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Original Article

Conservation of Nature

Influence of Urbanization on the Dynamics of the Urban Vegetation Coverage Index (VCI) in Erechim (RS)

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ABSTRACT

Vegetation fragments located in urban perimeters provide better environmental conditions for biological diversity and human well-being. The aim of this study was to evaluate the Vegetation Coverage Index (VCI) of the urban perimeter of Erechim, RS, between years 2010 and 2015. Mapping was carried out using *World View* 2 and *Pleiades* satellites images with spatial resolution of 0.5 m. Significant difference was found between VCI values of 2010 and 2015, as well as a decrease in the recommended rate in the range of 30% per neighborhood. Due to the influence of increased urbanization, there was reduction of 229.98 hectares in the vegetation coverage area of the urban perimeter during the study period. The expansion of urban areas reduced vegetation fragments and has contributed in an effective manner to the disordered occupation of the city, generating negative impacts to the environment and to the quality of life of the local population.

Keywords: geoprocessing, environmental planning, vegetation fragments, urban perimeter.

1. INTRODUCTION

The conservation and maintenance of vegetation fragments and forestation are essential for the structure and dynamics of the urban landscape. These factors provide better thermal comfort conditions, contributing to improvements in quality of life and the environmental condition of cities (Lima et al., 2007; Martini & Biondi, 2015). Vegetation is important for urban ecosystems, as it interferes in environmental factors such as relief, soil, climate, water and hydrological cycle, in addition to serving as a biological indicator of environmental quality (Cavalheiro, 1995).

The dynamics between natural environment and urban space are related to improvements in the quality of life of the population such as environment with recreation, leisure and aesthetic value (Gomes, 2013). The absence of vegetation affects fundamental mechanisms that reduce temperature, since vegetation acts on the climatic elements in urban microclimates, altering absorption capacity and heat transmission when compared to rural areas (Mascaró & Mascaró, 2009; Oliveira et al., 2013). These changes in ecosystems bring negative consequences to human well-being and reduce ecosystem services (MEA, 2005).

Disorderly population growth in cities generates conflicts between social environment and natural environment (Doulos et al., 2004). This factor has intensified since the second half of the nineteenth century and throughout the twentieth century, with changes taking place in the cities, mainly with an increase in population density and buildings, increasing the complexity of urban spaces both in structure (morphology) and functions (processes) (Monteiro, 2008).

To assist in managing cities, Geographic Information Systems (GIS) effectively contribute to urban environmental planning. The use of geoprocessing and GIS enable analyzing, interpreting and forecasting the growth of cities (Costa et al., 2014). The integrated use of GIS and high-spatial-resolution satellite images are important for landscape ecology studies, allowing analyzing vegetation fragments and their conservation status, representing an ally for planning urban environmental actions (Oliveira et al., 2008).

The maintenance of vegetation in urban areas is justified by its potential to provide improvements in the quality of life of the population (Bargos & Matias, 2012). However, there is concern about housing programs that make it possible to offer housing rights to the population, which directly influences vegetation. Therefore, the increase and incentive of public housing policies, the access to loans for acquisition purposes and the construction of adequate infrastructure has brought the need to include new areas in the urban perimeter via new subdivisions, whether they may be popular or medium- to high-class areas.

This study aimed to evaluate the Vegetation Coverage Index (VCI) in the urban perimeter of the municipality of Erechim between years 2010 and 2015, with the objective of verifying possible changes suffered by vegetation fragments due to the integration and conversion of these areas into urbanized spaces (housing developments, housing and urban infrastructure) caused by increased urbanization.

2. MATERIAL AND METHODS

The study area comprises the urban perimeter in the municipality of Erechim, Rio Grande do Sul, with area of 7,117.06 ha according to Law 4,729 dated from July 6, 2010, demarcated by 58 neighborhoods (Figure 1). It is inserted between geographical coordinates 27°28'53" to 27°47'03" latitude South and 52°08'53" to 52°20'27" longitude West, in the Northern region of Rio Grande do Sul (Erechim, 2010).

The municipality of Erechim was one of the first planned cities in Brazil, with urban road system layout in the form of a grid based on cities like Washington and Paris, with wide, long and green avenues and symmetrical and linear streets surrounded by squares (Oliveira et al., 2013). It has population of 96,087 inhabitants, total area of 430,668 km^2 and demographic density of 223.11 inhabitants/km^2 (IBGE, 2010). The climate is characterized as humid and subtropical temperate (Cfb according to the Köppen-Geiger classification), with average annual temperature of 17±1°C and average annual precipitation varying between 1900 and 2200 mm (Alvares et al., 2013). The municipality is part of the Atlantic Forest Domain and the vegetation is characterized by Atlantic Forest with Araucarias and Semi-deciduous Seasonal Forest (Oliveira-Filho et al., 2015).

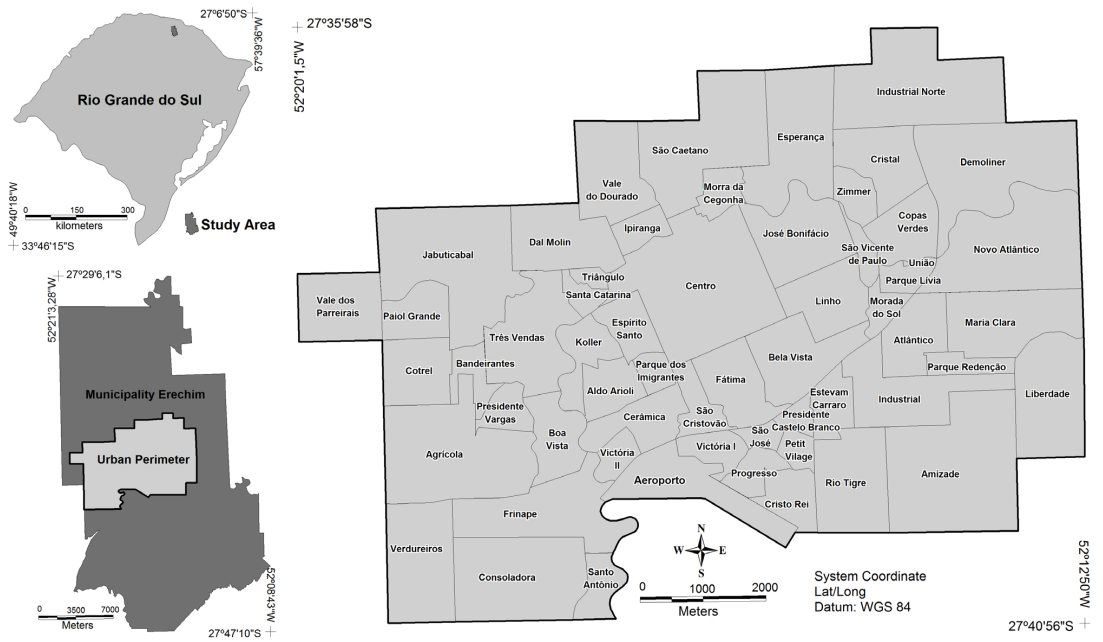

Figure 1. Location of the municipality of Erechim in the State of Rio Grande do Sul, its urban perimeter and neighborhoods.

One image from the *World View 2* satellite (acquisition date on March 18, 2010) and one image from the *Pleiades* satellite (acquisition date on September 15, 2015) were used for temporal analysis of VCI, both with spatial resolution of 0.5 meters, belonging to the collection of the Laboratory of Geoprocessing and Environmental Planning of the Integrated Regional University of Upper Uruguay and the Missions (URI Erechim). Images were treated for color, brightness, contrast and georeferencing in a UTM coordinate system, WGS84 22S. Digitization of the native vegetation and forest fragments were carried out in the *MapInfo Professional* 8.5 software and interpretation was performed using photointerpretation parameters such as texture, hue, color and roughness in order to differentiate native vegetation fragments from forest fragments.

With the identification of fragments, it was possible to spatialize and calculate areas (in hectares), perimeter (meters) and perform an analysis of multitemporal modifications between years 2010 and 2015, resulting in a digital geographic database. The temporal variation in relation to the vegetation was carried out through a combined classification of vegetation coverage data in years 2010 and 2015. The CrossTab module of the IDRISI Selva software was used for this operation (Eastman, 2012).

The VCI evaluation was adapted from Cavalheiro et al. (1999) and Nucci (2001), which defines vegetation coverage as "vegetation spots" seen by the naked eye in an aerial photograph and satellite images, considering all types of vegetation, street trees, squares, central gardens/flowerbeds, public and private areas. According to the adaptation of Cavalheiro et al. (1999) and Nucci (2001), all vegetation fragments (arboreal and shrub fragments) from satellite images with spatial resolution of 0.5 m were considered.

The Shapiro Wilk test was used to evaluate VCI differences between years 2010 and 2015 and to verify whether data fit normal Gaussian distribution. After the test, it was verified that data did not present normal distribution and then data were transformed into log x+1, thus obtaining data normality for the paired t-test, since sampling units showed dependence. Analyses were carried out in the statistic R environment (R Core Team, 2016).

3. RESULTS AND DISCUSSION

The analysis of native vegetation fragments and forest fragment of the urban perimeter of Erechim showed that they are not homogeneous, differing in size and shape, and associated to the perimeter

location, its topography and integration to the urban and structural center of the city. These vegetation fragments are randomly and radially distributed starting from central neighborhoods, which have lower indexes, and with areas and number of these fragments increase the closer to the edge of the urban perimeter, facing the Northern, Northeastern and Northwestern portions with steep slopes (Figure 2). This statement corroborates the municipal environmental legislation, which determines the preservation of slopes in the northern portion of the city through the visual protection of the landscape and restricting increase in density, thus stimulating the creation of parks, belvederes and related uses (Erechim, 2012).

The greater occurrence of vegetation in these places occurs due to the presence of slopes as a consequence of the irregular relief, which makes the urbanization process difficult. This factor creates obstacles, mainly for implantation in areas with high urban density and other infrastructures, resulting in the occupation of other areas, where there are urban voids (Erechim, 2011). These vegetation areas are protected by Federal Law (Law no. 12.651, of May 25, 2012) (Brasil, 2012), according to the Master Plan for Sustainable Urban and Environmental Development of Erechim. Thus, for the vegetation to be properly analyzed in the urban environment, its distribution and spatial dimension must be taken into consideration (Bargos & Matias, 2012).

Based on the mapping of vegetation fragments, native vegetation in year 2010 was quantified as 1,922.67 ha (hectares) and 328.84 ha of forestry areas, totaling 2,251.51 ha of vegetation coverage in the urban perimeter of Erechim. In 2015, native vegetation areas totaled 1,687.70 ha and 333.83 ha of forestry areas, corresponding to 2,021.53 ha of total vegetation coverage of the urban perimeter (Table 1).

During the study period, areas of native vegetation presented reduction of 234.97 ha for the urban perimeter. In turn, forestry areas presented increase of 4.99 ha during the same period. The reduction of native vegetation areas is mainly associated with human occupation through housing and infrastructure construction associated to new housing developments. Faced with these changes, it is necessary to constantly plan actions to ally the structural growth of cities while preserving the environment, following the National Environmental Policy (Law 6.938/1981) (Brasil, 1981), which advocates and provides rules for environmental licensing for urban expansion.

Data from the vegetation coverage analysis between 2010 and 2015 showed a suppression of 534.42 ha of native vegetation and 90.36 ha of forestry areas. Through the regeneration or vegetation recovery process, areas that did not have vegetation in 2010 totaled 263.89 ha of native vegetation in 2015 and forest cultivation represented 55.83 ha of forestry areas. In 2010, 45.25 ha of forestry areas were converted into native vegetation areas by 2015 through changes in their use. On the other hand, the suppression of native vegetation in 2010 into forest vegetation areas in 2015 increased by 91.57 ha. In this sense, urban problems are both qualitatively and quantitatively mitigated by vegetation and its spatial distribution. Vegetation coverage in the urban environment must be carefully evaluated, reflecting on the environmental quality and planning of the urbanized landscape (Nucci, 2001).

In this context, current municipal environmental laws determine the protection of the environment from any form of degradation. According to article 54. Law No. 6.256, of December 15, 2016, forests, woodlands, trees and shrubs of native species located in the urban perimeter of cities,districts and towns cannot be cut, as determined by an act of the Public Power. However, in terms of Federal Legislation (Law No. 12.651, of May 25, 2012), license from competent Municipal, Federal and State authorities is required for the pruning or cutting of any vegetation of arboreal size in the municipality jurisdiction, provided that it is proven not to be of public utility, native species of

Table 1. Vegetation coverage of the urban perimeter of Erechim (RS).

Vegetation coverage	2010		2015	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Native Vegetation	1,922.67	85.40	1,687.70	83.40
Forestry areas	328.84	14.60	333.83	16.52
Total	**2,251.51**	**100**	**2,021.53**	**100**

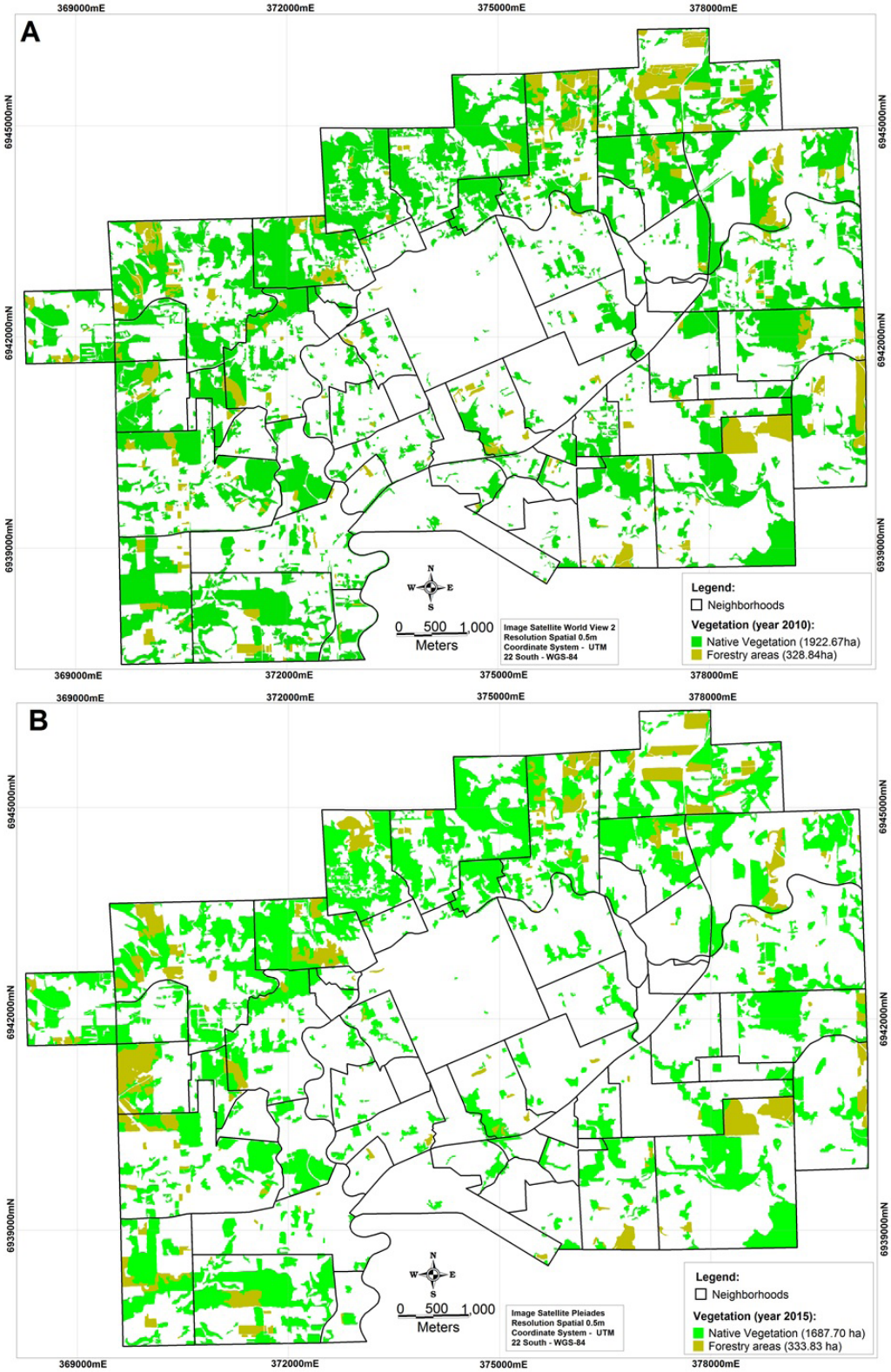

Figure 2. Vegetation coverage of the urban perimeter in 2010 (A) and 2015 (B), municipality of Erechim (RS).

the region or vegetation of significant importance to environmental balance (Erechim, 2012, 2016).

The loss of native vegetation causes negative impacts, hindering provision of environmental services that are fundamental to the population's well-being and quality of life. The removal of vegetation coverage brings negative impacts such as soil sealing, erosive processes, noise pollution, low air humidity, high temperatures, reduced water quality and biodiversity (Rocha & Werlang, 2005; Gomes & Queiroz, 2011).

In analyzing vegetation fragment areas between years 2010 and 2015, it was possible to identify that Novo Atlântico (30.68 ha), Agrícola (18.82 ha), Atlântico (14.56 ha), Liberdade (14.14 ha) and Frinape neighborhoods (12.91 ha), respectively, had reduction in their vegetation coverage areas. These neighborhoods were the target of expansion and implantation of new projects due to the increased demand for urbanized areas. On the other hand, Consoladora (12.61 ha), Vale dos Parreirais (6.88 ha), Cotrel (3.83 ha), São Caetano (3.48 ha) and Dal Molin neighborhoods (2.88 ha) showed increase in their vegetation areas.

The VCI found for year 2010 in the urban perimeter of Erechim was 31.63%, while for 2015, it was 28.40%, totaling reduction of 3.23%. A study carried out by Oke (1973 apud Lombardo, 1985) considered vegetation coverage index in the range of 30% as recommended to provide adequate thermal balance in urban areas. In turn, VCI less than 5% represents areas with undesirable characteristics (Lombardo, 1985).

For the urban perimeter, it could be inferred that 23 neighborhoods in 2010 had VCI above the ideal value of 30%, making up 39.6% of total neighborhoods. We could point out that Parque Lívia, Aeroporto, Progresso, São Cristóvão, Parque dos Imigrantes, União and Centro neighborhoods presented VCI lower than 5%.

In 2015, it was observed that 19 neighborhoods presented VCI values greater than 30%, making up 32.7% of total neighborhoods in the urban perimeter. Parque Lívia, Aeroporto, Progresso, São Cristóvão, Parque dos Imigrantes, União, Centro, Presidente Castelo Branco, Morada do Sol, São Vicente de Paulo and Vitória II neighborhoods presented VCI values below 5%. The results of this study show that central districts and neighborhoods with lack of urban infrastructure (outskirts) have high urban density and consequently low VCI (lower than 5%). This scenario corroborates the results of Buccheri & Nucci (2006), who found VCI of 16.85% in a central district of Curitiba, PR. A study carried out by Aves & Figueiró (2014) in the urban area of Santa Maria, RS, showed that there are still aggregated fragments; however, tree fragments were reduced in neighborhoods with greater urban densities.

By analyzing the VCI, it was possible to determine that the greatest losses in vegetation are related to the Eastern and Western areas of the urban perimeter, where the largest integrations for urban planning purposes have occurred. During the five-year period, 36 of the total of 58 neighborhoods maintained stable index, and three neighborhoods showed increase in VCI: Liberdade, Vale dos Parreirais and Cotrel. However, a reduction in this index was observed in 19 neighborhoods: Paiol Grande, Koller, Aldo Arioli, Presidente Vargas, Boa Vista, Vitória II, Frinape, Santo Antônio, Rio Tigre, Estevam Carraro, Presidente Castelo Branco, Atlântico, Maria Clara, Morada do Sol, Linho, São Vicente de Paulo, Zimmer, Copas Verdes and Novo Atlântico (Figure 3).

Statistical analysis of data was performed through the t-test ($t = 5.0788$, $df = 57$, $p < 0.001$) and showed a significant difference of data between 2010 and 2015. This enables inferring that there was a decrease in VCI between the study years. This difference is related to the increase in urbanization, since it is necessary to remove part of the vegetation coverage for implementing new urban areas in many cases, causing environmental problems. This scenario is evident in the municipality of Erechim, despite the environmental legislation foreseen in article 68 of Law 6,256 of December 15, 2016, which controls the exploitation of forest resources, deforestation and erosion, and any tree pruning/cutting, which can only be carried out based on the pertinent legislation and land movement upon license and inspection by the technical organ of the Municipality (Erechim, 2016).

The changes observed are mainly associated with the increase in demand for housing through urban densification stimulated by public housing policies, along with the implementation of new social settlements and their integration into the urban structure. In addition to reducing vegetation areas, urban expansion effectively contributes to unorganized city occupation, thereby

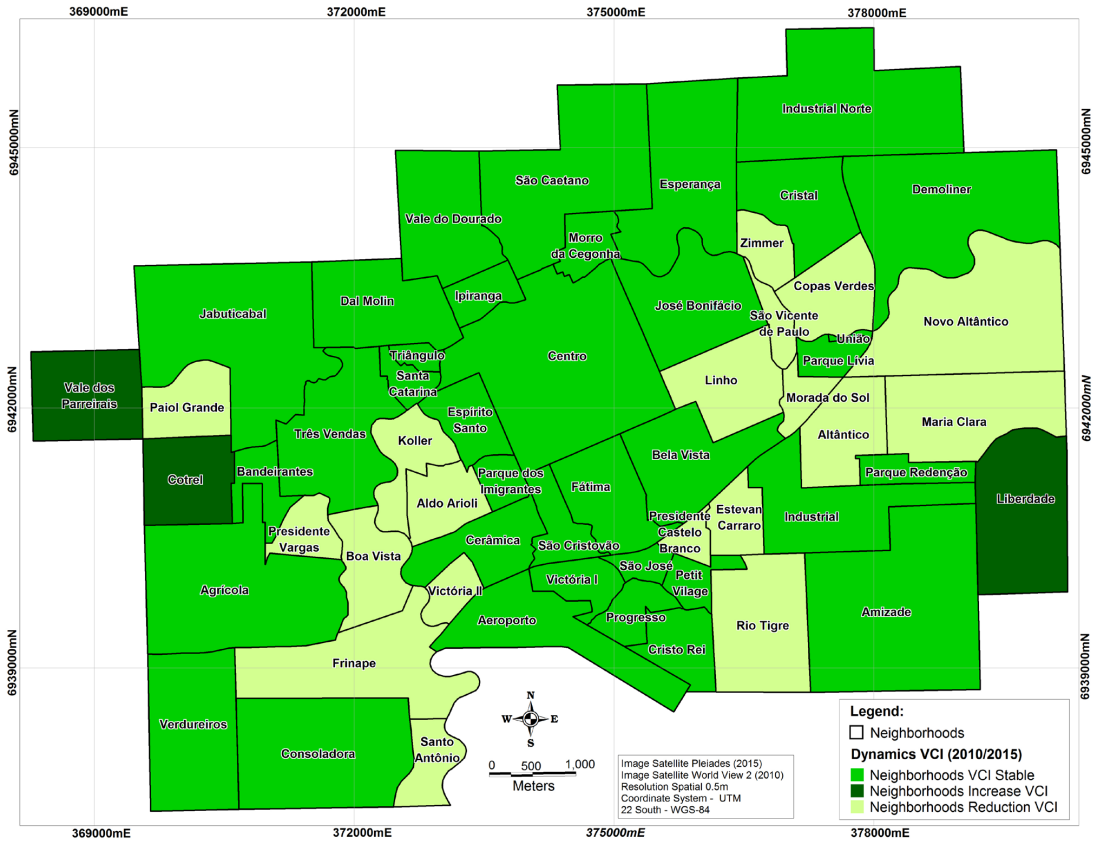

Figure 3. VCI dynamics of the urban perimeter for years 2010 and 2015, municipality of Erechim (RS).

generating negative impacts on the environment as well as on the quality of life of the local population.

4. CONCLUSIONS

The results of this study showed fragmented vegetation distribution and reduction in the VCI values of the urban perimeter of the municipality of Erechim from 2010 to 2015. The appropriation of natural spaces for residential and industrial urban use reduced areas of native vegetation during the evaluation period.

In a future scenario, maintaining the presented trend will cause greater reductions in native vegetation areas, which will compromise local environmental conditions. However, this scenario will correspond to an increase in forestry areas due to cultivation for economic purposes, or even for future urban real estate speculation.

The development of field studies aimed at evaluating the distribution of these green spaces within each neighborhood, the state of conservation and their accessibility should be highlighted. Finally, it is necessary to develop actions and public policies in the municipality aimed at the development of ecological corridors to maintain existing vegetation areas for their recovery and environmental regeneration, seeking to improve the quality of life of the population, the environment and local biodiversity.

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