Original Research Article

Influence of hypsometry in the occupation of semiarid areas

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ABSTRACT

This research aims with the help of geotechnologies to map the different uses and coverage of the earth by analyzing its effects in relation to the altitudinal gradient in semiarid regions.In order to do so, RapidEye images were acquired in the year 2014, after the organization of the database the digital processing of the acquired scenes was carried out which were performed contrast technique, segmentation, identified eight classes of use and land cover and submitted to Maximum Likelihood classification.The relationship between forest cover and different uses indicates that the most representative class was Agriculture and Livestock, as a consequence of the local economy being based on subsistence culture and the Lowland environment is the most affected. In addition, it is verified that there is a lower degree of anthropization in the tops evidencing that in the Plateau environment persists a greater density of native vegetation. This research confirms the hypothesis that the process of fragmentation of the native vegetation of the semi-arid region changes in relation to the altitudinal gradient, since the higher the altitude, the lower the degree of isolation and, consequently, the high forest coverage.

Keywords: altitudinal gradiente, semiarid regions, fragmentation, geoprocessing,

1. INTRODUCTION

Human activity in the environment often alters natural landscapes. As a result, forest suppression in semi-arid regions has increased, especially for cattle and agricultural expansion. This disorderly occupation and overuse of land exposes it to erosion and creates the potential for environmental degradation associated with scarce water resources [16]. The effects of this activity transform extensive and continuous forest areas into smaller fragments, affecting the availability and the quality of natural resources, resulting in an imbalance between supply and demand in the semiarid regions.

In recent decades, native vegetation has been deforested not only for the expansion of agriculture and livestock, but also for the extraction of wood by shallow cutting. This process, aimed at producing firewood to supply the industries, has a high-level impact on the environment and landscape, compromising the fauna and flora of the region [4]. In addition, these regions suffer from severe dry periods, which aggravates the development of vegetation. Topography can mitigate the effects of drought on vegetation along the altitudinal gradient of a hill through redistribution of soil moisture and atmosphere, in view of this there are different responses of drought tolerant species, in addition to topographical effects, environmental filtration can lead to complex changes in species composition along the altitude gradient [10]

Therefore, the identification of land use and occupation is essential for understanding the environment, which requires the use of cutting-edge technologies in the surveying of existing natural resources to rationalize their use and to ensure their sustainable development.

Thus, Remote Sensing and Geographic Information Systems bring significant advances in the development of research, in planning actions, in the management process and in several others related to the Geographic space structure [9]. They are efficient geotechnologies for obtaining data and interpretation of the landscape as well as of environmental planning and management, are like "most important holistic tools" for the analysis, that is, they understand the phenomena in their totality. The characterization and mapping of the forest cover using these tools can visualize and explain spatial relationships represented in forms of maps, helping in the management of decision making in relation to the landscape, mainly in relation to the maintenance and preservation of the natural resources [2] [10] [23].

The main objective of this research is to analyze the effects of different land coverages and usages on the altitudinal gradient in semi-arid regions with the help of geotechnologies.

2. MATERIALS AND METHOD

2.1. Location and characterization of study areas

The study areas were the region of Araripe, the Brígida River Basin, and the western part of the state of Pernambuco, Brazil. These areas have been pronounced semiarid in the lower part, with annual precipitation totals varying between 400 and 500 mm. In the part corresponding to the Chapada do Araripe, rainfall increases to averages between 700 and 800 mm, and the temperature ranging between 24°C and 26°C [13].

The landscapes analyzed had different dimensions because they were pre-defined for future research. Thus, a buffer of 2.5 km distance of each area was used for mapping and analyzing the landscapes to avoid overlap. Sampling was carried out in three environments with different altitudes: the Lowland environment with altitude of up to 600 m, the Hills environment with heights between 600 and 750 m, and the Plateau environment with altitudes above 750 m. The total samples included nine areas, three in each environment and located in the cities of Araripina, Ipubi and Exú (Figure 1).

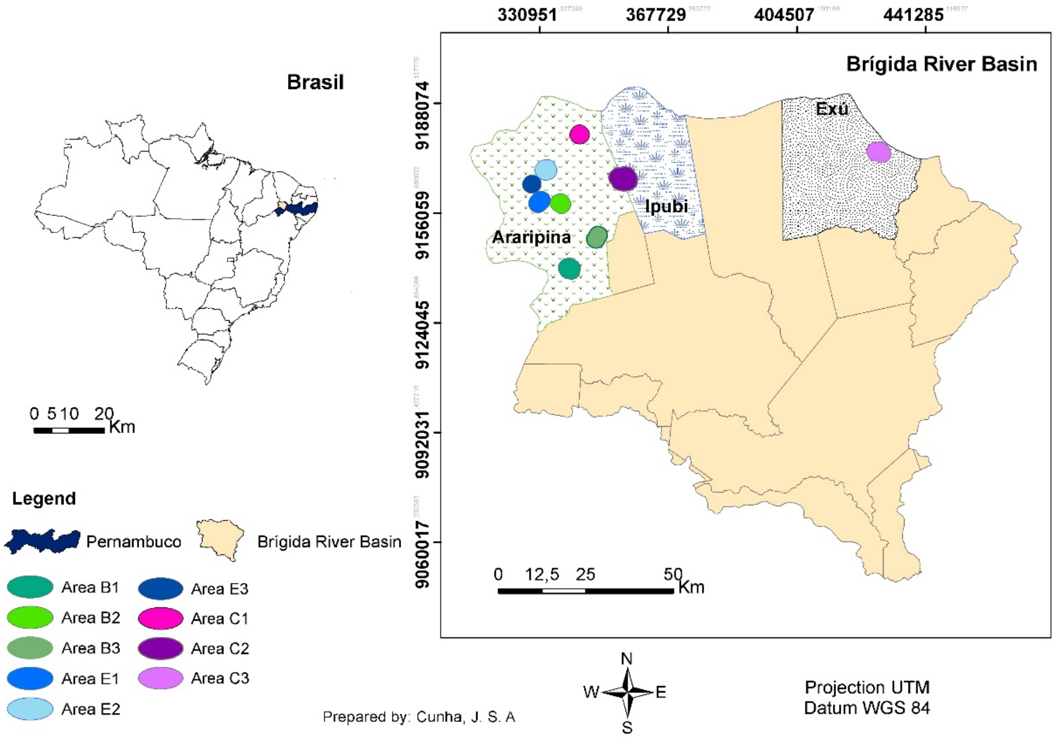

Figure 1: Location of study areas in semi-arid regions.

2.2. Data base

Initially, RapidEye images were acquired with scenes covering the study region (Table 2). The scenes were provided by the Federal Government distributed in the GeoCatálogo of the Ministry of the Environment [15] and orthorectified (level 3A) with pixel size in the field of 5 (five) meters.

Table 1. Characteristics of the RapidEye images obtained by the MOE (Ministry of the Environment) for the studied region.

IMAGE	CENA	DATA
RAPIDEYE	2435508	05/08/2014
	2435607	04/06/2014
	2435608	05/08/2014
	2435609	31/07/2014
	2435611	31/07/2014
	2435612	26/05/2014
	2435507	22/07/2015

2.3. Digital image processing

The digital image processing, vector mapping, and visual interpretation were performed in ArcGis 10.2.1 software. The images were imported to perform the mosaic and trimming of the buffers, comprising a distance of 2,5 (two and a half) km. The images were analyzed by the color composition (R5G3B2) of the bands, along with contrast enhancement, and then segmented.

Dense vegetation (arboreal forest formations) and sparse vegetation (shrub and bush vegetation), agricultural and livestock, exposed soil, bodies of water, urban areas, clouds, and shade were all observed. After defining the class standards, the samples were analyzed for class with spectral recognition, and the images were classified using the classification supervised by Maximum Likelihood. Thematic maps were prepared for the nine areas and the reliability of the digital classification of the study areas was assessed by the confusion matrix and classified using the Kappa coefficient [3] ranging from -1 to 1 (Table 3).

Table 2. Kappa coefficient intervals.

Kappa value	**Quality of Classification**
< 0,00	Terrible
0,0 – 0,20	Bad
0,20 – 0,40	Reasonable
0,40 – 0,60	Good
0, 60 – 0,80	Very Good
0,80 – 1,00	Excellent

By [11]

3. RESULTS

3.1 Class accuracy

The Kappa index values for the Lowland environment were 0.60, 0.70, and 0.84 for the areas B1, B2 and B3, respectively, so the classifications ranged from good to very good. Regarding the Hill environment, the values were 0.87, 0.88 and 0.69 for the areas E1, E2 and E3, respectively, indicating good to very good classifications. As for the Plateau environment, all areas demonstrated excellent quality in their classifications because the index values for areas C1, C2 and C3 were 0.97, 0.91 and 0.93 respectively.

3.2 Land use and occupation

In the Lowland environment of the three areas studied, the Agriculture and Livestock class was heavily represented (Figure 2), which is the main economic activity in the region. The field survey showed agricultural expansion in the three areas of this environment, especially of the bean and corn crops, causing pressure on the native vegetation and affecting the habitats of endemic species.

In area B1, the Forest class comprised approximately 37% of the area studied. The Agriculture and Livestock class made up about 40%, which together with the Exposed Soil class accounted for 63% of the total area. Areas B2 and B3 also presented high values for the combined Agriculture and Livestock and Exposed Soil classes with 45.5% and 48%. The Lowland environment has areas with high disturbance. However, in the Lowland environment, areas B2 and B3 are similar to Forest values of 53% and 52% respectively. This increase of the class in these areas as compared to B1 occurs due to their proximity to watercourses, even intermittent ones.

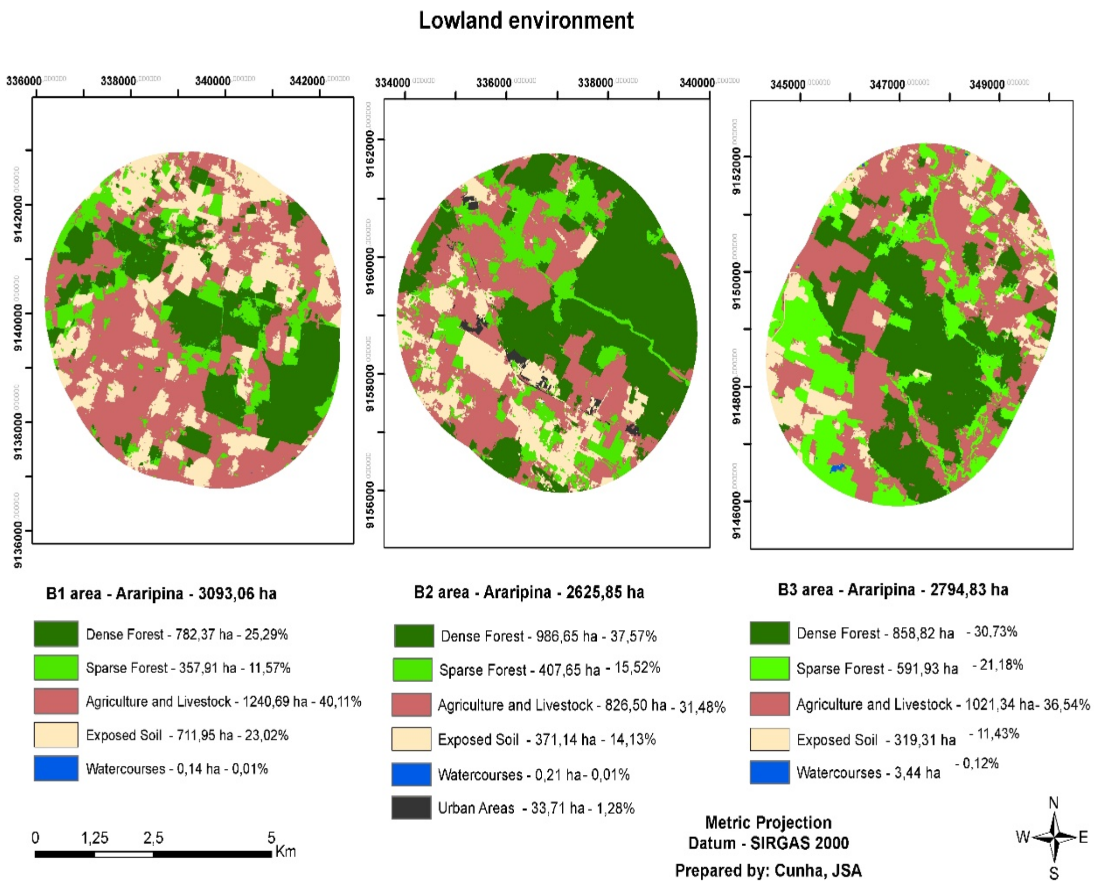

Figure 2: Map of use and land coverage in 2014, of the areas inserted in the Lowland environment in semi-arid regions.

The Hill environment (Figure 3) considering the combination of the Agriculture and Livestock and Exposed Soil classes shows values of 56% for area E1, followed by area E3 with 47% and with the smallest percentage of E2 that holds only 26% of its area with presence of these classes.

Area E1 has the lowest value for Forest, being about 44% of its total area, followed by E3 with approximately 52%. Even in the E3 area with a forest matrix, the data are relatively low, and the low values of these two areas (E1 and E3) are probably due to their proximity to the urban perimeter. On the other hand, the E2 area has no proximity to urban areas and has 74% of its total area in the Forest class, showing the interference of urban area proximity on other areas.

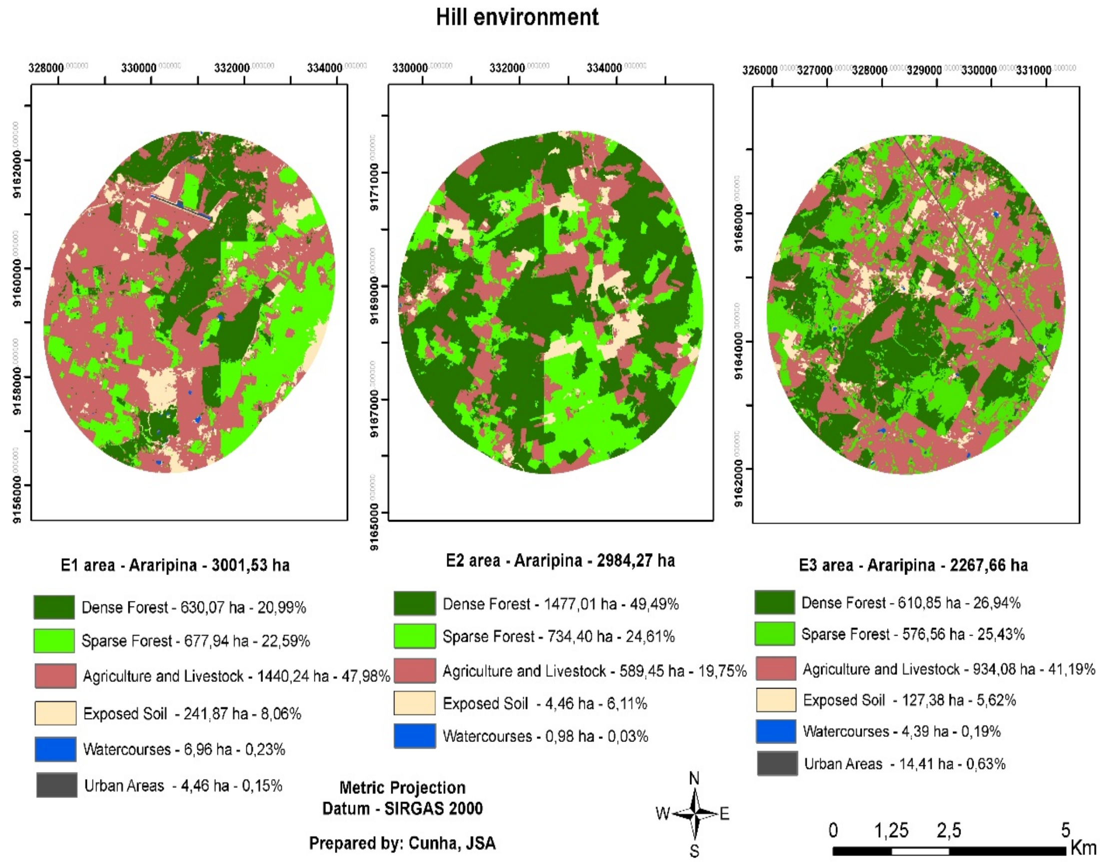

Figure 3. Use and land coverage map in 2014, of the areas inserted in the Hill environment in semi-arid regions.

In the Plateau environment, low percentages of 16%, 12%, and 12% for the Agricultural and Livestock class, and of 10%, 2%, and 4% for the Exposed Soil class, were observed for the total areas of C1, C2, and C3, in that order (Figure 4). It should be noted that the values found for the Agriculture and Livestock and Exposed Soil classes in this environment are lower than in the previous environments and that the matrices of the three areas of the Plateau environment are of Forest, which makes up 75% of the total area in C1, 81% in C2, and 85% in C3.

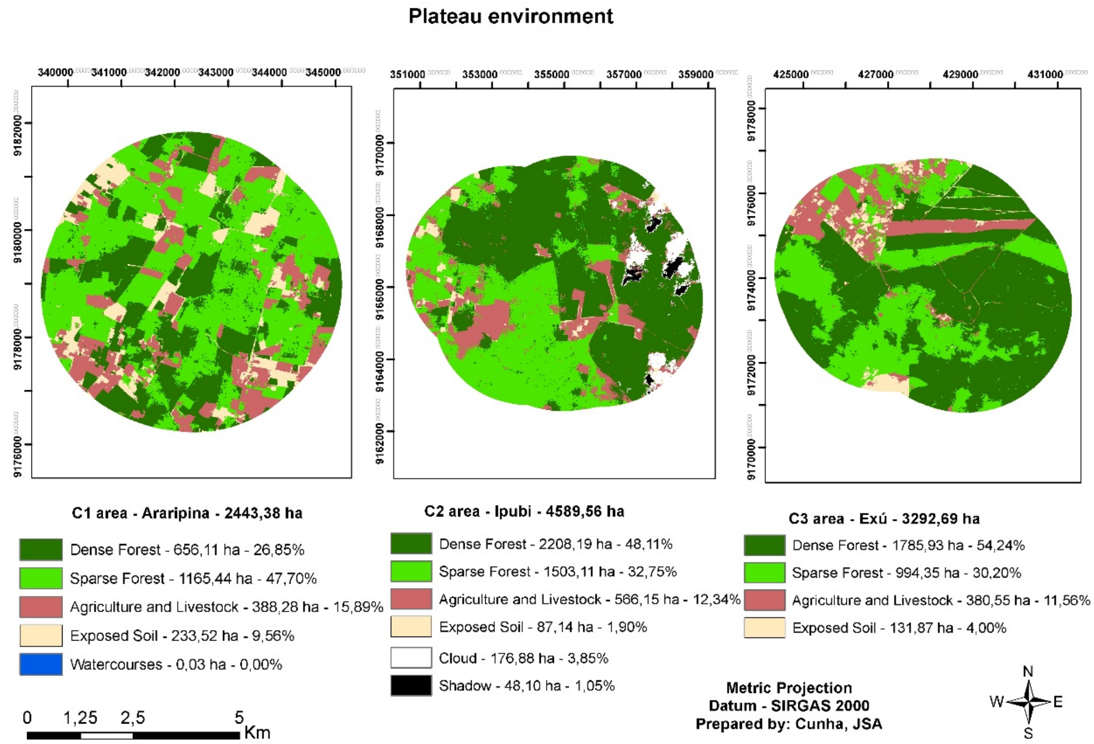

Figure 4. Map of land use and coverage in 2014, of the areas inserted in the Plateau environment in semi-arid regions

3.3 Class correlation

In evaluating the average percentage of land use and land coverage categories (Figure 5), the data showed that in the Lowland and Hill environments, the Agriculture and Livestock class is more prominent, and a decrease in the Exposed Soil class was observed when moving environments and, consequently, altitudes. These data may be associated with the dense and sparse Forest categories that increase with this change, showing that the Plateau environment that holds the highest altitudes has the lowest percentage of Exposed Soil and the highest average percentages for the Forest categories.

When correlating the quantifications of Forest classes (dense and sparse forest) with the classes of Agriculture and Livestock, Exposed Soil, and Urban Areas for all areas of the three environments, the anthropization value of 53.14% is estimated for the Lowland environment, 42.80% for the Hill environment, and 17.30% for the Plateau environment. These results identified the Lowland environment as the most pressured by the anthropization of the different uses in the landscape and increasing the vulnerability of these areas.

In regard to the percentage of forest coverage, there is a small difference between the Lowland and Hill environments, with 46.81% and 57%, respectively. However, in the Plateau environment, 80.51% of the landscape is covered by forest vegetation, evidencing a positive relationship between the number of forest species and the increase in altitude.

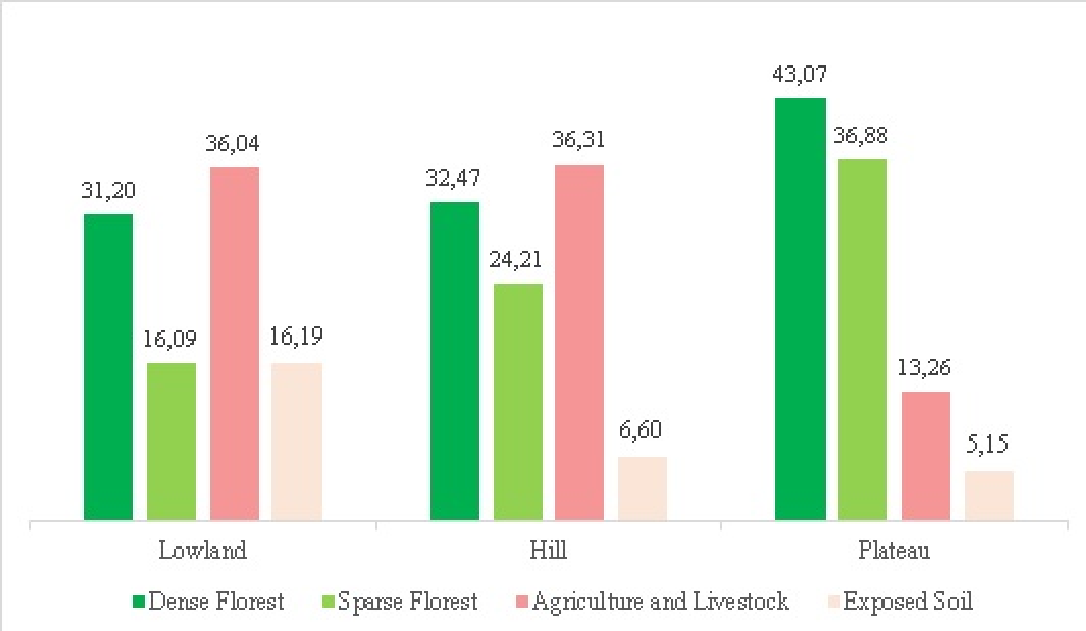

Figure 1. Average percentage of land use and land cover in lowland, hill and plateau environments in semiarid regions.

4. DISCUSSION

In the region, land use is rotated. According to personal communication with residents, after the suppression of vegetation, the exposed soil is used for agricultural cultivation. In dry periods, the area encompasses another activity, livestock, and at the beginning of the rainy season, the area that was used for grazing returns to agriculture as its main activity [21]. Residents further state that the historical form of shifting cultivation itself is a contributing factor in reducing the biodiversity of native vegetation, as farmers deforest, burn, and plant in a period of around two or three years, and then change to other areas to repeat the same practice. Thus, Brazilian semi-arid agriculture developed in the context of a disordered land occupation, with no tradition of planning and, consequently, with a disordered use of natural resources and, generally, without taking into account the equilibrium of environmental systems [6].

This lack of planning is evidenced in the Lowland environment, especially in B1 area, resulting in remnants immersed in a non-forest matrix, because of the combination of the Exposed Soil and Agriculture and Livestock classes that makes up 63% of the total area. Thus, it is defined as a matrix because the elements in question consisted of more than 50% of the total area analyzed [12].

B2 and B3 areas have similar low values for the Forest class and even if the numbers indicate that these two areas are inserted in a forest matrix, this amount of Forest is extremely low. According to [8], these values contribute to the increase of degraded areas susceptible to soil erosion, because these areas of exposed soil are former pastures transformed into desertified areas due to overgrazing.

This disorderly use of resources promotes degradation, and other authors highlight this issue. [22], [1], [7], [20] state that the forest coverage of the semi-arid region has been reduced over the years. The deforestation of the native vegetation of the region has different uses and one of them is in the use of firewood for the industry [18], leading to type conversion.

In addition, the Permanent Preservation Areas of the streams and bodies of water in the studied landscapes also suffered since agricultural and livestock farming is notorious in the margins of the rivers because their greater humidity and flat areas present greater fertility opportunities. As a consequence of this removal of the vegetation, the bare areas were voluntarily replaced by the exotic species Algaroba (*Prosopis juliflora* (Sw.) DC.), which according to [18], is disseminated by animals that consume the fruit (pod) and drink water at the edge of the waterways.

In the Hill environment areas E1 and E3 hold the lowest percentage of Forest, which is related to their proximity to urbanization. Population increase leads to an increase in vehicular traffic, the introduction of residential, commercial and industrial areas, as well as the opening of local roads, which can interrupt the movements of animals that are seed dispersers. Furthermore, this increase interferes with natural drainage, waterproofing the soil, reducing feed to aquifers, and producing solid waste that, when not intended and/or not properly collected, becomes a risk not only to human health, but also to coverage [19].

However, the E2 area is not introduced in an urban perimeter and presents the matrix of native vegetation in this area, which acts as a filter for the movement of species by the landscape. In addition to the urban actions, in these semi-arid regions the climate is quite irregular with low rainfall and prolonged dry periods, which exerts more pressure on the vegetation coverage and adds to the extraction of wood, construction of houses and/or roads, and the expansion of agriculture and livestock. All of these processes further damage the native forests, resulting in fragments immersed in non-forest matrices.

Plant and animal populations immersed in these matrices are imbalanced by reducing the number of specialized taxa since groups with low dispersibility are particularly sensitive to reducing the connection between the fragments, so a smaller distance in the landscape can be a limiting factor for the movement of some species [14].

The Plateau environment demonstrates the opposite results of the other two environments; the areas in the Plateau environment exhibit minimal Exposed Soil and Agricultural and Livestock class land, yet the Forest class features prominently. These good results are due to the Forestry Policy of the State of Pernambuco [17], which establishes that forests and other forms of natural vegetation located at altitudes above 750 meters are considered Permanent Preservation Areas. The results of the Forest category in this environment and shows the importance of intervening in this accelerated process of devastation of native vegetation due to the irrational use of this natural resource.

Despite this protection, still vegetation removal is quickly and progressively replaced by pasture and agriculture areas [2], mainly by cassava (*Manihot esculenta* Crantz) crops that contribute to the livelihood of local residents.

Thus, the distribution of vegetation in the environment is associated with climatic factors, the physiographic characteristics of the terrain, and the anthropic activities. In the case of the Brazilian semi-arid region, there are major changes in vegetation coverage because of the regional climate's two well-defined seasons: the dry season and the rainy season. These alterations are due to the poor distribution of rainfall in the time and space during the year, where different rainfall rates are observed between two seasons, summer (rainy) and winter (dry), providing rapid responses to environmental changes. However, anthropic action has intensified the degradation of the environment in recent decades with humanity's unbridled search for natural resources being carried out without any awareness or planning.

5. CONCLUSION

The natural vegetation of the semi-arid region is quite fragmented due to the disorderly suppression and the rotation of land use and occupation. This fragmentation occurs mainly in the Lowland environment, which has low altitudes, facilitating this process of replacing forest areas.

There is a lower degree of anthropization in the tops, demonstrating that in the Plateau environment a greater density of native vegetation persists, and a lower density exists in the Lowland Environment. Thus, the vegetation density native to the semi-arid region is connected to the altitudinal gradient. That is, the fragmentation of the native vegetation changes with respect to the altitudinal gradient, since the higher the altitude, the greater the connectivity of the fragments, and consequently, the greater the forest coverage.

The functionality of the natural areas will be compromised due to the reduced connectivity of the fragments if this exploitation is continued. For this reason, public policies are needed to stop this process, aiming at a more sustainable usage of forest products timber and non-timber. In addition to the recovery and maintenance of the permanent preservation of the areas in this region, such policies are highly relevant for the improvement of the integrity of the landscape.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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