Analysis of vegetation dynamics using the normalized difference vegetation index (NDVI) at the archipelago of Fernando de Noronha, Pernambuco, Brazil

Análise da dinâmica de vegetação utilizando o índice de vegetação de diferença normalizada (NDVI) no arquipélago de Fernando de Noronha, Pernambuco, Brasil

Análisis de la dinámica de vegetación utilizando el índice de vegetación de diferencia normalizada (NDVI) en el arquipélago de Fernando de Noronha, Pernambuco, Brasil

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Abstract: Island environments have specific biotic and abiotic characteristics, as fragility, limitation of natural resources, geographic isolation, and fragmentation are determining factors that directly affect these areas. Thus, it is relevant to understand the natural evolution of the landscape in the islands, considering the anthropic actions and climate changes in the transformation of vegetation cover, as a means of time series and study of satellite images. This paper aims to analyze the dynamics of the landscape (changes in vegetation cover) of the Fernando de Noronha Archipelago concerning urban development, and other anthropic activities that occurred between 1999 and 2018, through remote sensing images, to establish comparisons with the Island Management Plans that were elaborated in the years of 2005 and 2017. Also, this study intends to raise elements to assist in the spatial management of the Archipelago and to establish Public Conservation Policies for Fernando de Noronha and other island areas. Images from Landsat 7 and Landsat 8 were obtained for scenes from 1999 and 2017, respectively. These images were preprocessed and analyzed in Quantum GIS 2.18 software. And applied the NDVI calculation. It was also used the database found in the sustainable management plan of the archipelago provided by the state government of Pernambuco. With these data, it was possible to diagnose a vegetative growth on the island of about 45.36% in 17 years corroborating with the changes found in the data coming from the island's management plan. However, there are no changes in the phytosociological diversity of the island, this cause is pointed out to the invading and ruderals species of the island that are established and propagate.

Keywords: environmental impact; land use; vegetal cover.

Resumo: Ambientes insulares têm características bióticas e abióticas específicas, pois a fragilidade, limitação de recursos naturais, isolamento geográfico e fragmentação são fatores determinantes que afetam diretamente essas áreas. Assim, é relevante compreender a evolução natural da paisagem nas ilhas, considerando as ações antrópicas e as mudanças climáticas na transformação da cobertura vegetal, por meio de séries temporais e estudo de imagens de satélite. Este trabalho tem como objetivo analisar a dinâmica da paisagem (mudanças na cobertura vegetal) do Arquipélago de Fernando de Noronha em relação ao desenvolvimento urbano e outras atividades antrópicas ocorridas entre 1999 e 2018, por meio de imagens de sensoriamento remoto, e estabelecer comparações com Planos de Manejo da Ilha, que foram elaborados nos anos de 2005 e 2017. Além disso, este estudo pretende levantar elementos para auxiliar na gestão espacial do Arquipélago e estabelecer Políticas Públicas de Conservação para Fernando de Noronha e outras áreas insulares. Imagens do Landsat 7 e Landsat 8 foram obtidas para cenas de 1999 e 2017, respectivamente. Essas imagens foram pré-processadas e analisadas no *software* Quantum GIS 2.18 e aplicado o cálculo do NDVI. Também foi utilizado o banco de dados encontrado no plano de manejo sustentável do arquipélago fornecido pelo governo do estado de Pernambuco. Com esses dados, foi possível diagnosticar um crescimento vegetativo na ilha de cerca de 45,36% no período de 17 anos, corroborando as alterações encontradas nos dados provenientes

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do plano de manejo da ilha. No entanto não há mudanças na diversidade fitossociológica da ilha, esta causa é apontada para as espécies invasoras e ruderais da ilha que são estabelecidas e se propagam.
Palavras-chave: impacto ambiental; uso da terra; cobertura vegetal.

Resumen: Los ambientes de las islas tienen características bióticas y abióticas específicas, ya que la fragilidad, la limitación de los recursos naturales, el aislamiento geográfico y la fragmentación son factores determinantes que afectan directamente estas áreas. Por lo tanto, es relevante comprender la evolución natural del paisaje en las islas, considerando las acciones antrópicas y los cambios climáticos en la transformación de la cubierta vegetal, como un medio de series de tiempo y estudio de imágenes de satélite. Este trabajo tiene como objetivo analizar la dinámica del paisaje (cambios en la cubierta vegetal) del Archipiélago de Fernando de Noronha en relación al desarrollo urbano y otras actividades antrópicas ocurridas entre 1999 y 2018, por medio de imágenes de sensoriamiento remoto, y establecer comparaciones con Planes de TV Manejo de la Isla, que fueron elaborados en los años 2005 y 2017. Además, este estudio pretende levantar elementos para auxiliar en la gestión espacial del Archipiélago y establecer Políticas Públicas de Conservación para Fernando de Noronha y otras áreas insulares. Las imágenes del Landsat 7 y Landsat 8 fueron obtenidas para escenas de 1999 y 2017, respectivamente. Esas imágenes fueron preprocesadas y analizadas en el software Quantum GIS 2.18. Y se aplicó el cálculo del NDVI. También se utilizó la base de datos encontrada en el plan de manejo sustentable del archipiélago proporcionado por el gobierno del estado de Pernambuco. Con esos datos, fue posible diagnosticar un crecimiento vegetativo en la isla de cerca del 45,36% en el período de 17 años, corroborando las alteraciones encontradas en los datos provenientes del plan de manejo de la isla. Sin embargo, no hay cambios en la diversidad fitosociológica de la isla, esta causa se apunta a las especies invasoras y ruderales de la isla que se establecen y se propagan..
Palabras clave: impacto ambiental; uso de la tierra; cubierta vegetal.

1 INTRODUCTION

Island environments have specific biotic and abiotic characteristics, as fragility, limitation of natural resources; geographic isolation and fragmentation are determining factors that directly affect these areas. Thus, there are ecological vulnerabilities that occur in small islands, mainly by the anthropic actions (FERNANDES; PINHO, 2017). In this perspective, it is relevant to understand the natural evolution of the landscape in islands, considering the human actions and the climatic changes in the transformation of the vegetal cover (BUSTAMANTE *et al*., 2014). Thus, vegetation is under the direct influence of human activities, biotic interactions and environmental changes that, together or separately, and depending on the potential impact of these factors, can change ecosystem characteristics (CAÑELLAS-BOLTÀ *et al*., 2016). Study the island territories, with geographic isolation, as true “experimental laboratories” for a deeper analysis of the progression of biocenotic parameters and biotopes, since they are areas with high sensitivity and low resilience (BURJACHS *et al*., 2017).

Plant suppression in biomes, ecosystems, and tropical forests can cause climate change at local, regional, and global scales. In Brazil, since the colonization, the processes of use and occupation of the soil change the vegetal cover. In addition, colonization in this country characterized as exploitation, and the indiscriminate elimination of natural resources occurred. This colonization was not of the settlement, where the populations have the conservation of the environment as a relevant value (LAPOLA *et al*., 2015).

Analyzing the decline in the stock of natural resources in islands over a given period, especially in relation to the removal of vegetation, can guide and/or assist decision makers and stakeholders in the recovery of degraded areas, conservation, preservation, environmental diagnosis and prognosis (RÊGO; SOARES-GOMES; SILVA, 2018). Montenegro *et al*. (2018), studying the infiltration of water and soil erosive potential, highlights the importance of defining local strategies for soil and water conservation aimed at water security on the island. A study carried out for the process of planning seed collection and seedling production for restoration, especially where the Ecological Restoration process occurred in the Archipelago, performing a preliminary survey of flowering and seed production (MACHADO *et al*., 2013). Also understanding the landscape dynamics of island environments is relevant to establish actions that focus on the capacity of each environment support (SANTANA-CORDERO *et al*., 2017).

Facing this problem, the use of technological tools (remote sensing, geoprocessing) to diagnose the current situation of environmental degradation of different biomes and ecosystems, as well as, the evolution of plant suppression in different environments, is necessary to identify the causes and the consequences of these processes and indicate/establish solutions. Therefore, mapping with the use of these technologies will provide information on the change in the dynamics of the loss of vegetation cover, being fundamental in the implementation of programs and plans for conservation and environmental preservation (KLERK; BURGESS; VISSER, 2018).

These environments are considered recent because they are located in the tropical region of the South Atlantic Ocean and constitute one of the most important biodiversity hotspots in the world (HACHICH *et al*., 2015; BARROSO *et al*., 2016), and can provide ecological insights on resilience against climate change of the oceanic islands (LEÃO *et al*., 2016; SOARES *et al*., 2017). The United Nations Educational, Scientific and Cultural Organization (Unesco) has considered the archipelago as a Natural Heritage of Humanity, since 2001. These islands have productive ocean waters (TCHAMABI *et al*., 2017), which are important for the life cycle of fish, endangered chelonians and marine mammals (UNESCO, 2017). However, this marine ecoregion has increased human impact, increased fishing, navigation and climate change pressures (acidification of the oceans, sea surface temperature and rising sea levels), factors that influence local biocenosis (SOARES, 2018).

Studies on the vegetation dynamics of the main and single inhabited island of the Fernando de Noronha Archipelago are a fill reduced, since the researches developed analyze significant data on the flora and the fauna, but do not study the dynamics of the vegetation in response to the changes (RIDLEY, 2009, VITAL; GIANCOTTI; PURSELL, 1991, BATISTELLA, 1996, ABDALA, 2008). Pessenda *et al*. (2008), in a study on paleovegetation in the Archipelago, from the Middle Holocene, suggest that the climate, sea level oscillations and anthropogenic events were the main factors for vegetation changes in the last five hundred years. The Normalized Difference Vegetation Index (NDVI) frequently used in remote sensing studies. This index has a range of values between-1 and +1, where, in general, the value 0 (Zero) means the soil strip and values above 0 indicate the presence of vegetation (SAKUNO; KUNII, 2013). When below zero, this index points to non-vegetation surfaces, such as clouds, water, ice (SAHEBJALAL; DASHTEKIAN, 2013). Therefore, NDVI, or even only the use of the near infrared band, Band 4- LANDSAT 7 and Band 5- LANDSAT 8 (UNITED STATES GEOLOGICAL SURVEY [USGS], 2013), will be enough to differentiate vegetation from water (LUO *et al*., 2016).

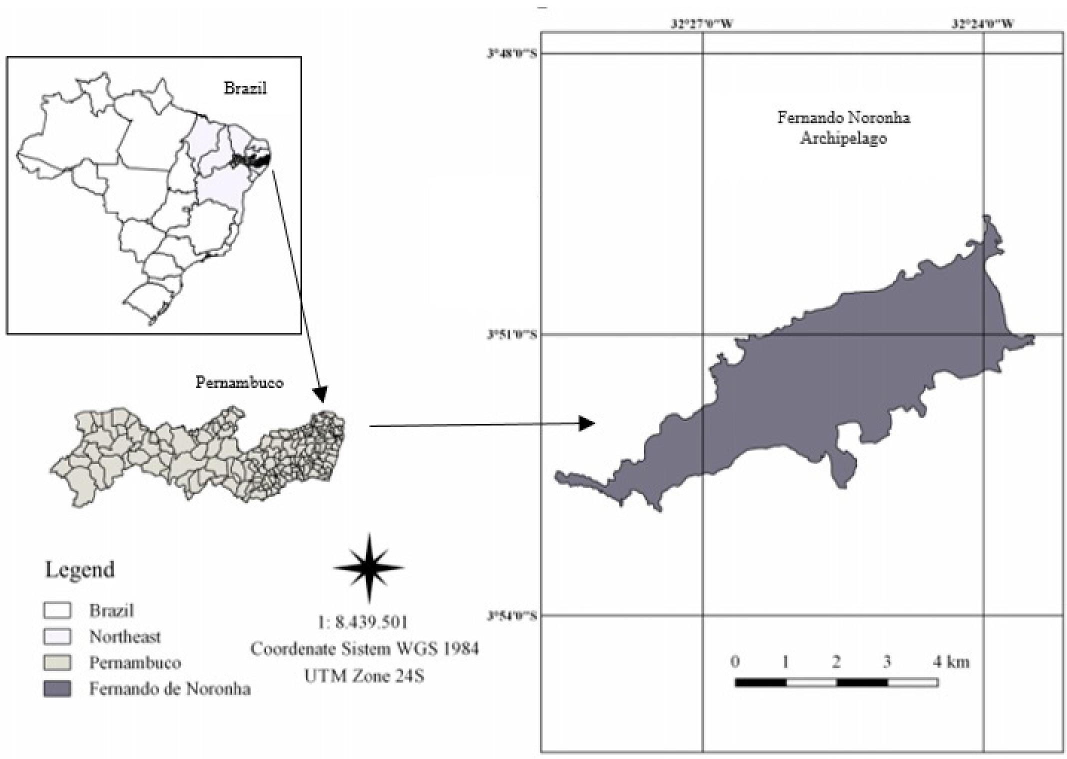
Thus, the objective of this study was to analyze the dynamics of the landscape (changes in vegetation cover) of the Fernando de Noronha Archipelago in relation to urban development and other anthropic activities that occurred between 1999 and 2018, through remote sensing images, and establish comparisons with the Island Management Plans that were elaborated in the years of 2005 and 2017. This article also aims to raise elements to assist in the spatial management of the Archipelago and to establish Public Conservation Policies for Fernando de Noronha and other island areas. Images from Landsat 7 and Landsat 8 were obtained for scenes from 1999 and 2017, respectively. These images were preprocessed and analyzed in Quantum GIS 2.18 software. And applied the NDVI calculation. It was also used the database found in the sustainable management plan of the archipelago provided by the state government of Pernambuco. With these data, it was possible to diagnose a vegetative growth in the island of about 45.36% in the period of 17 years corroborating with the changes found in the data coming from the island's management plan. The results and discussion present historical data on the occupation of the archipelago, associated with the impacts on environmental quality. Going through numerous occupations, they changed the activities there. The alteration of Shannon Index is discussed, demonstrating important changes in biodiversity, with the presence of invading species.

2 METHODOLOGY

2.1 Characterization of the area and study

The Fernando de Noronha Archipelago (Figure 1) is considered as a World Heritage Site by the United Nations (UNESCO, 2001). It is located 40 degrees below the Equator Line, with coordinates 03°50'41''S of latitude and 032°25'36''W of longitude and with distance 545 km of the city of Recife, capital of the State of Pernambuco, Northeast of Brazil. According to the Ministry of the Environment (MINISTÉRIO DO MEIO AMBIENTE [MMA], 2017), this island environment is internationally known for the natural landscapes and paradisiacal beaches, composed of 21 islands, islets and cliffs that occupy an area of approximately 26 km², of which 17 km² correspond to the main island, only inhabited.

Figure 1- The geographic location of the Fernando de Noronha Archipelago



Source: The authors.

Fernando de Noronha is an island of volcanic origin (JOHNSON *et al*., 2018) and is part of an alignment of submarine mountains, distributed along a strip with East-West direction, extending from the Atlantic Dorsal to the Brazilian Continental Shelf. The climate is tropical, Aw (Köppen-Geiger) (BECK *et al*., 2018) and has an annual average rainfall of 1,351 mm, since this environment is close to the Equator and has two well defined seasons (rainy and dry). According to the Brazilian Institute of Environment and Natural Resources (INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS NATURAIS RENOVÁVEIS [IBAMA], 2005), the average temperature is 26.7° C. Thus, climate, topography, substrate and anthropic action in the region have a direct influence on floristic composition, structure vegetation, and phytosociology (MMA, 2017).

Law n. 9.985 (BRASIL, 2000), which establishes the National System of Conservation Units, determines the objectives for the two Federal Conservation Units of the archipelago. (i) Fernando de Noronha National Marine Park (Parnamar/FN), which characterized as Integral Protection, since its main objective is to preserve nature, being allowed only the indirect use of the natural resources. (ii) Environmental Protection Area (EPA), which characterized as Sustainable Use, where the main objective is to reconcile nature conservation with the conservation of a portion of natural resources. This Panamar/FN is one of the 11 Marine protected areas in the coast of Brazil (BRANDÃO; MALTA; SCHIAVETTI, 2017).

The Parnamar was created by Presidential Decree n. 96.693 (BRASIL, 1988) and has the objective of preserving marine and terrestrial ecosystems, fauna, flora, and other natural resources, providing controlled opportunities for visitation, leisure, environmental education, and scientific research. Access to this area is more restricted since only the indirect use of natural resources is allowed. The APA/FN was created by the State Decree n. 13.553 (PERNAMBUCO, 1989) and has the objective of protecting ecosystems, reconciling human occupation with the elevation of environmental quality, allowing the direct use of natural resources, conditioned to the Management Plan, since this consists of a conservation unit of use sustainable development. In this way, access to this environment is restricted, monitored by the competent environmental agencies, so that the APA objectives are met (MMA, 2017). This archipelago has 1550 km2 of territorial sea (SILVA, 2017)

In addition, because it is an isolated continental environment, has unique characteristics, such as endemic species and the only insular mangrove in the South Atlantic. Located in the Bay of Southeast, is an environment suitable for experimenting with various hypotheses and understanding the historical and current processes of use and occupation of the soil, as well as the change of the landscape of the place over time.

Thus, the objective of this study was to analyze the dynamics of the landscape (changes in vegetation cover) of the Fernando de Noronha Archipelago between 1999 and 2018, through remote sensing images. To establish comparisons with the Island Management Plans that were elaborated in the years of 2005 and 2017. This article also aims to raise elements to assist in the spatial management of the Archipelago and to establish Public Conservation Policies for Fernando de Noronha and other island areas.

2.2 Methodological procedures

Initially, a bibliographic study was carried out on the "vegetation dynamics in insular environments". In addition, comparative documents were analyzed to evaluate the changes in the Management Plans of the Fernando de Noronha Archipelago of 2005 and 2017, in relation to the land use and occupation processes (SILVA; ALMEIDA; EL-DEIR, 2019). The satellite images were processed for temporal analysis of the vegetation cover and land use in the main island of the Archipelago, with the following methodological steps: (i) selection of the images; (ii) pre-processing of image classification (radiometric calibration and atmospheric correction); (iii) clipping area; generating (iv) the NDVI; and the final (v) maps and graphs (MINHONI *et al*., 2018).

2.3 Preprocessing of image classification

For the analysis of vegetation cover dynamics, two sets of images were selected in different years (1999, 2018), but in the same period, to avoid the influence of seasonality on the landscape, with a spatial resolution of 30m. For the first set, the LANDSAT ETM +- 7 Collection 1 Level 1 satellite was used, referring to November 1999. This equipment designed for the Earth orbit on April 15, 1999, having 7 spectral bands (Table 1) (NASA, 2015).

Table 1 – Nature of the ETM sensor of the LANDSAT-7 satellite

Spectral band	Spectrum	Wave-length (μm)
2	Green	0,525-0,605
3	Red	0,630-0,690
4	Infrared Near	0,760-0,900
5	Infrared Medium	1,550-1,750
6	Infrared Thermal	10,40-12,50
7	Infrared Near	2,090-2,350

Source: Nasa (2015).

The second set was obtained in November 2018 through the LANDSAT OLI- 8 Collection 1 Level 1 satellite, which was launched on February 11, 2013 and has two sensors *Operational Land Imager* – OLI (Table 2) and *Thermal Infrared Sensor* – TIRS, one with nine bands and the other with two bands, respectively (UNITED STATES GEOLOGICAL SURVEY [USGS], 2013). These images have been removed and are available at the *United States Geological Survey* (USGS), for free.

Table 2 – Nature of LANDSAT-8 satellite OLI sensor

Spectral band	Spectrum	Wave-length (μm)
2	Blue	0,45-0,51
3	Green	0,53-0,59
4	Red	0,64-0,67
5	Infrared Near	0,85-0,88
6	Shortwave Infrared 1	1,57-1,65
7	Shortwave Infrared 2	2,11-2,29

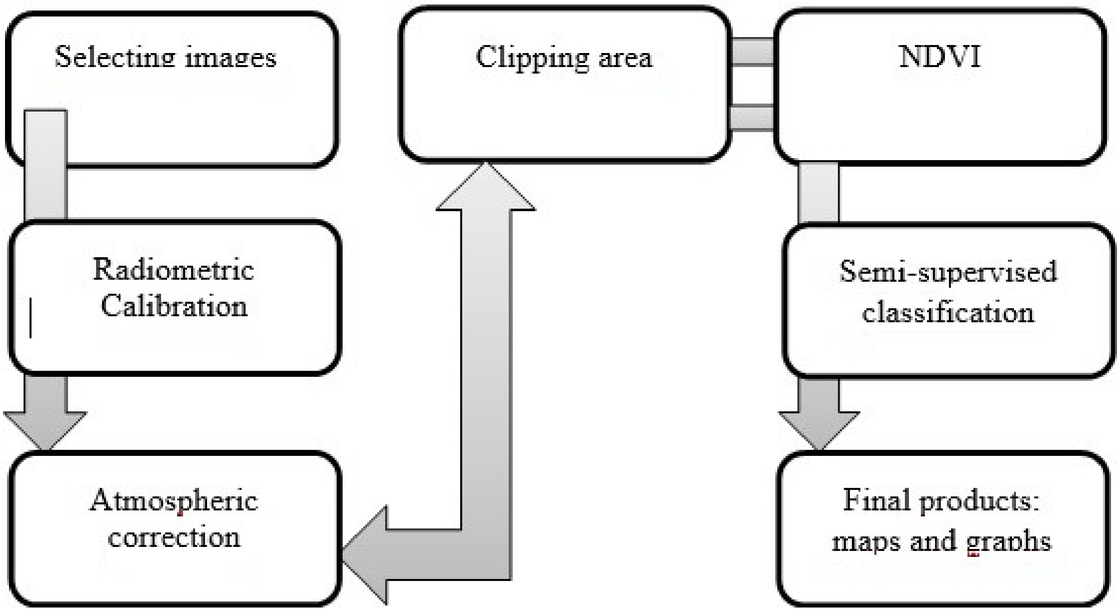
Source: Nasa (2015).

These LANDSAT satellites are of paramount importance for information on natural resources, assisting in decision making in environmental studies (NASA, 2015). The years chosen for this study were determined by meeting imaging criteria such as: the least amount of cloud and the least amount of noise in the LANDSAT ETM +- 7 Collection 1 Level 1 image, and also for representing a period before the existence of the Management of green areas for the archipelago (YANG *et al*., 2003; ZENG *et al*., 2010). The year 2018 is represented by the imagery through LANDSAT OLI- 8 Collection 1 Level 1. The latter is given for representing the earth, already in the post degradation period (after 2013, year of its launch in orbit), besides being the imaging of the most recent period for comparing changes in land use and land use estimates in the archipelago region (FLOOD, 2014; URBANSKI *et al*., 2016). The images processed in the TIFF format are located in path 213 and row 63 with a maximum cloud cover of 10%, georeferenced in the WGS84 Reference System in the GIS software Quantum GIS 2.18.

2.4 Radiometric Calibration

For the comparisons between satellite images of different periods, it was necessary to apply the atmospheric correction through the method Dark Object Subtraction (DOS1), a technique developed by Chavez Júnior (1988). This step was performed in conjunction with the radiometric calibration steps, which, in the foreground, are equivalent to the transformation of digital numbers (ND) to radiance and, subsequently, to reflectance. Due to the gross images that are projected in the Northern Hemisphere, repositioning to the Southern Hemisphere became essential. After this repositioning, the boundary of the bands used was manually defined, which was used to cut the area of interest in the two images selected (Figure 2).

Figure 2- Flowchart of applied methodology



Source: Adapted from Minhoni (2018).

3 RESULTS AND DISCUSSION

The process of land use and occupation on the island began in 1502 upon the arrival of the sea expeditions, which initiated the variations of the environmental quality, in front of the human action of colonization (OLIVEIRA; ABREU, 2010). There is controversy regarding the discovery of the archipelago. There are records made August 10, 1503, when the flagship was wrecked, with previous records on maps. Already Americo Vespucci, in 1504, made the rescue of the castaways during the second expedition to the Brazilian coast, becoming uninhabited. This expedition was funded by Fernan de Loronha, reason for the name of the Archipelago. Expeditions followed, recording the condition of human absence in the Archipelago. In 1604, Amaral (1604) records the presence of 14 indigenous slaves under the command of a Portuguese home, thus being the first register of inhabitants in the Archipelago. Description of Nieuhof (1981) points out that in 1630 was inhabited by Dutch. For Silva (2007), Dutch ownership ranged from 1629 to 1654, with a temporary and brief occupation, only to supply the ships and stay for days, with a small fixed population of about 270 people.

The first attempts of Portuguese occupation of Fernando de Noronha by the Portuguese date from 1694, without success. At 1700 it was determined that the Archipelago would be part of the Pernambuco Captaincy, but this attempt was unsuccessful (AULER, 1946). The island was unpopulated until the French occupation at 1738, men were forced to populate the archipelago, creating the Noronha Fort System (SILVA, 2007). In 1833 it becomes a prison, which in 1865, adopts model of agricultural colony, with the stimulation of families formation and the valorization of women in the island.

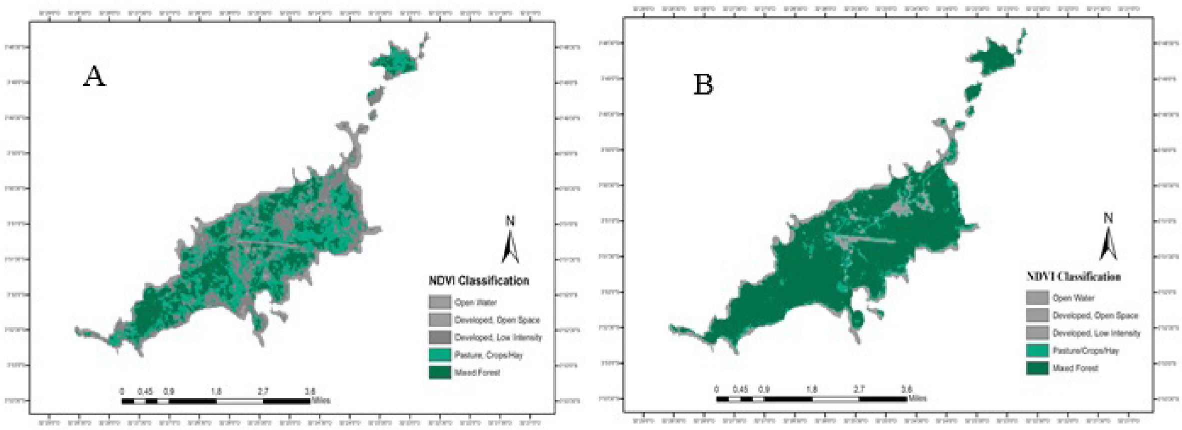
During World War II, the United States built a military base to support aircraft. With the construction of military bases, biodiversity has been changed indiscriminately and continuously, since the island was used as a form of punishment for individuals convicted of justice, becoming a prison in the twentieth century (ALBUQUERQUE, 2013). The most degrading activity in this period was deforestation, where the removal of vegetation caused innumerable environmental impacts of different orders in the environment, directly affecting the optimal process of the various animal and plant species in the ecosystems of Noronha, with the natural landscape being modified (CLETO, 2013). After the period of the great world wars, the establishment of a fixed population began in this island environment, with former military and prisoners, farmers and Indians from the interior of Pernambuco who taken to root agriculture.

Only in 1974 began commercial flights, seeking to structure the activity of tourism in the Archipelago. After 1988, the number of housing and hostel buildings increased to meet the number of residents and tourists in the region. In 1991, the population of Noronha was 1,600, in 2010 2,630 and currently its estimated that more than 3,000 people reside (IBGE, 2010; 2018). The number of tourists has increased from 5,900 in 1991 to 104,000 in 2018. (AUTARQUIA TERRITORIAL DO DISTRITO ESTADUAL DE FERNANDO DE NORONHA [ATDEFN], 1991 2019). Vegetation dynamics influenced by climatic and anthropogenic factors that have implications for the ecological, social and cultural history of island environments (RULL *et al*., 2015). Currently, the number of tourists and residents on the island already exceeds the Supportability Study- ECS (MMA, 2008). The ECS points out that with the island's fixed and fluctuating population increase, there is habitat loss, deforestation, disordered land use, favelization and the introduction of invasive species.

According to Costa *et al*. (2012) and Cleto (2013) the biodiversity was changed with exotic trees to Fernando de Noronha, resulting from anthropic actions. In a study by Silva Júnior *et al*. (1987), the low floristic diversity was observed, as evidenced by the Shannon index of H'=1.95. This is an expected feature for island ecosystems, where natural colonization depends on seed dispersal, dispersion agents, seed viscosity, distance from the dispersion center, and other factors (MELLO, 2014). Such data on native tree species indicate that this archipelago is a fragile ecosystem, especially when considering a large number of existing invasive species (BARCELLOS *et al*., 2011).

The first vegetation study of the island occurred in the late 19th century, with the identification of 182 species, distributed in 43 families, Among these, 44 exotic species were observed, which marked the first identification of non-endemic species of the archipelago (RIDLEY, 2009, PERNAMBUCO, 2009). Studies of Batistella (1996) have shown that there are 60 main dominant plant species, 33 herbaceous, 12 low woody (less than 2m) and 15 tall woody species (more than 2m) and with barochory seed dispersal like *Leucaena leucocephala*. These spatially divided into two groups. (i) Known distribution, ubiquitous species (with wide distribution in the island, do not present their spatial distribution associated to a particular ecological factor or determined local), leeward, windward, coastal, areas interior, of forested areas and of isolated occurrence. (ii) Unknown distribution, especially species of the family Convolvulaceae, invasive and planted or ornamental species (BATISTELLA, 1996). If the floristic densification observed in the Fernando de Noronha Archipelago in 1999 and 2018 (Figure 3), we can observe several points without vegetation that constitutes a surface with water or exposed soil.

Figure 3- Forest coverage's Fernando de Noronha island at 1999 (A) and 2018 (B)



Source: The authors.

The increase of the vegetation cover of the island can identified in the images in this space-time of 19 years. However, this growing evolution of the natural landscape should not be associated with only positive environmental impacts. The number of scientific researches focusing on invasive species in the archipelago has increased, given the increasing number of these in the insular environment. The problem of biodiversity loss and increasing the number of dominant individuals, making the density of vegetation on the island larger (PERNAMBUCO, 2009; SERAFINI; FRANÇA; ANDRIGUETTO-FILHO, 2010; SAMPAIO; SCHMIDT, 2013). The variations of the composite vegetative cover of mixed forest were expressive, with a decrease of Pasture/Hay/crops. However, the Open Water area presented a percentage reduction of area, a fact that can be explained by the high eutrophication of the Xareu Weir, which is decoded by the satellite images as spectrometry similar to vegetation (Table 3).

Table 3 – Changes in land use and coverage of the Fernando de Noronha Archipelago in 1999 and 2018

Classes	1999			2018			Evolução		
	Point/ Pixel	Hectare	Total área (%)	Point/ Pixel	Hectare	Total área (%)	Point/ Pixel	Hectare	Total área (%)
Open Water	1478	133.02	7.02	527	47.43	2,5	-951	-85.59	-4.52
Developed Open space	1847	166.23	8.77	1716	154.44	8,15	-131	-11.79	-0.62
Developed Low Intensity	5515	496.35	26.2	1425	128.25	6,77	-4090	-368.1	-19.43
Pasture/Hay/crops	7035	633.15	33.42	2659	239.31	12,63	-4376	-393.84	-20.79
Mixed Forest	5175	465.75	24.58	14723	132.,07	69,94	9548	859.32	45.36
Total	21050	1894.5	100	21050	1894.5	100			

Source: The authors.

In total, an area of 1894.5 ha was evaluated, and at 1999 the mixed vegetation of this insular environment presented 465.75 ha of the total area, while the other uses and occupations of the soil 1,428.75 ha. At the end of the twentieth century, the zoning of this island environment was incipient and limited, as there had been no Island Support Capacity Study to support decision-making. The first Management Plan of the Environmental Protection Area (IBAMA, 2005) promoted standards for the use of natural resources and zoning since each zone had specific objectives for land use and occupation, as well as the use of common property. Since then, projects focused on the sustainability of the island (ICMBIO/MMA, 2009; ICMBIO, 2011), where activities of reforestation and environmental education were intensified to restore the ecosystems present.

Based on several existing conflicts in certain areas and the need to establish actions to reduce negative environmental impacts caused by invasive species, the reformulation of this document was necessary. However, this has reduced the preservation and conservation areas of the archipelago, increasing the territorial extension of other areas. The area that was most enlarged, to the detriment of others, was the urban one. This increased from 9.98% of the land area of the Environmental Protection Area (EPA) in 2005 to 17.79% in 2017 (Table 4). This shows the increasing population increase on the island (MMA, 2017).

Table 4 – Variations of the zoning between the Management Plans

Nomenclature	EPA area (%) 2005	EPA area (%) 2017	Differences (%)
Wildlife Protection	23.88	23.48	0,40
Conservation	46.08	37.75	8,33
Recovery	6.74	4.01	2,73
Historical-Cultural*	0.00	0.80	+0,8
Agriculture and Livestock	4.61	3.90	0,71
Special Use	8.71	12.62	+3,91
Urban área	9.98	17.67	+7.69

* The data referring to the area of historical-cultural zoning counted since the limits of this zoning are inserted in the conservation zone in the EPA Management Plan of Fernando de Noronha.

Source: Modified from Ibama (2005) and MMA (2017).

After 19 years of intensive soil use and negative environmental impacts (MONTEIRO; DO SUL; COSTA, 2018) and positive, there was an expansion of areas with mixed vegetation, reaching 1325.07 ha, which represents almost 70% of the total area archipelago. This shows an increase of approximately 46% between 1999 and 2018. However, the current vegetation cover of the island can transmit to visitors and residents a preserved natural beauty, but the environmental impacts caused by invasive species in the area are diverse and negative for biodiversity of the region, giving the false impression of rich and diverse vegetation. According to Batistella (1996), Cleto (2013) and Mello (2014), Noronha presents exotic species that potentiate the elimination of most other species, altering biodiversity and being one of the main threats to the conservation of this insular environment. These were introduced from the 18th century, with the occupation of the Captaincy of Pernambuco. This promoted the destruction of the vegetation cover of all the large trees of the island, and was a preventive measures to avoid leaks through the construction of rafts, besides of the cut of the small trees had the objective of avoiding hiding places (CHAVES JÚNIOR, 2017).

Despite the relevant changes in vegetation cover during the observed time interval, the vegetation in Noronha increased with the passage of the years. However, the amount of invasive species on the island is increasing significantly. This have affects in plant dynamics and modifies the natural landscape. In this sense, it is of fundamental importance to carry out further studies in insular environments to better understand the dynamics of vegetation. Also to locate these invasive species on the island, use of environmental tools such as geoprocessing, indicators, and bioindicators of environmental quality to establish (LI *et al*., 2018) that the human action proves in this environment.

4 CONCLUSION

Vegetation suppression activities in the Fernando de Noronha archipelago promote habitat loss and change in local biodiversity, with negative implications. Zoning variations in management plans identify the loss of conservation and environmental preservation areas. Moreover, given the demographic explosion observed in recent decades on the main and only inhabited island, there is the expansion of the urban area and other areas that support population growth and tourism.

The use of environmental geoprocessing and remote sensing of natural resources proved to be fundamental in the diagnosis and evolution of the local landscape, and may provide inputs for decision makers to formulate public policies for the preservation of the environment. Despite all the changes observed since the discovery of the island, land use and land use maps explain the increase in vegetation cover. However, the island is undergoing constant biological invasion processes that may justify this increase, given that populations of invasive plant species in the archipelago are increasing and forming dense forests of exotic individuals of the same species. Considering the aspects presented, there is a trend towards conservation of the environmental protection areas of the Fernando de Noronha archipelago and a growing increase in the vegetation population, comparing the history of images 1999-2017.

The islands' sustainable management plans are from 2005 and 2017. Despite the growth of biomass, this is not necessarily an asset to the island, due to the increase of species considered invasive, and ruderals that, because they have seed dispersion and it occupies a large area in the use and occupation of the soil. Those species are stabilizing in several regions of the archipelago, reducing forest diversity and causing impacts on the phyto and sociological aspects of the study area.

Remote Sensing and Geoprocessing Techniques such as NDVI can help identify changes in vegetation throughout the years by assisting in diverse approaches, since know what is happening at the area right away, to decision making. All of those can assist in the management of invasive species in islands, aiming at the conservation and preservation of habitats in this archipelago.

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