THE USE OF GEOPROCESSING TECHNIQUES FOR THE ENVIRONMENTAL PLANNING OF THE FERNANDO DE NORONHA ARCHIPELAGO, BRAZIL

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Abstract

This paper summarizes some results obtained by a research of five years about the Fernando de Noronha Archipelago. It was carried out through the use of photointerpretation (1:10,000 scale) and digital mapping of ecological parameters, what could be done thanks to the recent development of geoprocessing in Brazil. After the delimitation of the physical environment and of the vegetation physiognomy, the data gathering envolved also field surveys, including the application of 618 pre-codified questionnaires with 54 variables each, and the collection of 128 soil samples. The cartographic treatment comprised the elaboration of a digital elevation model, conversion of topological formats, slicings, reclassifications, overlays, and area measurements. The results included analytical and synthetic maps related to the main physical, vegetal and anthropic variables of the landscape. This contribuition intends to provide some scientific elements for the ecological conservation and economic development of the Fernando de Noronha Archipelago.

1. INTRODUCTION

Until few years ago, Fernando de Noronha was known as a distant land, just reached by the local population, the researchers and the administrators.

Since its discovering in 1503 by Americo Vespucci, this Equatorial Atlantic Archipelago has a history of drastic land use and ecological changes, victim of several economic, politic and personal interests.

In the last decade, for instance, the Archipelago was administrated by the Brazilian Army, the Department of Interior and also by the State of Pernambuco. Each one of these institutions had their own strategies and priorities for the use of the renewable resources.

The first attempt for the land use planning of these islands occured in 1988 with an Agroecological Zoning, made by the Brazilian Agency for Agriculture Research (EMBRAPA) and the NGO Ecoforça. Five months later, part of the Archipelago became a Marine National Park, that included 70% of the terrestrial ecosystems.

With the media appeal about the "Atlantic's Paradise", the touristic activities increased a lot, changing once more the local socioeconomic dynamics.

However, there was few information about the biotic portion of the terrestrial ecosystems. Certanly, this paper does not intend to exhaust this subject, but to begin the discussion about the landscape ecology of Fernando de Noronha through the use of some geoprocessing tools.

2. MATERIAL

2.1. Study area

The Fernando de Noronha Archipelago is located at 3° 50' S and 32° 24' W geographic coordinates, 345 Km far from the nearest point on the Brazilian coast (Figure 1). With 17 small islands (1926 ha), it represents the remainings of a 4000 m tall volcanic building (Almeida, 1958).

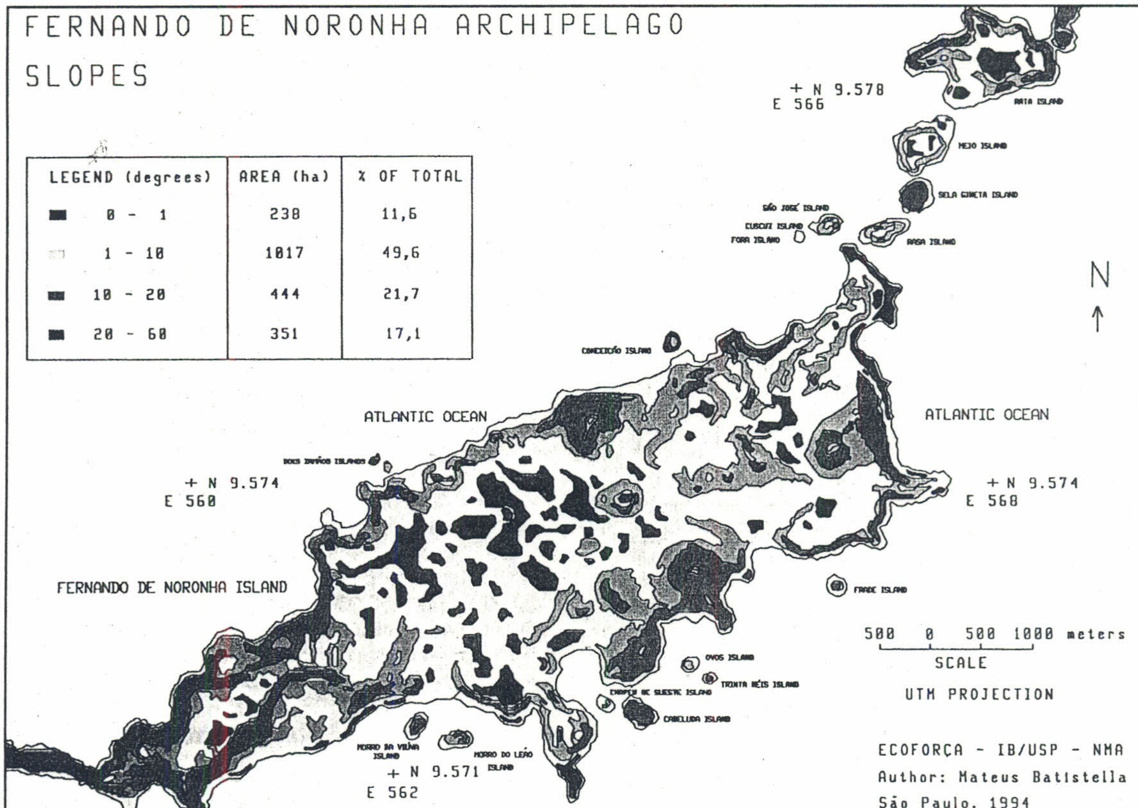
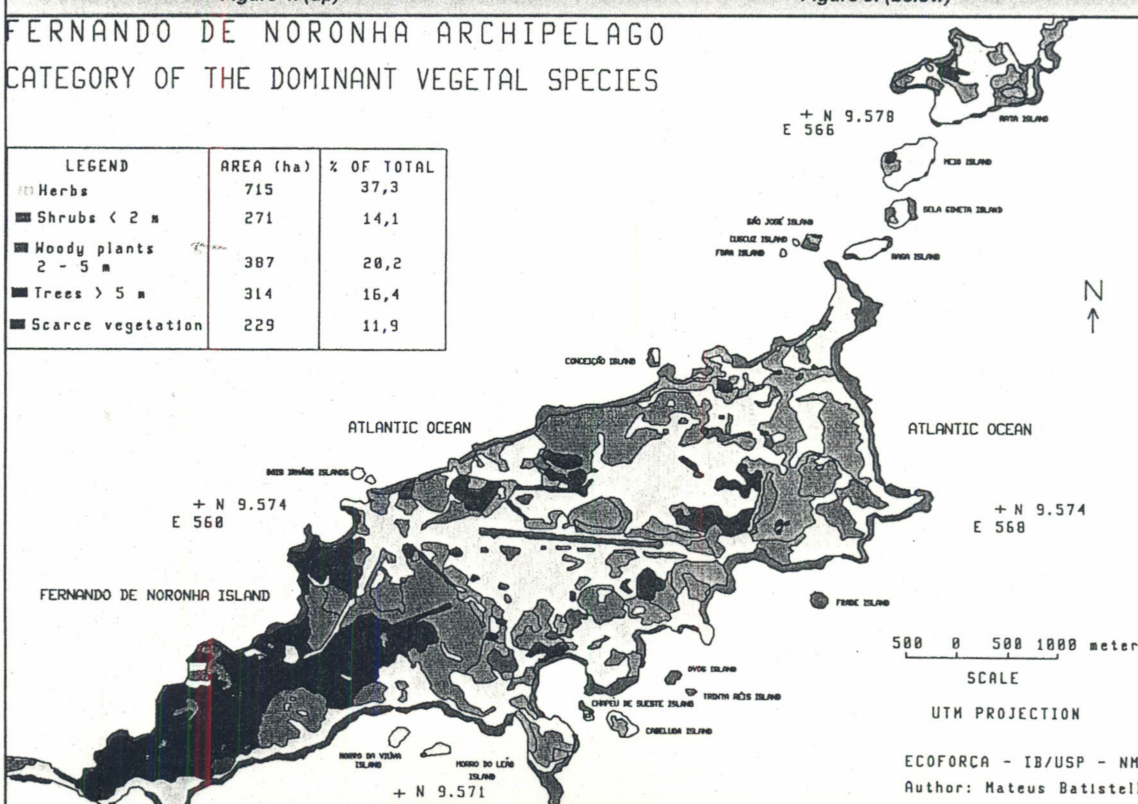


Figure 4. (up)

Figure 5. (below)



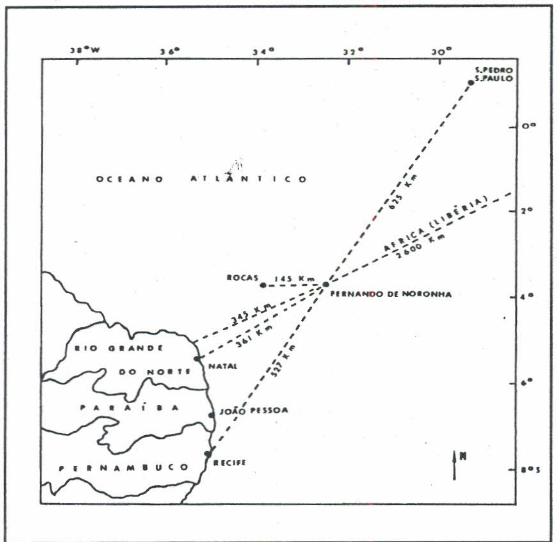


Figure 1. Location of the Fernando de Noronha Archipelago on the Atlantic Ocean.

The biggest island (1766 ha) is also called Fernando de Noronha. It's the only Brazilian oceanic island inhabited for more than four centuries.

The temperature annual average is about 25° C. The monthly averages are also high, making the annual termic amplitude lower than 2° C. The precipitation annual average is about 1400 mm, but with a large interannual variation. The seasons are well defined and the rainy period goes from March to July. The evaporation is very high, due to the equatorial radiation and the intense ESE winds.

The present geomorphology is a consequence of the climatic, marine and fluvial actions over the volcanic substratum, varying from sandy or basaltic plateaus to amazing cliffs (Figure 2).

As for the biological aspects, Fernando de Noronha has several endemic species, but low faunistic and floristic richness. Probably, the distance from continents, the unfavourable maritime currents and winds, the small surface and the semi-arid climate are the main causes of this poor biodiversity.

The singular features of these insular systems and the recent touristic activities stimulated the generation of an ecological cartography of the Archipelago, as a basis for an equilibrium between the economic development and the environmental conservation.

2.2. Bibliographic, cartographic and photographic data

About 800 bibliographic titles were catalogued in DBase files, helping the automatic search and retrieve of these data.

The cartographic base at 1:10,000; 1:15,000; 1:20,000; and 1:50,000 scales was classified in accordance to its priorities of use.

The panchromatic aerial photos (1:10,000) were the main primary data for the cartographic delimitation.

2.3. Equipments, digital system and softwares

During five field expeditions, several equipments were used: compass, altimeter, thermometer, pH paper, auger, binocular, photographic cameras, etc.

The lab equipments included a zoom stereoscope; a PC 486 with 180Mb hard disk, 5.1/4" e 3.1/2" drives, 8Mb

Figure 2. Typical scene of Fernando de Noronha Archipielago showing different relief variations

RAM and a coloured video terminal; a graphic board UVI-340; a Super VGA high resolution video terminal, for images display; an A_0 digitizing tablet; an A_4 scanner; an A_0 coloured electrostatic plotter; and a laser printer.

The rectification of the photointerpreted data to the UTM cartographic base at 1:10,000 scale was made with optical instruments.

The GIS software was developed by the Brazilian Institute of Space Research (INPE) and is called SGI 2.4.

Other softwares included: WINDOWS 3.0, VENTURA PUBLISHER 3.0, MICROSOFT WORD 5.5, DBASE 4.0; QUATTRO PRO 1.01, FLOW CHARTING 3.0, NORTON EDITOR 1.3B e SCANNING GALLERY PLUS 5.0.

3. METHODS

3.1. Photointerpretation and digital cartographic base

The photointerpretation occured in two main steps: one for the physical landforms and another for the land use and vegetation phyisiognomy.

The landforms mapping process consisted of the definition of areas with the same structure, evolution and problems, by the analysis of the various components of this environment (climate, relief, material, waters, morphogenesis, pedogenesis). These territory areas are called morphopedological units or types of environment (Kilian, 1981).

For the land use, the zones with similar vegetation physiognomy were mapped (Goldsmith et al., 1986).

At this moment, all the available maps were stored into a digital base, with the same resolution and topological format.

The contour and hydrographical maps were digitized with a precision of 0.1 mm. Some zoning proposals, the geomorphologic and vegetation photointerpreted limits were also digitized.

3.2. Field surveys

The photointerpretation confirmed the environmental heterogeneity of the Archipelago at scales smaller than 1:10,000. This fact suggested the choice of a random stratified sampling (Legendre and Legendre, 1983) and the utilization of a standard questionnaire.

The questionnaire had 8 recognizing variables about the ecological site, 22 variables related to the physical environment, 17 about the vegetation and 7 related to the human influence over the environment.

At the end of the field surveys, there were 618 completed questionnaires and also the data about 128 soil samples. All these data were organized into numeric files, related to the photointerpreted polygons.

3.3. Digital cartographic treatments

3.3.1. Digital elevation model (DEM)

The contour map of Fernando de Noronha was digitized from its 10 m equidistant lines and some isolated points.

The samples were digitally organized and the DEM was generated with a rectangular grid of 45 m resolution.

This vectorial data was converted into a raster file with pixels of 15 m and 256 grey tones. Several new layers were generated by slicing operations, synthetic shading, slope generation algorithms, etc.

3.3.2. Conversion of formats and reclassifications

All the data input was made by vectors digitizing. The GIS automatic functions for the format conversion produced raster files with specific resolutions, allowing later digital handlings.

The reclassifications, for instance, were used in accordance to the field collected data (Batistella, 1993).The procedure consisted in giving a label for each polygon and making a file with association rules in ASCII. The new maps were the results of the numeric reclassifications.

3.3.3. Overlays

One of the main tools of a GIS is the possibility of integrating two or more layers.

Using boolean algorithms, the overlays were obtained with AND, OR and NO operations between the classes of the thematic maps. The results were raster files with the same resolution of the combined maps.

3.3.4. Area measurements and map generation

Although the maps store spatial information, many times it's important to get some numeric data from them (Goodchild, 1990).

After the data input and manipulation, one of the quantitative analysis options was the automatic area measurement. For each layer of the cartographic database, a table with the classes areas was produced.

The results were showed by the cartographic products and their legends.

4. THE ENVIRONMENTAL PLANNING OF THE FERNANDO DE NORONHA ARCHIPELAGO (RESULTS)

4.1. Physical variables of landscape

The physical variables of the Archipelago landscape were described with mensurable parameters and the delimitation of the essential physiographic zones or morphopedological units.

The DEM showed that the physical landscape heterogeneity is represented by several landforms: low plateaus with flat relief, cliffs, plains, valleys, etc. The highest point is a 323 m tall phonolitic hill.

The DEM permitted also 3-D visualizations (Figure 3). The grey tones simulate the amazing landscape of the Archipelago, in relation to its morphological aspects.

Slicing operations produced cartographic generalizations, showing that almost 40% of the islands surface are between 40 and 80 m high, including the main Archipelago plateau.

The slope, more than altimetry, was one of the main variables that affected the land use patterns (Batistella and Miranda, 1992). Although it varies from 0º to 60º, more than 60% of the Archipelago have slopes lower than 10º, supporting the human occupation and even the agriculture mechanization (Figure 4).

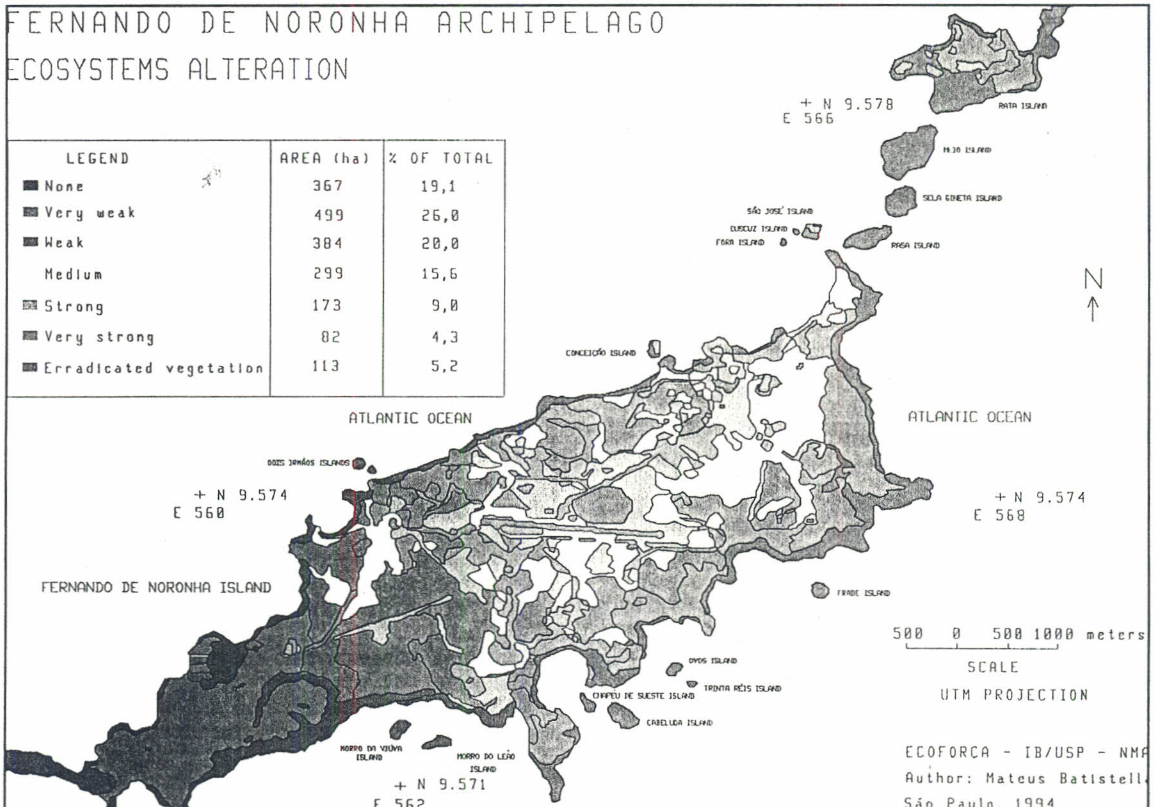
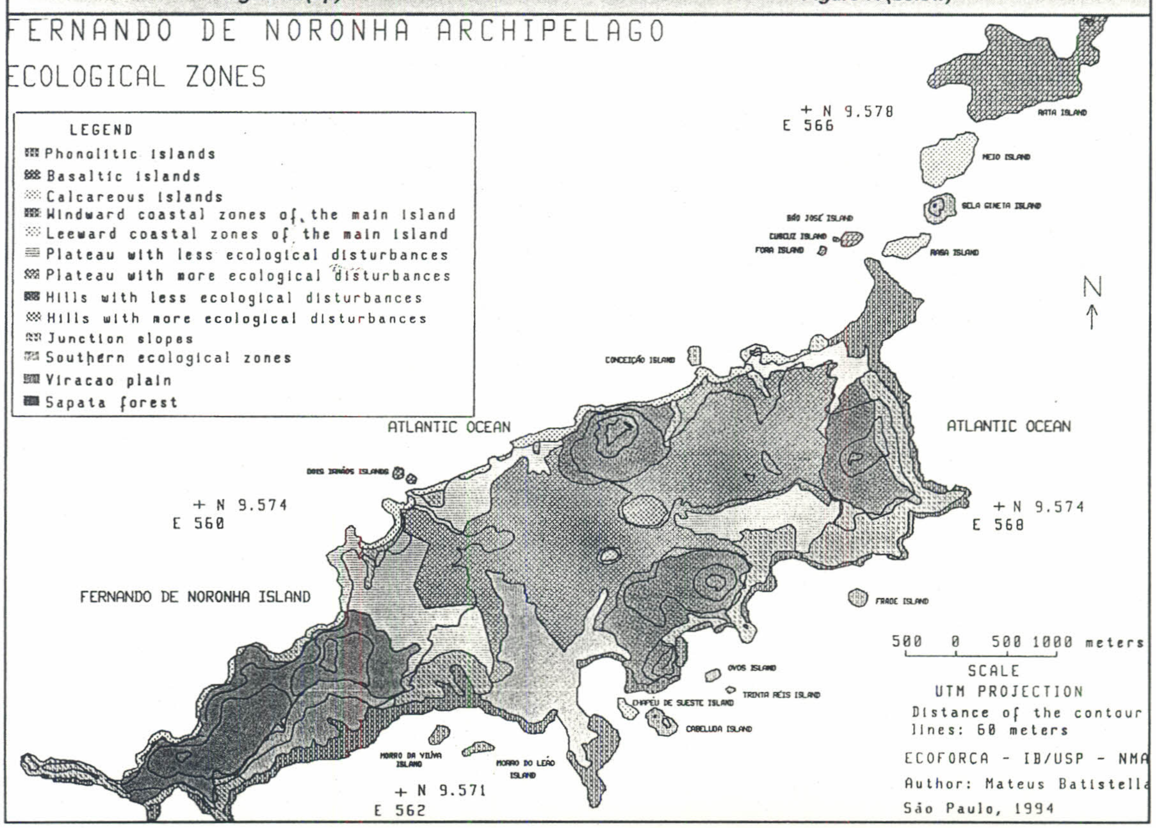


Figure 6. (up)

Figure 7. (below)



The slopes orientations were also mapped in slices of 45°. The cartographic result delimited the watersheds and classified the landforms in relation with the wind and radiation consequences.

Besides the analytical results, some synthetic maps were produced. The morphopedology, for instance, integrated the geomorphology with soil parameters and other environmental variables.

This physical landscape classification shows a relative determinism for the vegetation. The smaller islands landscapes, for example, are explained basically by their morphopedology. The phonolitic islands are rocky cliffs, with thin soils and scarce vegetation. The calcareous islands show a flat relief, with permeable soils and herbaceous vegetation. And the basaltic islands have variable reliefs, deeper and fertile soils and complex vegetal formations, with herbs, shrubs and woody plants.

On the other hand, in the Fernando de Noronha Island, the bigger surface, the greater relief heterogeneity, the geological and soils diversity, and the human activities produce more complex ecosystems.

This fact induced the study and presentation of the second part of the results: the vegetal variables of landscape.

4.2. Vegetal variables of landscape

The cartographic base integration with the field numeric data was the main tool for the vegetal landscape analysis. Using the GIS functions for polygons reclassification, about 70 maps were produced, including the vegetation types, vegetation structure, wind action, ecosystems alteration and the spatial distribution of the 60 dominant vegetal species, for example.

The herbaceous species are dominants in 37% of the Archipelago, mainly on the windward natural grasslands and on more degraded ecosystems, where the original vegetation was replaced by exotic plants. On the other hand, the higher woody plants are dominant on the southweastern areas, where the vegetation is preserved, mainly because of the relief heterogeneity (Figure 5).

All those vegetation types are influenced by natural and anthropic factors. The ESE winds, for example, produce visible effects on the vegetal physiognomy and even on the dominant species ocurrence.

The species distribution were also mapped. The results permitted the identification of the groups of species, related to their main habitats: coastal zones, plateaus, degraded areas, agriculture fields, etc.

4.3. Anthropic variables of landscape

The unplanned land use brought disturbances to the natural ecosystems of the Archipelago. The human activities induced the classification of the ecosystems alteration degrees and the phytodinamic conditions, by analytical maps.

The preserved ecosystems occur at the small islands and in great part of the coastal zones and cliffs of the main island, because of their difficulty of access. The degraded ecosystems are represented by the pasture and agriculture fields, and the areas where the vegetation was totally erradicated, like the airport, dams, roads, villages, etc. (Figure 6).

The overlay between the category of the dominant species map (Figure 5) and the ecosystems alteration map (Figure 6) showed the relation of the vegetation structure with the anthropization.

At the present time, there is a balance between the ecological preservation rules of the National Park with the increase of the touristic activities. This dynamic allowed a vegetation recuperation in several parts of the Archipelago and stronger alterations in areas intensively used by man.

4.4. The ecological zones of the Fernando de Noronha Archipelago: a synthetic approach

The present terrestrial landscapes of Fernando de Noronha are resultants of the interaction of morphogenesis, pedogenesis, and vegetation, under the climate and human influences.

In a synthetic effort, reclassifications and overlays were used to map the ecological zones or homogeneous areas that could allow interpolations and generalizations (Long and Le Moal, 1978).

At this perception level, the main variables are the topographic positions, local climate parameters (wind and radiation, for example), and surface features, as they are

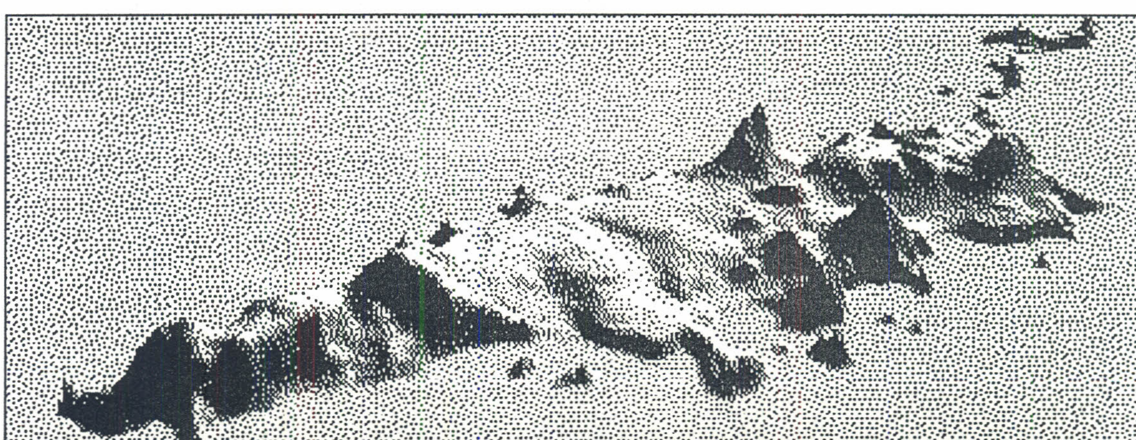


Figure 3. The Fernando de Noronha Archipelago, seen by a DEM 3-D simulation

the substratum for the vegetation. The ecosystems alteration degrees, produced by the human activities, were also analysed for each one of the different zones.

The result was the map of the ecological zones of the Archipelago (Figure 7), that identifies 13 different classes.

In the smaller islands, the difficulty of access, the reduced surface and the low potentiality for agriculture production promoted their preservation.

For the Fernando de Noronha Island, the main landscape variables can be summarized by the morphopedology (including climate factors like the wind influence), category of the vegetal species and the ecosystems alteration degrees. This last one is one of the most effective variables for the main island, influencing directly the organization of the ecological space, the vegetation and even the dominant species occurrence. The plateau zones, the hills with more or less disturbances, the junction slopes and the southeastern ecological zone are the best examples of this situation.

In the zones where the anthropic influence is weaker, other variables are more important. The coastal zones, for instance, are distinguished mainly by the winds orientation.

Other example is the Viração plain, where the physiographic isolation promotes special features of microclimate and vegetation. The Sapata forest was also preserved because of its steep relief.

5. CONCLUSIONS

The natural resources of the Fernando de Noronha Archipelago and its beatiful landscapes were always of great interest. Unfortunately, this fact does not impede the terrestrial ecosystems alteration.

The responsibility for the Archipelago administration has increased, since it is a National Park and there are environmental problems caused by the touristic activities.

This research project intended to provide some scientific elements for the environmental planning of Fernando de Noronha, through the use of geoprocessing techniques.

All the maps and the digital database are available at the EMBRAPA/NMA and the NGO Ecoforça. Certainly, the use of the results could improve, with greater objectivity, the association of the socioeconomic development with the conservation practices.

REFERENCES

ALMEIDA, F. F. M., 1958. ***Geologia e petrologia do Arquipélago de Fernando de Noronha.*** *MARA-DGM, Monografia 13, Ministério da Agricultura-Divisão de Geologia e Mineralogia, Rio de Janeiro, 181 p. il.*

BATISTELLA, M., 1993. ***Cartografia ecológica do Arquipélago de Fernando de Noronha.*** *Dissertação de Mestrado, DEG/IB-USP, São Paulo, 235 p. il.*

BATISTELLA, M.; MIRANDA, E. E. de., 1992. ***Ecologia da paisagem do Arquipélago de Fernando de Noronha.*** *In: Congresso Latinoamericano de Ecologia, 2; Congresso Brasileiro de Ecologia, 1, Caxambu, Brazil, pp.177-178.*

GOLDSMITH, F. B.; HARRINSON, C. M.; MORTON, A. J., 1986. ***Description and analysis of vegetation.*** *In: Moore, P.D.; Chapman, S. B. (eds.), 1986. Methods in Plant Ecology, Backwell, Oxford, pp. 437-524.*

GOODCHILD, M. F., 1990. ***GIS and basic research: The National Center for Geographic Information and Analysis.*** *NCGIA, Santa Barbara. 15 p.*

KILIAN, J., 1981. ***Assessment of environmental stability and instability in morphopedological cartography with a view to agricultural development.*** *University of Bern, Bern, 10 p.*

LEGENDRE, L.; LEGENDRE, P., 1983. ***Échantillonnage et traitement des données. In: Frontier, S., 1983. Stratégies d'échantillonnage en écologie.*** *Masson, Paris, 494 p.*

LONG, G.; LE MOAL, Y., 1978. ***Bases écologiques et socio-économiques du développement alternatif des zones rurales marginalisées.*** *Économie Rurale, 124 (2), pp. 23-29.*