sociedade
& natureza

DOI: 10.14393/SN-v35-2023-68219
Receveid: February 07, 2023 | Accepted: April 06, 2023 | Published: April 17, 2023

Papers

Assessment of Ecosystem Services Provided by a Green Urban Infrastructure in Brazilian Atlantic Forest Biome Areas – Dourados, Mato Grosso Do Sul

Maycon Jorge Ulisses Saraiva Farinha[1]
André Geraldo Berezuk[2]
Luciana Virginia Mario Bernardo[3]
Adelsom Soares Filho[4]

Keywords
Opportunity cost Urban Ecological Corridor Environmental Valuation Urban green areas

Abstract

Urban infrastructure is a challenge for municipal managers in Brazil, given the rapid urbanization that has occurred in the country and the population growth in these locations. The inclusion of green characteristics in the urban space has contributed to the human needs of residents in this space, areas that allow the filtering of pollutants in the air and water, greater absorption of rainwater, noise reduction, scenic beauty, among other characteristics that are related to ecosystem services. In this context, the objective of the study is to identify the opportunity cost for the existence of urban green areas. This was done using the methodological resources available in environmental economics, which employs the opportunity cost based on the assessment of the net benefit of conservation. Primary and secondary data were used, the sources being literature and satellite images. Considering the analysis period from 2018 to 2020. The results indicate that the opportunity cost is greater than the amounts that can be collected through the commercialization of ecosystem services, implying that the landowners of the Urban Ecological Corridor projected in the municipality of Dourados - Mato Grosso do Sul, should be financially supported to maintain these services in green areas, given their importance to people's quality of life.

[1] Universidade Federal da Grande Dourados – UFGD, Dourados, MS, Brazil. maycondds@hotmail.com
[2] Universidade Federal da Grande Dourados – UFGD, Dourados, MS, Brazil. andreberezuk@ufgd.edu.br
[3] Universidade Federal da Grande Dourados – UFGD, Dourados, MS, Brazil. lucianamario@ ufgd.edu.br
[4] Universidade Federal da Grande Dourados – UFGD, Dourados, MS, Brazil. adelsomfilho@ ufgd.edu.br

INTRODUCTION

In order to achieve economic growth, the natural resources of a locality are often exploited in an orderly and unsustainable manner, causing environmental damage (TABARELLI et al., 2010; SANTOS et al., 2018). The consequences of these actions are directly related to the provision of ecosystem services (GRIZZETTI et al., 2016), that is, the benefits that individuals receive from nature (DAILY, 1997; GUERRY et al., 2015). These benefits or contributions help people all over the world with activities ranging from food production to coastal resilience (PASCUAL et al., 2017). As a result, ecosystem services are essential for human survival.

In this context, the changes caused by urban areas to ecosystems are well known, ranging from natural vegetation deforestation to land use change, habitat degradation, chemical and noise pollution, and sewage disposal, among others (KERTÉSZ et al., 2019). Given their high consumption of energy and resources, urban areas can thus be considered sources of anthropogenic environmental impact. Moreover, it is estimated that urban areas consume 70% of the total energy produced (AVTAR et al., 2019). This situation may deteriorate in the coming years as demand for these inputs increases, given that it is estimated that by 2050, approximately 68% of the global population will live in urban centers (UNITED NATIONS, 2019). The challenges in this context are exacerbated when problems caused by urban areas in developing nations are considered (COLLIER; VENABLES, 2017), primarily because cities in developing regions are rapidly experiencing urbanization, making it more difficult to provide services such as sanitation and drinking water, food, and clean energy to the entire population (SIMATELE; SIMATELE, 2015; DOS SANTOS et al., 2017).

In this sense, urban green areas are related to the creation of sustainable cities, in view of the critical role that these areas play for: the maintenance of the physical and mental health of the urban population (PICARD; TRAN, 2021; MARTÍNEZ, 2021); the reduction of heat islands (SODOUDI et al., 2018; BATTISTA et al., 2019), the improvements in air and water quality (NYELELE; KROLL, 2021), the creation of positive feelings, which influence the mental health of children (WARD et al., 2016), among other characteristics that benefit people's quality of life (ZHU et al., 2021).

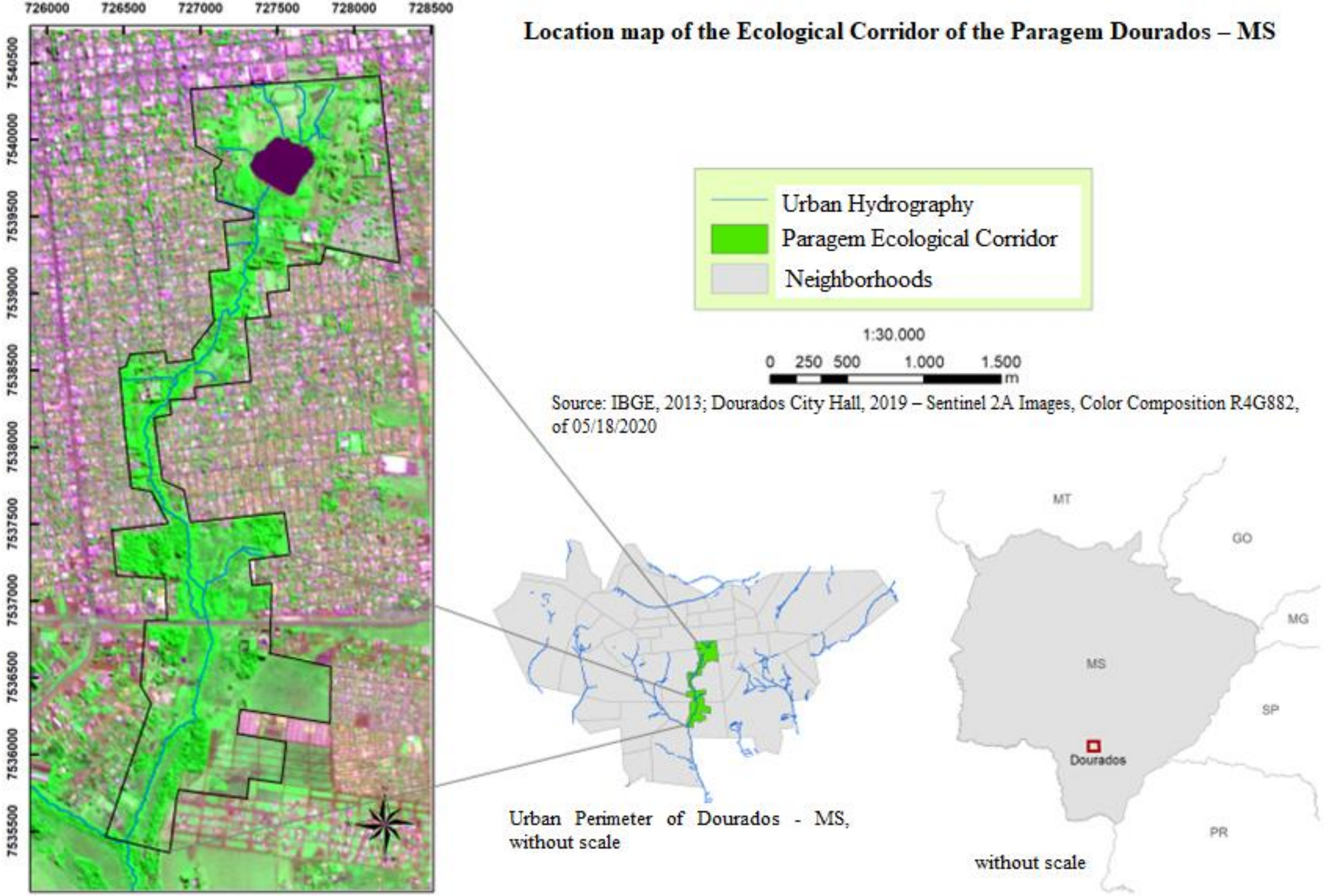
However, in this context, urban lands are characterized by the competition for their land use (SCOTT; STORPER, 2015), in which the intentions of protecting existing natural resources in urban areas and the desire to allocate the same area to other more traditional uses, such as gray spaces, can be incompatible (PIETROSTEFANI; HOLMAN, 2020). The objective of this study is to calculate the opportunity cost for maintaining urban green spaces based on the valuation of ecosystem services. Previous environmental economics research has found that actions in favor of environmental conservation influence people's willingness to pay to visit areas where there is a conservation initiative for endangered species (CHOI; FIELDING, 2013); protection of marine biodiversity (HALKOS; MATSIORI, 2017); and the possibility of obtaining environmentally friendly meals (WIDEGREN, 1998). However, studies on urban green spaces in the context of environmental valuation are scarce, in developing countries (TAVAREZ; ELBAKIDZE, 2021).

METHODOLOGICAL PROCEDURES

Characterization of the study area

Dourados is a municipality in the Brazilian state of Mato Grosso do Sul, in the country's center-west region. The municipality is divided into two biomes: the Cerrado (which covers approximately 51% of the municipality's land area) and the Atlantic Forest, covering approximately 49% of the municipality's land area (IBGE, 2021). Both biomes are considered biodiversity hotspots, with the Cerrado biome (MYERS et al., 2000; ALHO, 2005) being described as the world's richest and most endangered tropical savanna (KLINK; MACHADO, 2005). Additionally, despite having lost more than 92% of its original cover (BRASIL, 2010), the Atlantic Forest biome (TABARELLI et al., 2005) still has high levels of biological diversity (MURRAY-SMITH et al., 2008).

Figure 1 - Location of the study area in Dourados – Mato Grosso do Sul



Source: IBGE, 2013; Dourados City Hall, 2019 – Sentinel 2A Images, Color Composition R4G882, of 05/18/2020

Source: The authors (2021).

The study area is known as the Córrego Paragem Ecological Corridor, which is located in the municipality of Dourados. Ecological corridors are considered elements of sustainable territorial development in Brazil (MINISTÉRIO DO MEIO AMBIENTE, 2016). This corridor is located in the municipality's urban area, and it includes the Arnulpho Fioravanti Park, the Paragem Municipal Natural Park, and the private forest remnant that connects both municipal parks. Given that there are other locations in the municipality with similar potential, the selection of this area allows for inciting public interest in the possibility of officially recognizing the existence of ecological corridors. Figure 1 depicts the location of the corridor study area in the municipality of Dourados and, as it can be seen, conservation of the delimited area can benefit the water resources available in the urban area and in the municipality, in addition to issues related to vegetation.

The corridor is composed of blue and green lands, as can be seen in Figure 1. The blue land in urban areas is constituted of water resources and flooded areas (MITSCHA; DAY, 2006), and in this case, the Paragem Stream and the lake located in the Arnulpho Fioravanti Park. Connections between rivers and lakes, as shown in Figure 1, can help to increase communication between materials and aquatic organisms, resulting in improvements in water resource purification, biodiversity, and ecological restoration, and thus aiding in the protection of water resources (LI et al., 2011). Furthermore, the blue land is thought to be a natural "sponge" that can help with urban drainage issues. Hence, urban planning that includes "blue areas" can benefit local purification, biodiversity, and water penetration (WU, 2016).

As illustrated in Figure 1, green lands are composed of vegetation. When it comes to green spaces, attention is frequently focused on the format or quantity rather than the quality of these areas, resulting in fragmented spaces. Green areas must be integrated so that the ecosystem services provided are of higher quality and diversity, ensuring ecological security (LI et al., 2017).

Urban green space is defined as vegetation-covered urban areas, whether made up of natural or exotic elements, inserted in public or private land, and regardless of size, that is large or small areas. Water bodies (blue spaces) present in urban cities are also included in this context (WHO, 2017). Due to the various environmental, social, and economic benefits that can be associated with these spaces, these areas are unarguably an essential component of urban planning in cities (CONNOP et al., 2016). These spaces can aid in the reduction of noise, air and water pollution, the regulation of the local microclimate, and can be used for recreation purposes (WOLFF et al., 2015). The connectivity between green areas available in urban centers is an important measure for the survival of different species as they integrate habitats, and we refer to this relationship as Urban Ecological Corridors (ZHANG et al., 2019).

Calculation of the opportunity cost

Opportunity cost is an economic concept related to the use of financial resources to make an investment when there are different application opportunities for the same resource. Thus, this concept refers to a decision that provides more satisfaction than other available options (BEUREN, 1993). Environmental valuation, achieved through the concept of opportunity cost, was first adapted by Norton-Griffiths and Southey (1993) for a case study in Kenya. The opportunity cost was calculated from the following equation (1):

$$\text{BLconservation} = (\text{BLdirect use} + \text{BLindirect use} + \text{BLno use}) - \text{COconservation} \quad \text{(Equation 1)}$$

Where:

BLconservation = net conservation benefit
Direct use = carbon credit
Indirect use = protection of biome characteristics (soil and water preservation)
No use = existence value estimated by Santos et al. (2000)
COconservation: opportunity cost of the preserved area.

In this study, indirect use values were identified from ecosystem services for the Atlantic Forest biome, as discussed by Costanza et al. (1997), Oliveira et al. (1995) and Santos et al. (2000), according to Table 1:

Table 1 - Ecosystem Environmental Services – Atlantic Forest Biome

Service	**US\$.m^{-2}.Year^{-1}**	**Reference**
Disturbance regulation	0.0005	Costanza et al. (1997)
Climate regulation	0.0223	Costanza et al. (1997)
Water regulation	0.0006	Costanza et al. (1997)
Water supply	0.1610	Oliveira et al. (1995)
Erosion control	0.0245	Costanza et al. (1997)
Soil formation	0.0010	Costanza et al. (1997)
Nutrient recycling	0.0922	Costanza et al. (1997)
Tailings treatment	0.0087	Costanza et al. (1997)
Biological control	0.0021	Santos et al. (2000)
Recreation	0.0112	Costanza et al. (1997)
Culture	0.0002	Costanza et al. (1997)
Existence value	0.0003	Santos et al. (2000)
TOTAL	**0.3246**	**0.3246 x 5.13* = BRL 1.6652/m^2/year** *Dollar exchange rate on July 15, 2021

Source: IBAMA (2002).

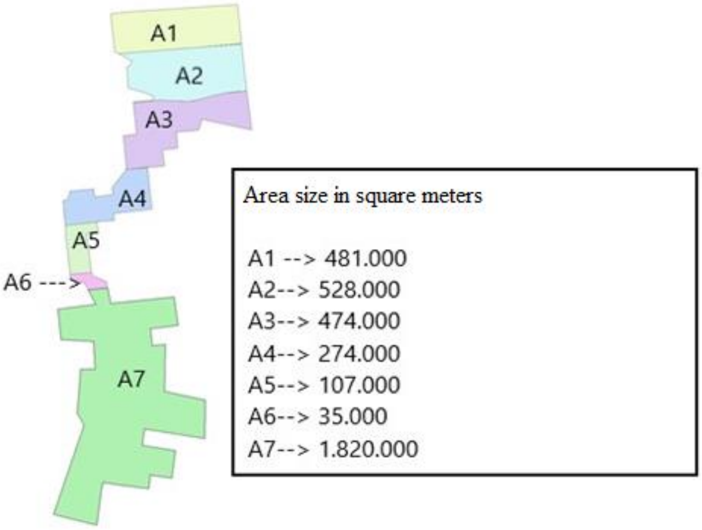
The identified value (roughly BRL 1.67) must be multiplied by the property area. The estimated area is the result of the total area reduced by the area that corresponds to the available water resources in the area. Thus, based on the use of geo-technological resources, the area used in the study is estimated as 3,719,000 m^2. Following this estimation, equation (1) should be equivalent to equation (2):

$$\text{BLconsevation} = (\text{BLdirect use} + (1.67 \times 3{,}719{,}000) - \text{COconservation})$$

(Equation 2)

Civil construction is the industry studied for the study of economic activity that characterizes COconservation. The construction defined for this study is land that can be used for house construction on the ecological corridor's surroundings. The market value of a residential land is determined by the value of the m^2 and its location. The value of land near an ecological corridor is determined by the neighborhood in which it is located. In light of the importance of this characteristic in determining COconservation, the area was divided (Figure 2) by region of real estate value. The areas are located in the following neighborhoods: A1 - Vila Sulmat; A2 - Jardim Del Rey; A3 – Izidro Pedroso; A4 – Jardim Água Boa; A5 – Parque dos Coqueiros; A6 – Jardim Flamboyant and A7 – Jardim Colibri. The values used are of primary nature and were collected by a professional (architect) who works in the region, given that values used to calculate the Urban Property and Territorial Tax do not always reflect the reality of the real estate market.

Figure 2 - Division of the Paragem Ecological Corridor by land value



Source: The authors (2021).

According to the usual local characteristics, the established land size is 360m². It should also be noted that the amount spent on m² for construction depends on the standard adopted, and thus their respective values for this stage were not considered in this study.

Estimate of carbon fixation or net primary productivity

For the collection of BLdirect information, this benefit refers to the carbon credit resulting from the carbon fixation in the existing vegetation in the area. For this, information on carbon sequestration was collected from the net primary productivity. This study used Sentinel-2A satellite images, 21KYR scenes, from October 16, 2018, October 31, 2019, and May 18, 2020. The Sentinel-2A, MSI (Multispectral Instrument) sensor was chosen for its spatial resolution and spectral capabilities. The MSI has 13 spectral bands ranging from the visible to the near-infrared range to the short-wave infrared range (from 443 to 2202 nm - nanometers), with spatial resolutions of four bands of 10 meters, six bands of 20 meters, and three bands of 60 meters, respectively. The images were obtained at intervals ranging from 0 to 4095 potential light intensity values, with a radiometric resolution of 12 bits (THE EUROPEAN SPACE AGENCY, 2021).

The three MSI scenes with a spatial resolution of 10 meters were pre-processed with the ENVI software's FLAASH® (Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes) algorithm to correct the scattering and absorption of atmospheric components from the parameters obtained directly from the scenes. Atmospheric correction was applied to the scenes, converting radiance data to reflectance. These transformations can either enhance the information that was not visible in the original images or preserve information content (for a given application) with fewer transformed bands (PONZONI; SHIMABUKURO, 2009).

The colored composition of bands 8 in the near-infrared (835.1nm), and bands 2 and 4 in the visible spectrum (496.6nm and 664.5nm, respectively) were used to delimit the Urban Ecological Corridor area, all with a spatial resolution of 10 meters. Various vegetation indices have been proposed in the literature to investigate the spectral properties of vegetation in the visible and near-infrared spectral bands. The vegetation index is related to net primary productivity (GOWARD et al., 1985). In this case, the index chosen was the Normalized Difference Vegetation Index — NDVI (ROUSE et al., 1973) (4).

$$NDVI = \left(\frac{R_8-R_4}{R_8+R_4}\right) \qquad \text{(Equation 3)}$$

R8: reflectance in band 8 of Sentinel 2A;
R4: reflectance in band 4 of Sentinel 2A.

To calculate the NDVI, bands 8 (near infrared) and 4 (visible) of the Sentinel 2A satellite were used, with a mask applied over the scenes to eliminate external interference and extract spectral information. Data on global solar radiation were obtained from the EMBRAPA meteorological station (2021), referring to the municipality of Dourados.

Photosynthetically active radiation (PAR) was used to estimate the net primary productivity because it is linearly related to this productivity (MONTEITH, 1977). Furthermore, PAR is the proportion of global solar radiation that is available for photosynthesis, and the Absorbed Photosynthetically Active Radiation (APAR) can be used to estimate net primary productivity (NASCIMENTO, 2009) (4).

$$NPP = \varepsilon \, x \, \Sigma \, APAR \qquad \text{(Equation 4)}$$

NPP = net primary productivity; ε = light use efficiency factor; APAR = Absorbed Photosynthetically Active Radiation
APAR is calculated through equation (5).

$$APAR = fAPAR \; X \; IPAR \qquad \text{(Equation 5)}$$

APAR = Absorbed Photosynthetically Active Radiation; fAPAR = fraction of the Absorbed Photosynthetically Active Radiation; IPAR = Incident Photosynthetically Active Radiation.

The IPAR value was identified considering 50% of global solar radiation (FERREIRA, 2006; SZEICZ, 1974; MONTEITH, 1973). Solar radiation was extracted monthly for the period of analysis. The fraction of photosynthetically active radiation absorbed — fAPAR, estimates the energy absorption capacity of the plant canopy (McCALLUM et al., 2010). The value was calculated using the model developed by Ruimy et al. (1994), who included atmospheric corrections in the formulation of his parameterized equation (6).

$$fAPAR = -0{,}025 + 1{,}25 \, x \, NDVI \qquad \text{(Equation 6)}$$

The light efficiency factor — ε was calculated using the NDVI and can thus be classified into three classes, as shown in Table 2 (SOBRINO; RAISSOUNI, 2000).

Table 2 - ε classes according to the NDVI

NDVI value	ε calculation	Based on
NDVI < 0.2	ε= 0.980 – 0.042* Ch1	the light use efficiency factor is calculated on channel 1 of the reflectance
0.2 < NDVI < 0.5	ε = 0.971 + 0.018*Vp	Vp = ((NDVI – 0.2)$^{2)}$)/0.09
NDVI > 0.5	ε = 0.985	

Vp = vegetation proportion; Chl = reflectance channel 1. Source: Sobrino and Raissouni (2000).

As in most of the period and area the NDVI observed is greater than 0.5, ε = 0.985 was adopted. Furthermore, APAR, fAPAR, and IPAR were calculated in millijaules per square meter year (MJ/m^2.year), ε was calculated in grams per square meter per day (g/MJ), and the yield will be expressed in tons per year (t/year).

RESULTS AND DISCUSSION

Due to the different neighborhoods included in the Ecological Corridor, it was necessary to divide the total area of the Ecological Corridor, and thus the market value of the square meter is different. Table 3 provides information on each region, including the area size, the number of plots with the potential to organize the total area, the value of the square meter in the area, the unit value of the plot, and the total area value, based on the number of plots with the potential to be created.

Table 3 - Characteristics of the corridor by region for the destination of the area for civil construction

Land						
Region	**Total area of the region (m²)**	**Unit area (m²)**	**Number of plots (Total Area / Unit area)**	**m² value in the region – Local Data (BRL)**	**Plot unit value (Unit area X value m²) (BRL)**	**Total area value (Plot Value X No. of plot) (BRL)**
A1	481,000	360	1,336	2,000.00	720,000.00	961,920,000.00
A2	528,000		1,466	850.00	306,000.00	448,596,000.00
A3	474,000		1,316	600.00	216,000.00	284,256,000.00
A4	274,000		761	500.00	180,000.00	136,980,000.00
A5	107,000		297	450.00	162,000.00	48,114,000.00
A6	35,000		97	400.00	144,000.00	13,968,000.00
A7	1,820,000		5,055	350.00	126,000.00	636,930,000.00
Total land value						**2,530,764,000.00**

Source: The authors (2021).

This means that if the area corresponding to the ecological corridor studied were to be commercialized, the collection would total BRL 2,530,764,000,00 at current market values. However, it can be observed that the maintenance of the environmental area in the urban space, such as the existing parks in London, Seoul, and Beijing (GANT et al., 2011), can be considered spaces of restrictions for urban expansion, and also benefit the local population, due to the provision of ecosystem services. If the study's green area is commercialized, changes in land use may be facilitated, potentially leading to the substitution of natural vegetation for gray structures (the expansion of urban land use has the attribute of being carried out through rapid changes in land cover, as demonstrated by Angel et al. (2011) and Seto et al. (2012).

These changes in land cover are associated with excessive consumption of natural resources, resulting in environmental issues (LINARD et al., 2013), which are regarded as a major challenge for city management, urban expansion, and the sustainable development of this expansion (WEY; HSU, 2014; ACHMAD et al., 2015). Because the study area is composed of traditional municipal neighborhoods, the estimated values may be associated with the characteristics identified in the literature. Land prices in urban areas, on the other hand, can be considered an effective measure for regulating urban expansion (ZANG et al., 2015; WANG et al., 2017), at least for a set period of time and for people with reduced purchasing power.

Regarding the values referring to direct use, an estimate of BRL 1,591.08 can be observed for the total of the three years analyzed, an amount that could be collected by the municipality with the sale of carbon fixed in the area, according to the relative price quotations. This result may be related to Brazil's difficulties in developing its carbon market and, as a result, to the values used for carbon credits. Among the difficulties associated with this market in the country are the challenges in transacting with markets that pay better (DUARTE et al., 2020). In 2018, the ton of carbon in Sweden was estimated to be US$ 130, indicating that during the same period, the Nordic countries' emissions were reduced without reducing economic growth. Furthermore, there are difficulties in setting a price for emissions related to production or deforestation in Brazil, as well as establishing mandatory emission reduction targets for companies based on their productive sector, a measure adopted in other parts of the world (DOMINICI, 2018).

Table 5 - Estimates of carbon fixation and commercialization in the study area from 2018.

Months 2018	**Global Solar Radiation – MJ/m²**	**IPAR – 50% of Global Solar Radiation MJ/m²**	**fPAR (-0,025+(1,25 x NDVI)**	**APAR (fPAR x IPAR)**
January	1.41	0.705	0.7875	0.56
February	1.43	0.715		0.56
March	1.45	0.725		0.57
April	1.61	0.805		0.63
May	1.42	0.71		0.56
June	0.93	0.465		0.37
July	1.43	0.715		0.56
August	1.31	0.655		0.52
September	1.41	0.705		0.56
October	1.41	0.705		0.56
November	1.54	0.77		0.61
December	1.81	0.905		0.71
			∑APAR	**6.76**
			ε	0.985
			NPP (ε * ΣAPAR)	**6.7**
			Area (m²)	3,719,000
			NPP	**24,917,300 g C m^{-2} $year^{-1}$**
			NPP Area	**24.9 T C $year^{-1}$**
			Carbon Tonne Quotation	**BRL 21.34[1]**
			Total year value	**BRL 534.35**

Source: The authors (2021).

Table 6 - Estimates of carbon fixation and commercialization in the study area from 2019.

Months 2019	Global Solar Radiation – MJ/m^2	IPAR – 50% of Global Solar Radiation MJ/m^2	fPAR (-0.025+(1.25 x NDVI)	APAR (fPAR x IPAR)
January	1.74	0.87	0.602	0.69
February	1.39	0.695		0.55
March	1.54	0.77		0.61
April	1.38	0.69		0.54
May	1.25	0.625		0.49
June	1.31	0.655		0.52
July	1.33	0.665		0.52
August	1.49	0.745		0.59
September	1.62	0.81		0.64
October	1.64	0.82		0.65
November	1.8	0.9		0.71
December	1.67	0.835		0.66
			∑APAR	**5.47**
			ε	0.985
			NPP (ε * ΣAPAR)	**5.4**
			Area (m^2)	3,719,000
			NPP	**20,082,600 g C m^{-2} year^{-1}**
			NPP Area	**20 T C year^{-1}**
			Carbon Tone Quotation	**BRL 26.03[2]**
			Total year value	**BRL 520.60**

Source: The authors (2021).

Table 7 - Estimates of carbon fixation and commercialization in the study area from 2020.

Months 2020	Global Solar Radiation – MJ/m^2	IPAR – 50% of Global Solar Radiation MJ/m^2	fPAR (-0.025+(1.25 x NDVI)	APAR (fPAR x IPAR)
January	1.63	0.82	0.7826	0.64
February	1.62	0.81		0.64
March	1.77	0.89		0.70
April	1.74	0.87		0.69
May	1.33	0.67		0.52
June	0.96	0.48		0.38
July	1.12	0.56		0.44
August	1.38	0.69		0.54
September	1.47	0.74		0.58
October	1.49	0.75		0.59
November	1.77	0.89		0.70
December	1.78	0.89		0,70
			∑APAR	**7.07**
			ε	0.985
			NPP (ε * ΣAPAR)	**6.96**
			Area (m^2)	3,719,000
			NPP	**25,884,240 g C m^{-2} year^{-1}**
			NPP Area	**25,9 T year^{-1}**
			Carbon Tone Quotation	**BRL 20.70[3]**
			Total year value	**BRL 536.13**
			Total value of the triennium	**BRL 1,591.08**

MJ/m^2 → megajoule per square meter; **IPAR** → incident photosynthetically active radiation; **fPAR** → fraction of photosynthetically active radiation absorbed; **PAR** → Photosynthetically Active Radiation Absorbed; **ε** → Light Efficiency Factor; NPP → net primary productivity.

[1] Quotation available at investing – on October 16, 2018; [2] Quotation available at investing – on October 31, 2019 and [3] Quotation available at investing – on May 18, 2020

Source: The authors (2021).

Returning to equation (2) and including the information identified regarding: BLdirect use (BRL 1,591.08); BLindirect use and BLno use (BRL 6,210,730.00 x 3 years); and COconservation, the BL of conservation is BRL -2,512,130,218.92, and the negative result indicates that the value of COconservation is greater than the sum of BLdirect use, BLindirect use, and BLno use for the three years. This result indicates that, from an economic point of view, it would be a better investment to commercialize the area that corresponds to the ecological corridor. However, in the context of climate change discussions, the economic bias is insufficient to support the discussion on the possibility of reducing green areas in urban centers. According to the literature, sustainable development is required for the organization of urban space (WEY; HSU, 2014; ACHMAD et al., 2015), as greenhouse gas emissions have increased in recent years (CRIPPA et al., 2019). In this case, continued emissions can result in higher levels of global warming, increasing the likelihood of severe and irreversible impacts on ecosystems, particularly in areas where economic resources are scarce (IPCC, 2014). In this scenario, the challenge is to develop strategies for reducing emissions while also adapting to climate change (ORSATO et al., 2019).

Furthermore, areas such as the study's ecological corridor have aided in the composition of city green infrastructure and can be significant strategies for land conservation and urban planning that includes sustainable practices for the local environment, that is, for people living in cities (BENEDICT; MCMAHON, 2012; BOTTALICO et al., 2016). Additionally, urban Ecological Corridors are multifunctional spaces (AHERN, 2013; GASTON et al., 2013; LI et al., 2017), as they promote various natural flows that aid in the natural resistance of the ecosystem to pressures caused by human action in the urban context. These spaces can also be used for recreation and environmental education, allowing people to observe local characteristics and their benefits, among other didactic strategies that public officials can use to promote environmental awareness (PENG et al., 2017).

FINAL CONSIDERATIONS

From an economic standpoint, the findings of this study may initially indicate that the ecological corridor under consideration should be divided and marketed for land use aimed at civil construction. As a result, the local government and private property owners would collect values that could be used for other purposes. In the case of the city hall, i.e., the public representatives of the municipality, the collected resources could be directed toward uses deemed more urgent at the time, such as education, health, public lighting, and security, among others. This measure may initially benefit the municipality by making the population happier with their managers because temporary problems will be alleviated or resolved.

However, when viewed from an interdisciplinary perspective, and considering what has already been described in the literature about urban green spaces and the irreplaceable essential services that these areas provide to local, regional, and global populations, this first analysis may be insufficient or incomplete. Urban green spaces are essential for all people, and some individuals directly benefit from them through visitation, landscape observation, and physical activities. Other people benefit from the gains generated by these areas in indirect and frequently abstract ways. Because of this characteristic, it is difficult to recognize the importance of these places for everyday issues such as improving air quality and capturing and draining water, which are often imperceptible until people are deprived of this resource, resulting in complex and future problems that would be difficult to solve.

Thus, the findings of this study reveal that the COconservation is greater than the values that could be collected through the payment of ecosystem services performed in the study area. This indicates a direct need for environmental public policies aimed at valuing and encouraging the existence of urban green areas in municipalities, in order to promote the payment of ecosystem services to locations where these areas exist, as well as in cases where COconservation is estimated to be worth more than the values of these services, new economic benefits should be added to the municipality, with the goal of assisting its cost (given that the benefits generated by urban green areas are not restricted to the municipality, they are outsourced to the region and the world).

As a perspective of continuing the research, it is believed that the estimate of the soil carbon stock can be carried out in the locality, it would be interesting to identify this issue in urban green areas. The set of urban green areas could also be the focus of research, as there are other ecological corridors in the municipality. Other methodological procedures could also be used to identify valuation, in order to compare results and possible advances.

REFERENCES

ACHMAD, A.; HASYIM, S.; DAHLAN, B. et al. Modeling of urban growth in tsunami-prone city using logistic regression: Analysis of Banda Aceh, Indonesia. **Applied Geography**, v. 62, p.237–246, 2015. https://doi.org/10.1016/j.apgeog.2015.05.001

AHERN, J. Urban landscape sustainability and resilience: The promise and challenges of integrating ecology with urban planning and design. **Landscape Ecology**, v.28, p. 1203–1212, 2013. https://doi.org/10.1007/s10980-012-9799-z

ALHO, C.J.R. Desafios para a conservação do Cerrado, em face das atuais tendências de uso e ocupação. In: SCARIOT, A.; SOUSA-SILVA, J.C.; FELFILI, J.M. (Org.). **Cerrado**: ecologia, biodiversidade e conservação. Brasília: Ministério do Meio Ambiente, p.367-381, 2005.

ANGEL, S.; PARENT, J.; CIVCO, D. L.; BLEI, A.; POTERE, D. The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. **Progress in Planning**, v. 75, n. 2, p. 53–107, 2011. https://doi.org/10.1016/j.progress.2011.04.001

AVTAR, R.; TRIPATHI, S.; AGGARWAL, A. K.; KUMAR, P. Population–urbanization–energy Nexus: A review. **Resources**, 8(136), 2019. https://doi.org/10.3390/resources8030136

BATTISTA, G.; DE LIETO VOLLARO, R.; ZINZI, M. Assessment of urban overheating mitigation strategies in a square in Rome, Italy. **Sol. Energy**, v.180, p. 608-621, 2019. https://doi.org/10.1016/j.solener.2019.01.074

BENEDICT, M.; MCMAHON, E. In: BENEDICT, M; MCMAHON, E. (Eds.). **Green infrastructure. Linking landscape and communities**. Washington, DC. 2012.

BEUREN, I. M. Conceitualização e contabilização do custo de oportunidade. **Caderno de Estudos n. 8, FIPECAFI**, São Paulo, 1993. https://doi.org/10.1590/S1413-92511993000100003

BOTTALICO, F.; CHIRICI, G.; GIANNETTI, F.; DE MARCO, A.; NOCENTINI, S.; PAOLETTI, E.; TRAVAGLINI, D. Air pollution removal by green infraestructures and urban forest in the city of Florence. **Procedia**, v. 8, p. 244–251, 2016. https://doi.org/10.1016/j.aaspro.2016.02.099

BRASIL. Ministério do Meio Ambiente. Secretaria de Biodiversidade e Florestas. Núcleo Mata Atlântica e Pampa. Org.: Maura Campanili e Wigold Bertoldo Shaffer. Mata Atlântica: Patrimônio Nacional dos Brasileiros. **MMA**. Série Biodiversidade, 408p., 2010.

CHOI, A.S.; FIELDING, K.S. Environmental attitudes as WTP predictors: a case study involving endangered species. **Ecol. Econ**. v.89, 24–32, 2013. https://doi.org/10.1016/j.ecolecon.2013.01.027

COLLIER, P.; VENABLES, A. J. Urbanization in developing economies: The assessment. **Oxford Review of Economic Policy**, 33, p. 355–372, 2017. https://doi.org/10.1093/oxrep/grx035

CONNOP, S.; VANDERGERT, P.; EISENBERG, B.; COLLIER, M.J.; NASH, C.; CLOUGH, J.; NEWPORT, D. Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. **Environmental Science & Policy**, 62, 99-111, 2016. https://doi.org/10.1016/j.envsci.2016.01.013

COSTANZA, R.; D'ARGE, R.; DE GROOT, R. The value of the world's ecosystem services and natural capital. **Nature**, v.387, p. 253–260, 1997. https://doi.org/10.1038/387253a0

CRIPPA, M.; OREGGIONI, G.; GUIZZARDI, D.; MUNTEAN, M.; SCHAAF, E.; LO VULLO, E.; SOLAZZO, E.; MONFORTI-FERRARIO, F.; OLIVIER, J.; VIGNATI, E. **Fossil CO2 and GHG emissions of all world countries**, EUR 29849 EN, Publications Office of the European Union, Luxembourg, 2019.

DAILY, G. C. **Nature's services**. Washington, DC: Island Press., 1997.

DOMINICI, M.C.M. **Comércio internacional de carbono - possibilidades para o Distrito Federal**. Companhia de Planejamento do Distrito Federal, 2018.

DOS SANTOS, S.; ADAMS, E.; NEVILLE, G.; WADA, Y.; DE SHERBININ, A.; BERNHARDT, E. M.; ADAMO, S. Urban growth and water access in sub-Saharan Africa: Progress, challenges, and emerging research directions. **Science of the Total Environment**, v.607, p.497–508, 2017. https://doi.org/10.1016/j.scitotenv.2017.06.157

DUARTE, B.B.; TUPIASSU, L.; NOBRE, S. O mercado de carbono na política de mitigação das mudanças climáticas. **Revista de Direito Ambiental e Socioambientalismo,** v. 6, n.2, p.93–108,2020. https://doi.org/10.26668/IndexLawJournals/2525-9628/2020.v6i2.7203

EMBRAPA. **Guia Clima**. 2021. Available: https://clima.cpao.embrapa.br/?lc=site/estatisticas/estatisticas. Access on: jun. 2021.

FERREIRA, W. P. M. **Radiação Solar em Sete Lagoas – MG**. Sete Lagoas: Embrapa, 2006. 21p.

GANT, R. L.; ROBINSON, G. M.; FAZAL, S. Land-use change in the ‘edgelands’: Policies and pressures in London’s rural–urban fringe. **Land Use Policy**, v. 28, n. 1, p. 266–279, 2011. https://doi.org/10.1016/j.landusepol.2010.06.007

GASTON, K. J.; ÁVILA-JIMENEZ, M. L.; EDMONDSON, J. L. Managing urban ecosystems for goods and services. **Journal of Applied Ecology**, v. 50, n. 4, p. 830–840, 2013. https://doi.org/10.1111/1365-2664.12087

GOWARD, S. N.; TUCKER, C. J.; DYE, D. G. North American vegetation patterns observed with the NOAA-7 advanced very high resolution radiometer. **Plant Ecology,** v. 64, n.1, p.3-14, 1985. https://doi.org/10.1007/BF00033449

GRIZZETTI, B.; LANZANOVA, D.; LIQUETE, C.; REYNAUD, A.; CARDOSO, A.C. Assessing water ecosystem services for water resource management. **Environ. Sci. Policy**, v. 61, p. 194-203, 2016. https://doi.org/10.1016/j.envsci.2016.04.008

GUERRY, A.D.; POLASKY, S.; LUBCHENCO, J.; CHAPLIN-KRAMER, R. DAILY, G.C.; GRIFFIN, R. et al. Natural capital and ecosystem services informing decisions: From promise to practice. **Proceedings of the National Academy of Sciences**, v. 112, n. 24, p. 7348-7355, 2015. https://doi.org/10.1073/pnas.1503751112

HALKOS, G.; MATSIORI, S. Environmental attitude, motivations and values for marine biodiversity protection. **Journal of Behavioral and Experimental Economics** v.69, p. 61–70, 2017. https://doi.org/10.1016/j.socec.2017.05.009

IBAMA – INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS NATURAIS. **Modelo de valoração econômica dos impactos ambientais em unidades de conservação – Empreendimentos de Comunicação, Rede Elétrica e Dutos – Estudo Preliminar**. Rio de Janeiro: IBAMA/RJ, 2002.

IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Banco de Informações Ambientais**. 2021. Available: https://bdiaweb.ibge.gov.br/#/home. Access on: may. 2021.

IBGE. **Malhas Municipais**. 2013. Disponível em: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html. Acesso em: nov. 2021.

IPCC. **AR5 Climate Change 2014**: Impacts, Adaptation, and Vulnerability. Disponível em: https://www.ipcc.ch/report/ar5/wg2/. Acesso em: out. 2021.

KERTÉSZ, A.; NAGY, L.A.; BALAZS, B. Effect of land use change on ecosystem services in Lake Balaton Catchment. **Land Use Policy, v.**80, p. 430–438, 2017. https://doi.org/10.1016/j.landusepol.2018.04.005

KLINK, C.A.; MACHADO, R.B. Conservation of the Brazilian Cerrado. **Conservation Biology**, v.19, p. 707–713, 2005. https://doi.org/10.1111/j.1523-1739.2005.00702.x

LI, F.; LIU, X.; ZHANG, X.; ZHAO, D.; LIU, H.; ZHOU, C.; WANG, R. Urban ecological infrastructure: An integrated network for ecosystem services and sustainable urban systems. **Journal of Cleaner Production**, v.163, p.S12–S18, 2017. https://doi.org/10.1016/j.jclepro.2016.02.079

LINARD, C.; TATEM, A.; GILBERT, M. Modelling spatial patterns of urban growth in Africa. **Applied Geography**, v.44, p. 23–32, 2013. https://doi.org/10.1016/j.apgeog.2013.07.009

LI, Y.Y.; LI, J.Q.; LI, Z.L.; LIU, X.J.; TIAN, Y.; LI, A.H. Issues and challenges for the study of the interconnected river system network. **Resour. Sci.,** v.33, p. 386-391, 2011.

MARTÍNEZ, L. Health differences in an unequal city. **Cities**, 108, 2021. https://doi.org/10.1016/j.cities.2020.102976

McCALLUM, I.; WAGNER, W.; SCHMULLIUS, C.; SHVIDENKO, A.; OBERSTEINER, M.; FRITZ, S.; NILSSON, S. Comparison of four global FAPAR datasets over Northern Eurasia for the year 2000. **Remote Sensing of Environment, v.** 114, n. 5, p. 941–949, 2010. https://doi.org/10.1016/j.rse.2009.12.009

MINISTÉRIO DO MEIO AMBIENTE. **Corredores Ecológicos**: iniciativa brasileira no contexto continental. P. 41, 2016.

MONTEITH, J. L. Climate and efficiency of crop production in Britain. **Philosophical Transactions of the Royal Society of London**, v. 281, p. 277-294, 1977. https://doi.org/10.1098/rstb.1977.0140

MONTEITH, J. L. **Principies of environmental physics**. London: Edward Amold, 1973. 241 p. https://doi.org/10.1098/rstb.1977.0140

MITSCHA, W.J.; DAY JR., J.W. Restoration of wetlands in the Mississippie-Ohio-Missouri (MOM) River Basin: experience and needed research. **Ecol. Eng**. v.26, p. 55-69, 2006. https://doi.org/10.1016/j.ecoleng.2005.09.005

MURRAY-SMITH, C.; BRUMMITT, N.A.; OLIVEIRA-FILHO, A.T.; BACHMAN, S.; MOAT, J.; LUGHADHA, E.M.N.; LUCAS, E.J. Plant diversity hotspots in the Atlantic coastal forests of Brazil. **Conservation Biology**, v. 23, n. 1, 151-163, 2009. https://doi.org/10.1111/j.1523-1739.2008.01075.x

MYERS, N.; MITTERMEIER, R.A.; MITTERMEIER, C.G.; FONSECA, G.A.B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature**, v.403, p.853–858, 2000. https://doi.org/10.1038/35002501

NASCIMENTO, R. S.; BRITO, J. I. B.; BRAGA, C. C. Estimativa da Produtividade Primária usando dados de IVDN para o Estado da Paraíba. **Anais XIV Simpósio Brasileiro de Sensoriamento Remoto**, INPE, p. 5321-5327, 2009.

NORTON-GRIFFITHS M.; SOUTHEY, C. The opportunity costs of biodiversity conservation: a case stufy of Kenya. **CSERGE GEC**. Centre for Social and Economic Research on the Global Environment, 1993.

NYELELE, C.; KROLL, C.N. A multi-objective decision support framework to prioritize tree planting locations in urban áreas. **Landscape and Urban Planning**, v.214, 2021. https://doi.org/10.1016/j.landurbplan.2021.104172

OLIVEIRA, R.R.; ZAÚ, A.S.; LIMA, D.F.; RODRIGUES, H.C.; AMORIM, H.B. Formulação de custos ambientais no Maciço da Tijuca (Rio de Janeiro, Brasil). **Oecologia Brasiliensis: Estrutura, Funcionamento e Manejo dos Ecossistemas Brasileiros**, v.1, p. 557-568, 1995. https://doi.org/10.4257/oeco.1995.0101.30

ORSATO, R. Social Learning for Anticipator y Adaptation to Climate Change. **Organization & Environment,** 32(4): 416-440, 2019. https://doi.org/10.1177/1086026618775325

PASCUAL, U.; BALVANERA, P.; DÍAZ, S.; PATAKI, G.; ROTH, E.; STENSEKE, M. et al. Valuing nature's contributions to people: The IPBES approach. **Current Opinion in Environmental Sustainability**, v.26, p.7-16, 2017. https://doi.org/10.1016/j.cosust.2016.12.006

PENG, J.; ZHAO, H.; LIU, Y. Urban ecological corridors construction: A review. **Acta Ecologica Sinica**, v. 37, n.1, p. 23–30, 2017. https://doi.org/10.1016/j.chnaes.2016.12.002

PICARD, P.M.; TRAN, T.T.H. Small urban green areas. **Journal of Environmental Economics and Management**, v.106, 2021. https://doi.org/10.1016/j.jeem.2021.102418

PIETROSTEFANI, E.; HOLMAN, N. The politics of conservation planning: A comparative study of urban heritage making in the Global North and the Global South. **Progress in Planning**, 2020. https://doi.org/10.1016/j.progress.2020.100505

PONZONI, F. J.; SHIMABUKURO, Y. E. **Sensoriamento remoto no estudo da vegetação**. São José dos Campos, SP: A. Silva Ed., 2009.

ROUSE, J. W.; HAAS, R. H.; SCHELL, J. A.; DEERING, D. W. Monitoring vegetation systems in the great plains with ERTS. In: **Proceeding of ERTS-1**, v. 3, p. 309-317, 1973. https://doi.org/10.1109/TGE.1973.294284

RUIMY, A.; SAUGIER, B.; DEDIEU, G. Methodology for the estimation of terrestrial net primary production from remotely sensed data. **Journal of Geophysical Research**, v. 99, p. 5263-5283, 1994. https://doi.org/10.1029/93JD03221

SANTOS, J.E.; NOGUEIRA, F.; PIRES, J.S.R.; OBARA, A. T.; PIRES, A. M.Z.C.R. **Funções Ambientais e Valores dos Ecossistemas Naturais Estudo de Caso**: Estação Ecológica de Jataí, v.1., São Paulo: Rima Editora, 2000.

SANTOS, J.S.; LEITE, C.C.C.; VIANA, J.C.C; DOS SANTOS, A.R.; FERNANDES, M.M.; DE SOUZA ABREU, V.; DO NASCIMENTO, T.P.; DOS SANTOS, L.S.; DE MOURA FERNANDES, M.R.; DA SILVA, G.F.; DE MENDONÇA, A.R. Delimitation of ecological corridors in the Brazilian Atlantic Forest. **Ecol. Indic.**, v.88, p. 414-424, 2018. https://doi.org/10.1016/j.ecolind.2018.01.011

SCOTT, A.; STORPER, M. The Nature of Cities: The Scope and Limits of Urban. Theory. **International Journal of Urban and Regional Research**, v. 39, n. 1, p. 1–15, 2015. https://doi.org/10.1111/1468-2427.12134

SETO, K. C.; GÜNERALP, B.; HUTYRA, L. R. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. **Pnas**, v. 109, n.40, p. 16083–16088, 2012. https://doi.org/10.1073/pnas.1211658109

SIMATELE, D.; SIMATELE, M. Climate variability and urban food security in sub-Saharan Africa: Lessons from Zambia using an asset-based adaptation framework. **South African Geographical Journal**, v.97, p. 243–263, 2015. https://doi.org/10.1080/03736245.2014.924873

SOBRINO, J. A.; RAISSOUNI, N. Toward remote sensing methods for land cover dynamic monitoring: application to Marocco. **International Journal of Remote Sensing**, v. 21, p. 353-363, 2000. https://doi.org/10.1080/014311600210876

SODOUDI, S.; ZHANG, H.; CHI, X.; MÜLLER, F.; LI, H. The influence of spatial configuration of green areas on microclimate and thermal comfort. **Urban For. Urban Green.**, v.34, p. 85–96, 2018. https://doi.org/10.1016/j.ufug.2018.06.002

SZEICZ, G. Solar radiation for plant growth. **Journal of Applied Ecology**, v.11, p. 617-36, 1974. https://doi.org/10.2307/2402214

TABARELLI, M.; AGUIAR, A.V.; RIBEIRO, M.C.; METZGER, J.P.; PERES, C.A. Prospects for biodiversity conservation in the Atlantic Forest: Lessons from aging human-modified landscapes. **Biol. Conserv**., v.143, p. 2328-2340, 2010. https://doi.org/10.1016/j.biocon.2010.02.005

TABARELLI, M.; PINTO, L.P.; SILVA, J.M.C.; HIROTA, M.M.; BEDÊ, L.C. Desafios e oportunidades para a conservação da biodiversidade na Mata Atlântica brasileira. **Megadiversidade**, v. 1, n.1, p. 132-138, 2005. https://doi.org/10.1016/j.biocon.2010.02.005

TAVAREZ, H.; ELBAKIDZE, L. Urban forests valuation and environmental disposition: the case of Puerto Rico. **Forest Policy and Economics**, v.131, 2021. https://doi.org/10.1016/j.forpol.2021.102572

THE EUROPEAN SPACE AGENCY (União Europeia). **Sentinel Online**. 2021. Available: https://sentinel.esa.int/web/sentinel/home. Access on: 04 oct. 2021.

UNITED NATIONS. Department of Economic and Social Affairs. **Population Division World urbanization prospects**: The 2018 revision (ST/ESA/SER.A/420), United Nations, 2019.

UNITED NATIONS. **E/2018/25-E/CN.9/2018/7**. Commission on Population and Development, Report on the fifty-first session, Economic and Social Council. 2018. Available: https://digitallibrary.un.org/record/1626675/files/E_2018_25%26E_CN-9_2018_6-EN.pdf. Access on: sep. 2021.

WANG, M.; KRSTIKJ, A.; KOURA, H. Effects of urban planning on urban expansion control in Yinchuan city, western China. **Habitat International**, v.64, p. 85–97, 2017. https://doi.org/10.1016/j.habitatint.2017.04.008

WARD, J.S.; DUNCAN, J.S.; JARDEN, A.; STEWART, T. The impact of children's exposure to greenspace on physical activity, cognitive development, emotional wellbeing, and ability to appraise risk. **Health Place**, v.40, p.44–50, 2016. https://doi.org/10.1016/j.healthplace.2016.04.015

WEY, W.; HSU, J. New urbanism and smart growth: Toward achieving a smart national Taipei university district. **Habitat International**, v.42, p. 164–174, 2014. https://doi.org/10.1016/j.habitatint.2013.12.001

WHO. **Urban Green Spaces**: a brief for action. WHO Regional Office for Europe Copenhagen. 2017.

WIDEGREN, O. The new environmental paradigm and personal norms. **Environ. Behav**. v. 30, n. 1, p. 75–100, 1998. https://doi.org/10.1177/0013916598301004

WOLFF, S.; SCHULP, C.; VERBURG, P. Mapping ecosystem services demand: A review of current research and future perspectives. **Ecological Indicators**, v.55, p. 159–171, 2015. https://doi.org/10.1016/j.ecolind.2015.03.016

WU, Y.G. **Sponge City Design**. Phoenix Science Press, Nanjing, p. 88, 2016.

ZANG, B.; LV, P.; WARREN, C. M. J. Housing prices, rural-urban migrants settlement decisions and their regional differences in China. **Habitat International**, v.50, p. 149–159, 2015. https://doi.org/10.1016/j.habitatint.2015.08.003

ZHU, X.; GAO, M.; ZHANG, R.; ZHANG, B. Quantifying emotional differences in urban green spaces extracted from photos on social networking sites: A study of 34 parks in three cities in northern China. **Urban For. Urban Green.**, v.62, 2021. https://doi.org/10.1016/j.ufug.2021.127133

AUTHORS CONTRIBUTION

Maycon Jorge Ulisses Saraiva Farinha conceived the study, collected and analyzed the data and wrote the paper. André Geraldo Berezuk conceived the study, wrote and revised the article. Luciana Virginia Mario Bernardo conceived the study, collected and analyzed the data and wrote the paper. Adelsom Soares Filho analyzed the data and revised the paper.