THE SEMI-ARID OF BRAZIL

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Abstract

Human pressures on ecosystems from the use and suppression of vegetation cover cause negative actions on biodiversity, impacting nature and the ecosystem services provided by it. The focus of this research is to evaluate the capacity to provide Ecosystem Services in the Seridó River Basin (RN/PB). Modeling techniques were applied from the USLE, in addition to vegetation and organic carbon indices. The results showed that the highest NDVI values are found in areas of greater elevation and slope, and the lowest values are found in flat areas. 06 classes of land use were identified, namely: Water bodies, urban area, Pasture and exposed rock, Subshrub Caatinga, Subarboreal and Arboreal. As a result, the most relevant areas for providing Organic Carbon stock services are in the higher areas, with the areas of greater erosion control located in areas of escarpments. In this way, understanding the spatialization of the capacity of areas to provide certain services is to provide decision-making agents with an environmental planning product aimed at ensuring the provision of ecosystem services.

Keywords: Ecosystem Services; Modeling; Caatinga; Semiarid; Hydrographic Basin.

Resumo / Resumen

SERVIÇOS ECOSSISTÊMICOS DE REGULAÇÃO EM UMA BACIA HIDROGRÁFICA NO SEMIÁRIDO DO BRASIL

As pressões humanas sobre os ecossistemas a partir do uso e supressão da cobertura vegetal provocam ações negativas na biodiversidade, impactando a natureza e os serviços ecossistêmicos prestados pelo o mesmo. O enfoque desta pesquisa é avaliar a capacidade de prestação de Serviços Ecossistêmicos na Bacia Hidrográfica do Rio Seridó (RN/PB). Foram aplicadas técnicas de modelagem a partir da USLE, além de índices de vegetação e Carbono Orgânico. Os resultados mostraram que os maiores valores do NDVI estão em áreas de maior elevação e declividade, e os valores mais baixos encontrados em áreas planas. Foram identificadas 06 classes de uso da terra, são elas: Corpos hídricos, zona urbana, Pastagem e rocha exposta, Caatinga Subarbustiva, Subarbórea e Arbórea. Com isso, as áreas de maiores relevâncias de prestação de serviços de estoque de Carbono Orgânico estão nas áreas mais elevadas, sendo que as áreas de maior controle de erosão localizadas em áreas de escarpas. Dessa froma, entender a espacialização da capacidade das áreas em prestar determinados serviços é proporcionar aos agentes tomadores de decisão, um produto de planejamento ambiental voltado a assegurar a prestação dos serviços Ecossistêmicos.

Palavras-chave: Serviços Ecossistêmicos; Modelagem; Caatinga; Semiárido; Bacia Hidrográfica.

SERVICIOS ECOSISTÉMICOS DE REGULACIÓN EN UNA CUENCA DEL SEMIÁRIDO DE BRASIL

Las presiones humanas sobre los ecosistemas por el uso y supresión de la cubierta vegetal provocan acciones negativas sobre la biodiversidad, impactando la naturaleza y los servicios ecosistémicos que la misma brinda. El enfoque de esta investigación es evaluar la capacidad de brindar Servicios Ecosistémicos en la Cuenca del Río Seridó (RN / PB). Se aplicaron técnicas de modelado de USLE, además de índices de carbono orgánico y de vegetación. Los resultados mostraron que los valores más altos de NDVI se encuentran en áreas de mayor elevación y pendiente, y los valores más bajos se encuentran en áreas planas. Se identificaron seis clases de uso del suelo, a saber: Cuerpos de agua, área urbana, Pastizales y rocas expuestas, Caatinga Subarbustiva, Subarbórea y Arbórea. Como resultado, las áreas de mayor relevancia para la prestación de servicios de almacenamiento de carbono orgánico se encuentran en las áreas más altas, con las áreas con mayor control de erosión ubicadas en áreas escarpadas. De esta manera, entender la espacialización de la capacidad de las áreas para brindar determinados servicios es brindar a los agentes decisorios un producto de planificación ambiental orientado a asegurar la prestación de los servicios ecosistémicos.

Palabras-clave: Servicios de los ecosistemas; Modelado; Caatinga; Semi árido; Cuenca hidrográfica.

INTRODUCTION

The advance in understanding the importance of environmental systems in terms of providing various Ecosystem Services - SE to society, led to the emergence of a very coherent approach regarding the integration between the levels of consumption required by humanity in relation to the capacity of the environment in provide certain services (DE GROOT et al., 2010; POTSCHIN; HAINES-YOUNG, 2011). The understanding that economic activities in the face of natural resources generate ecological imbalances, encourages discussion of the limits of anthropic pressures on ecosystems, initiating the development of strategies aimed at conservation (COSTANZA, 1998; COSTANZA et al., 2017).

It was from the 1980s onwards that conservation efforts were intensified, considering the natural dynamics of ecosystems and social demands, as well as the deepening of the discussion between society and nature (VASENTINI, 1997). In this regard, the concept of Ecosystem Service emerges to promote advances in discussions of this approach from the perspective of conserving ecosystems through the integration of environmental and socioeconomic concepts (FISHER et al., 2009; BURKHARD, 2014).

In this way, authors such as Costanza et al. (1997); Potschin; Haines-young (2011); Haines-Young and Potschin (2013), characterize them as tangible and intangible goods produced by ecosystems, where they are used directly or indirectly by society, in pursuit of its well-being. These services relate to aspects related to the provision, regulation and maintenance and cultural aspects.

Emphasizing regulatory services, in which the vegetation cover is an important element of carbon retention and storage, as well as the reduction of soil erosion processes (BOTELHO, 2011; SANTOS, 2018), the River Basin Seridó, in the Brazilian semi-arid region, has characteristics modeled by the dynamics of land use and occupation through plant suppression to increase pasture and extensive agriculture, which generate instability in the ecosystem (PENNINGTON; PRADO; PENDRY, 2000; PEREIRA NETO, 2016).

These anthropic pressures trigger a sequence of imbalances throughout the environmental system, causing losses in the quality of the provision of these Services (BOTELHO; SILVA, 2011). Thus, it is necessary to spatialize the capacity of the study area to provide certain regulation and maintenance services (COSTANZA; DALY, 1992; COTANZA et al., 1997).

Therefore, this research aimed to evaluate the capacity to provide SE from the modeling of the Universal Soil Loss Equation (EUPS) and the equation of carbon sequestration indices for the Seridó River Basin (RN-PB).

MATERIALS AND METHOD

DESCRIPTION OF THE STUDY AREA

The Seridó River Sub-basin is characterized as a Hydrographic Basin at the Federal level because it is inserted in two States (Paraíba and Rio Grande do Norte). Featuring an intermittent drainage typical of semi-arid regions, the drainage headwaters are located in the Serra do Alagamar or Serra dos Cariris (Municipality of Cubati/PB), occupying an area of approximately 9,923 Km², which represents 22.7% of the total area of the Basin in which it is inserted, the Piranhas Açu River Basin (43,683 Km²), thus configuring its main Hydrographic Sub-basin (Figure 1).

Regarding the integrated analysis, the Seridó River Basin - BHRS is formed by natural and anthropic acting systems that model the landscape for the increase of occurrences of areas in desertification (28% of the basin), as highlighted by the works developed by Sampaio et al. (2003), Costa et al. (2009); Perez--Marin et al. (2012), Pereira Neto (2016), Rabelo and Araújo (2019).

The climate of the study area is classified, according to the Koppen climate update BSw'h' (ALVARES et al., 2013), highlighting the concentration of the rainy season in the first half of the year, in which the rainfall varies between 400mm and 600mm annually (LUCENA et al., 2018).

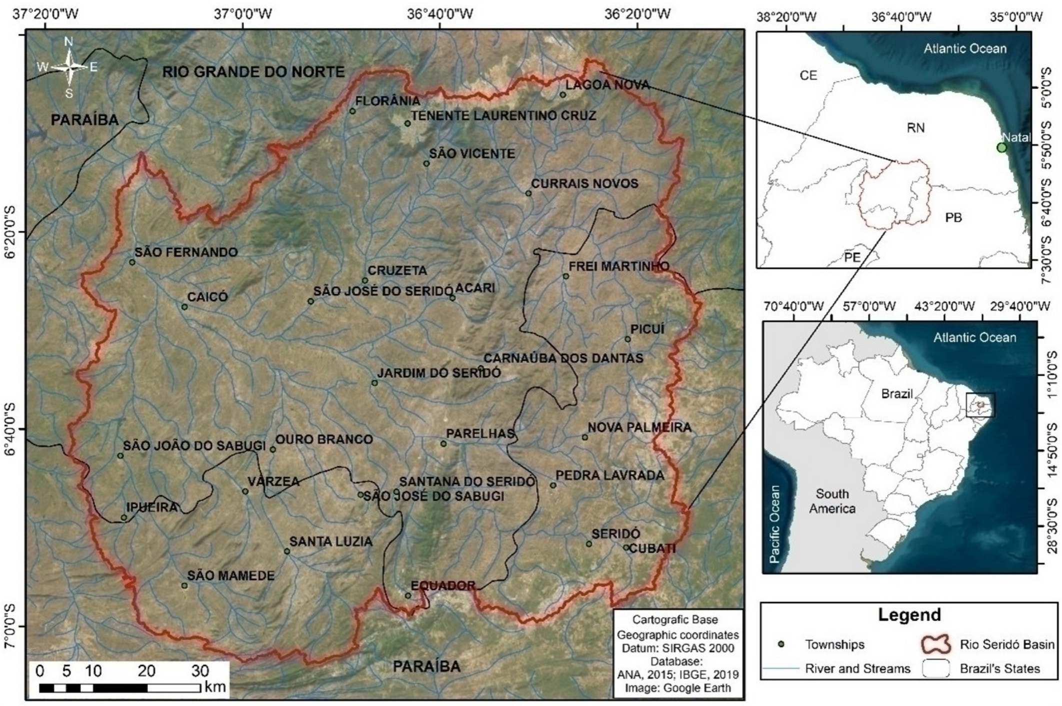


Figure 1 – Location map of the Seridó River Basin (PB/RN). Source: Elaborated by the author.

Regarding geological and geomorphological aspects, the basement of the basin consists of rock layers originating in the Brasiliano cycle, (MAIA, 2014). These geomorphological units are characterized by the predominance of the Sertaneja Depression unit with broad tabular relief forms and little depth, presenting a pediplaned surface with topographic elevations varying between 100m and 800m in altitude (MAIA; BEZERRA, 2020).

In ecoregional terms, the study area presents a vegetation called Caatinga Seridó, as classified by Duque (1953) and Rizzini (1997), with characteristics of evolution and adaptation to the extreme semi-arid environment, in which they are constituted of areas totally transformed by anthropic actions (AMORIM et al., 2005). This vegetation was historically modeled by anthropic interference, forming deciduous, thorny and low-sized species, which often have a microphyly physiognomy, in addition to a seasonal herbaceous extract that is reinvigorated at each rainy period (ANDRADE-LIMA, 1981; GRAEFF, 2015).

The soil classes with the highest occurrence in the area are the Crômico Luvisols, followed by Litholic Neosols and Regolithic Neosols, which are unfavorable soils for agriculture and whose existence is linked to the severe conditions of arid climate and little rainfall (CORRÊA et al., 2019).

TECHNICAL PROCEDURES

To map the vegetation cover, images from the Sentinel 2B satellite (Sensor: MSI; date: 08/15/2019), with a spatial resolution of 10 meters, were used. With the help of QGIS software version 2.14.1 (Essen/GNU - General Public License©) (QGIS TEAM, 2015). In the pre-processing of the images, radiometric calibration and atmospheric correction were performed using correction by Dark-Object Subtraction – DOS (CHAVEZ-JR, 1988). It is important to highlight that, according to the European Space Agency (ESA, 2017), the Sentinel-2 satellite images are already provided in the Top-Of-Atmosphere (TOA) reflectance.

After pre-processing, a false color composition was performed through bands 02, 03 and 04, respectively in the blue, green and red channels, then the Image classification tool was applied to generate the raster classified according to the types of land cover. Regarding the method of analysis of laminar soil loss in a GIS environment, the Universal Soil Loss Equation - USLE methodology was used, based on the equation developed by Wischmeier and Smith (1978):

$$A = R \cdot K \cdot LS \cdot C \cdot P \qquad (1)$$

Where:

A - Soil loss per unit area over (t.year^{-1});

R - Erosivity factor caused by rain (MJ.mm.ha^{-1}.hr^{-1}.ano^{-1});

K - Soil erodibility factor (t.h.ha.MJ^{-1}.mm^{-1});

LS - Topographical factor;

C - Soil coverage and management;

P - Conservation practices.

The R factor was obtained through rainfall data from the meteorological stations of INMET - National Institute of Meteorology and EMPARN - Agricultural Research Company of Rio Grande do Norte, for the municipalities of Caicó, Cruzeta, Ouro Branco and Florânia, in Rio Grande do Norte.

Norte, and from the Water Management Executive Agency - AESA for the municipalities of Santa Luzia, Patos, Picuí and Pedra Lavrada, in Paraíba, in which historical data of precipitation between the years 2002 and 2018 were obtained, accounting for a historical series of 16 years.

Then, the equation proposed by Bertoni and Lombardi Neto (1985) was applied:

$$R = \sum_{i=1}^{12} 89{,}823 \left(\frac{Pm^2}{Pa}\right)^{0.759} \qquad (2)$$

Where:

R - Rain erosivity (MJ.mm.ha^{-1}.ano^{-1});

Pm - Average monthly precipitation (mm);

Pa - Total annual precipitation (mm).

Regarding the K factor, data on fine sand, silt, clay and soil organic carbon were obtained from the Soils database of Embrapa – Empresa Brasileira de Pesquisa Agropecuária, from the FAO Digital Soil Map of the World (DSMW) platform. and the World Digital Soil Map (MDMS).

For data analysis, the procedure described by Williams (1975) was followed, through the following equation:

$$K = fareiag \cdot far - sif \cdot COrg \cdot fareiaf \qquad (3)$$

Where:

Fareiag - Coarse sand fraction;

Far-sif - Clay and silt fraction;

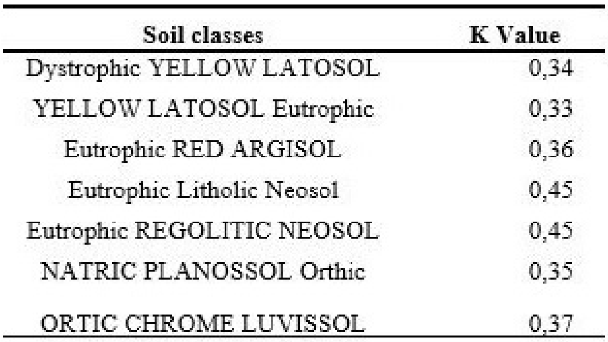
Corg - Organic carbon fraction;

Fareiaf - Fraction of fine sand contained in the soil sample.

The factors are dimensionless, and each factor of this equation is calculated separately, through specific equations that can be obtained from Williams (1975).

After obtaining the K values through the equation described above, each soil fragment identified in the municipality received its due K factor values in the GIS environment (Table 1), where the soil map produced by EMBRAPA (2011) was adopted on the scale of 1:5,000,000.

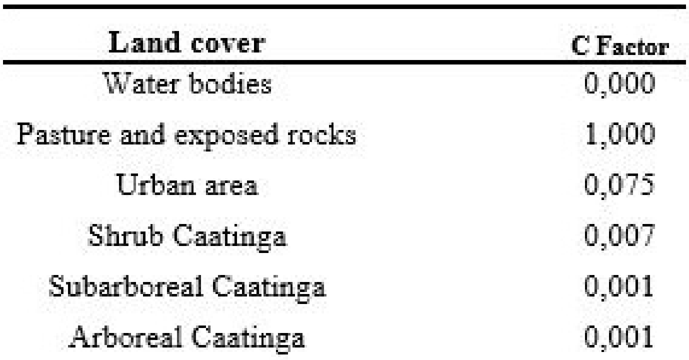
Table 1 – K factor values for the different soil classes that occur in the Seridó River Basin. Source: EMBRAPA (2011); MDMS (2019)



Soil classes	K Value
Dystrophic YELLOW LATOSOL	0,34
YELLOW LATOSOL Eutrophic	0,33
Eutrophic RED ARGISOL	0,36
Eutrophic Litholic Neosol	0,45
Eutrophic REGOLITIC NEOSOL	0,45
NATRIC PLANOSSOL Orthic	0,35
ORTIC CHROME LUVISSOL	0,37

For the C factor, the recommended values for Caatinga areas in the northeastern semi-arid region used by Farinasso et al. (2006). For this purpose, the vegetation cover classes were described according to the classification by Chaves et al. (2008), where: Shrub Caatinga (< 1,5m); Subshrubby caatinga (< 1.5m and > 3m); Subarboreal caatinga (< 3 and > 4.5m); and arboreal caatinga (< 4.5m) (table 2).

Table 2 – Seridó River Basin (RN/PB): Vegetation cover classes, 2021. Source: Adapted de FARINASSO et al. (2006).



Land cover	C Factor
Water bodies	0,000
Pasture and exposed rocks	1,000
Urban area	0,075
Shrub Caatinga	0,007
Subarboreal Caatinga	0,001
Arboreal Caatinga	0,001

The LS factor was obtained through the image of the ALOS/Sensor PALSAR satellite, with a spatial resolution of 12.5 meters, being worked in GIS through the equation proposed by Moore and Bruch (1986).

$$LS = \left(\frac{F * \Delta}{22{,}13}\right)^{0.4} * \left(\frac{\sin\theta}{0{,}0896}\right)^{1.3} \qquad (4)$$

Where:

F - Flux accumulated by each of the cells;

Δ - Size of each image cell in metrics;

ϴ - Slope angle.

For the P factor, the value of 1 was adopted for the entire study area due to the lack of information on the existence of conservationist practices in the area. This procedure was also adopted by Farinasso et al. (2006); Irvem et al. (2007) and Silva et al. (2012).

To assess the carbon sequestration potential, images from the Sentinel 2-B satellite (Sensor: MSI; image date: 08/15/2019) were used. The vegetation index by normalized difference (NDVI) was generated according to the formula developed by Rouse et al. (1973):

$$NDVI = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}} \tag{5}$$

Then, the photochemical reflectance index (PRI) and the carbon dioxide flux potential index (CO2 Flux) were applied, based on the methodology described by Silva et al. (2018). To verify alterations in the carotenoid pigments of the leaves, the photochemical reflectance index (PRI) was used, being calculated from the following equation:

$$PRI = \frac{\mathrm{blue} - \mathrm{green}}{\mathrm{blue} + \mathrm{green}} \tag{6}$$

From obtaining the PRI, it is necessary to correct its values to positive, which is of paramount importance to normalize the data of the greenest areas of vegetation, as described by Silva and Baptista (2015), expressed by the following equation:

$$sPRI = \frac{(\mathrm{PRI} + 1)}{2} \tag{7}$$

To obtain the carbon sequestration potential flux index (C Flux), it is necessary to multiply the products generated from the NDVI and the sPRI, which will determine the potential for carbon sequestration by photosynthetically active vegetation, from the equation proposed by Rahman et al. (2000):

$$\mathrm{C\ Flux} = NDVI * sPRI \tag{8}$$

Regarding the mapping of ES, the Common International Classification of Ecosystem Services – CICES (HAINES-YOUNG; POTSCHIN, 2017) methodology was used, developed from work on environmental accounting carried out by the European Environmental Agency (EEA). The mapping classes will be described according to the potential service matrix of the classification by Burkhard et al. 2014; Burkhard; Mothers, 2017.

In this sense, the ability to provide erosion regulation and control services will be assessed, as well as the regulation of organic carbon flows which, according to Costanza et al. (2017), this service is aimed at the functioning of ecosystems and their ecological processes that help regulate environmental characteristics that can interfere with human well-being.

To carry out the statistical analysis, the values in hectare (ha) of carbon sequestration and land cover were tabulated, as well as the surface erosion values, all converted to percentages (%) in order to work with values close to the sample . For this purpose, descriptive statistics were applied through simple linear regression to measure the level of relationship between carbon sequestration and land cover classes, in addition to the boxplot graph through superficial erosion values, seeking the concentration between the quartiles of sampling (GOTELLI; ELLISON, 2011).

RESULTS

According to the mapping generated from the vegetation index, the results obtained from the NDVI ranged from -0.55 to 0.88 (Figure 2). Where the highest values are observed in the areas of higher altitude, areas such as the Borborema plateau, in addition to the isolated inselbergs and the slopes in the higher areas.

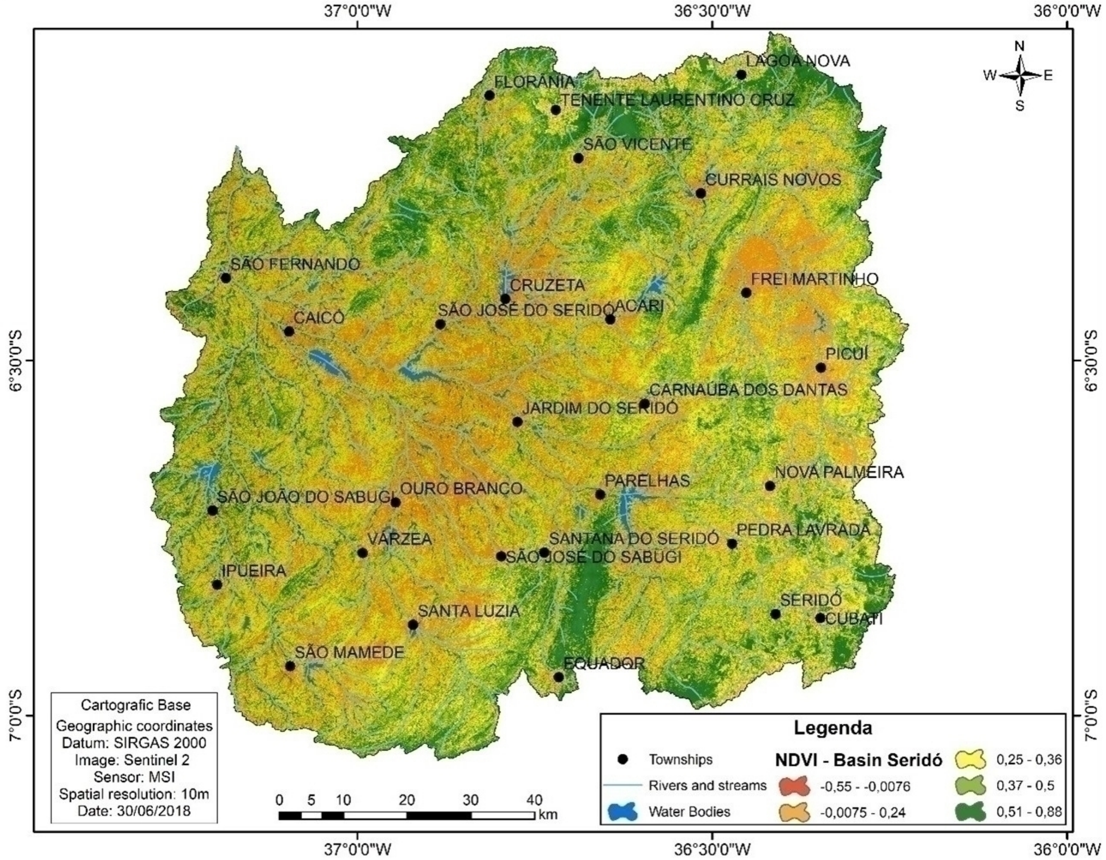


Figure 2 - Map of the NDVI vegetation index in the Seridó River Basin (RN/PB). Source: Elaborated by the authors.

From the results obtained by the NDVI, in addition to field reconnaissance work, it was possible to identify 06 land cover classes: Water bodies, urban zone, Pasture and exposed rock, Subshrub Caatinga, Subarboreal Caatinga and Arboreal Caatinga (Figure 3). It is important to emphasize that, according to the work test theme, riparian forest and dense vegetation were considered as the same type of class because they present phytophysiognomic parameters with the same reflectance value.

The data obtained were quantified in hectare values for each of the cover classes, with a predominance of more than 50% of the shrubby Caatinga class (51.75%). They are characterized by shrubs with little species diversity within the same radius of vision, as described by Albuquerque et al. (2020). The Caatinga Arborea class had 24.95% of vegetation cover, which provide important services, such as the release of O2 in the system and control of erosion and flows of organic carbon in the soil (FERNANDES et al., 2020).

The Subarboreal Caatinga class are precisely those areas that presented vegetation of shrub and arboreal size, but whose phytophysiognomic characteristics are predominant of shrubs or that presented clearings within the fragment, as was evidenced in loco. These are areas that already present an advanced state of succession in terms of greater diversity of species, thus seeking the stability of their ecological functions regarding the improvement of interactions between ecological functions and the provision of services (ANDRADE et al., 2020).

The Pasture and exposed rock classes and the Urban zone class, both presented land cover values around 2.19% and 2.56%, respectively. The urban zone class can also be characterized as exposed soil, the same happens with the Pasture and exposed rock class, with a pixel mix in the final product, this result being expected because they present larger areas with no vegetation cover. In this sense, they are areas that have little capacity to provide services because they are, for the most part, areas totally altered by human action and that are no longer characterized as a natural system.

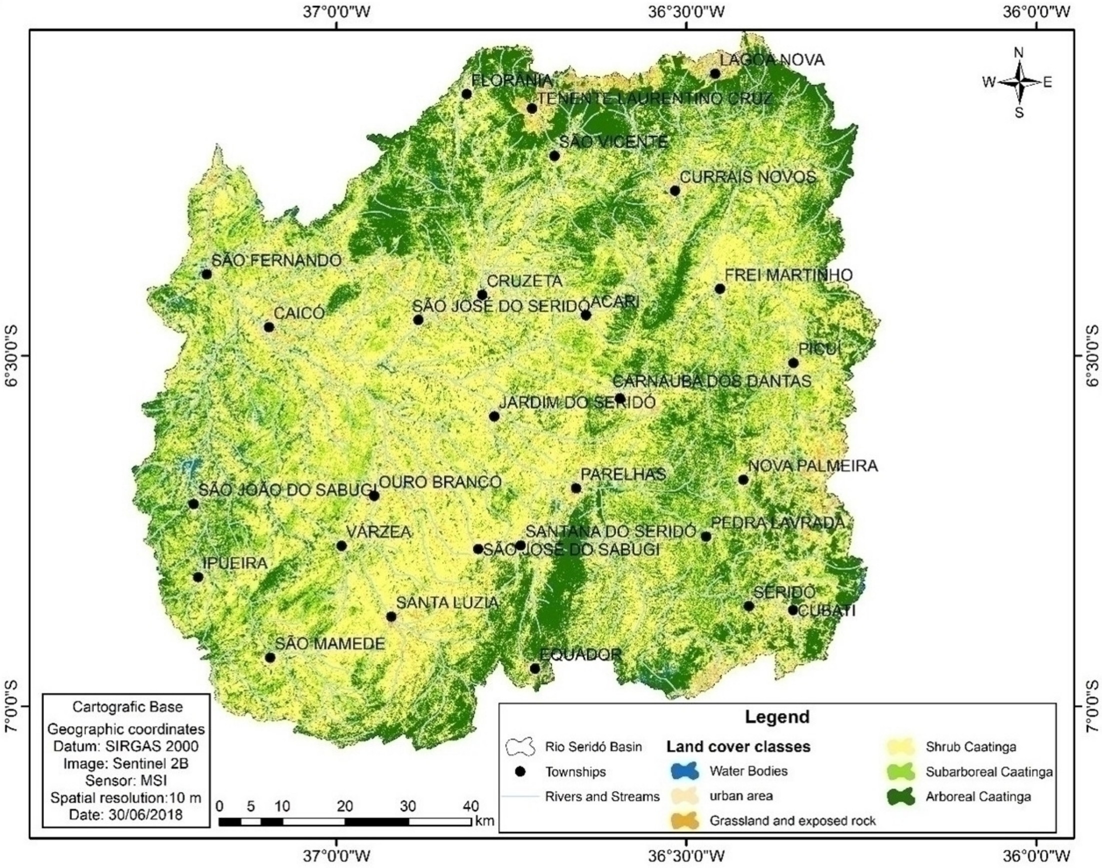


Figure 3 - Map of vegetation cover in the Seridó River Basin (RN/PB). Source: Elaborated by the authors.

The class of water bodies presented values around 2.28% of the total coverage of the study area, and this value is subject to change based on the annual hydrological dynamics of the study area. For a better understanding, Table 3 brings the values in hectare of each land cover class.

Table 3 – Values in hectare of land cover in the Seridó River Basin (RN/PB). Source: Elaborated by the authors.

Class	**Hectare**	**(%)**
Water bodies	22.635,90	2,28
Urban area	25.430,40	2,56
Grassland and exposed rock	21.725,30	2,19
Shrub Caatinga	513.793,06	51,75
Subarboreal Caatinga	161.532,10	16,26
Arboreal Caatinga	247.715,02	24,95
Total	992.831,79	100

Regarding the potential for carbon sequestration in the study area (Figure 4), even though it is characterized as favorable areas and others already in the process of desertification, the results showed a well-defined spatial distribution from the relief units with the highest occurrences of the carbon sequestration sites defined by the highest hypsometry values.

Considering the methodological content from the classification proposed by Burkhard et al. (2014) of the ability to provide flow regulation services based on the CICES table, areas classified as having no relevant service capacity for carbon fluxes are precisely the areas of water bodies, as they are features in the landscape in which there is no have vegetation cover.

As for the areas characterized by greater relevance with regard to the provision of services, the places where they presented a very high relevant capacity are spatialized closer to the edges of the study area, being characterized by areas of escarpments, being areas of greater difficulty of implantation of extensive agriculture and livestock activities, as highlighted by Silva and Barbosa (2017).

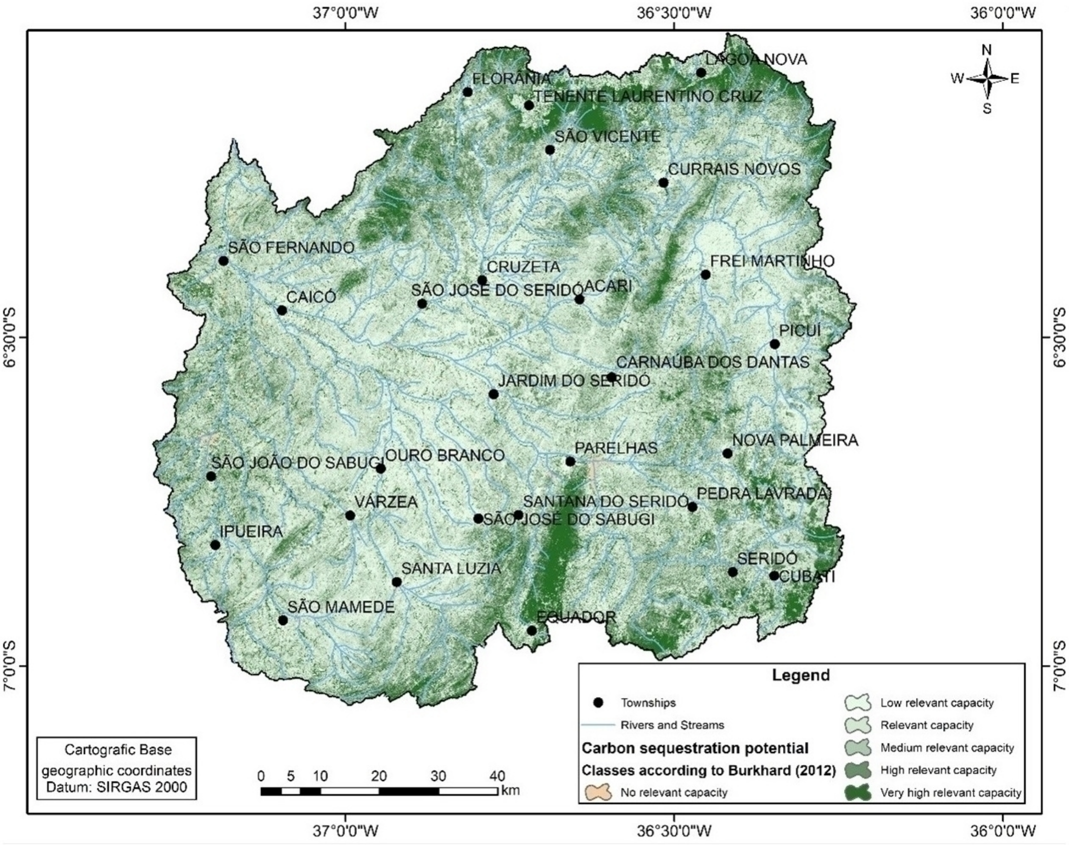


Figure 4 - Capacity to provide flow regulation services in the Seridó River Basin (RN/PB). Source: Elaborated by the authors.

With regard to the quantitative values, the areas classified as relevant capacity had the highest hectare value (29.66%) along with the medium relevant capacity class (27.01). Another interesting fact is that the values of the different classes of high relevant ability and low relevant ability presented very close values (17.82 and 16.83, respectively). The class of very high relevant capacity presented values of 7.93% of the study area and the class that was characterized as no relevant capacity presented values below 1% (table 4).

Table 4 – Values in hectare of carbon sequestration in the Seridó River Basin (RN/PB). Source: Elaborated by the authors.

Carbon Sequestration Potential	Hectare	(%)
No relevant ability	7.482,05	0,75
Relevant low capacity	167.086,50	16,83
Relevant capacity	294.463,76	29,66
Medium relevant capacity	268.206,78	27,01
Relevant high capacity	176.880,90	17,82
Very high relevant capacity	78.731,32	7,93
Total	992.831,31	100

Considering the coverage variables and the carbon sequestration potential, the results of the descriptive statistics from the simple linear regression showed a greater relationship between the classes of Dense and intermediate Caatinga.

In this sense, based on the R2 value, it was possible to identify that the land cover variable explains 92% of the carbon absorption values, showing a strong connection between the two variables. Which, in turn, were considered as outliers or more discrepant points among the values of the statistical analysis, the classes of water and exposed soil (Figure 5).

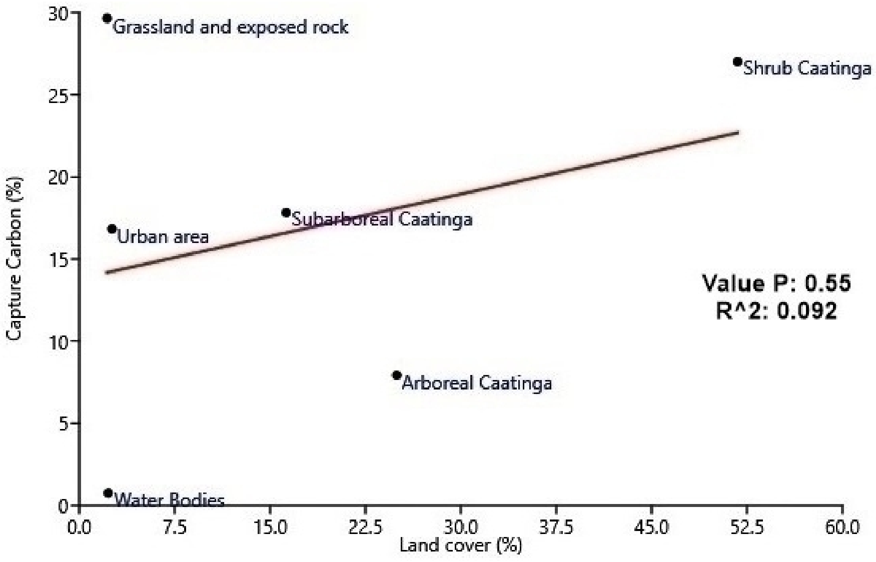


Figure 5 - Simple linear regression between carbon sequestration potential and land cover. Source: Elaborated by the authors.

Based on the erosion control SE classification, the areas with the greatest tendency to balance sediments were identified (Figure 6). However, what was noticeable is that there is no area of greater representation that presents a very high relevant capacity in the service provision classification.

Regarding the values of each service provision class, what drew attention was the predominance of a single class, that of low relevant capacity (78.8%), showing the ineffectiveness of providing erosion control services. This reflects on the current dynamics of the landscape, showing areas of bare soil and/or formed by vegetation that presents aspects of degradation (bifurcation in the basal area; spatialization between individuals, among others), being areas that receive a strong energy in the system, either from solar radiation or from the concentration of hydrogeological energy flows in a short period of the year.

The relevant capacity class was the second largest in terms of hectares, with 9.48%, followed by the very high relevant capacity class (4.48%), being on the edges of the study area and which, in its conjuncture, are formed by dense vegetation. The classes of medium relevant capacity and high relevant capacity presented similar values, with 3.29% and 2.10%, respectively. Finally, the class with no relevant capacity is represented by 1.83%, being formed by areas of water bodies.

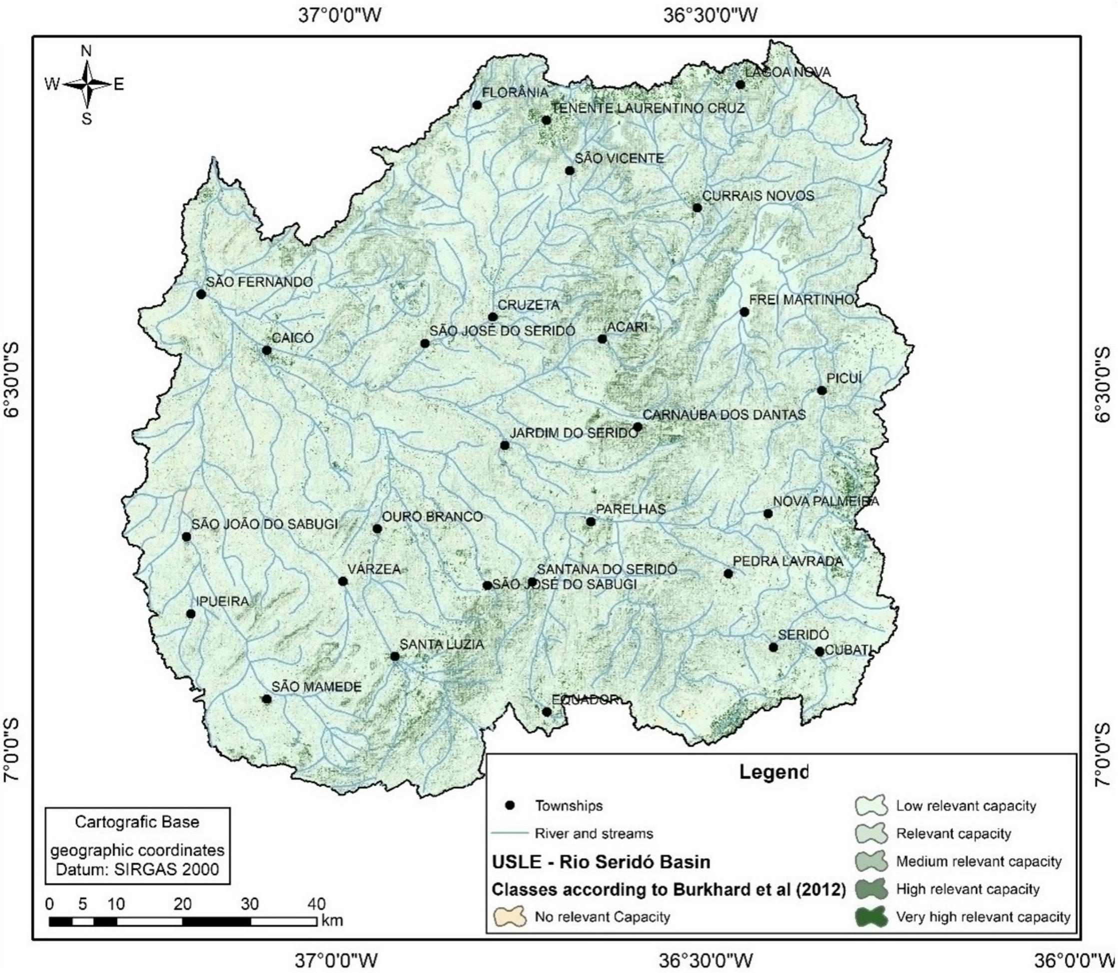


Figure 6 - Spatialization of areas for the provision of soil surface erosion control services. Source: Elaborated by authors.

Table 5 - Provision of soil surface erosion control service. Source: Elaborated by authors.

Surface erosion control	Hectare	(%)
No relevant ability	18.183	1,83
Relevant low capacity	780.511	78,80
Relevant capacity	93.928	9,48
Medium relevant capacity	32.609	3,29
Relevant high capacity	20.803	2,10
Very high relevant capacity	44.414	4,48
Total	992.831,18	100

DISCUSSION

As can be seen in figure 03, it was possible to map 6 land cover classes. They are: Water bodies, urban area, Pasture and exposed rock, Subshrub Caatinga, Subarboreal Caatinga and Arboreal Caatinga. However, it is important to highlight that NDVI values around 0.78 were also found in higher areas by Albuquerque et al. (2020) in the municipality of Parelhas-RN, in which it is inserted in the study area.

In other words, these rocky outcrops constitute a selective barrier to the occupation and establishment of plant species. In them, the rupicolous habitats are characterized mainly by the absence and/or scarcity of soil, by edaphic characteristics, by limiting micro-climatological factors potentiated by geomorphological characteristics and by the geological nature of the rocks (ABREU et al., 2012; ARRUDA et al. , 2015; CARLUCCI et al., 2015).

It is worth emphasizing the importance of works aimed at soil management and conservation practices in the pasture areas that cover the basin, since this activity occupies extensive areas. Because according to Dias-Filho (2010) the lack of care reflects in the low productive longevity of the pasture with the formation of vast degraded areas, encouraging deforestation for the formation of new areas or, even, the expansion of pasture areas in areas of vegetation Natural.

Ponzoni et al. (2012), point out that NDVI values may be higher in areas that are in the process of regeneration, when compared to forested areas, because of high photosynthetic activity. In this sense, the arboreal Caatinga areas that are influenced by agricultural activities, generally presented lower NDVI values.

Giving a greater focus on the discussion and understanding of the high value of the relevant low capacity class (Figures 7A and 7B), a temporal deepening in the understanding of landscape typologies is necessary, with anthropic pressures shaping these systems for about 300 years, as highlighted by Costa et al. (2009); and Silva and Barbosa (2017).

In this sense, the process of land use and occupation shapes the landscapes, contributing to the process that characterizes the vegetation arising from its evolutionary history, developing adaptations to establish itself in a semi-arid environment and strong anthropic pressure (GRAEFF, 2015).

From the boxplot graph represented by figure 7B, the relevant low ability class was precisely representing the outlier of the sample, that is, the anomaly within all sample values distributed between the interquartile distance which, in turn, the median presented values closer to the value of the first quartile, as well as the minimum value of the sample. In this sense, this graph showed a strong relationship between the variables presented, except for the relevant low ability class.

These environmental variations are responsible for the diversification in the composition and physiognomy of the vegetation, mainly portrayed in the density and in the horizontal and vertical stratification of the plant communities (RODAL, 1992), which, depending on the rainfall regime and the type of soil, vary from Savannas a Tall and dry forests up to 15-20 m high (RIZZINI, 1997; CARDOSO-SILVA et al., 2018).

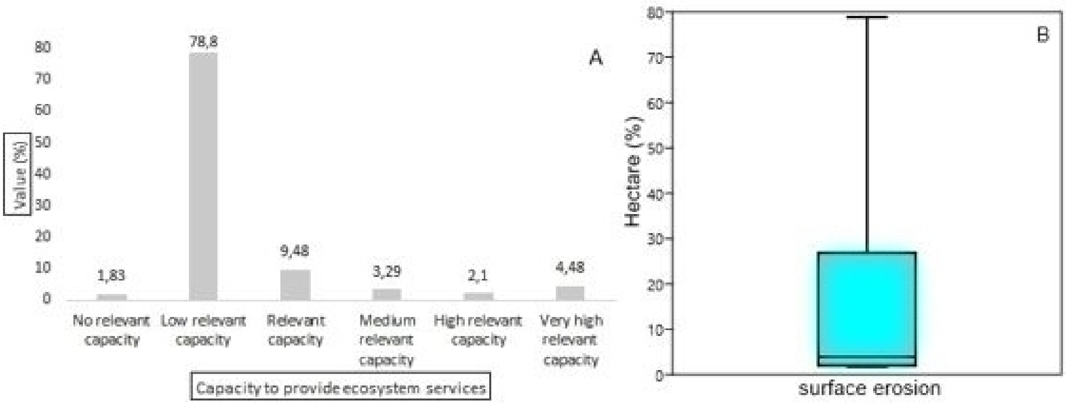


Figure 7 - Variation in the ability to provide soil surface erosion control services. Source: Elaborated by authors.

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It is worth noting that tropical forests are probably the type of vegetation most associated with South America in people's minds (MORO et al., 2016). Due to this focus on tropical forests, other biomes such as semi-arid formations were often neglected, both from the point of view of conservation strategies and from the point of view of scientific research (PRADO, 2000; SANTOS et al., 2011). And despite being quite altered, the Caatinga is a biome of great biodiversity, with biological relevance and considerable peculiar beauty, with emphasis on the multiplicity of plant communities, formed by a range of combinations between edaphic types and microclimatic variations, in addition to an expressive proportion of rare and endemic taxa (CARDOSO-SILVA et al., 2018).

In this scenario, it is observed that most scientific efforts for the study and conservation of tropical vegetation have focused on tropical forests, while little attention has been given to tropical dry forests (MOONEY; BULLOCK; MEDINA, 1995; SIYUM, 2020) , being considered among the most threatened ecosystems on Earth (PRADO, 2000; OLSON et al., 2001; HOEKSTRA et al., 2004; CARDOSO-SILVA et al., 2018), with high rates of deforestation, requiring actions that seek the conservation of these forests (MILES et al., 2006).

CONCLUSION

From the results obtained, it can be concluded that the vegetation cover stage of the Seridó River Basin allowed inferring the degree of human interference in this landscape, with the most representative area characterized by Caatinga Shrub, in which it is configured as a vegetation that has suffered degradation. However, the pasture and exposed rock class had the lowest coverage value (2.18%), although this value varies according to the period of the year due to the variation in chlorophyll of plants in semi-arid regions.

Regarding Organic Carbon fluxes and erosion control, the Caatinga Arborea class was of greater relevance in the provision of these SEs, although these remnants are isolated in areas of greater altitude and slope, in which they tend to control erosion soil surface.

The methodology proposed in this work proved to be effective based on GIS modeling. It is possible to make a spatialization and distinction of the different degrees of capacity to provide services per environmental unit within the hydrographic basin, allowing the correlation between its hydrological dynamics and the characteristics of the environment, being able to generate future modeling for decision-making along with environmental planning.

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