Environmental Vulnerability of the Caravelas Coastal Plain – Whale Coast Region As Subsidy To Environmental Planning.

Sírius Oliveira Souza*, Cláudia Câmara do Vale**

* PhD student of University of Campinas (UNICAMP)
** Associate Professor at the Federal University of Espírito Santo (UFES)

Abstract. The use pressure on coastal zones and their effects on the equilibrium of ecosystems have been a subject often discussed in the scientific literature. This situation takes the planners to look for summarize the scientific information to develop models of integrated coastal studies. From these studies, this paper aims to analyze the environmental vulnerability of the Caravelas Coastal Plain in the state of Bahia (Brazil) by means of geoprocessing techniques in a Geographic Information System, with the purpose of subsidize the environmental planning. Lastly, this research has generated environmental vulnerability levels as from the integration of geological, soil conditions, slope and use and occupation of land characteristics. The classes that have high and very high vulnerability include mangroves, the floodplains and shoreline. In the class that has an average environmental vulnerability is included areas of the coastal plain and the slopes of the trays. The classes of low and very low vulnerability include the trays located at the northwest portion of the study area. The results obtained allowed understand the different degrees of vulnerability of each unit front of some human pressures, can be used as a tool for local and regional environmental planning.

Keywords: coastal geomorphology; land use and occupation; coastal zones.

1. Introduction

The functionality of the natural environment is altered by human actions in a faster pace than that normally produced by nature. When unplanned, these changes provide a series of functional imbalances that often cause drastic consequences to human life and nature. After all, as it claims

Ross (2006, p.56): "[...]. The human inserts for more structured they may be, do not create nature, do not change the laws of nature, only interfere with flows of energy and matter changing their intensity, forcing nature to find new points of functional balance. ".

Examples of these environmental imbalances can be viewed in most municipalities along the Brazilian coast. These, in recent decades suffered from the improper implementation of new forms of use and occupation of land. Deforestation, discharging effluents into the waterways, the landfill and construction in coastal areas denounce the lack of concern for spatial planning. Such forms often did not consider the environmental vulnerability of these areas, causing irreversible damage to ecosystems present. In considering environmental vulnerability as a higher or lower susceptibility of an environment with a potential impact caused by anthropogenic use (TAGLIANI, 2002), it is clear that the assessment of landscape carrying capacity constitutes, nowadays, a need to avoid the impairment of natural resources and the potentialization of negative morphogenetic processes.

With 8698 km of extension and approximate area of 514 square kilometers, the Brazilian coast is in a continuous challenge to management in the face of the diversity of the existent problems. There are approximately 300 municipalities front of the sea, which have, on the beach strip, a privileged space for the development of tourism activities, leisure, fishing, among others (NICOLODI and Peterman, 2010). In this dynamic scenario and mobility high, both physical and socioeconomic, that reside approximately 26% of the population, and 16 of the 28 metropolitan areas are on the coast.

These areas of population density living with large expanses of scattered and rarefied population. Are the habitats of artisanal fishermen communities, the remnants of runaway slave, indigenous tribes and other groups immersed in traditional life of genres (NICOLODI and Peterman, 2010). Also according Moraes (op.cit) in the coastal area of Bahia, the average population density is 96 inhabitants / km². This data is located above the national density is 22 inhabitants / km², according to the author.

However, this value is low in relation to the states of Pernambuco and Rio de Janeiro with 913 inhabitants / km² 806 inhabitants / km², respectively. Thus, due to the moderate population density of the Bahia coast, it can still be planned / thought of to minimize the vulnerability found in other parts of the Brazilian coast.

Along the Bahian coast, we chose to study the Caravelas Coastal Plain Region , located in the extreme south of the state, with about 580 km² area, comprising the municipalities of Alcobaça, Nova Viçosa and Caravelas. The choice is justified by its length when compared with the other coastal plains of Brazil, as well as its ecological representativeness, considered an ecological sanctuary, attested by the presence of the Extractive Reserve Cassurubá.

Therefore, it became imperative to perform a work that at the same time producing information and knowledge about an area located in this portion of the coast, is a useful tool to support planning, zoning and the use of management and use of land in coastal regions . Thus, this study aims to analyze the environmental vulnerability of the Caravelas Coastal Plain Region as a subsidy to environmental planning.

2. METHODS AND MATERIALS

2.1 Study area characterization

The Caravelas Coastal Plain Region is located in the extreme south of Bahia state, precisely in the coastal belt known as the Whale Coast, covering the municipalities of Alcobaça, and Nova Viçosa (Figure 01). Situated between the parallels 17 ° 37'52 "S and 17 ° 51'44" S 39 ° 22'7 and meridians "and 39 ° 12'7.11" W Greenwich, this plain is limited to the north by the Itanhém river basin , south and west by the Peruípe river basin and east by the Atlantic Ocean. The climate is classified as tropical type, very humid to wet, no dry season (IBGE, 2007).

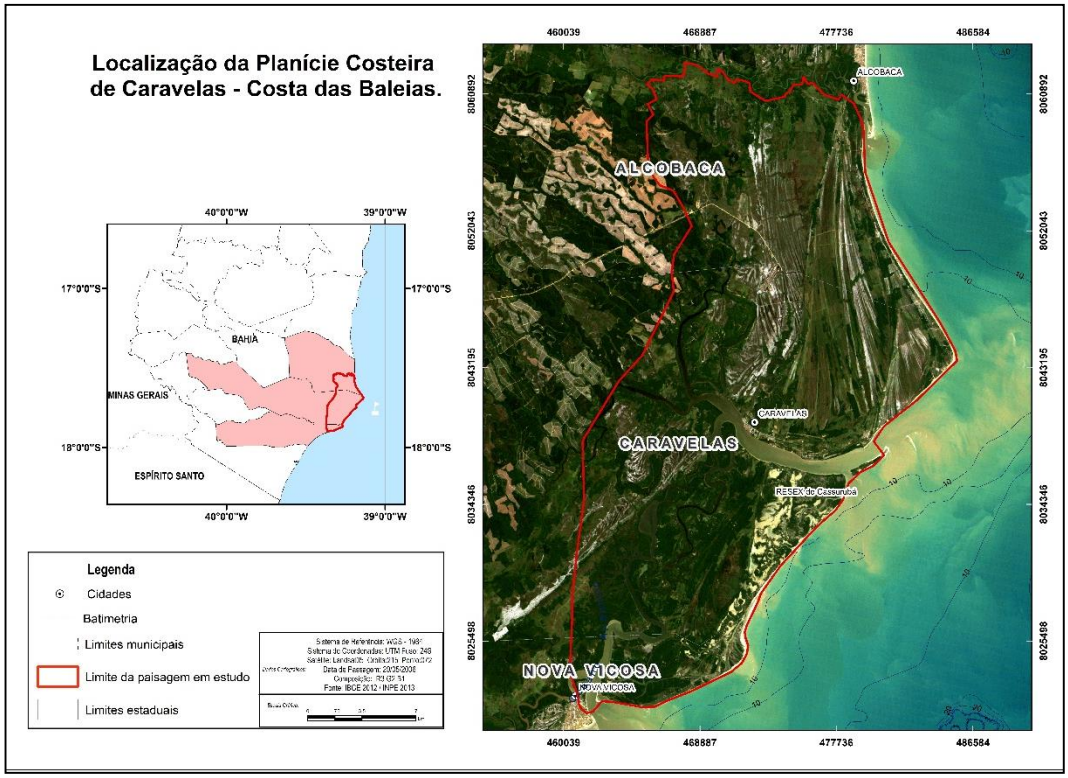

Figure 01 - Map Location of the Caravelas Coastal Plain .

The analysis of the pluviometric regime of the study area shows a gradual loss of rainfall of the coast toward the interior of the continent, with values on the coast around 1,350 mm and 1,050 mm in nearby continental areas per year (SOBRINHO, 2008). What contributes to the development of the following types of vegetation: Rain Forest and Pioneer Formations (DOMINGUEZ, 2008). Based on the remaining and ecological gradients, Dominguez (2008) clarifies that in the study area, the Rain Forest (Atlantic Forest) occupies the coastal plains and the wetter portions of the hills near the coast. Such training conglomerate diversified mosaic of forest ecosystems with structures and very floristic composition individualized , with the common element the exposure to oceanic humid winds.

Also according to the author, there are only a few remnants of this vegetation set on the sides of valleys Formation Barreiras. This situation is made mainly due to the introduction of pastures, forestry, especially eucalyptus, and farms of short cycles. In respect to the Pioneer Formations,

Dominguez (2008) illustrates that they cover areas of marine influence, fluvial and fluvial. The areas of marine influence comprise the spaces whose sandy substrate is covered by vegetation on the sandbank of dry forest. While the areas of fluvial influence, are subject to cyclical floods along the rivers are covered with herbaceous and graminoids formations.

The areas of fluvial influence are characterized by fluctuations of the tides and clayey soil in which grow vegetation that composes the mangroves. Although they were occasionally changed, according to the author, such formations are still well preserved. In geological and geomorphological context, the Caravelas Coastal Plain Region is seated secondarily on the sandy-clay sediments of Tertiary age of Formation Barreiras, which are distinguished by the existence of deep valleys and steep edges, and a general surface inclined towards the coast, constituting the coastal plains. And especially on the Quaternary plain, formed by deposits of Pleistocene and Holocene regressive coastal sands . Such deposits ended their accumulation controlled by relative sea level that affected the Brazilian coast during the Quaternary (ANDRADE and DOMINGUEZ, 2002).

The soil formation in this area _ is directly related to the different geological and geomorphological units present. Thus, sediments that make up the coastal plains, install themselves pedogenetic processes that gave rise to Argisols Yellow Dystrophic, Oxisols, Vertisols, among others. In both rivers and plains fluviomarinhas, install up processes that originate Hydromorphic Espodossolos, Gleissolos Haplic and Organosols Haplic. Finally, sediments that make up the ridges of quaternary plains, are implanted the Quartzarenic Neosols (ANDRADE, 1994).

Finally, on the slope, according to Souza (2013) 93% of the Region Caravelas Coastal Plain Region have a slope of 0% to 2%, being considered by Young (1981) cited by Oliveira (2003) as spaces with greater propensity to flooding. This percentage corresponds to an area of 539 square kilometers. It is observed also that only 7% of the study area have slopes above 2% were classified as flat and / or slightly undulating surfaces. In this area, where there are coastal plains, the slope ranges from 0 to 15%, which by Brazilian Law No. 6,766 / 1979 in Article 3, if you have as area susceptible to urbanization without restrictions. Therefore, there is evidence of its urban potential, and justified the need for a guided planning in the analysis of environmental vulnerability present.

2.2 Methodological Procedures

Considering the identification of environmental vulnerability through the methodological proposal of Nascimento and Dominguez (2009) which makes use of the variables shown in Table 01 proceeded to the development of Geographic Information System routines (GIS), such as scanning,

georeferencing and scanning the specific variables, linear and beaches. Among the available software for preparation of maps, we used the ArcGIS 10.1 for presenting the most complete and varied tools options applied to spatial data, in addition to providing an excellent standard in the export of property of the products generated.

Variables	Features	Source and Material Scale
Geology	Geological Time	Dominguez (2008) – 1:100.000
Soil	Maturity Pedogenetic	Adapted from SEI (2012) – in scale 1:100.000
Slope	Variations Slope	Made with ASTER images in scale 1: 100.000.
Land use and occupation	Types of Use	Made with Landsat/07 images and confirmed in field in scaale 1:100.000

Table 1. The variables used in determining the environmental vulnerability.

Using these variables in a raster format proceeded to develop the algebraic operation by assigning values (1 to 5) to each criteria and then adding them together using the Reclassify and Intersect tool. In the sequence to determine the vulnerability classes the values assigned to each class were interpolated using the raster calculator tool. The assigned values are given in Table 02, 03, 04, and 05 and are based on searches made by Nascimento and Dominguez (2009), Tangliani (2002) and Crepani et al., (1996).

Slope %	Vulnerability value
0 ┤ 1	*5*
1 ┤ 2	5
2 ┤ 5	2
5 ┤ 10	1
10 ┤ 15	3
15 ┤ 23	3

Categories	Vulnerability value
Urban Area	**4/5**
Agricultural area	**1,5/5**
pasture	**4**
Forest Area	**1/3**
Mangrove / swamp	**4/5**
Solo Exposed	**5**
Water bodies	**5**

Table 02 and **Table 03**- environmental vulnerability values for the slope units and units of Use and occupation of Earth.

Source: Adapted from Nascimento and Dominguez (2009) and Tagliani, (2002).

Letter symbol of classes Soil	Soil Classes Value	Vulnerability value
GT/SM	Glei Tiomórfico / Mangroves soils	5
OX	Organosol Haplic	5
GXbd	Gleysol Haplic	5
RUbe	Fluvic Neosol Tb eutrophic	4
RQg	Quartzarenic Neosol Hydromorphic	4
EKg	Spodosol Hydromorphic	3
PVAd	Argisol Red-Yellow Dystrophic	2
LAd	Yellow Latosol	1
LVAd	Red-Yellow Latosol	1

Table 04- Environmental vulnerability values assigned to different soil classes. Source: Adapted from Crepani et al. (1996).

Symbol	Lithology	Vulnerability value
QHm	Quaternary - Holocene. Clay-organic deposits of mangrove; rich in organic matter;	**5**
QHla	Quaternary - Holocene Deposits of current coastal sands; Fine sand and medium well selected; bar rivers and sandy spits.	**5**
QHtu	Quaternary - Holocene Clay-organic deposits; argillaceous sediments rich in organic matter sometimes capped with layers of peat; swamps and marshes	**4,9**
QHl	Quaternary - Holocene Deposit of regressive coastal sands; fine sand and medium well selected with plane-parallel stratification face the beach; ridges.	**4,75**
QHfl	Quaternary - Holocene River sandy-clay deposits; argillaceous rocks deposited in levees and abandoned channels associated with the current water streams.	**4,6**
QPl	Quaternary - Pleistocene	**4**

	Deposit regressive coastal sands; fine and medium sand well selected, sandbank.	
QPla	Quaternary - Pleistocene Hand fans of alluvial deposits; sandy-clay sediments with pebbles.	**3,5**
Qar	Undifferentiated quaternary Fine quartz sands to very thick with beads and quartz pebbles.	**3,25**
Tb	Tertiary Barriers ; sandy-clay sediments.	**3**

Table 05 - Environmental Vulnerability values for lithological units.

Source: Adapted from Nascimento and Dominguez (2009) and Crepani et al. (1996).

The Environmental Vulnerability Index of Caravelas Coastal Plain Region is the result of the arithmetic average found distributed into five classes, with intervals shown in Table 06.

Classification	Ranges
Very Low	4 –| 8
Low	8 –|10
Average	10 -| 12
High	12 –| 15
Very High	15 -| 19

Table 06 - Average math for Environmental Vulnerability classes.

Source: Adapted from Nascimento and Dominguez (2009)

3. Results and Discussion

From the criteria and procedures described above, is presented in Table 07 and Figure 02 the results obtained in the analysis of environmental vul-nerability of the Caravelas Coastal Plain Region . These results show that the study area falls in all classes within the methodology proposed by Nascimento and Dominguez (2009), they are: Very Low, Low, Medium, High and Very High Vulnerability.

Environmental Vulnerability Level	Area	
	(km)	(%)
Very Low	11,85	2,04
Low	39,55	6,81
Average	134,55	23,17
High	323,91	55,79
Very High	70,64	12,16

Table 07 - Environmental Vulnerability level of the Caravelas Coastal Plain Region

Begins the discussion by areas of very high environmental vulnerability. This class covers 70.64 square kilometers of the Caravelas Coastal Plain Region Region of , about 12.16% and includes vast areas of mangroves and marshes that occupy the plains tide, lowered areas and spaces of Bare Soil. This class includes, therefore, the most sensitive ecosystems in the region. These are subject to flooding, is, by rainwater, either by overflowing rivers, or even by the tides, which act as constraining factors to agricultural use.

The areas of very high environmental vulnerability are cut by multiple channels that serve as ducts for the entry and exit of the tides. Configure totally unstable environments since they are subject to river flooding, storm and periodic sea. Include shoreline stretches, showing in some places moderate coastal erosion, as in the northern section of whale Point, which relates to changes in the mouth of the Peruípe river in Alcobaça (BA).

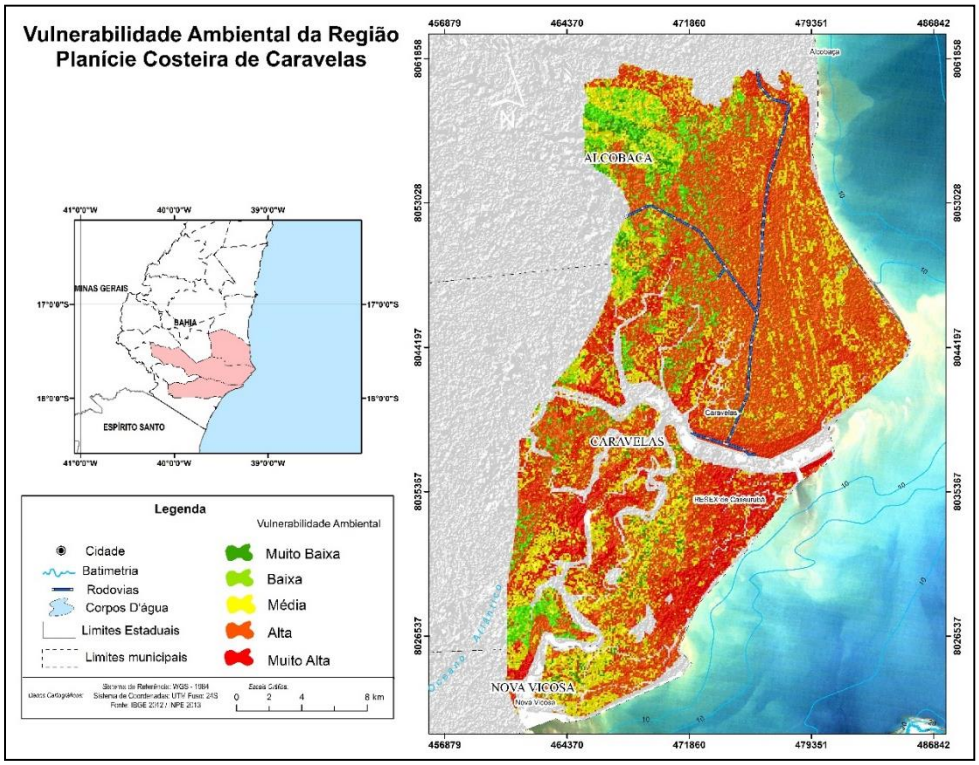

Figure 02 - Environmental Vulnerability Map of the Caravelas Coastal Plain Region

The Figure 03 illustrates the region south of the channel in Cassurubá Island, classified in this study as an area very high environmental vulnerability.

Figure 03 - Detail of very high environmental vulnerability region.

Source: Google Earth ™, 2013.

In this region the sand deposits have little thickness and sit directly on plastic sludge gray, of marine origin. As Andrade and Dominguez (2002, p.14) these plastic sludge, on which the Sandy Terraces sit can change the physical properties of the substrate and cause geotechnical problems (deformation and sinks ment of engineering works).

In view of this, areas of very high environmental vulnerability, appear topographically very low, predominantly the Organosols and Gleissolos, soil proven to manifest a high risk of account-tion, and are plastic soils and therefore unable to support human occupation, such as houses, roads, developments, without deformation.

Thus, any placement in these areas would involve the performance of landfills and thus eliminating this environment. Therefore it is suggested as a measure environmental planning the overall conservation of this unit, combined with the maintenance of the Extractive Reserve Cassurumbá. Once your occupation is particularly problematic due to reduced water table depth and plasticity of soils.

In the Caravelas Coastal Plain Region predominates high environmental vulnerability category occupying a total area of 323.91 square kilometers, about 55.79% and covering the terraces Sandy, formed by deposits of _ quaternary Pleistocene and Holocene regressive coastal sands. Are rather flat areas and presenting micro relief in the form of ridges, consisting of alternating ridges morphology with wet depressed areas, with the outcropping rein optical sheet. In almost all its extension the Quartzarenic Neosols up and prevail Hydromorphic Espodossolos, covered by forest vegetation Restinga Seca or the Eucalyptus forestry, and several associated uses, such as pasture, Agricultural Areas and Forest Areas.

The main constraint on the occupation of this unit is its low dirt-holding capacity due to its high permeability, absence of clay, low organic matter in the soil and shallow it is in the piezometric surface (ANDRADE and DOMINGUEZ, 2002).

Therefore it is suggested as a measure environmental planning the preservation of areas belonging to RESEX Cassurubá and areas not yet occupied and / or amended and monitoring / monitoring of busy and / or altered areas. Since the distortion of this environmentthat occurred by earthmoving for the implementation of agro-pastoral activity, tourist, residential or even certainly result in the destruction of praiais crests, and the Dry Forest Restinga, and the grounding of periodically flooded depres sions, assuming therefore irreversible in this landscape, which may condition a high risk of pollution of surface and underground water resources present.

It is also suggested to be incorporated in this unit, when around waterways, buffer strips and preservation according to the criteria spelled out in the resolution of CONAMA nº004 / 85 and the Brazilian Forest Code Law No. 12,651, May 25, 2012 (BRAZIL , 2013).

The middle class of environmental vulnerability comprises about

134.55 square kilometers, which corresponds to 23.17% of total area. This class occurs mainly in the coastal plain and secondarily in the coastal tablelands. The coastal plain includes almost the entire length Espodossolos consisting of sandy-clay sediments, covered by rain forest vegetation associated with grazing activity.

The Tablelands, the average vulnerability class of comprises the slopes between 2% and 15%, including grassland, crops coconut, and some eucalyptus forestry snippets. As they have most of its length within the area of RESEX, it is suggested as a measure environmental planning maintenance and monitoring of these environ-tes. Because such environments are as endemic areas of transition between the high and low vulnerability environments.

Lower classes environmental vulnerability and Very Low environmental vul-nerability added feature only 51.4 square kilometers, comprising about 8.65% of the total area. Together, these classes occur predomi-nantly in the Coastal Plains, characterized by interfluvia plans carved by numerous valleys in a "U", with steep walls and flat bottom (DOMINGUEZ, 2008). In almost all its extension are observed Udult Dystrophic soil associated with Spodosol Hydromorphic soil, covered by eucalyptus plantations, the main use of the Agricultural Areas.

The deposits of this unit according to the research of Dominguez (2008) are constituted by sandy clay sediment selected poorly with moderate levels of permeability and cemented by iron oxide. The geotechnical point of view this unit is straightforward to occupation. Since the sandy-clay soils have good carrying capacity is suggested as a measure ordering that the interfluve of the trays are considered urban use area and agricultural, controlled, within the limits described in the Brazilian environmental legislation. Always seeking preventive measures against environmental degradation and activities in this unit are managed properly taking into account the type of pollutant load and the self-purifying capacity of the system, and the distance (vertical and horizontal) between the pollution source and underground and surface water sources.

As a measure environmental planning, it is suggested to be considered as permanent preservation areas the remaining Atlantic Forest province, threatened by the constant deforestation, as well as other parts provided in the Brazilian Forest Code.

4. Closing Remarks

The analysis of environmental vulnerability classes of the Caravelas Coastal Plain Region Region showed that natural systems have two different degrees of environmental vulnerability. The coastal plain is predominates

high and very high environmental vulnerability and trays to low- and middle-environmental vulnerability, despite the different land use intensities in these areas, prevailing in general the intrinsic limitations of these ecosystems.

Thus, the identification of the five classes of vulnerability presented in this study shows some support criteria for planning the use and occupation of land, mainly in those areas that had very high environmental vulnerability. For these areas should be established usage limitations and occupation supported by environmental legislation and the existing management tools for the conservation and restoration of ecosystems present.

On the other hand, the less vulnerable areas have higher potential for use in the face of greater sustainability offered by more stable soils evolved lithologies and old, as in the case of the trays of the northwest sector of the study area.

We can see the need the development of research in this area aimed at increasing and preserving both the natural environment, as the historical and cultural heritage, supported by tools that help in minimizing the negative effects of human action.

A study like this becomes important in that it can be used as a guiding management policies for this part of the coastal zone and contribute to new occupations and economic and social development be made compatible with environmental preservation. Clearly the need for more detailed studies to obtain a delimitation use more "sustainable", which aims to meet human needs and maintenance of coastal resources.

5. Bibliography

Andrade, A. C. S.; Dominguez J.M. L., (2002). Informações Geológico-Geomorfológicas como Subsídios a Análise Ambiental: o Exemplo da Região Planície Costeira de Caravelas – Bahia. Boletim Paranaense de Geociências, Paraná. v. 51, p.9–17.

Brasil. Lei nº 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nºs 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de agosto de 2001; e dá outras providências. Portal da Legislação: Leis Ordinárias. 2013. Disponível em: <http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651.html.> Acessed em 15 sept. 2014.

Brasil. Lei n. 6.766, de 19 de dezembro de 1979. Dispõe sobre o Parcelamento do Solo Urbano e dá outras Providências, Brasília, DF. Portal da Legislação: Leis Ordinárias, 2013.Disponível em: < http://www.planalto.gov.br/ccivil_03/leis/l6766.htm>. Acessed 10 de Jan. 2014.

Crepani, E.; Medeiros, J. S.; Azevedo, L. G.; Hernandez Filho, P.; Florenzano, T. G.; Duarte, V.;(1996). Curso de sensoriamento remoto aplicado ao zoneamento ecológico-econômico: metodologia desenvolvida para subsidiar o Zoneamento Ecológico-Econômico. INPE, São José dos Campos.

Dominguez, J. M. L. (org.). (2008). Costa das Baleias: Caracterização da Zona Costeira dos Municípios de Alcobaça, Caravelas, Nova Viçosa e Mucuri. Salvador: CBPM / UFBA – CPGG / LEC.

Instituto Brasileiro De Geografia E Estatística – Ibge, Mapa de climas do Brasil, diretoria de geociências, 2007. < disponível em http://www.ibge.gov.br/home/geociencias/default_prod.shtm#MAPAS. Acessed 18 de dec.2013.

Moraes, A. C. R.. (2007). Contribuições para a gestão da zona costeira do Brasil: elementos para uma geografia do litoral brasileiro. São Paulo: Annablume.

Nascimento, D. M. C.; Dominguez, J. M. L.;(2009). Avaliação da vulnerabilidade ambiental como instrumento de gestão costeira nos municípios de Belmonte e Canavieiras, Bahia. Revista Brasileira de Geociências, 39:395-408.

Nicolodi, J. L.; Petermann, R. M.. (2010). Mudanças Climáticas e a Vulnerabilidade da Zona Costeira do Brasil: aspectos ambientais, sociais e tecnológicos. Revista da Gestão Costeira Integrada, v. 10 n. 2, p. 151-177.

Oliveira, R. C..(2003). Zoneamento Ambiental como subsídio ao planejamento no uso da terra do município de Corumbataí-SP. Tese. (Doutorado em Geociências e Meio Ambiente). UNESP - Rio Claro, Rio Claro.

Ross, J. L. S., (2006). Ecogeografia do Brasil: Subsídios para planejamento ambiental. 1ª ed. Editora Oficina de Textos, São Paulo.

Superintendência De Estudos Econômicos E Sociais Da Bahia - Sei.(2012). Mapas digitalizados do Estado da Bahia: base de dados. Salvador: SEI, (CD-ROM).

Souza. S. O.. (2013). Vulnerabilidade Ambiental da Planície Costeira de Caravelas (Bahia): Uma proposta geossistêmica. Dissertação, (Pós Graduação em Geografia).UFES – Vitória.

TAGLIANI, C. R. A..(2002). Técnica para avaliação da vulnerabilidade de ambientes costeiros utilizando um Sistema Geográfico de Informações. Porto Alegre, UFRGS. Disponível em: < http://www.praia.log.furg.br/Publicacoes/2003/2003c.pdf >. Acessed 10 jan. 2014.