

**VULNERABILITY AND RESPONSE MEASURES TO NATURAL
HAZARD AND SEA LEVEL RISE IMPACTS:
LONG -TERM COASTAL ZONE MANAGEMENT, NE OF THE
STATE OF PARÁ, BRAZIL**

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Dedicated to my father,

Julio Szlafsztajn

(1931-1999)

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Abstract

The Federal Constitution of Brazil states that extreme care should be taken for natural resources preservation and use of areas considered part of natural heritage as the *Coastal Zone*. Particularly, the Coastal Zone Management Program of the State of Pará (GERCO-PA) has divided the area in three sectors. The Atlantic Sector, the study area of this work, is located at the NE region of the State and is integrated by 22 municipal districts distributed in 16,000 km².

In a first phase of the present work, field observations were used for adapting existing vulnerability methodologies to the local characteristics. These show among other conflicts, the problems related to natural hazards, particularly erosion and flooding are already significant in many areas. Their impacts, although not economically quantified yet, are evident in the main urban centers (e.g. Salinas, Marudá). Considering these aspects, and that since 1995, the GERCO-PA has only accomplished the preliminary stages, the present study aims to (1) analyze how the natural hazards and relative sea-level rise issue can be incorporated into broader planning contexts of a *long-term* integrated coastal management program for the NE of the State of Pará, and (2) to support, with a scientific and methodological basis, state and municipal governments.

Therefore, within a modified *PSIR (Pressure-State-Impact-Response)* framework, not only the current *pressures* are considered but also the potential ones and their respective consequences on the coastal system. Among them, the sea level rise (global and relative) impacting on a low lying coastal topography, and the growing human population and development scenarios – based on large-scale socioeconomic parameters, changes in the production strategies, and new and better infrastructure - are analyzed as pressure factors on the coastal zone system of Pará for the next 50 to 100 years.

The analysis of the regional *vulnerability* allowed assisting in the identification of the most susceptible sectors to the erosion and flood process *impacts*. For this reason, a Geographical Information System (GIS)-based Composite Vulnerability Index (CVI) was created combining more than 20 natural and socioeconomic variables. The socioeconomic vulnerability principally depends on the wealth and social development of the municipalities, the total population of each Census Collection District, and the total population of children and elderly that inhabit each district. The natural vulnerability is particularly influenced by the absence of protection measures in the shorefront districts, the

coastline and fluvial network total length in each municipality, and the total area flooded. In general terms, the coastal area has a relatively low vulnerability to natural hazards, being bigger in some coastline regions and more important urban centers.

Adaptation *response* strategies and measures to natural hazards and sea level rise impacts were described and analyzed according to the Intergovernmental Panel for Climate Change (IPCC) classification: *no action*, *protection*, *accommodation*, and *retreat*, in order to identify which of them have been recently adopted, the causes of success or failure, and also, to understand whether strategies, measures, people and authorities are prepared to face extreme events in consequence of global changes. The accommodation strategies and measures particularly analyzed are: the land use legal framework, the building style, the natural disaster relief program, the insurance system, and the people, and peoples and authorities knowledge level.

Finally, in order to subsidize the Coastal Zone Management Program of the State of Pará, some recommendations have been proposed not only to permit implementing new strategies and measures, and modifying and improving those already existent, but also to indicate the best places (by Census District) to apply these strategies and measures.

Zusammenfassung

Die Bundesverfassung Brasiliens schreibt vor, dass die Nutzung und der Schutz natürlicher Ressourcen von Gebieten des „Naturerbes“ wie beispielsweise die Küstenzone unter extremer Behutsamkeit erfolgen soll. Definiert wird die Küstenzone in Brasilien als der geographische Raum von Wechselwirkungen zwischen Luft, Meer und Land, der den marinen und terrestrischen Streifen einschließlich natürlicher Ressourcen umfasst. Im Nordbrasilien hat das Programm zum Management der Küstenzone im Bundesstaat Pará (GERCO-PA) dieses Gebiet in drei Sektoren unterteilt. Der „Atlantik-Sektor“, Untersuchungsgebiet der vorliegenden Arbeit, befindet sich im Nordosten des Staates und besteht aus 22 Munizipien verteilt auf 16.000 km².

In der ersten Phase der Arbeiten wurden Felderhebungen durchgeführt zum Zwecke der Anpassung bestehender Methodologien für die Erfassung der Küstenvulnerabilität an die lokalen Gegebenheiten. Diese Erhebungen zeigten, dass in einigen Gebieten bestimmte, aus natürlichen Prozessen resultierende Gefahren für die Küstenzone, wie Erosion und Überschwemmungen, bereits ein signifikantes Ausmaß erreichen. Die Auswirkung dieser Prozesse sind zwar noch nicht ökonomisch quantifiziert worden, zeigen sich aber deutlich in den größeren urbanen Zentren wie z.B. Salinas und Marudá. Dennoch befindet sich das 1995 lanzierte GERCO Programm erst noch in einer vorläufigen Phase. In Anbetracht dieser Aspekte war es ein Hauptziel dieser Arbeit zu analysieren, in welcher Form die o.g. natürlichen Gefahren, in ein langfristiges, breites Konzept des integrierten Küstenmanagements für die Region eingefügt werden konnten und die Effekte eines relativen Meeresspiegelanstieges besonders berücksichtigt werden. Dies sollte mit einer wissenschaftlichen und methodologischen Basis die diesbezügliche Handlung auf staatlicher und kommunaler Ebene unterstützen.

Zu dem o.g. Zweck wurden im Rahmen eines modifizierten *PSIR (Pressure-State-Impact-Response)* Ansatzes nicht nur der gegenwärtige sondern auch der künftige Druck auf das Küstensystem und seine jeweiligen Folgen berücksichtigt. Dabei wurden Szenarien über die Auswirkung des Meeresspiegelanstieges auf eine niedrig liegende Küstentopographie sowie auf eine rasch wachsende Bevölkerung und rasche ökonomische Entwicklung analysiert. Besonders betrachtet wurden dabei großskalige sozioökonomische Parameter, wie die Veränderungen an Produktionsstrategien und Infrastruktur als Druckfaktoren in der Küstenzone Pará in den nächsten 50 bis 100 Jahren.

Die Analyse der regionalen Vulnerabilität ermöglichte die Differenzierung von Küstenabschnitten mit unterschiedlich hoher Anfälligkeit gegenüber Effekten von Erosion- und Überschwemmungsprozessen. Ein GIS-basierter CVI (Composite Vulnerability Index) wurde unter Anwendung von mehr als 20 natürlichen und sozioökonomischen Parametern für alle Munizipien berechnet. Die sozioökonomische Vulnerabilität ist vor allem abhängig vom der Bevölkerungszahl und der Anzahl der Zuwanderer, Kinder und Senioren im überflutungsgefährdeten Küstenstreifen. Die natürliche Vulnerabilität wird insbesondere von der Existenz oder dem Fehlen einer Schutzinfrastruktur, von der Gesamtlänge des Küsten- und Flussnetzwerks und von der Ausdehnung der Überschwemmungsfläche in jeder Küstengemeinde beeinflusst. Es wurde eine 5 stufige Klassifizierung der Küstengebiete entsprechend ihrer Gesamt-Vulnerabilität vorgeschlagen: sehr niedrige, niedrige, mittlere, hohe und sehr hohe Vulnerabilität (Gefährdung). Es lässt sich feststellen, dass einige Küstenstreifen und urbane Zentren im Nordosten Parás in die Kategorien gefährdet und sehr gefährdet fallen.

Anpassungsstrategien und Maßnahmen als Antwort auf Effekte des Meeresspiegelanstiegs und damit verbundene Gefahren wurden gemäss dem vom International Panel for Climate Change (IPCC) empfohlenen Schema beschrieben und analysiert: *keine Maßnahmen (Abwarten), Schutz, Anpassung und Rückzug*. Zweck dieses Ansatzes war die Identifizierung von aktuellen Reaktionen, die Bewertung deren Effektivität und damit der Eignung der Strategien und Maßnahmen seitens Bevölkerung und Behörden gegen potentielle extreme Ereignisse. Besondere Beachtung fanden bei der Analyse: die relevante Gesetzgebung zur Raumnutzung, die unterschiedlichen Bauweisen in der Küstenzone, das Versicherungssystem und das Bildungsniveau von Bevölkerung und Behörden. Zum Schluss wurden Empfehlungen zur Implementierung neuer Strategien und Maßnahmen sowie zur Verbesserung bereits bestehender erarbeitet. Darüber hinaus wurden geeignete Gebiete für einen optimalen Einsatz der Strategien und Maßnahmen auf der Skala von Zensusbezirken vorgeschlagen.

Resumo

A Constituição Federal do Brasil estabelece que devem extremar-se os cuidados com a preservação dos recursos naturais e uso das áreas consideradas como parte do patrimônio natural da Nação como a *zona costeira*. No Brasil, ela é definida como o espaço geográfico onde interagem o ar, o mar, e a terra, incluindo seus recursos renováveis ou não, compreendendo as faixas marinhas e terrestres. Particularmente, o Programa de Gerenciamento Costeiro do Estado de Pará (GERCO-PA) dividiu a área em três setores. O Setor Atlântico, a área de estudo deste trabalho, fica situado na região NE do Estado e é integrado por 22 distritos municipais distribuídos em 16.000 km².

Na primeira etapa do presente estudo, observações de campo foram utilizadas para adaptar as metodologias de análise da vulnerabilidade às características locais. Entre outros conflitos, os problemas relacionados com perigos naturais, particularmente erosão e inundação, já são significantes em muitas áreas. Seus impactos, embora ainda não economicamente quantificáveis, são evidentes nos centros urbanos principais (ex. Salinas, Marudá). Considerando estes aspectos, e que desde o ano 1995, o GERCO-PA realizou só suas fases preliminares, o presente estudo tem como objetivo analisar como podem ser incorporados às temáticas dos perigos naturais e do aumento do nível do mar no contexto do planejamento do Gerenciamento Integrado *em longo prazo* da Zona Costeira do NE do Estado do Pará, e conseqüentemente apoiar, com base científica e metodológica, os governos dos Estado e Municípios.

Então, dentro do contexto das modificações realizadas no esquema PSIR (Pressão-Estado-Impacto-Resposta), não só as *pressões* atuais são consideradas, mas também as potenciais pressões e suas conseqüências respectivas no sistema litoral. Entre eles, são considerados como fatores de pressão no sistema de zona litoral de Pará durante os próximos 50 a 100 anos, a elevação do nível do mar (global e relativo) atuando sobre um litoral de baixo relevo, e a crescente população e desenvolvimento humano (baseado em amplos parâmetros socioeconômicos, mudanças nas estratégias de produção, e uma nova e melhor infra-estrutura).

Uma análise da vulnerabilidade regional permite ajudar na identificação dos setores mais suscetíveis aos impactos dos processos de inundação e erosão. Para isto, um Índice de Vulnerabilidade Composto (CVI) baseado num ambiente de Sistema de Informação Geográfico foi criado combinando mais de 20 variáveis naturais e socioeconômicas. A

vulnerabilidade socioeconômica principalmente depende do maior concentração de população pertencentes aos grupos de maior susceptibilidade (crianças, idosos, população não local) nas zonas mais afetadas pelos processos costeiros. A vulnerabilidade natural é particularmente influenciada pela ausência de medidas de proteção nos distritos costeiros, as dimensões da linha de costa e da rede fluvial em cada município, e da área total inundada. A zona costeira do NE do Estado do Pará apresenta valores de vulnerabilidade altas e muito altas principalmente nas regiões de litoral e centros urbanos mais importantes.

Estratégias e medidas de adaptação ante aos impactos dos perigos naturais e aumento do nível do mar foram descritas e foram analisados de acordo com a classificação do Painel Intergovernamental do Cambio Climático (IPCC): *nenhuma ação, proteção, acomodação, e retrocesso* para identificar quais deles foram adotados recentemente, as causas do sucesso ou fracasso, e também, entender se as estratégias e as medidas, assim como as pessoas e as autoridades estão preparadas para enfrentar eventos extremos por causa de mudanças globais. As estratégias e medidas de acomodação particularmente analisadas são: o quadro legal do uso de terra, o estilo das edificações, o Sistema da Defesa Civil, o sistema de seguros, e o nível de conhecimento da população e das autoridades.

Finalmente para subsidiar o Programa de Gerenciamento da Zona Costeira do Estado do Pará, algumas recomendações não só foram propostas com objetivo de permitir implementar novas estratégias e medidas, assim como modificar e melhorar as já existentes, mas também para indicar os melhores lugares (utilizando Setores Censitários) de aplicação destas estratégias e medidas.

CHAPTER 1

COASTAL ZONE MANAGEMENT OF THE NE OF THE STATE OF PARÁ: THE NATURAL HAZARDS ISSUE

The Federal Constitution of Brazil (Brasil, 1991) assures the well-being of present population and future generations guaranteeing, among other rights, the so called ‘social rights’. Education, health, employment, leisure and safety (art. 6), the full development of the urban social functions (art. 182), and the right to live in an ecologically balanced environment (art. 225) are among the principal ones.

Considering the environmental issue, several instruments have been created in order to reach this right. Some of them are the preservation and restoration of essential ecological processes and genetic patrimony, the delimitation of especially protected areas, the promotion of environmental education in all levels, and the requirement to assess environmental impacts previously to the installation of potentially risky activities. Particularly, extreme care should be taken for natural resources preservation and use of areas considered part of the national heritage such as: *Mata Atlântica* forest, *Serra do Mar* highland, *Pantanal Mato-Grossense* wetland and the *coastal zone* (Figure 1.1).



Figure 1.1 Localization map of the areas and ecosystems belonging to the national heritage (Source: Programa Educar, Universidade de São Carlos, 2002).

The Brazilian coastline faces the Atlantic Ocean from the equatorial to the temperate regions. This zone reaches an extension of approximately 8,000 km, between latitudes of $4^{\circ}52'N$ and $33^{\circ}45'S$, and has a variable width. The large territory of Brazil, ranging from equatorial to tropical and sub-tropical climates, allows a considerable diversity of coastal and geomorphic exposures, in addition to a high variety of contiguous ecosystems (coral reefs, mangroves, coastal lagoons, barrier islands, salt marshes, tidal flats, beaches, front and field dunes and cliffs, island and submerged banks, deltas, etc.).

According to Silveira (1964), it is possible to divide the Brazilian coast in five large sectors based on its geographical characteristics (Figure 1.2). The North sector mainly consists of lowlands, with a macro tidal regime. Along this coast, estuaries are frequent and muddy tidal flats occupied by mangroves are dominant. Towards the continent, the mangroves are followed by coastal salt marshes. In the central portion of this coast, the presence of the “Amazonian Gulf” is responsible for the development of a deltaic-estuarine complex. The Northeast coast has a mesotidal regime. From Baía de São Marcos up to Cabo Calcanhar the coast is particularly semi-arid where coastal plains and barrier-lagoon systems occur. To the South (up to Baía de Todos os Santos), there are beach rocks fringing reefs, which serve as substrate for calcareous algae and true coral reefs. Near the main rivers systems, coastal plains are occupied by coastal lagoons with mangroves and by beach ridges. On the East coast, extending from the city of Salvador (State of Bahia) to the city of Cabo Frio (State of Rio de Janeiro), high cliffs alternate with lowlands with well developed coastal plains where estuaries and deltaic complexes are frequent. The Southeast coast until Cabo Santa Marta is dominated by highlands that have an abrupt contact with the sea (cliffs). The reduced coastal plains occur at the mouth of some fluvial systems, where lagoon barrier systems favour the occurrence of mangroves. The South coast is part of a large coastal plain which main part is a long barrier island separated from the mainland by a large lagoon system. Well-developed beaches, dunes, wetlands and aeolian flats characterize the barrier.

Although it is not explicit, the relevance conferred to the “coastal zone” in the Federal Constitution would not only respond to the necessity of protecting the rich ecosystem diversity, but also to the significant socioeconomic role that those areas have been playing throughout Brazilian past and present.

In the past, the Brazilian coastal area was site of first human settlement and highly productive agriculture. During the “Colonial Period” (16th to 19th centuries), these areas were used as trade centers and as the gateway to hinterland conquest, where mineral and agricultural resources were abundant. Most cities were usually located on the coastline (Azevedo, 1956). During the second-half of the 19th century, most of the important economic activities (coffee, rubber and sugar-cane plantations) shifted to the hinterland. However, since 1950, pursuing the *Brazilian industrial economic model*, heavy industries (chemical, petrochemical, fertilizer, etc.) have been located in estuaries and bays next to fragile coastal ecosystems (Diegues, 1999).

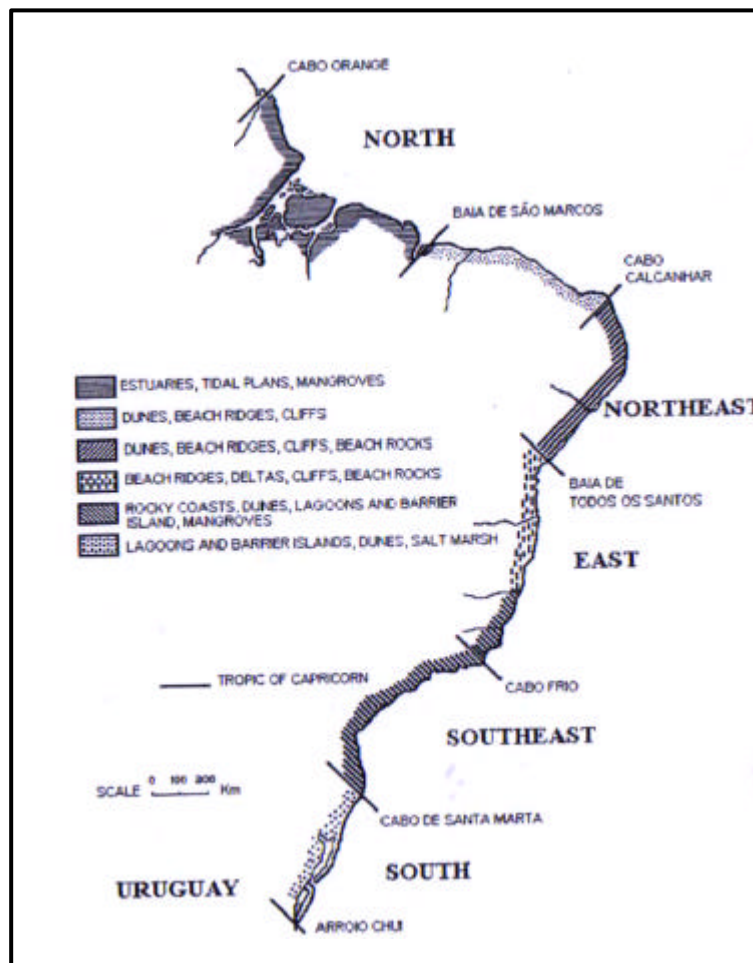


Figure 1.2 Main sectors of the Brazilian coastal area classified by their geographical characteristics (Silveira, 1964).

At present, parts of 17 states¹ integrate the coastal area of Brazil and concentrate almost a quarter of the country's total population (178,000,000 inhabitants). This coast can be considered an area of huge contrasts. On the one hand, there are intensive urbanized regions (5 Brazilian metropolitan regions and 13 State capitals are on the coast), industrial activities (specially those sectors that depend on external inputs and marine shipping), port systems (process about 90% of all foreign trade), tourism exploration (responsible for establishment of second homes, revitalization of cities, and occupation of new areas), as well as fishing and oil exploitation activities. On the other hand, huge areas of low population density and well preserved ecosystems of great environmental value exist, which unfortunately also start to be site of an accelerated occupation process (MMA, 1999), particularly in the Northeast and North regions. The Northeast coastal zone of the State of Pará - the study area of the present work - is located in the North region.

¹ Brazil is a Federal Republic integrated by 26 states and a Federal District (Brasília).

1.1 The NE Coastal Zone of the State of Pará – The Study Area

The coastline is clearly distinct as the boundary between the land and the sea. However, the concept of a coastal zone or fringe is not generally tightly defined; it varies not only according to the geographical areas, but also according to the point of view of different specialists. It can be defined as a combination of terrestrial, intertidal and near-shore marine areas (Finlayson, 1999), the interface where the land meets the ocean, encompassing shoreline environments, and adjacent coastal waters (Post and Lundin, 1996), a linear band or corridor of land and water paralleling the coast (Clark, 1995), as well as an area that include the inner part of the continental shelf, the coastline, and hinterland a few kilometers in width (Charlier and De Meyer, 1997). For planning purposes these definitions are frequently quite unrealistic; in this sense, coastal zone must be a “special area”, endowed with particular characteristics by specific problems to be tackled. Then, in these cases the boundaries to be used not only depend on natural conditions, but also on jurisdictional limits.

In Brazil, considering the variable width of the coastal area, the diversity of geomorphic features and ecosystems, and the planning purposes, the coastal zone is defined by the National Coastal Zone Management Plan (PNGC – *Plano Nacional de Gerenciamento Costeiro*) as “the geographical space of air, sea and land interactions, including its resources”, that embraces the following strips:

- *Marine strip or the “wet” side*: the totality of the Brazilian Territorial Sea.
- *Terrestrial strip or the “dry” side*: the municipal districts that suffer direct influence of events occurring in the coastal zone as: (i) the shorefront municipal districts; (ii) the non-shorefront municipal districts that constitute part of coastal metropolitan areas; (iii) the municipal districts near to the coastline (until 50 km), that allocate in their territory activities or infrastructures of great environmental impact on the coastal zone or high relevance ecosystems; (iv) the municipal districts which border estuaries and lakes of high relevance for marine coastal dynamics (v) the municipal districts contiguous to great cities or coastal state capitals with conurbation process, and (vi) the non-shorefront municipal districts that limit the municipal districts previously referred. Then, a broad coastal zone (388,000 km², approximately 5% of the total area of Brazil) is delimited, based on municipal limits that extend the borders from hundreds of kilometres inland and at the other extreme, the seaward boundary, to a 12 nautical mile width.

Considering natural and socioeconomic characteristics, the coastal zone of the State of Pará (82,596 km², 6.5% of the total area of Pará), particularly, has been divided in three sectors (i) Sector 1 or Atlantic; (ii) Sector 2 or Continental-Estuarine; (iii) Sector 3 or Insular-Estuarine (Figure 1.3). The study area of this work, “Sector 1 or Atlantic” (Figure 1.4), is integrated by 22 municipal districts distributed in 16,215 km² - 19.5% of the total area of the coastal zone of Pará. This area, located at the NE region of the State of Pará, has been chosen for the present work considering that it is the only sector of the coastal zone that has, at present, some activities related to the State Coastal Zone Management Program. This study is part of the project “Mangrove Dynamics and Management - MADAM”², which has its activities headquarter and facilities in the Municipality of Bragança.

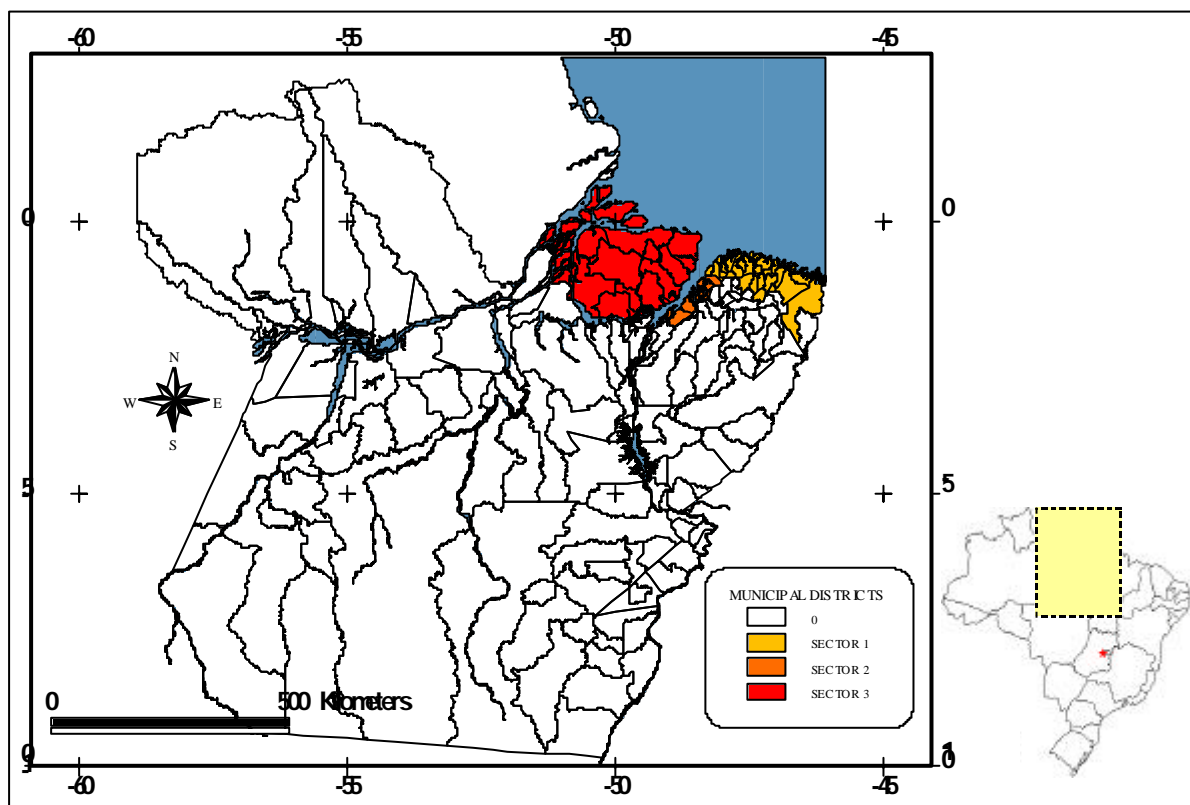


Figure 1.3 Localization of the three sectors of the coastal zone of the State of Pará, sector 1 or Atlantic; sector 2 or Estuarine, and sector 3 or Marajó Island.

From the geological point of view, the Northeastern region of the State of Pará shows a Late Cenozoic sedimentary evolution defined by three litostratigraphic units (Rosseti, 2001):

² The project MADAM is a research cooperation established between the Federal University of Pará (Brazil) and the University of Bremen (Germany). Since 1996, several disciplines such as botany, zoology, geology and geochemistry, socio-economy, theoretical ecology and modelling, geography, remote sensing and GIS has been included. This integrated approach aims to provide the scientific basis for understanding, modelling and predicting mangrove behaviour under changing environmental conditions.

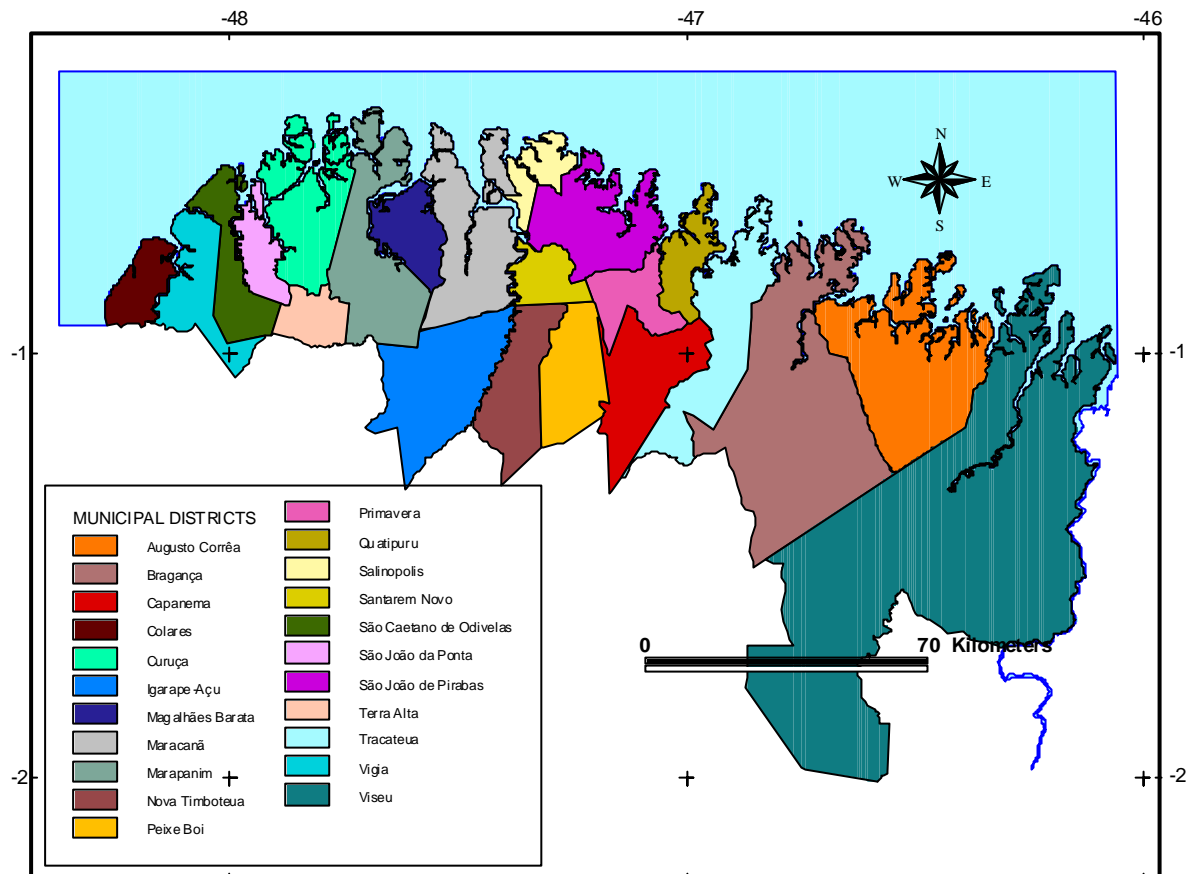


Figure 1.4 Study area: "Sector 1 or Atlantic".

- The Pirabas Formation (late Oligocene-early Miocene), originally defined as fossiliferous calcareous rocks (Maury, 1925), at present also includes gray to yellowish, massive limestones interbedded with black, gray and greenish laminated mudstones and minor calcareous sandstones (Goes et al., 1990).

- The Barreiras Formation (late early Miocene to mid-Miocene) consists of multicolored, non fossiliferous siliciclastic deposits (Oliveira and Leonardos, 1943). This unit has traditionally been considered continental in origin (Goes and Truckenbrodt, 1980); however, studies emphasizing facies analysis along the Bragantina platform have revealed a variety of sedimentary features attributed to marine processes (Rosseti et al., 1990).

- The Pós-Barreiras sediments, applied indiscriminately to all deposits unconformably overlying the Barreiras formation, include unconsolidated to semi-consolidated sands of uncertain age between the Plio-Pleistocene to the present (Rosseti et al., 1989). To the East of the Amazon River mouth, the coast is characterized by a fringe of muddy sediments covered by mangroves, which have been deposited in front of a higher hinterland of the Barreiras Formation (Szlafsztein et al., 1999).

The Atlantic sector is an irregular estuarine coast where the high relief of the cliffs decreases in indented entrances which penetrate about 50 km into the continent and are about 20 km wide in the outer parts and present depths of about 5 m (Barbosa and Pinto, 1973). Four different units can be recognized according to morphology, sediment source and vegetation: *alluvial plain*, *estuarine plain*, *coastal plain*, and an undulating plateau - *Planalto Rebaixado da Amazônia* (Souza Filho, 1995).

This region is characterized by well-developed mangrove where the dominant species are, in order of abundance *Rhizophora mangle*, *Avicennia germinans*, and *Laguncularia racemosa*. The vegetation in the saline marshes is predominantly *Alecharias sp*, while in the Cheniers and dunes arbustive vegetation is observed (Souza-Filho, 2001). Crop farms with secondary growth (*campos naturais and capoeiras*) and forest are the most dominant vegetation types in the inland area of the coastal zone (Brasil, MME-DNPM, 1973; Brasil, MME-DNPM, 1974). Mangroves and wetlands build peninsulas crossed by several tidal channels, which link the forest with the estuaries (Szlafsztein et al., 1999).

The NE Pará climate could be described as tropical warm and humid, with a drier period (less rainfall) that occurs from June through November. The coastal meteorological stations of Belém and Turiaçu, in Maranhão State document a mean annual temperature of 26.1°C. Maximum and minimum temperatures range between 31.7 and 18 °C in Belém, and between 33.2 and 15.1 °C in Turiaçu. The registered mean annual precipitation is 2277 mm in Belém, and 2134 mm in Turiaçu (Martorano et al., 1993).

It is worth to highlight that the NE coast of the State of Pará lacks systematic studies on hydrodynamic and oceanographic parameters. However, the little already existent information indicates that the main winds are the Trade winds blowing from NE to SW that are originated by two subtropical anticyclones: the *Atlantic Tropical* (ATA) and the *North Atlantic Tropical* (ATAN). They result in the formation of the ITCZ area (Intertropical Convergence Zone) with weak winds and variable directions that directly act on the coastal zone in the rainy season (DHN, 1986; IBGE, 1986). The oceanic tides are the main hydrodynamic feature of the region. The tides of semi-diurnal nature present maximum amplitude of 5.5 m in Salinópolis (DHN, 1994), characterizing a macro-tidal regime according to Davies (Davies jr. and Hayes, 1984). Finally, the main currents existing along the coast are the tidal and the littoral ones. The first ones are present during the whole year, and are directly related to the tidal variability. When they reach their highest speed, they have an E-NE direction in the ebb tide, while in the flood tide they

have a W-SW direction, constituting the flow and ebb currents that mainly form the estuaries and tide channels. The littoral currents have WNW direction, due to the wave front incidence angle generated by the Trade winds winds that reach the coast according to the ENE direction (Pinheiro, 1987).

The total population in the NE coastal zone of the State of Pará in 2000 (539,324 inhabitants), represents approximately 8% of the total population of Pará. The spatial distribution of the population is not homogeneous in the whole region, major concentrations being observed in urban areas. 171,548 people, 31% of the coastal zone total population, reside in the capital cities of the municipalities of Bragança, Capanema, Vigia, Salinópolis, Viseu and Igarapé-Açu. The coastal zone has a very low population density (33 inhabitants/km²); however, there are sectors where this parameter surpasses the number of 3,000 inhabitants/km² reaching almost 10,000 inhabitants/km² at the localities of Primavera, Bragança, Emborai (municipality of Augusto Corrêa), Caratateua (municipality of Bragança), Colares, Vigia, Viseu, Salinópolis and Fernando Belo (municipality of Viseu).

This area, with very low industrial development³, is moderately used for agricultural purposes - rice and manioc cultivation (“slash and burn” method) and cattle farming. The mining activities are concentrated in the extraction of iron (municipality of Viseu) and of gemstones (diamond, tourmaline, topaz, opal, amethyst, etc.) in the municipalities of Capanema, Primavera and Viseu (O Liberal, 1999). Socio-economic surveys (Glaser, M., Unpublished) show that a large percentage of the inhabitants earn their living from the mangrove ecosystem. Crab collection (*Ucides Cordatus*) and fishing are the economically most important activities (Figure 1.5). Fish, shrimp and other invertebrates, as well as mangrove timber are used, even though the latter is predominantly used to light kilns for brickwork (Berger et al., 1998). As part of the government tourism policy and in order to facilitate access to coastal resources for the local population, roads have been constructed, to connect the hinterland and the beaches.

1.2 The Integrated Coastal Zone Management Programs of Brazil and the State of Pará

Independent of the land occupation intensity, socio-economic and environmental problems among various types of users of the coastal zone are inevitable. Therefore, coastal areas

³ The principal industry is a cement factory in the city of Capanema (municipality of Capanema).

have been calling the attention of national and local government agencies, because they constitute a privileged field for different strategies of environmental planning and sustainable management of land and resources use (Szlafsztein, 2000).



Figure 1.5 Typical views of the activities of the crabs' collectors (region of Bragança).

The last 20 to 30 years have seen the gradual evolution of management strategies aiming at an integrated assessment of the problems, instead of *ad hoc* mitigation on a local scale (Schneider, 1997). According to Rotmans and Van Asselt (1996) integrated assessment can be defined as “*an interdisciplinary and participatory process of combining, interpreting and communicating knowledge from diverse scientific disciplines to achieve a better understanding of complex phenomena*”. One of these kinds of assessments is the *Integrated Coastal Zone Management (ICZM)*. The ICZM is a process which enables policy makers to strike a socially acceptable balance between economic welfare and environmental well-being. That means, it aims at determining the expected and desired development of the coastal region, and at designing and controlling the complex interactions between the coastal resources system and its potential uses and users in a systematic and sustainable way, including present and future problems in the coastal zone (Cincin-Sain, 1993; IPCC, 1991; Turner and Bower, 1999).

In Brazil, during the last decades important coastal issues have been also discussed, among them the evaluation of coastal conditions and the planning of appropriate strategies for resource management and land use. These considerations have been developed in order to give support to the national and regional governments toward the implementation of a coastal zone management program. In 1970, the Brazilian government claimed the 200 nautical-mile territorial sea for coastal and ocean resource rational utilization and development. However, there was neither a regulatory nor a coordinating agency or laws to

rule Brazil's coastal resources and environment (Cincin-Sain and Knecht, 1998). Therefore, the Interministerial Commission of Marine Resources (CIRM - *Comissão Interministerial dos Recursos do Mar*) was created to develop a national ocean resources policy, to promote and manage research and rational development of marine resources, and to intergovernmental and interministerial conflict management (Federal Decree 74557/74). The CIRM, headed by the Ministry of the Navy (*Ministerio da Marinha*), was established definitively in 1979, and assumed responsibility for coordinating three major projects (i) ocean resources, (ii) Antarctic research, and (iii) coastal zone management (Pires Filho and Cycon, 1987; Herz, 1989). In 1983, the CIRM initiated the coordination of the Coastal Zone Management Program (PROGERCO - *Programa de Gerenciamento Costeiro*) providing grants for coastal resources research. In order to attain legal clout for the effective implementation of PROGERCO, CIRM sponsored a draft National Coastal Zone Management Act (PNGC - *Plano Nacional de Gerenciamento Costeiro*) which was passed by the National Congress in 1988 (Federal Law 7661). In 1990, the administration of PNGC, a part of the National Policy for Resources from the Sea (*Política Nacional dos Recursos do Mar* - PNRM) and of the Environmental National Policy (*Política Nacional do Meio Ambiente* - PNMA), was transferred from CIRM to the Brazilian Environment Institute (IBAMA - *Instituto Brasileiro do Meio Ambiente*), which belongs to the Ministry of the Environment, Water Resources and Amazonia (Andriguetto Filho, 1993; Herz and Mascarenhas Jr., 1993).

The PNGC acts on 426 municipal districts distributed in an area of 420,000 km². Its most important objectives are the elaboration and execution of norms for the rational use of the coastal zone resources, the contribution to improve local population well-being, and the conservation of the natural, historical, cultural and ethnical heritage. Particularly, the PNGC should foresee the zoning for use and activities in the coastal zone, giving priority, among other things, to the conservation and protection of reefs and algae banks, sandbanks and dunes, littoral forests and mangroves, as well as fluvial, estuarine and lacustrine systems. The management program establishes a methodological order that implies, from a technical point of view, the use of four basic instruments (i) *Large-scale zoning of social and environmental units*; (ii) *Information system of the coastal administration*; (iii) *Monitoring system of management proposals implementation*; and (iv) *Specific management plans*.

According to Good et al. (1999), the ICMZ programs establish a unique state-national partnership designed to encourage states to develop programs for more effectively managing coastal resources. In Brazil, the Federal Constitution (Brasil, 1991) indicates that the three governmental levels have simultaneous competence to legislate on environmental problems, public patrimony administration, and natural resource conservation (art. 24). Therefore, the PNGC not only has a strong environmental component, but also the responsibility to provide bases for state and municipal planning of coastal zone management policies, observing the national norms and guidelines. The states assume responsibility for legislating and performing a continuing survey about the established coastal zone rules on soil, subsoil and water use and exploitation limitations. The State of Pará established its Environmental Policy (State Law 5587/95), a group of objectives, instruments and guidelines to preserve and protect the natural environment, and to improve the human well-being, in harmony with socio-economic development for current and future generations. Its principal objectives are (i) the definition of priority areas for government actions, (ii) the preservation of the natural patrimony biodiversity, and (iii) the creation and implementation of environmental control instruments. As one of these instruments, the Coastal Zone Management Program of the State of Pará (*GERCO/PA - Programa de Gerenciamento Costeiro do Estado do Pará*) has been designed in order to plan and manage socioeconomic activities that control, conserve and recuperate the coastal natural resources and ecosystems, and exert an effective control over pollution sources or other forms of environment degradation that affect or could affect the coastal zone. The Institute of Socioeconomic Development of the State of Pará (*IDESP - Instituto de Desenvolvimento Socioeconómico do Estado do Pará*) has taken charge of the coordination of GERCO/PA.

In Brazil, for many years, the results reached by the secretaries and other agencies dealing with environmental policy problems have been mainly related to coastal zone environmental and political-institutional diagnosis⁴ (Barragan Muñoz, 1998; Diegues, 1999). In Pará, particularly, the little success in the implementation of the coastal management program is caused by several factors such as (i) the weak support from the society and local communities, (ii) conflicts of jurisdiction and lack of coordination among institutions at the three governmental levels, and (iii) lack of available information and financial resources. In the first case, it has been observed that the management program has

worked more in response to public needs and demands than in response to a motivation of scientific understanding of the problem involved. In the second case, an analysis of the general budget of the State of Pará in the period 1996-2001 (IOEPA, 1992-2001) highlights that only about US\$ 830,000⁵ have been destined to the Coastal Zone Management Program of the State of Pará (0.001% of the total budget) (Figure 1.6). The extinction of IDESP, and the transfer of GERCO/PA's activities to the Executive Secretary of Science, Technology and Environment (SECTAM - *Secretaria de Ciência y Tecnologia do Estado do Pará*) (State Law 6211/99) have also had a deep influence on it because this Secretary has many responsibilities and other priorities than coastal management.

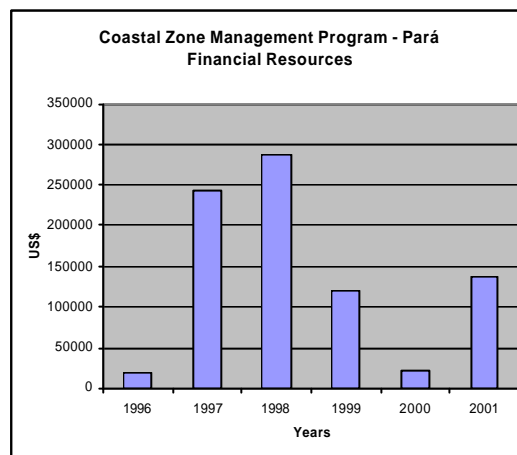


Figure 1.6 Amount of money destined to the Coastal Management Program of the State of Pará in the period 1996-2001 (source: IOEPA, 1992-2001).

1.3 The Coastal Zone: An Integrated System and the P-S-I-R Framework

Although coastal management *per se* is not unique, the ICZM programs, independent of the type, localization and scale, have been implemented to achieve wise use and protection of the coastal zone land and water resources (ecological, cultural, historical and aesthetic values), taking into full consideration the needs for compatible economic development (Good et al., 1999). In this sense, it is possible to summarize that the ICZM Program is a dynamic process in which a coordinated strategy is developed and implemented to achieve a balance among three principal factors (Figure 1.7):

- Physical Features: which include diverse types of natural processes (geologic, geomorphologic, and climatic) that take place in the coastal area, characterized by different frequencies and magnitudes.

⁴ Most of the States have only finished the first two steps of the PNGC's methodology *Large-scale zoning*, and *System of information of the coastal administration*.

- Economic Features: related to the natural resources existent in the region (fauna, flora, soils and mineral), and how human beings utilize and conserve them.
- Human Features: which condition the manner in which coastal areas are utilized by diverse social and economic activities.

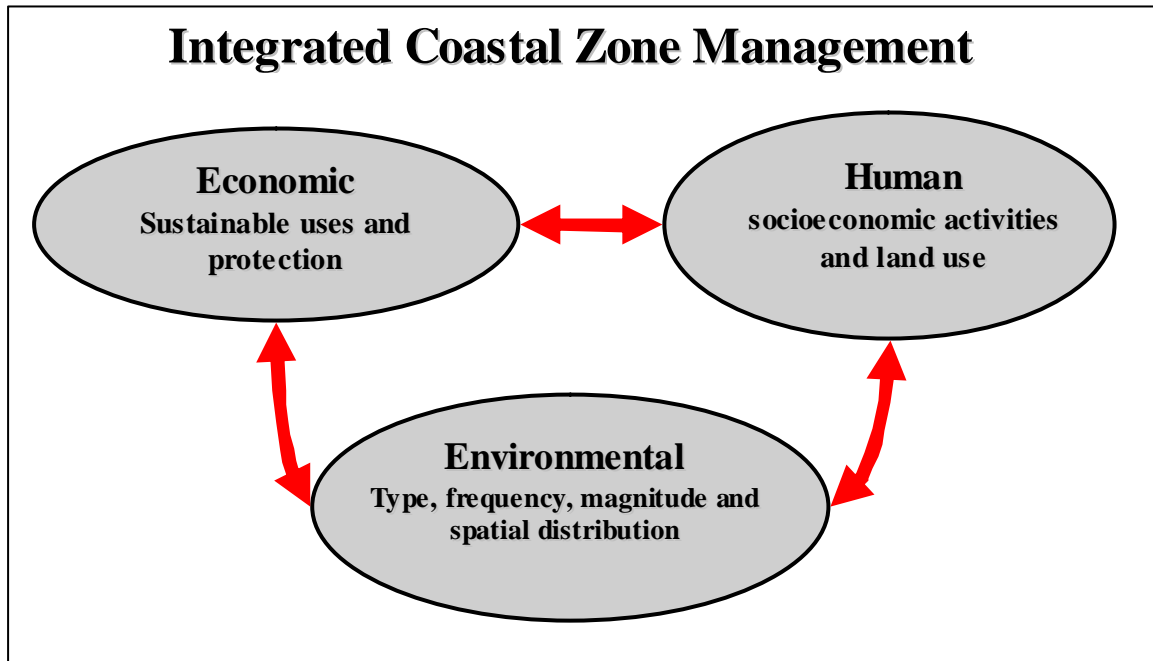


Figure 1.7 Factors to be integrated in coastal management (modified from Burbridge, 1999).

The three sets of very complex factors interact; then ICZM programs do not have an easy task trying to establish equilibrium among them. On the one hand, the coastal zones constitute high energy areas, with very active and complex dynamics and considerable instability, as the Quaternary geological record in the North of Brazil has clearly shown (Behling and Da Costa, 2000; Rosseti, 2001). On the other hand, coastal areas are currently experiencing intense and sustained environmental stress built-up via a range of socio-economic driving forces, which have been increasing in their intensity over many decades, and are augmented by natural systems variability (Turner and Salomons, 1999). In Brazil, the coastal area also receives environmental pressures as a result of the action from different demographic (Moraes, 1995) and economic (Egler, 1995; Melo and Gonzalez, 1995; Leão, 1993) driving forces. Nevertheless, in order to reach the several issues, problems, and arguments surrounding the coastal areas management, a wide range of instruments (administrative, social and technical) is commonly used - many of them not specific to the coast. Most of these approaches use a simplified organisational framework,

⁵ Considering the variability of the US\$ - R\$ (Brazilian Real) exchange rates, in the whole study the following estimated relationship has

the *P-S-I-R cycle* (Pressure - State - Impact - Response). The objective of this approach is to clarify multisectoral inter-relationship and to highlight the dynamic characteristics of ecosystem and socio-economic changes (Olsen et al., 1997). In the present study, the *P-S-I-R cycle* has been also adopted with some modifications (Figure 1.8).

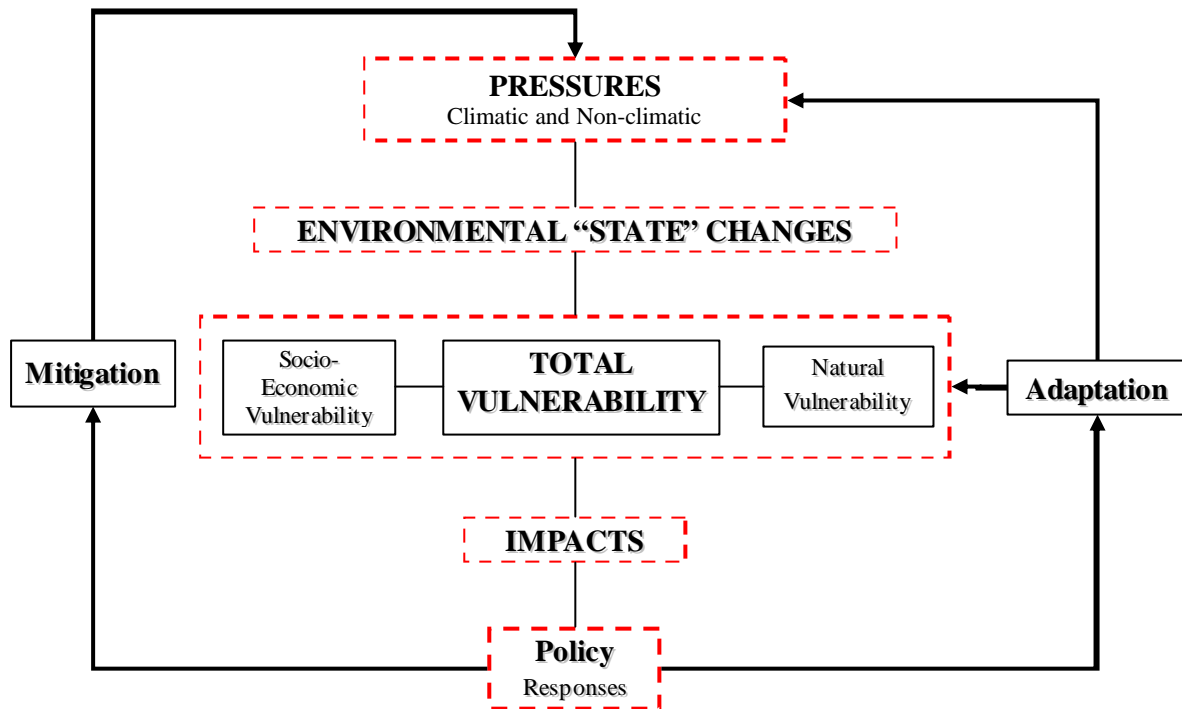


Figure 1.8 PS-I-R framework: continuous feedback process in coastal areas (modified from Klein and Nicholls, 1999; Turner and Salomons, 1999).

All coastal areas face a growing range of stress and shock when, for natural or human-related reasons, some of the coastal zone factors (physical, economic, human) present certain behavioural change. Thus, *Pressures* cause partial or total imbalance on the coastal system. The first effects are environmental *State* changes such as pollution of soil and water, degradation of habitats, changes in land cover and land use, etc. This disequilibrium (pressure and environmental changes) results in a number of perceived *Impacts* that affect the natural processes, the resources uses and protection, and the socioeconomic activities that take place in coastal areas. These impacts can be classified by their magnitude and intensity, duration (permanent or temporary), capacity to return to its original condition (reversible or irreversible), and spatial distribution (homogeneous or heterogeneous).

The *impacts* do not only result from the type of *pressure* that affects the coastal system, but are also a function of its *Vulnerability*. It can be defined as the susceptibility of natural resources and ecosystems to negative impacts (NOAA, 1999) and/or the individual and

society capacity to anticipate, cope with, resist, and recover from the effect provoked on the system (Adger, 1999; Adger and Kelly, 1999). It is important to highlight that one of the specific objectives of PNGC is *to obtain a correct dimension of the coastal zone vulnerabilities* (Barragan Muñoz, 1998).

Although vulnerability assessments could be considered as important components of any attempt to define the magnitude of the threat, this analysis also provides a starting point for the determination of effective means of promoting remedial action to limit impacts and recover, as soon as possible, the original conditions (previous to the uneven occurrence) by supporting coping strategies and facilitating adaptation. These spontaneous or planned policies - *Response Measures and Strategies* - could be regarded as the interference in the natural processes or in the socioeconomic activities. On the one hand, it is possible to try to mitigate (total or partially) the causes of the imbalance in global scale (e.g. limiting greenhouse effect by reducing emissions and/or augmenting carbon sinks and reservoirs) and in local/regional level (e.g. limiting the factors that accelerate subsidence) (Haq and Milliman, 1996). On the other hand, in order to be adapted to the new reality (modified by the effects taken place in the system), adjustments on the behaviour of the coastal zone components (individual or collectively) are necessary. Adaptation responses mainly aim to reduce the system vulnerability; however, they can also cause changes on the *pressures*, thus collaborating indirectly with mitigation policies (Figure 1.8).

1.4 Problem Definition – The Natural Hazards Impacts in the NE of the State of Pará

The *P-S-I-R* framework could be applied to many coastal management initiatives that usually respond to a demand for solving problems such as conflicting coastal resources exploitation, population growth and urbanization, pollution, and environmental degradation, as well as natural hazard impacts - events or processes with potential harm for people, property and environment (Kay and Alder, 1999). The very active and complex coastal areas dynamic - resulting from the interface between atmosphere, hydrosphere and lithosphere - is the origin of the processes of shoreline erosion and sedimentation and low-lying coastal flooding that have direct and indirect consequences for coastal communities (Charlier and De Meyer, 1997). In order to understand its magnitude, from the world's coastal areas, more than 70% have shown net erosion over the past decades (Bird, 1985) and particularly in Brazil, approximately 30% of the coastline has been suffering from erosion processes (Mascarenhas and Augusto Filho, 1997).

The coastal zone of the State of Pará can also be described as a system affected by natural hazards and risks, principally including flooding and erosion, which can lead to loss of land, alteration of ecological characteristics, and severe property damage. In many opportunities, the dramatic effects of these negative impacts are reflected in numerous newspaper reports (Figure 1.9).



Figure 1.9 An example of a newspaper report informing about coastal flooding; headline “*Salinas residents face the power of the March tides*” (O Liberal, March 13, 2000).

In the *Bragantina* Region⁶, the beaches have been affected by erosive processes, which provoked a shoreline retreat of 50 m at most in one year of observation— from March 1998 to March 1999 (Krause, 2002). Souza Filho (2001) describes that in *Vila dos Pescadores* (municipality of Bragança) successive flooding and erosion events have constantly affected the residents' life (Figure 1.10). In the last five years, about 500 m of the village next to the estuary has been eroded; on the beach area, the erosion rate is slower due to the beach dissipation profile and the wave incidence angle - almost parallel to the coastline. Alves (2001) describes that on the beach of Ajuruteua (municipality of Bragança), the NW sector has been impacted by an erosive process, due to its localization next to the margins of a tidal channel, to the wave incidence angle (about 7°), and to the tidal range varying from 4 to 6.5 m during March and April (Figure 1.11). Such conditions caused a coastline retreat of 22 m in 2000. On *Farol* and *Buçucanga* beaches (municipality of Bragança), the action of waves and tide currents also provokes a retreat of the shoreline, developing beach cliffs (10-meter-maximum height) sculpted in coastal longitudinal dunes. Cohen and Lara (2003)

⁶ Municipalities of Augusto Corrêa, Bragança, Capanema, Igarapé-Açu, Nova Timboteua, Primavera, and Santarém Novo.

use temporary changes on mangrove vegetation boundaries to localize and calculate coastal erosion and sedimentation processes.



Figure 1.10 Flooding event in *Vila dos Pescadores* (municipality of Bragança) (Source: Maneschy, 1988).

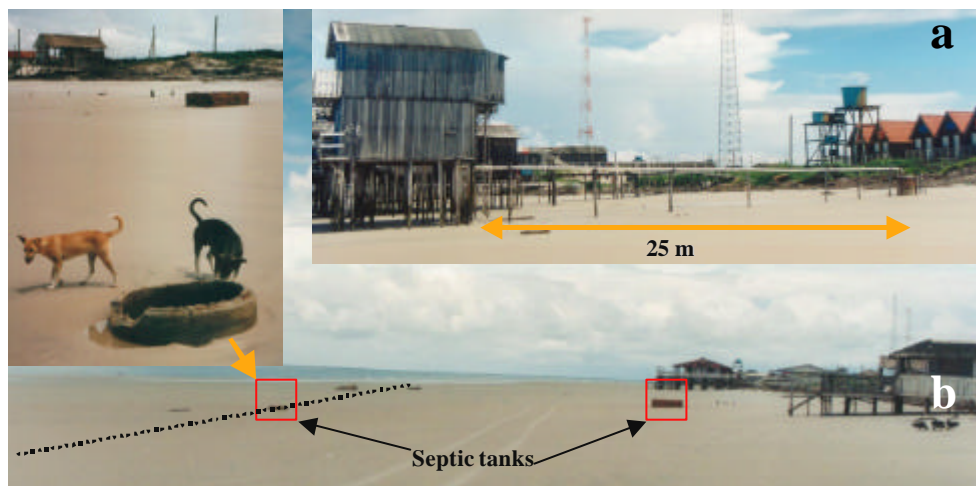


Figure 1.11 Erosion evidences on the beach of Ajuruteua (municipality of Bragança). (a) The cesspits are usually constructed about 25 m from the back part of the houses. (b) Lines of old cesspits (dotted line) allow estimating erosion rates in the last 25 years.

In the municipality of Marapanim, Silva (1995) and Santos (1996) estimate an erosion rate of 15 m/year in Marudá region and describe a cliff retreat of 200 m in Camboinha, on Algodal Island. A large storm-surge event was the origin of disaster situations on the beach of Crispim and Augusto Corrêa, impacting the local population, their houses and economic activities (IOEPA, 1992-2001). Other impacts from natural hazards, many times related to human settlements in hazard prone areas, can also be found in several sectors of the coastal zone of the State of Pará such as the municipality of São João de Pirabas (Silva Jr, 1998), Vigia (Figure 1.12), and Maracanã (Figure 1.13).



Figure 1.12 Human settlements in natural hazard prone areas in the city of Vigia (municipality of Vigia).



Figure 1.13 Human settlements in natural hazard prone areas in the city of Mocooca (municipality of Maracanã).

For the last years, several authors (Franzinelli, 1982; Mendes, 1998; Castelo Reis, 1999) have studied the oceanographic characteristics and described numerous erosion evidences in different sectors of the coast of the municipality of Salinópolis - Atalaia and Maçarico beaches (Figures 1.14 and 1.15). Muehe and Neves (1995a) indicate this region, the main center of vacation and tourism in the North coast of Brazil, as the sector with higher socioeconomic susceptibility to the impacts of potential sea-level rise.



Figure 1.14 The wave power on Atalaia beach (municipality of Salinópolis).



Figure 1.15 Several evidences of coastal erosion on Maçarico and Atalaia beaches (municipality of Salinópolis) affecting high value houses and coastal protection measures.

Unfortunately, official data on the economic impacts (damages and recovery costs) of the natural hazards in the State of Pará do not exist; however, it does not impede the consideration of their effects in a regional context, as one of the main problems that are presented in the coastal zone of the State of Pará.

1.5 Final Considerations

Throughout the world, coastal areas are facing a growing number of problems as a result of development and increased population pressures in natural hazard-prone areas, particularly erosion and flooding. In consequence, functions and values normally associated with coastal areas have been degraded, and public safety and economy have been impacted.

The recognition by scientists that many coastal areas are hazardous and dynamic zones (Viles and Spencer, 1995), and that the consequences for human development are so potentially devastating has led to an increasing need of government attention in understanding and solving coastal risks. Considering that it is usually neither economically feasible to totally neutralize hazards through engineering (e.g., by building giant seawalls) nor socially acceptable to completely exclude people and structures from hazard zones, a balanced management approach is needed. According to Clark (1995), an ICZM-type program, a balanced approach, is a good vehicle because it can control development patterns and combine coastal natural hazards prevention with resource conservation.

Along the 20th Century, most of the human settlement and development planning has taken place in a conceptual framework of “*relative constancy*” - socio-economic and environmental (climate and other physical aspects) variables are relatively “stable” - driving to the elaboration of *short-term* coastal management programs. However, many authors (IPCC, 1990; Warrick and Farmer, 1990; Hoolligan and Reiners, 1992) state that the change and evolution of the different coastal zone components (with the time) should be considered, at present, when the impacts of coastal hazards on an ICZM framework are analyzed - driving to a *long-term* approach. On the one hand, while these risks are substantial and commonly recognized, the local benefits of using coastal resources outweigh the risks, and continue to attract human activity and development to the coastal zone. If populations in coastal areas continue to grow, a concomitant increase in population density, infrastructure and property values will be spurred; then balancing environmental and development concerns will be increasingly difficult (Neumann et al., 2000). On the other hand, predicted changes in climate and potential sea level rise will exacerbate many of these coastal problems, particularly on small islands, deltas and low lying coastal plains (Pethick, 2001). Modest sea-level rise may have serious effects in combination with extreme sea-water levels and impingement of high waves (Hanson and Lindh, 1993). Coastal strips wider than 20 km may be also affected by inundation (Vellinga and Leatherman, 1989), and, according to Rosseti (2001) and Muehe and Neves (1995a), the extremely low relief of the coastal platform of the NE of the State of Pará implies that a change of a few meters in relative sea level would be enough to flood large areas into the continent. The mangrove ecosystem, so important for the socio-economic development of the coastal area of Pará (Prost et al., 2000), is also one of the more sensitive natural ecosystems to global climate change (Ellison and Stoddart, 1991; Semeniuk, 1994; Woodroffe, 1990).

The *long-term* Coastal Management programs force policy makers to integrate existing *short-term* plans regarding the coastal zone with future scenarios of both natural characteristics changes and projected population growth and investment rates, and their effects on management decisions (Pernetta and Elder, 1992; Nicholls and Leatherman, 1995a).

Although decision-makers in Brazil are only beginning to understand the ways in which long-term changes could influence their plans, something has been done since 1992. The Agenda 21 adopted at the United Nations Conference on Environment and Development

accomplished in Rio de Janeiro, indicates in the Chapter 17 - Program E (UNCED, 1992), among other things that, “*The countries must take measures to adapt the coastal management to the probable climate change and sea-level rise*”. The Interministerial Commission for the Resources of the Sea (CIRM) establishes the Brazilian Pilot Program for GOOS (Global Ocean Observing System) in order to continuously monitor oceans and sea-level rise and coastal erosion areas. In 1999, the Interministerial Commission of Global Climate Change was created, in order to develop studies on vulnerability and adaptation to impacts of climatic changes, and consequently elaborate, among others, appropriate plans for the Brazilian coastal zones. Also, the Brazilian Forum of Climatic Changes (Presidential Decree 3515/00) has the objective of mobilizing the society for discussion and action taking on current problems of climatic change due to the greenhouse gases effect.

Considering all aspects previously explained - the "importance" of coastal zones ecosystems and resources, natural hazard impacts, scenarios of climatic changes and increasing socio-economic development, and necessity of establishing long-term management programs - the present study aims to: (1) analyze how the natural hazards issue can be incorporated into broader planning contexts of a *long-term* integrated coastal zone management program of the NE of the State of Pará, and (2) support, with scientific and methodological basis, state and municipal governments, who generally lack expertise in this area.

In this sense, the objectives of this study are to provide tools to:

- i) Describe the future scenarios of global climate and sea-level rise change, as well as growing population and investment, and explore their implications as *pressures* on the coastal region of the North of Brazil for natural hazards management (Chapter 2).
- ii) Analyse natural hazards (erosion and flooding) and potential sea level rise *impacts*, identifying, assessing and classifying natural and socio-economic *vulnerabilities* of the coastal zone by means of a Geographical Information System-based coastal vulnerability index (Chapter 3).
- iii) Evaluate the capability of Brazil, the State of Pará and the coastal municipal districts for implementing *response* strategies and measures to cope with the impact of natural hazards within a broad coastal zone management framework (Chapter 4). For that, some urgent research questions are:

-
- Which adaptation strategies and measures have been adapted by the population and the authorities recently in order to face the action of natural coastal processes?
 - Considering their performance, which are the causes of success or failure of the adopted strategies and measures?
 - Will these strategies and measures be suitable to face extreme events in consequence of global changes?
 - Are there institutions or people already thinking about adaptation strategies and measures for a future scenario of climatic change? Which institutions or populations will be able to adapt quickly and which ones will not?
- iv) Finally, propose new strategies and measures or strategic adjustments in order to support the natural hazard and Sea-level rise issues on the long-term coastal management program of the State of Pará (Chapter 5).

CHAPTER 2

PRESSURES ON THE COASTAL ZONE SYSTEM: SEA LEVEL RISE AND HUMAN DEVELOPMENT FUTURE SCENARIOS

The coastal zone is one of the most dynamic environments on the earth's surface. In general, its position has moved significantly landward over the last 18,000 years due to a global sea level rise of about 100 meters. The changes continue today. While shoreline position is an interplay between wave energy, sediments supply and sea level, it has been argued that sea-level rise is a major causal factor in these recent changes (Vellinga and Leatherman, 1989). The present and predicted sea-level rise and its possible acceleration are not the only pressures that impact on the coastal systems. Significant human development and population growth are also occurring in the coastal zone at global scale (Nicholls and Leatherman, 1995b). Increased development in coastal areas often result in changes of natural habitats, which reduce the ecosystems natural buffering capacity, in the increase of population infrastructure, and so in the associated economic investment at risk (Burke et al., 2001).

The presence of human beings and their activities as they interact with naturally occurring coastal processes define the coasts as areas of potential risk - e.g. the changing climate may cause more severe and frequent storms and thus increase the risk of flooding for both inland and coastal areas; then the society would be exposed to more frequent flooding and property damage (Griggs, 1994; Hudgens, 1999). Unfortunately, most current and planned developments do not consider existing coastal hazards, let alone the possibility of accelerated sea-level rise. Although it is apparent that sea-level rise will generally exacerbate existing problems rather than fundamentally create new ones, without appropriate management actions, these two pressure trends - sea level rise and human development - place the coastal zone on a "collision course" (Figure 2.1).

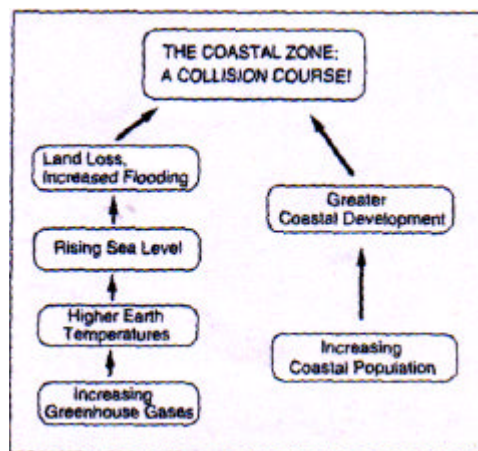


Figure 2.1 Pressures on the coastal system - sea level rise and human development, defining a "collision course" (Source: Nicholls and Leatherman, 1995).

Consequently, in addition to the pressing short-term problems, management activities need to address these long-term issues (Nicholls and Hoozemans, 1996). Societal planning is an exercise on thinking about the future; however, it also compels to think about the present and the past, considering the reformulation of historical and present knowledge into statements about the future, that is, the creation of a *predictive knowledge* that allows describing potential future scenarios (Lundgren, 1993).

The ability to define possible scenarios is critically dependent on understanding past and present factors and their changes. Therefore, the **exact** sea level rise or human development to occur at the coastal zone is not known; hence scenarios that delineate some different possibilities must be assumed. Although a lapse of 50 to 100 years is relatively short, the potential scenarios for the coastal zone long-term management are based on this period because the climate changes - trends and fluctuations - that occur at time scales up to 100 years may be irreversible, and this time scale corresponds to economic planning and development period, and possibly also to social changes period (Hoozemans et al., 1993a). The defenses against the sea and many coastal facilities as highways, bridges, and jetties are also conceived and calculated for an approximate 50-year period (Pugh, 1990).

Therefore, this chapter describes the potential scenarios and discusses the implications of sea-level rise, increasing population, and socioeconomic development as *pressure* factors on the coastal system, for the long-term planning and management of the NE of the State of Pará.

2.1 Climate change and global and relative sea-level rise

In the past years, no environmental issue has risen so scientific, political and public interest and debate as the potential global climate change as a result from the “Greenhouse Effect” (Milliman and Haq, 1996). Generally speaking, the weather and climate on the earth are naturally extremely variable; however, recent analyses suggest that the current rise in temperature is very unlikely to be the product only of natural causes (SwissRe, 1996). This effect is the result of a recent increasing concentration, in the atmosphere, of the main greenhouse gases - carbon dioxide, methane, chlorofluorocarbons (CFC), and nitrous oxide (Ramanathan et al, 1985). The gas concentration change probably has a human origin - during the last 250 years, industrial activity has been increasing and so the combustion of fossil fuels, which produce these gases; deforestation and changing agricultural land use are also growing (Houghton, 1999). According to Roeckner (2000), since pre-industrial

times, the concentration of carbon dioxide in the atmosphere has increased around 30%, and if CO₂ emissions due to the combustion of fossil fuels continue to grow unabatedly, a doubling of the current CO₂ concentration of about 360 ppm can be expected for the next years. This problem was first posed in the mid 1960s, when it was demonstrated that greenhouse gases were accumulating in the atmosphere and that they absorb infrared radiations (Lutjeharms and Valentine, 1991; Pirazzoli, 1996; Titus et al., 1991).

Most widely employed climate change scenarios are based upon highly complex general circulation models (GCMs) of the atmosphere and the ocean (including land surface processes and sea ice) that project a relatively smooth path of global average temperature rising (Weaver and Green, 1998). One of the most accepted scenarios of the impact from past and future greenhouse gases and sulphur emission on the global mean temperature evolution from 1860 to 2050 is shown in the Figure 2.2. The simulated warming has ranged from about 2°C to 3.5°C/century (IPCC, 1996). In these situations, the concentrations of greenhouse gases have been prescribed according to observations (1860 to 1990) and according to the CO₂ increase of 1%/yr scenario called *IS92a* (IPCC, 1992a). These results are still uncertain due to the natural temperature variability, doubts about modeling, and lack of available data on the south hemisphere (Etkins and Epstein, 1982; Houghton, 1999).

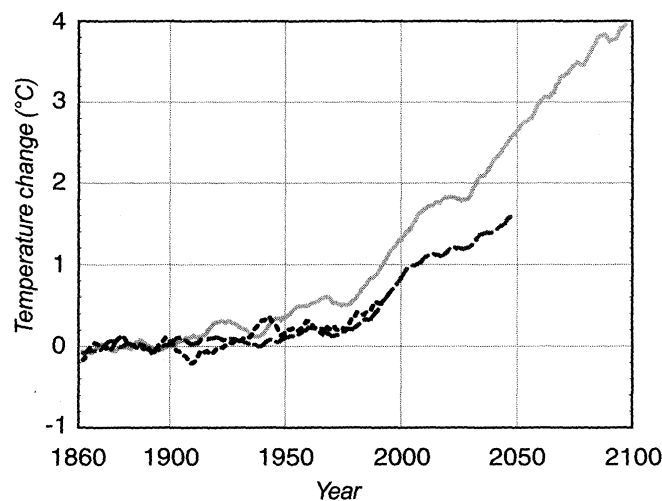


Figure 2.2 Temporal evolution on simulated and observed global annual mean surface air temperatures as deviations from long-term means (1860 to 1890 for observations *stippled curve*). *Full curve*: greenhouse gas only experiment assuming increasing concentrations of CO₂, CH₄, N₂O and CFCs according to observations (1860 to 1990) and according to scenario *IS92a* thereafter. *Dashed Curve*: Greenhouse gas + sulphate experiment (in addition to the increase greenhouse gases, the increase in tropospheric ozone is prescribed, and the sulphate aerosol effects are calculated) (Roeckner, 2000).

Available observational evidence indicates that global climate changes have already affected a diverse set of physical and biological systems in many parts of the world.

Examples of observed and predicted environmental changes include shrinkage of glaciers, thawing of permafrost, late freezing and early break-up of ice in rivers and lakes; lengthening from mid to high latitude growing seasons, poleward and altitudinal shifts of plant and animal ranges, declines of some plant and animal populations, and early flowering of trees, emergence of insects, and egg-laying in birds (IPCC, 2001a); tropical cyclone intensity increase (Walsh and Ryan, 2000); and drainage basin modifications (Tucker and Slingerland, 1997). According to Berz (1999), and Walsh and Pittock (1998), global climate change, more and more also influences the frequency and severity of natural catastrophes. However, it must be highlighted that one of the most important effects of global climate change is sea-level rise.

Although the level of the oceans has always fluctuated according to changes in global temperature (Nicholls and Leatherman, 1995a), a rise in average sea level is not only an expected consequence of the enhanced greenhouse effect - thermal expansion of the upper ocean layers, as a result of higher sea surface temperature (*Steric effect*), and the melting of Arctic and Antarctic ice sheets and mountain glaciers (*Eustatic effect*) (Titus et al., 1991), but also a consequence of the late-Quaternary subsidence movements in areas covered by large masses of unconsolidated sediments, prevailing in deltaic environments (Milliman et al., 1989) and the *isostatic* adjustments of the Earth's crust adjacent to the regions that have been covered by thick Pleistocene ice sheets (Gornitz et al., 1982). According to Sterr (2000a), thermal expansion and the contributions for melting glaciers and ice caps to the ocean are probably the most significant factors for a climate-driven sea level rise.

Concern over the consequences of global warming has led to many conclusions on the rate of sea level rise from:

- (i) Historical tide gauge long records (last 100 to 200 years) to separate the trend from inter-annual variability (Pirazzoli, 1996),
- (ii) Comparison among a broad range of stations in many coastal regions in order to correct sea level models from local and regional effects of crustal deformation,
- (iii) Rate estimation of land movement through the analysis of geological evidence in locations adjacent to the gauges (Sterr, 2000a), and
- (iv) Data from satellite-based altimeter TOPEX/POSEIDON, ERS1 and GEOSAT missions that have recently become available for comparison with the tide gauge records (França, 2000; Hinton, 2000).

The evaluation of the historic data sets show a global average sea level rise for the last 100 to 150 years from 1.4 to 1.8 mm/yr (Gornitz, 1995; Woodworth, 1991). Compared to the changes in the late Holocene time estimated through well documented geological records (0.1 to 0.2 mm/yr.), there seems to be a pronounced recent acceleration in the rate of sea level rise (Gaffin, 1997).

Will any of such trends continue in the future? As the earth's average temperature increases, a scientific consensus has gradually emerged - there is a serious risk that the rate of sea level rise will accelerate during the 21st century in spite of the international effort for greenhouse gas emission mitigation (Smith and Tirpack, 1989). The sea level rise projections for the 21st century have used the same instruments as the estimation of climate change, and highly complex numeric models, based on a broad range of parameters, as well as on information and data on the atmosphere-ocean energy coupling. The model produces results for global mean thermal expansion of the oceans. Meltwater contributions are added for separate, using models which represent small glaciers, the Greenland ice sheet and Antarctica (Wigley and Raper, 1992).

The exact global rate of sea level change to occur is not known so it is not unexpected that a wide range of sea-level change predictions for the next century may be found in the literature, and that the assumed scenarios delineate possible upper and lower envelopes (Hoozemans et al., 1993; Lutjeharms and Valentine, 1991).

One of the most accepted results has originated in the Intergovernmental Panel of Climate Change (IPCC) models. Initially, the IPCC First Assessment Report on Climate Change produced a consensus view on the possible magnitude of global warming and sea level rise (Houghton et al., 1990) (Figure 2.3). Estimated sea level rising under the so-called *BaU* (Business as Usual) scenarios range from high 110 cm to low 31 cm, the "best estimate" was for a 66-cm rise by the year 2100. In 1992, the IPCC issued a "supplement" to the IPCC'90 report (Houghton et al., 1992). This work created six new BaU scenarios, which considered three new factors in the assessment. They are the *CO₂ fertilization effect*, which allows for the existence of a strong terrestrial biosphere sink for atmospheric CO₂; an *ozone depletion feedback*, whereby decreases in stratospheric ozone from CFCs will have a cooling effect on the troposphere; and *sulphate aerosol cooling*, in which sulphur compounds in the atmosphere induce a net cooling effect. These three factors tend to lower projections for future sea level rise (Warrick, 1993a). The most equivalent to the BaU 1990 version was called *IS92a*, which included an infrared radioactive cooling from aerosols,

resulting in a high estimate of 60 cm by 2100 (Figure 2.4), substantially lower than the IPCC '90 high estimate.

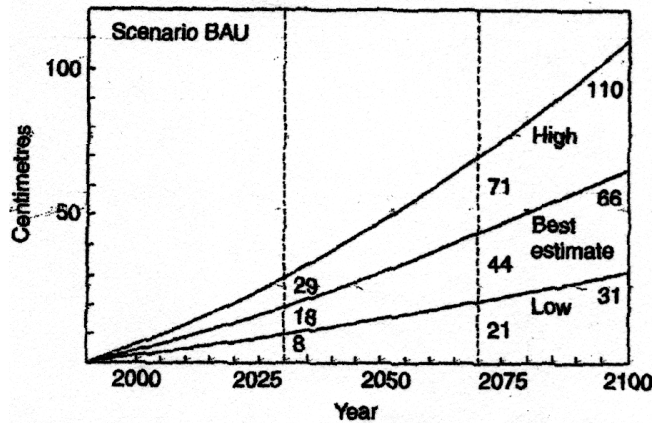


Figure 2.3 Projected global sea level rise for IPCC '90 "Business-as-Usual" scenario (Warrick and Oerlemans, 1990).

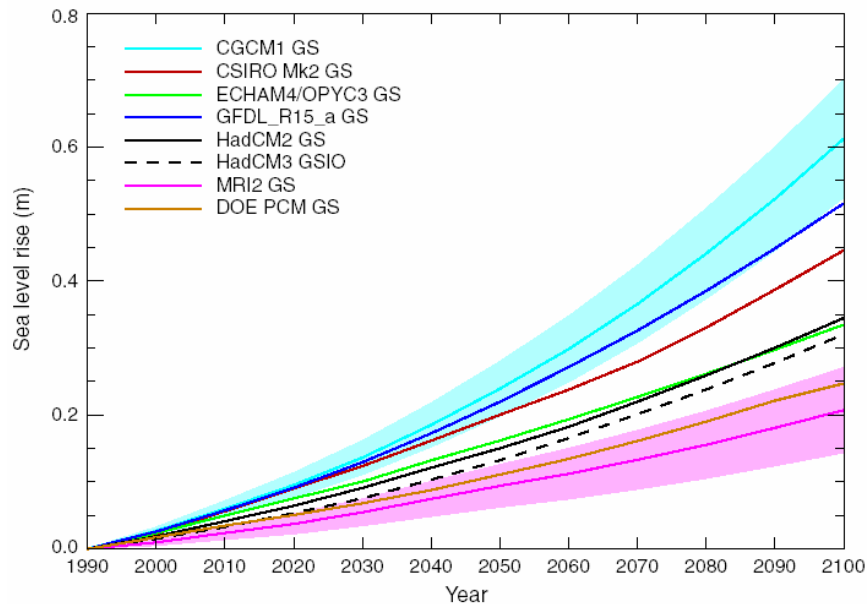


Figure 2.4 Global average sea level rise 1990 to 2100 for the IS92a scenario, including the direct effect of sulphate aerosols. The outermost limits of the shaded regions indicate the range of uncertainty in projecting sea level change for the IS92a scenario (IPCC, 2001b).

Future greenhouse gas-induced climate change will have implications for global mean climate and sea level, but, more importantly, it will not necessarily raise sea level by the same amount everywhere; there will be contrasting regional manifestations (Jettic, et al., 1992; Hulme and Viner, 1998; Maul, 1993; Titus et al., 1991). A rise or fall of land surface also causes a relative local fall or rise of sea level. Given that land uplift/subsidence varies from place to place, then relative sea-level change similarly varies from place to place (Nicholls and Leatherman, 1995b). From a planning perspective, it is the future relative

sea-level rise that needs to be considered, but developing reliable scenarios can be difficult without high precision land positioning technology, and absolute gravity measurements (Parker, 1991).

2.1.1 Climate and Sea-Level Changes in the NE Pará

The stratigraphic distribution and characteristics of the depositional sequences on the NE coastal area of the state of Pará provide a basis for discussing the history of relative sea level fluctuations during the late Cenozoic (Rosseti, 2001).

By the end of early Miocene / early mid-Miocene, sea level rise slowed and eventually began to fall, as suggested by the nature of the Pirabas Formation and lower portion of the Barreiras Formation, which is recorded in shoaling upward cycles formed by the vertical superposition of outer shelf deposits with restricted shelf/lagoon and mangrove/mud flat deposits.

Relative sea level rose again during the middle (to early late?) Miocene, resulting in laying of tidal-influenced cross stratified sandstones and mudstones within tidal channels and widespread tidal flats and mangroves (middle and upper portions of the Barreiras Formation).

Following the mid-Miocene transgression, the NE region of the State of Pará emerged once more, due to a drop in sea level recorded by the surface discontinuity with evidence of sub aerial exposure. The precise period while the sea maintained a low level is uncertain. Following the period of erosion and soil development resulting from the late Miocene low stand, sediments began to accumulate again, resulting in the called “Pos-Barreiras sediments”. Determining the palaeoenvironmental significance of these deposits is hampered by the scarcity of sedimentary structures. However, indirect characteristics suggest at least one relatively dry period following the late Miocene low stand.

Many studies on Holocene relative sea level rise changes have focused on the east Brazilian coastal region (Angulo and Lessa, 1998; Suguio et al., 1985; Pirazzolli, 1996; Mesquita and Leite, 1985; Silva and Neves, 1991). However, there is little information on Holocene relative sea level changes and coastal evolution for the North Brazilian coast (Behling et al., 2001; Behling and Da Costa, 1997; Behling and Da Costa, 2001; Souza Filho, 1995).

Unfortunately, there are not enough accurate and homogeneous data to analyse the regional changes in the last 100 years in South America in a similar way to the analyses on other countries in the Northern Hemisphere.

According to Aubrey et al. (1988) from 55 records by the Permanent Service for Mean Sea Level in South America, Central America and the Caribbean Sea that cover more than 10 years, only 14 extend until 1970. The data about the city of Belém cover a 20-year period (1949-1968). The simplest means of determining the long-term trend is to analyse separately, by linear regression, the series of mean annual sea levels at each station. Because changes of land level dominate the tide gauge, the results are expressed by (+), which means relative rise, and (-) which means relative fall of land levels. The Belém station has documented minor subsidence at a rate of - 0.3 mm/yr, and is on a structural low marked by continuing subsidence (Figure 2.5). Figure 2.6 shows that all recorded ports in the Brazilian coast are experiencing an increase in the relative sea level height of nearly 4 mm/year (Mesquita, 2000).

The difficulties that emerge from applying GCMs in South America for climate and sea-level predictions can be explained by the nature of the available historical meteorological record that has been used to validate the models and, in part, to structure the models themselves.

The historical meteorological data in South America have serious shortcomings. Jones et al. (1986) while working on surface air temperature variations for the southern hemisphere (1981-1984) mention that the most striking fact is the number of records that could not be analysed because cover less than 20 years. 46% of the 610 stations in the whole Southern Hemisphere fall into this category, while over half (54%) of the South American stations cannot be checked. Most of these stations are in three countries - Peru, Argentina, and particularly Brazil.

The structure of the GCMs is the second cause of uncertainty in applying these models to sub-regional predictions and to short periods of time in South America. Besides the differences between the models in the parameters used to simulate the physical processes in the atmosphere and the conditions of ocean/earth surfaces, the spatial resolution of the grid points adopted seems to be too large, the topographical relief has been smoothed over units of approximately 500 X (700-800) km, and important features such as the Andean range in South America cannot be properly represented (Burgos et al., 1991).

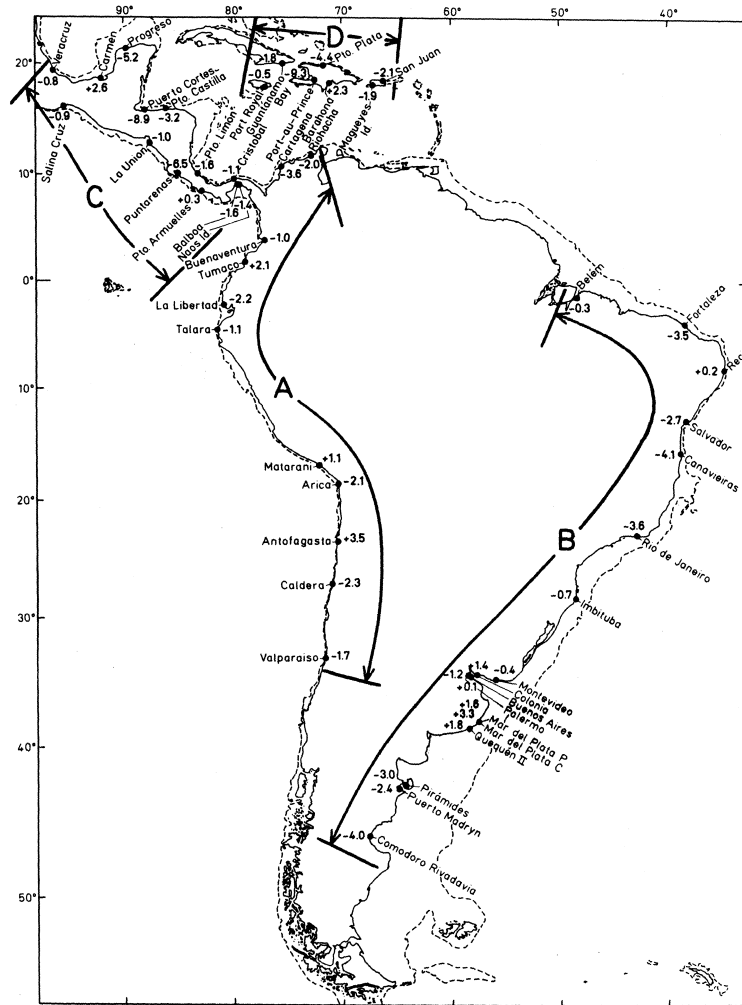


Figure 2.5 Position of tide-gauge stations in South America, Central America, and the Caribbean islands whose records cover more than 10 years. Negative values areas where land is sinking relatively to sea level, whereas the positive values indicate areas in which land is rising (source: Aubrey et al., 1988).

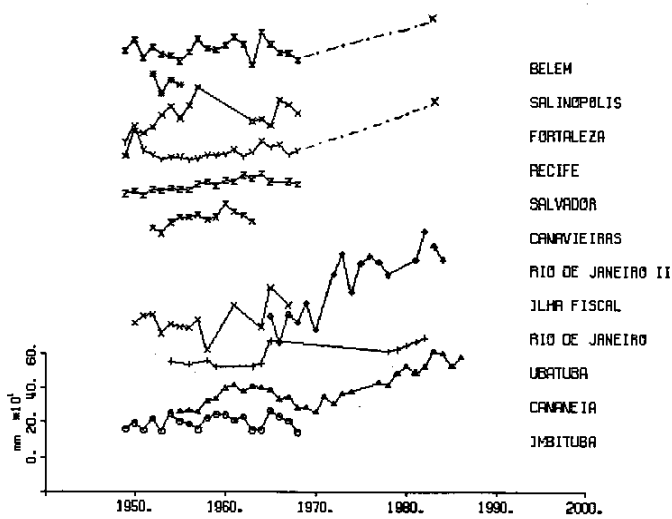


Figure 2.6 Series of annual values on the relative mean sea level (cm), in Brazilian ports. Data after 1968 in Belém are extrapolated (França, 2000).

2.1.2 Sea-Level Rise Effects on Coastal Areas

In addition to already existing problems of coastal erosion, subsidence, pollution, land use pressures, and ecosystems deterioration (El-Raey et al., 1999), future relative sea-level needs to be considered. A rise in sea level due to a global rise or local subsidence will have exactly the same physical impacts at local scale.

Although on actively submerging coasts sea-level effects already exist, these problems will probably worsen in the future (Pirazzoli, 1996). According to Sterr (2000b) the analysis of the consequences of sea-level rise on coastal zones calls for a comprehensive assessment of primary and secondary effects. First of all, the hydrodynamic and morphodynamic processes are affected and subsequently, these have a lasting influence on the ecological and socio-economic mechanisms. It is important to highlight that the impacts extent and nature in one coastal location will obviously differ from any other coastal site.

Considering the primary effects, many coastal areas are expected to suffer from sea-level rise because it would inundate wetlands and lowlands, accelerate coastal erosion, exacerbate coastal flooding, raise water tables and increase the salinity of the rivers, bays and aquifers (Barth and Titus, 1984; Leatherman and Nicholls, 1995). The impacts that would result, if nothing is done to address sea level rise, are briefly described in the following.

Coastal erosion also occurs where the sea level is stable or falling, especially where weak or unconsolidated geological materials face high wave energy; however, this process is facilitated by a rising sea level. Sea-level rise brings wave action to progressively higher levels and permits larger waves to reach the coast through deepening near-shore waters (Pirazzoli, 1996). Therefore, although coastal erosion is not a reliable indication of a rising sea level, it is more extensive and more rapid in areas where tide gauge records show that the sea is rising. This way, it is possible to expect that the predicted sea-level rise produced by the greenhouse effect will initiate erosion on coasts that are presently stable or growing, and intensify existing coastal erosion (Milliman and Haq, 1996). Although the so-called Bruun-rule states that the equilibrium profile of a sandy coast is quickly relocated further inland when the sea level rises, estimating the possibility of actual coastal erosion due to sea-level rise is extremely complicated, because it depends on a wide range of factors, some directly or indirectly influenced by climatic change, type of coast, and others explicitly created by actions of local inhabitants, such as the building of coastal structures (Leatherman, 1990; Lutjeharms and Valentine, 1991).

The future rise in sea level would have its most severe effects in low-lying coastal regions, deltas, estuaries and river plains (Milliman et al., 1989), being the extension of the affected area dependent on the land gradient. Coastal zones would become more vulnerable to flooding for three reasons (1) a higher sea level provides a higher base for storm surges to build upon (Kana et al., 1984), (2) higher water levels would increase flooding due to rainstorms by reducing coastal drainage, and (3) a rise in sea level would raise water tables (Titus et al., 1987).

A rise in sea level, higher tidal range and frequency of extreme storm surges would enable saltwater to penetrate farther inland and upstream in rivers, bays, wetlands, estuaries, and also infiltration into coastal aquifers, which would be harmful to some aquatic plants and animals, and would threaten human use of water (drinking and irrigation) (Sterr, 2000b).

Some studies and reviews have evaluated potential impacts on particular biological communities and coastal biodiversity (Reid and Trexler, 1992). From the biological and ecological effects point of view, coastal wetlands will be among the most severely affected ecosystems, since they form largely in the intertidal zone. They are valuable ecosystems because they serve as breeding grounds and habitats for a vast number of marine and terrestrial species and serve as a basis for the development of complex food web (Almeida, 1996). The response of a salt marsh or mangrove to rising sea level depends on the rates of submergence vs. vertical accretion or sedimentation. First, because of the gentle gradient of sediments, this environmental setting is both selective and fragile. So a small change in mean sea-level would result in considerable change in the period of immersion of the mangrove, thereby causing plant mortality (Blasco et al., 1996). Second, due to the increase of storm surges frequency and other extreme events, many of these ecosystems would be degraded or eroded, changing shoreline position (Ellison and Stoddart, 1991; Souza-Filho, 2000; Woodroffe, 1990) (Figure 2.7). The partial or complete loss of these ecosystems would diminish their buffering and the protection capacity of the adjacent land against the sea since they dissipate a major portion of the wave energy before the waves reach the shore. Nevertheless, many of these ecosystems maintain its areal extent or even grow under sea-level rise, if sedimentation rates at least match submergence rates. The mangrove would extend landward. This migration might only be hindered by an increase in slope upland, as well as by economic development of the interior. Some studies (Ellison and Farnsworth, 1997; Semeniuk, 1994) also analyse the probable anatomy, physiology, growth, and reproduction mangrove alteration. Many coral islands would have an average

elevation of only 1.5 - 2 m above present sea level, and therefore would also be at risk of inundation (Buddemeier and Smith, 1988; Gornitz, 1991).



Figure 2.7 Aerial view of a storm surge impact on coastal mangrove in the municipality of Bragança.

The biogeochemical cycles in shallow waters would also change massively because the continuous flooding of low-lying areas with salt water causes the remobilization of nutrients and other mineral compounds (Sterr, 2001b).

2.2 Increasing Population and Development

The northern coastal area of Brazil has been colonized since the first early 1600s¹, having not only the responsibility to protect the region, mainly the mouth of the Amazon river against other countries, but also with the obligation of supplying food (agricultural and fishing production) to the city of Belém. These activities, together with commerce, have allowed the region to accompany the different cycles of economic prosperity in the State of Pará, and the growth of Belém, particularly in the beginning of the 20th century. Since the extinction, in 1965, of the *Belém-Bragança* railway, and the construction of the federal road *Belém-Brasilia* (BR-010), the isolation of Belém from the rest of the country, and its dependence on the NE region of the State of Pará has been finished. In consequence, a gradual economic collapse of the city has begun. Consequently, the NE State region shows numerous areas which are isolated, have difficult access, and no electricity, limiting its main economic activities to small scale agriculture, fishing, crab collection, and tourism.

Diverse sectors of the State Government and public services companies (e.g. energy distribution) affirm that an "official" scenario of future development for the study area does not exist. Also, few ideas have been carried out, with this objective, on the coastal

¹ The city of Bragança was established in 1613, and the city of Maracanã in 1654.

management state program context. However, in the last years, numerous and different statistical data, information and signals allow to establish the bases for describing potential “conservation” and “socioeconomic development” scenarios for the next 30-50 years. Most of those data have been collected from newspapers, interviews, and several governmental secretary reports.

Some sectors, mainly belonging to the Ministry of the Environment, and to the fishermen and farmers local communities have already planned a regional scenario of low-level development, and protection of numerous mangrove and estuary areas through the implementation of a kind of environmental conservation units called *Reservas Extrativistas Marinhas* (Marine Extractive Reserves) in the municipalities of Augusto Corrêa, Bragança, Curuçá, Maracanã, Salinópolis, Santarém Novo, São João da Ponta, Tracuateua and Viseu² (Figure 2.8). This would finally allow establishing, due to the biodiversity and the existent ecosystems sensitivity, a large coastal preservation strip (*Corredor Ecológico*) between the State of Maranhão and Amapá, in the Northern coastal area of Brazil (Table 2.1) (O Liberal, 2002a).

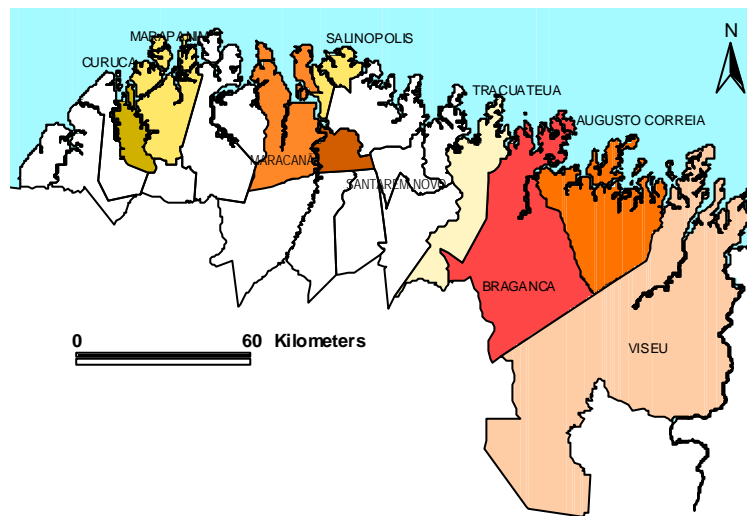


Figure 2.8 Municipal districts where the marine extractive reservations will be located.

Although this “*non-development*” model is prioritized by some sectors; the Government and several economic actors of the State have depicted and are already dynamically implementing a “*socioeconomic development*” scenario for the coastal zone of Pará.

² This issue is analysed with more details in Chapter 4.

Table 2.1 Conservation units already implemented on the North coastal area of Brazil. Source MMA, 1999.

Conservation Unit - Name	State	Conservation Unit – Type
<i>Rio Cajari</i>	Amapá	Extractive Reserve
<i>Cabo Orange</i>	Amapá	National Park
<i>Ilhas de Maracá and Jipiocá</i>	Amapá	Ecological Station
<i>Lago de Piratuba</i>	Amapá	Biological Reserve
<i>Arquipélago de Marajó</i>	Pará	Environmental Protection Area
<i>Algodual – Maiandeuá</i>	Pará	Environmental Protection Area
<i>Reentrâncias Maranhenses</i>	Maranhão	Environmental Protection Area

2.2.1 The Socioeconomic Development Scenario

Coastal areas are an attractive location for human progress all over the world, but development and population increase pressures on coastal areas result on a growing number of problems. On the one hand, the coastal zone system is subject to diverse anthropogenic pressure because people heavily rely on food, recreation and natural resources. On the other hand, in many areas, increasing functions and values normally associated with coastal areas are being degraded by flooding and erosion; all of them have major public safety and economic consequences (Gaffin, 1997, Goldberg, 1994). Therefore, one must include in any calculation on the effects of sea level rise in coastal areas, a growing human development as a pressure on the coastal system, since this implies larger population and infrastructure concentrated and exposed to natural hazards.

Although many increasing and new socio-economic activities result from autonomous and spontaneous decisions, most of them have originated in strategies and measures established at different scales within the study area (Figure 2.9): (i) international/national (the Amazon region and neighbouring countries), (ii) regional (the area containing the three capital cities of the Brazilian northern coastal zone, Amapá, Belém and São Luis), and (iii) local (the NE coastal zone of the State of Pará). The parameters that allow delineating the socioeconomic development scenario in the coastal zone can be grouped in three categories: large-scale socioeconomic parameters, changes in productive strategies, and infrastructure improvements.

2.2.1.1 Large-Scale Socioeconomic Parameters

Scenarios of future population sizes estimate that in 30 years more people will live in the world's coastal zones than today (NOAA, 1994). The State of Pará had a population

increase of approximately 25% between 1990 (4,950,000 inhabitants) and 2000 (6,189,550 inhabitants), its annual growth (2.54%) being higher than the Brazilian one (1.63%). Belém is among the fifteen most populous municipal districts in Brazil with 1,279,861 inhabitants (around 3,000,000 inhabitants considering all the metropolitan area) (O Liberal, 2001a). The reason of this increase considers not only the vegetative growth, but also the people migration from other areas (e.g. State of Maranhão) principally to urban areas (Figure 2.10).



Figure 2.9 The three levels of coastal zone socioeconomic development strategies and measures analysis. International/national (solid line), regional (dashed line), and local (dotted line) levels.

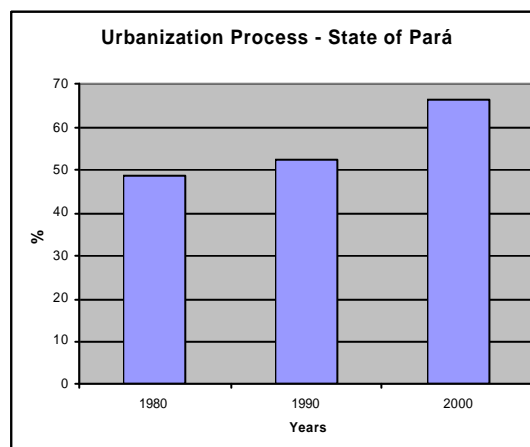


Figure 2.10 Urbanization process in the State of Pará (1980-2000) expressed as % of people living in urban areas. Source: O Liberal, 2001a.

The NE coastal zone of the State of Pará has also registered a population increase (10%) in the last 10 years - 509,292 and 555,651 inhabitants in 1991 and 2000, respectively. The municipalities that have recorded a growth are: Capanema, Colares, Igarapé-Açu, Magalhães Barata, Marapanim, Nova Timboteua, Peixe Boi, Salinópolis, São João de Pirabas, and Terra Alta (Figure 2.11). Although the population growth rate in the coastal

zone is smaller than the rest of the State, further research is needed to know if it is related with vegetative growth or the result of the changes in number and boundaries of the municipalities in the late 80s and early 90s.

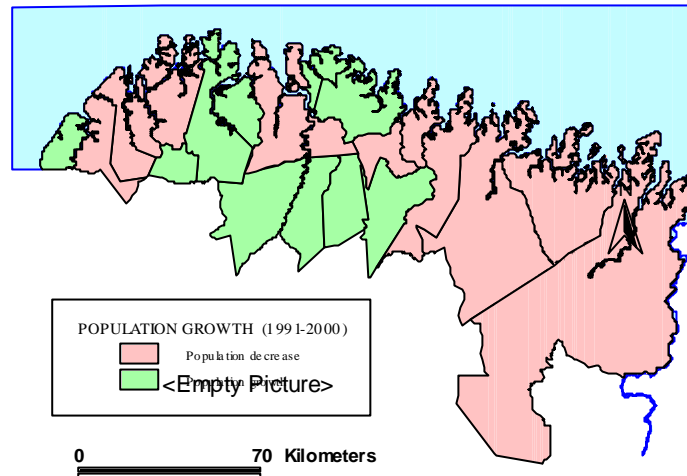


Figure 2.11 Population changes in the NE coastal zone of the State of Pará (1991-2000). Source: Instituto Brasileiro de Geografia e Estatística – IBGE.

However, these growth rates, as well as absolute population numbers, do not account for the growth in seasonal populations associated with coastal tourist trade. Seasonal population in some coastal areas may double or triple the number of permanent residents, resulting in greater development intensity and pressures than census data would suggest (Good et al., 1999).

Another important factor that allows predicting a possible development scenario can be related with the growth of the Gross Development Product (GDP) of the State in the last years (Figure 2.12).

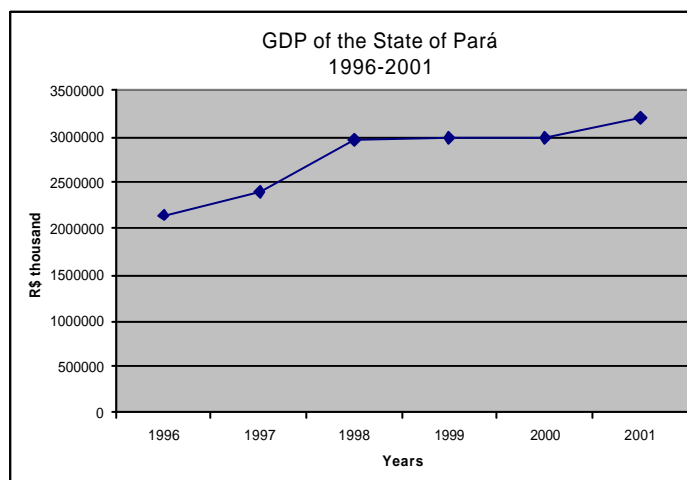


Figure 2.12 GDP growth of the State of Pará (1996-2001). Source: Secretaria da Fazenda do Estado do Pará.

2.2.1.2 Changes in the Productive Strategies

After an entire economic history based on primary products extraction and trade, the State of Pará has recently adopted some strategies in order to change its economic profile, such as the improvement of primary production, incentive to local industrialization and to the establishment of new activities (Pará, 2001a). Although there have been many efforts to develop and to modernize the agricultural activity (e.g. manioc, beans, fruit, etc.) allowing to transform subsistence production into a medium scale, the main change evidences can be described in fishing and tourism activities.

a. Fishing

The north coast of Brazil is an extensive area benefited by influence of the Amazon River and several other rivers and mangroves, which significantly favours fish and crustacean abundance through the supply of nutrients. The exploration of renewable natural resources, particularly fishing resources, is among the most traditional and relevant activities of the local populations (Isaac and Barthem, 1995). Commercial and industrial exploitation, and lately, recreational fishing, and aquaculture are also described among the increasing economical activities in the area.

Small scale fishing (Figure 2.13), clearly shows an increment in the last years. Although the average production in the period 1996-1997 was of 34,347 tons./yr, representing 6.7% of the Brazilian production (CEPNOR/IBAMA, 1997), the year 2000 showed the State of Pará as the third fish producer in Brazil, with 120 thousand tons/yr., and about 80 thousand people daily involved with this activity (O Liberal, 2001b). According to governmental information, in 2002, 50% of the fish captured in the Amazon region came from the State of Pará, what means 10% of the national production, employing around 100,000 families that are directly or indirectly related with small and industrial scale fishing. At present, the whole shrimp production is practically exported. In 2001, the State of Pará sold abroad US\$ 20.1 million worth of shrimp (each ton of Brazilian pink shrimp is quoted US\$ 12,000). Although the State of Pará does not appear in official documents as a lobster producer, it is. In the coastal zone of Bragança and Augusto Corrêa about 300 boats from other States (mainly Ceará and Rio Grande do Norte) have been operating on crustacean fishing. From the total volume marketed by the State of Ceará, the greatest exporter of lobster in Brazil, 80% is originated from the littoral of Pará (Pará, 2002a).



Figure 2.13 The port of Bragança, one of the most important on the NE coastal zone of the State of Pará.

Among the main strategies and measures adopted in the last years in order to increase the fishing activity on the coast of Pará can be mentioned:

- The creation of the first Course of Fishing Engineering in the Rural Federal University of Amazonia (*Universidade Federal Rural da Amazonia - UFRA*) and of technical training courses (Pará, 1999).
- The commitment terms signed by the government of Pará and the governments of Iceland, Chile, Ireland, and Japan in order to modernize small-scale and to expand large-scale fishing activities, and to enlarge the fish markets infrastructure, improving national and international commercialization conditions (Pará, 2000).
- The Decree of the State of Pará 4649/01, which reduced the Tax for *Circulation of Goods and Services (ICMS)* from 17% to 4% for fish and shrimp trade and export, in order to promote the development and modernization of this economic sector, stimulating the productive chain establishment, and the income and job generation (Pará, 2001b).
- The adhesion of the State of Pará to the “Diesel Oil Subsidies Program” of the Ministry of Agriculture, extending, this way, its application to small-scale fishing activities - the program had been only applied to industrial activity since 1997 (O Liberal, 2001c).
- The aquaculture sector expansion in the State of Pará, which has been exponential in the last years, not just for fish but for other emerging marine resources, such as shrimp. While the State produced about 53,700 fish in 1995, this number jumped to more than 1.5 million in 1996, and 13,110,000 fish in 2000. In 2001, there were 1,414 producers of fish in 124 municipal districts of the State. Shrimp production has also significantly increased in the

last years. 89 shrimp producers in 35 cities (mainly in the municipal districts of Curuçá and Salinópolis), have surpassed the production of 8,600 shrimp in 2000 (Pará, 2001c).

- The many agreements that have been made by *Banco da Amazonia - BASA*, a federal bank, and the Secretary of Agriculture of the State of Pará with the local fishermen communities in the municipalities of Tracuateua, Curuçá, Salinópolis, Bragança, Marapanim, Capanema, São Caetano de Odivelas, Viseu, Augusto Corrêa, and Vigia in order to support and incentive small ship construction and distribution (O Liberal, 2002b).

b. Tourism and Recreation

The State of Pará has a great tourist resource potential. The region comprises natural features as rivers, islands, lakes, beaches, flora, and fauna, and also cultural expression (historical-artistic-monumental patrimony, indigenous craft, and folklore). The exuberance and the diversity of the ecosystems, also characterize the Amazon Forest as a powerful attraction, mainly for the practice of eco-and scientific tourism, as well as sport fishing and bird watching. However, having good resources is not sufficient condition to be a competitive tourist destination. The great distance from Brazilian (São Paulo, Rio de Janeiro, Belo Horizonte, etc.) and foreign (Europe, United States, Mercosul) centers contributes to accentuate the negative effects of lack of appropriate access, communication and hotel infrastructure. At present, most of the territory of the State of Pará offers a precarious situation in these points.

However, considering that the international and domestic tourism is recognized as the world's most growing industry, and one of the main potential sources of foreign revenue, particularly for regions with limited development options, strategies and measures at three governmental levels related with this activity have been established in the State of Pará, in order to popularise the natural beauties, and create economic incentives to construct new and/or improve the existent infrastructure.

At national level, the Federal Law 6513/77 already determined the creation of special areas for tourist interest in order to preserve their cultural and natural values, and also accomplish tourist development plans and projects. Tourist interest areas are defined as ecological stations and reserves, extraordinary landscapes, appropriate places to rest and practice recreational, sport, or leisure activities, hydromineral sources, particular climatic condition regions, and areas that hold historical, artistic, archaeological or prehistoric values and cultural manifestations. They are classified as *priority areas*, where there are

significant tourists and visitor flows, and satisfactory touristic and urban infrastructure; or *reserve areas*, where there is tourist high potential but there are not indispensable infrastructure equipments, and measures that assure the preservation of the environmental balance and the cultural and natural patrimony protection. There are organs, entities, and federal agencies that support tourist activity programs, and must give technical assistance and priority for the concession of any fiscal or financial incentives, to States and municipal districts that are regarded by the present law. Some of them are:

- The Ecotourism Development in the Amazon Region Program (*PROECOTUR - Programa de Desenvolvimento do Ecoturismo na Amazônia Legal*) by the Ministry of the Environment, which in partnership with the States addresses resources (US\$ 220 million) for investment in order to improve ecotourism activities in the Amazon region of Brazil.

- The National Program of Tourist Infrastructure (*Programa Nacional de Infraestrutura Turística - PROINTUR*), which aims to propitiate conditions for tourist infrastructure and service development as the construction, enlargement or reform of airports, heliports, marinas, piers, railway terminals, hotels, convention centers, public parks, museums, craft product commercialization centres, tourist information centres; the recovery of historical equipments and buildings, and the urbanization of maritime/fluvial border. The program has financial support from the Brazilian General Budget (*Orçamento Geral da União*).

- The National Program of Tourism Municipalization (*Programa Nacional de Municipalização do Turismo - PNMT*) which is a program of the national government financially supported by resources from the Brazilian General Budget, in order to endow tourist municipal districts with better urban cleaning infrastructure and services.

- The Regional Tourism Development Program (*Programa de Desenvolvimento do Turismo Regional - PRODETUR*) that is financed by *Banco da Amazonia* (BASA) in order to support conventional and ecological tourism activities, vehicle and ship acquisition, hotel and restaurant construction, etc.

- The Domestic Tourism Support Program (*Programa de Apoio ao Turismo Interno*) which is a *Caixa Econômica Federal* (Public Bank) initiative to stimulate domestic tourism, by financing tickets and lodging

- The credit operations for small tourism companies that are another *Caixa Econômica Federal* initiative, and can be used for investment, reform and enlargement of

restaurants, hotels, stores and small trades, stock maintenance, advertising, and staff recruitment.

As a matter of fact, in 2001 the State of Pará received 487,650 tourists in its hotels, 31,717 being from other countries, and 455,933 from other Brazilian states, confirming the previous years' growth rate. Analysis by PARATUR (*Empresa Paraense de Turismo*) on 2002 (O Liberal, 2002c) indicated a tourist growth rate of 5.8% and a total of 538,086 tourists registered in hotels is foreseen for 2004 (Figure 2.14).

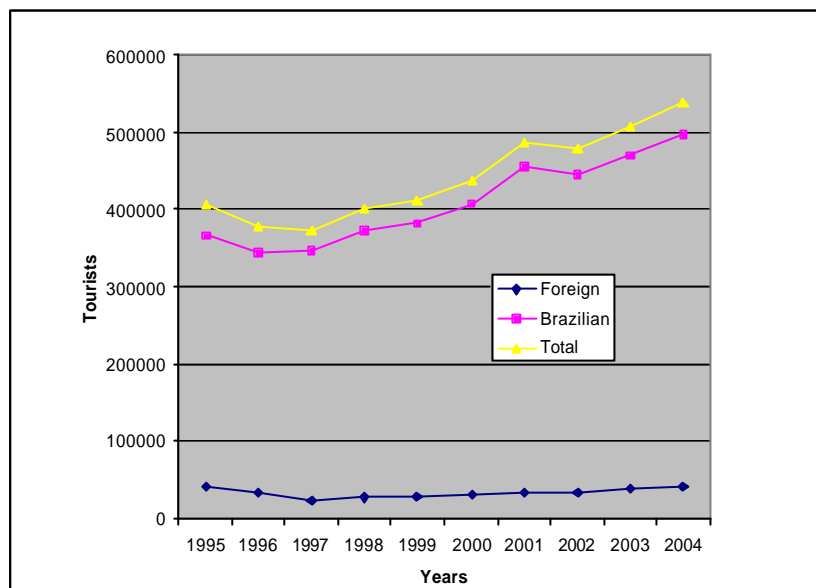


Figure 2.14 Number of national and foreign tourists in the State of Pará (1995 – 2004). The 2002-2004 data are estimated. Source: Paratur, 2001.

This has allowed defining the tourist activity as one of the main instruments for the development of the State (State Law 6035/97). Therefore, according to the Plan of Tourist Development of Pará (*Plano de Desenvolvimento do Turismo do Estado do Pará*), the State divides its territory in six tourist areas - Belém, the Atlantic coast, Marajó, Tapajós, Xingu and Araguaia/Tocantins (Figure 2.15) (Paratur, 2001).

Leisure and recreation activities on the coastal zones have flourished adding new dimensions to coastal development. The steadily growing demand for tourist facilities triggers an important increase of coastal accommodations (villas and other buildings, camping grounds, pleasure harbours), and industrial and service jobs are created (Charlier and De Meyer, 1997; Silva and Mattos, 2000). Therefore, stimulated by the scenic beauty, and climatic and environmental characteristics, and considering that the marine coast differentiates the state of Pará from other components of the Amazon region, a political decision to assign tourist use to the costal zone of Pará has been taken.

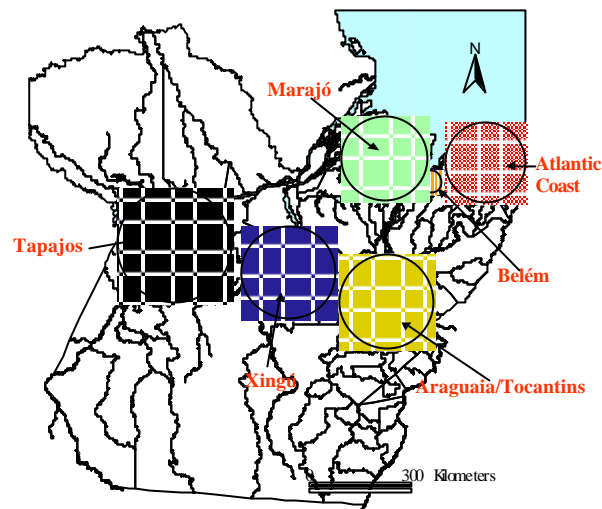


Figure 2.15 Main tourist areas defined by the Plan of Tourist Development of the State of Pará.

Before the main tourist areas definition, the coastal zone had already been considered an important region for tourism development in the State. *Special areas of tourist interest* had also been created at state or municipal levels. The State Law 5770/93 established the requirements for the sites classification into municipal districts, towns, or delimited areas as hydromineral, climatic or tourist resorts. Considering that one of the minimum requirements for the creation of tourist stays is the presence of a marine or fluvial beach, this law (art. 6) at once defined, among others, the municipalities of Salinópolis, Vigia, Marapanim, Curuçá, and Bragança and the town of Algodual (municipality of Maracanã) as Tourist Stays. The State, directly or through agreements, would provide benefits, subsidies, or aids for the economical and social development of those and potential stays, establishing urbanization and environmental preservation goals and programs.

Regarding the *Atlantic Coast* tourist sector, integrated by the municipalities of Augusto Corrêa, Curuçá, Maracanã, São João de Pirabas, Tracuateua, Viseu, Bragança, Marapanim and Salinópolis, the three last ones have been defined as the main areas for tourism development because they synthesize the cultural, geographical and historical values of the region (Figure 2.16).

Tourism can be an environmentally appropriate industry if managed correctly, but there are many examples of places where this has not been the rule. In those cases, not only the natural resources have diminished, but also the local communities and economy have suffered. Throughout the developing world, including Brazil, coastal resorts are often established with little consideration for social (e.g. displacement of local and native residents), and environmental issues (Silva and Mattos, 2000, Correia and Sovierzosc,

2000). Environmental issues include developing tourist facilities impacts that alter the natural landscape, disturb natural areas, become a source of pollution, and if they are not properly located, suffer natural hazard impacts.



Figure 2.16 Typical panorama of tourist activity on the beach of the NE coast of Pará. Left: Atalaia (municipality of Salinópolis) and Right: Marudá (municipality of Marapanim).

c. New Economic Activities

Some long-term established activities are now being displaced by new ones, such as exploitation of mineral resources, and industrialization of agricultural products.

In 2001, the National Petroleum Agency (ANP - *Agencia Nacional do Petróleo*) offered twelve areas for exploration in the North region of Brazil. The area including the mouth of the Amazon River is a totally unexplored basin in spite of the activities developed by *Petrobrás* in the 70s, when 80 wells were drilled in shallow waters (O Liberal, 2001d). *British Petroleum of Brazil*, *Petrobrás*, and *ESSO* companies have started a new three-year phase of gas and oil exploration on the coast of Pará and Amapá States, in front of the Amazon River mouth, since 2002 (Figure 2.17). The potential results of oil and natural gas resources exploration can give a great incentive to the economic development of the coastal area. The Federal Constitution (art. 20) assures the municipalities a participation in the economic result of hydrocarbons exploration - *royalties* (Brasil, 1991). Particularly, the Brazilian energy policy law (Federal Law 9478/97) states, among other things that in case of off-shore exploration the municipalities located in front of the oil fields and those that are affected by petroleum and natural gas shipment operations will receive a fraction of the royalties.

Another new activity in the area is the production of honey. The State of Pará is motivating the production of honey without the use of chemical products, mainly in the municipalities of Viseu, Bragança, Santarém Novo, Nova Timboteua, Peixe Boi and Augusto Corrêa. There is also an agreement with *Mercedes Benz of Brazil Company* which is implementing the use of coconut fibres and natural latex in the manufacture of pieces used in the seats of

its cars. These materials are processed in diverse municipalities on the coastal zone, mainly in the municipalities of Primavera, Augusto Corrêa, Curuçá, Marapanim and Salinópolis.

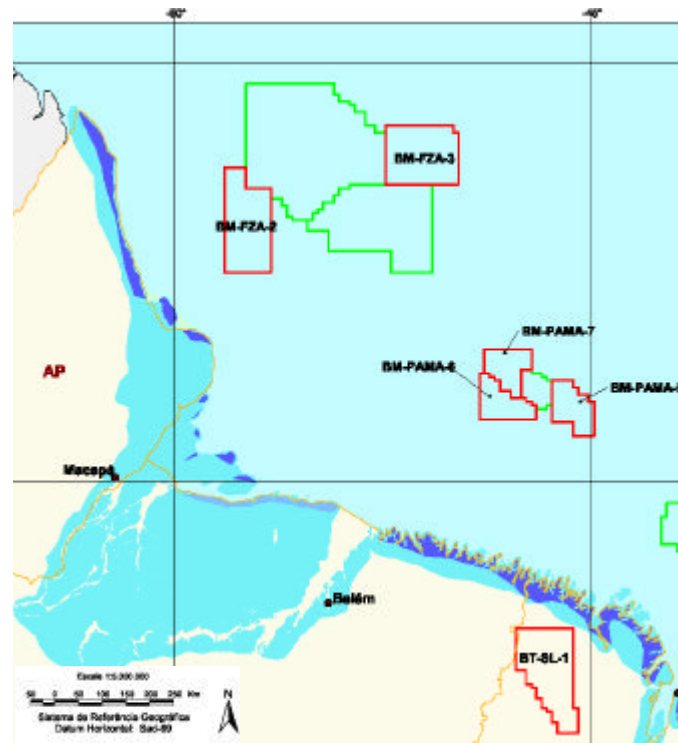


Figure 2.17 Localization of oil and gas exploration fields in the mouth of the Amazon River. Source: IBAMA, 2002a.

2.2.1.3 Improved Infrastructure

Without a good-quality infrastructure no kind of development is possible. Therefore, considering the need of improving the regional integration of the coastal zone (e.g. appropriate commercialization ways, and opening roads for tourism), several actions and resource investments have been recently evident in the Amazon region, in the State of Pará, and particularly in its NE coast. This way, the electrification of rural areas, and the recuperation and construction of road and waterway systems has started an intensified use of the coastal zone (Krause et al., 2000).

a. Means for Regional and International Integration

In order to solve one of the main problems of the Amazon region, its *isolation* state, the policies that try to impel the development of the NE coastal area of Pará can not be analysed separately from a large scale context.

The Brazilian transport system, based mainly on the terrestrial transport, communicates the coastal area with the rest of the country through an only highway - *BR 010* that links

Belém to Brasília. Thus, this region is not connected to other areas, many of them extremely close and important as the cities of Macapá (State of Amapá) and São Luis (State of Maranhão). In order to solve this problem the *Waterway of Marajó* and the *BR-308 Road* are being built.

A navigable way that crosses the Island of Marajó, from the bay of Marajó to the North channel of the Amazon River is quite an “old” idea. It will not only connect directly Belém and Macapá, but also facilitates the transport and the communication within the island. Some studies highlight the option of the *Waterway of Marajó*, considering that the connection between the rivers *Afuá* and *Anajás* Rivers is the most direct way between the two capitals. This waterway represents an investment of US\$ 10 million, principally applied in the construction of a 32-km-long channel that will interconnect the rivers. This waterway can shorten the Belém - Macapá trip to 432 km, 148 kilometres less than the current fluvial distance, which corresponds to a 10-hour-shorter trip (Figure 2.18).



Figure 2.18 The waterway of Marajó island project, connecting Belém to Macapá.

Despite the importance of accelerating the transport between the NE coastal area of the State of Pará and Macapá, there are also efforts in order to pave the *BR-156* highway (Macapá-Oiapoque, State of Amapá), to construct a bridge connecting Brazil to French Guiana (Presidential decree 4737/02), and to construct the *Trans-Guyana* highway, linking the coastal area and capital cities of French Guyana, Suriname and Cooperativist Republic of Guyana. It would allow integrating the region not only in a national, but also in an international³ one context (Figure 2.19).

³ This is the only one border between the European Union and the South American Common Market (Mercosur).



Figure 2.19 Road system connecting Macapá (State of Amapá) to the coastal areas of French Guyana (Caiena), Suriname (Paranaibo) and Cooperativist Republic of Guyana (Georgetown). Picture of Brazil-France international bridge over the Oiapoque River. Source: Rede Brasileira de Centros Internacionais de Negócios (www.ficr.org.br/cin) and Government of Amapá.

Even though the study area is located next to the biggest industrial port on the north coast of Brazil, São Luis, there is not a direct and quick connection among them yet. It would bring economic and social development to the coastal region and particularly to the municipalities of Bragança, Augusto Corrêa and Viseu (300,000 inhabitants approximately), offering the possibility of new investments, opening tourist sectors and the facilitating the transport of products. Then the Federal Law 9830/99 establishes the construction of a road (BR-398), connecting Bragança to São Luis. Most part of the road already exists, being thus necessary only to construct a 285m-concrete bridge over *Gurupi* River and to open 32 km across a mangrove area (Figure 2.20). The route from Belém to São Luis, going through Capanema, Bragança, and Viseu will then have 644 km, 144 km less than the present distance.

b. Waterways

The several all-year navigable rivers are the most concrete and viable natural “routes” in the Amazon region. They can serve to transport agricultural and mineral products, combining a low-cost development perspective with environmental conservation. Concerning that, the Brazilian Government (AHIMOR, 2003) has planned the construction of several waterways that allow, when converging on the coast of Pará, not only to make it closer to international markets than other ports in the S and SE Brazil, but also to attract new investments and development for the coastal area of the State of Pará (Figure 2.21).

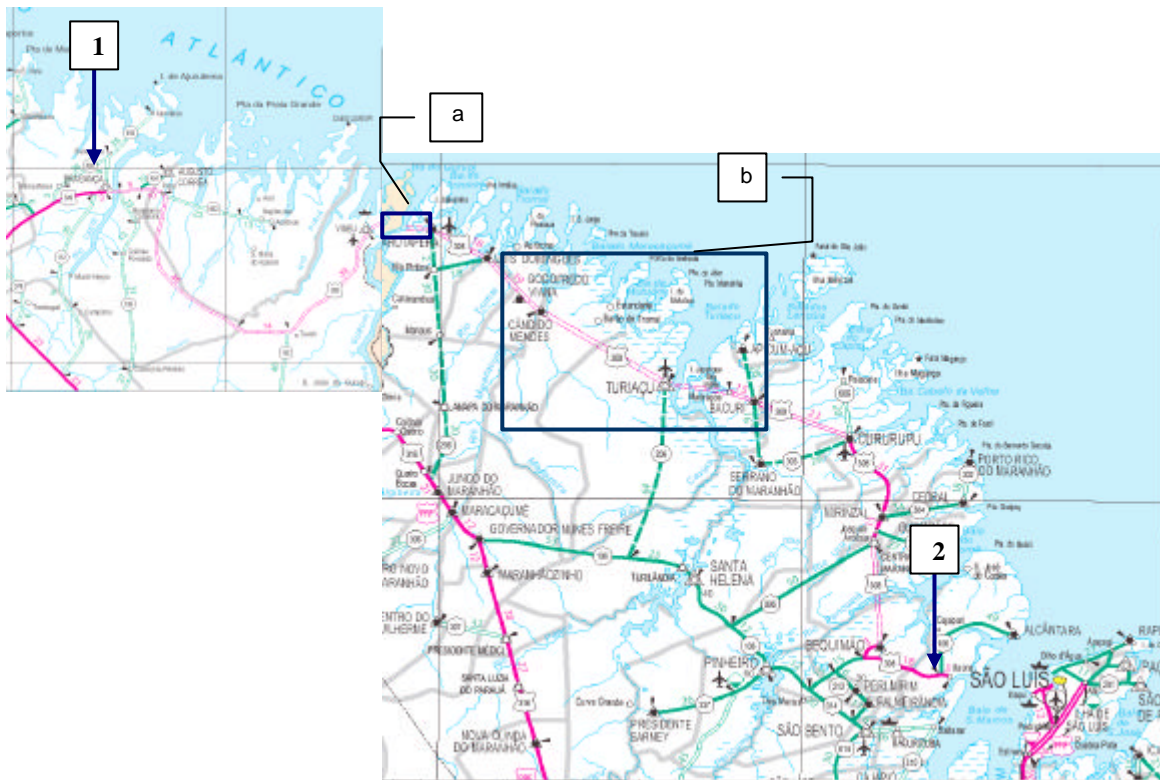


Figure 2.20 BR-308 Road between (1) Bragança and (2) Itaiana, highlighting the necessity of constructing (a) a bridge across Gurupi River, and (b) a road sector crossing a mangrove area between the localities of Cândia Mendes and Bacuri. Source: Departamento Nacional de Infraestrutura de Transporte - DNIT, 2002.



Figure 2.21 Mainly implemented and projected federal waterways in the Amazon region, highlighting the location of the coastal zone of Pará as production outflow seeking international markets. Source: AHIMOR (www.ahimor.gov.br).

The *Capim* River (600-km-long) rises in the Southwest of the State of Pará. Its 400-km long waterway does not present any serious obstacles to large-ship traffic, guaranteeing the direct access to Belém for kaolin and bauxite deposits, and agricultural products.

Tocantins and *Araguaia* rivers cross the Center-West and North regions with immense mineral and agricultural potential. The *Araguaia-Tocantins* waterway (2,012 km) can be a decisive factor of large scale exploration of those resources considering that it can direct, with low operational cost, the regional production from *Barra do Garças* (State of Mato Grosso) to the port of *Vila do Conde* (municipality of Barcarena, Pará).

The *Tapajós-Teles Pires* waterway can be considered an important option for the implementation of agricultural products foreign trade, generating jobs and attracting new investments. *Tapajós* River, right-margin tributary of the Amazon River, is 851-km-long and its mouth is located next to the city of Santarém - 950 km far from Belém.

Madeira River is navigable in an extension of 1,056 km between Porto Velho (State of Rondonia) and its mouth, in the Amazon River (State of Amazonas). With investments from the federal government (US\$ 10 million), the State Governments, and private companies (US\$ 35.6 million), this waterway aims to assure the navigation conditions of great convoys - up to 18.000 ton, reducing the costs of grain⁴ transport and then, increasing the competitiveness of the Brazilian soy in the international market.

c. State and Federal Roads

In order to improve the fishing and agricultural production transport and to facilitate the inflow and movement of tourist to the beaches, a good quality and dense road network has fundamental importance. Considering the availability of roads (federal, state, municipal and local) in the NE coastal zone of the State of Pará (Figure 2.22a) and that the construction of some of these routes has provoked severe environmental impacts in this area⁵, the State of Pará has been giving priority for repairing and paving numerous roads in detriment of the construction of new ones (Table 2.2). For this reason, the construction of a coastal route that connects the cities of Vigia and Salinas, is the only new one planned (Figure 2.22b).

d. Rural Electrification

The Ministry of Mining and Energy with the financial (US\$ 700 million) and technical support from *Eletrobrás*⁶, is setting the largest rural electrification program already accomplished in Brazil, called "*Luz no Campo* - Light in the rural area" (Presidential

⁴ The grains transported by the Madeira River Waterway are produced in the States of Acre, Amazonas, Rondônia, and Mato Grosso.

⁵ The main impacts affect the mangrove ecosystems, i.e. the route PA-458 that connect Bragança to Ajuruteua (Carvalho, 2000).

⁶ *Centrais Elétricas Brasileiras SA* (Electric Power Companies of Brazil).

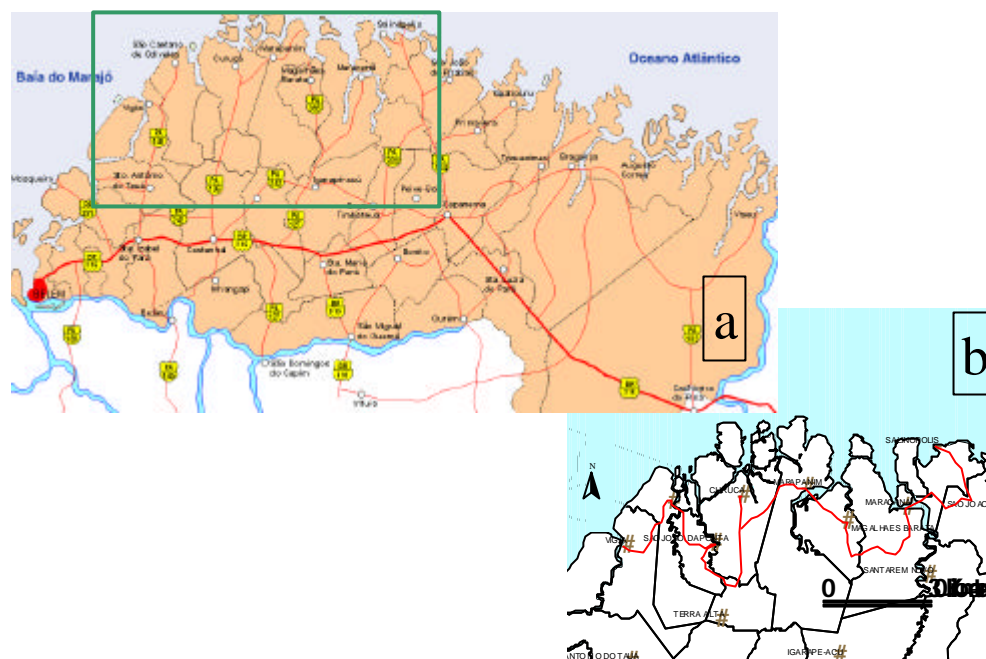


Figure 2.22 (a) Road map of the Metropolitan and NE areas of the State of Pará. Source: Secretaria de Transportes do Estado do Pará, and (b) detail of the only State planned road next to the coast connecting the localities of Vigia and Salinas.

Table 2.2 Main state roads fixed in the NE coastal zone of the State of Pará (1994-2002). Source: Secretaria de Transportes do Estado do Pará -SETRAN.

Road	Localities connected	Reparation purpose	Cost US\$
PA 124	Capanema – Santa Luzia de Pirabas	Agricultural production transport and access to the City of Salinas (tourism).	2,150,000
PA 242	Capanema – Bragança	Tourism	2,470,000
PA 127	Igarapé Açu – Maracanã	Tourism	
PA 136	Castanhal – Curuçá	Access to the Beach of Abade (municipality of Curuçá)	
PA 140	São Caetano de Odivelas – Santa Isabel do Pará	Acess to the municipality of Vigia and fishing production transport	
PA 238	Construção da Ponte sobre furo da Laura	Tourism at the municipality of Colares	3,000,000
PA 458	Bragança – Ajuruteua	Tourism	Paving: 100,000 Bridge over the <i>Furo Grande</i> tidal channel: 357,500

Decree from December 2nd, 1999). In the next years, the federal government intends to provide a million properties and rural homes with electric power, which will benefit about five million inhabitants all over the country in order to helps the rural areas great socioeconomic problems. The program objectives are to increase the rural electrification - one of the most important factors for the reduction of migration to urban areas; to provide

several benefits for the local and regional economy - income and tax collection increase; to improve local small-scale rural and fishing activities - irrigation, mechanization, conservation of food. Table 2.3 shows some examples of the rural electrification program in the NE coastal zone of the State of Pará since 2000.

Table 2.3 Examples of rural electrification on the NE coastal zone of the State of Pará. Source: O Liberal, 2002d; Pará, 2002b; Pará, 2002c.

Municipality	Population benefited	Economic Cost	Technical characteristics
Bragança	5,000 people	US\$ 1 million	150 km of distribution network
Viseu		US\$ 3 million	190 km of cables from Bragança
Vigia	2,000 people in eight communities	US\$ 70,000	
Maracanã	Eight communities of fishermen		90 km of distribution network
Primavera	Localities of Bicobal, Basilio, Leitelandia and Rio dos Peixes	US\$ 64,000	

2.3 Final Considerations

The research community is beginning to come to grips with the implications of a long recognised truth: future emissions of greenhouse gases, their climatic effects as sea-level rise, and the resulting environmental and economic consequences are subject to large uncertainties (IPCC, 1990; Reilly et al., 2001).

Although many hundreds of coastal and island tide gauges around the earth regularly produce sea level data, the reliability of historic data evaluations on a global scale is still hampered by considerable uncertainties (Plag, 1993). Some major gaps still exist as to both the geographical distribution of gauge stations (mostly in the North hemisphere and in the land) and to the available long time series (> 50 years) of gauge records (Douglas, 1991). Short tide gauge records are of little use for determining the global trend of sea level because of very large local and regional interannual fluctuations of sea level (Pugh, 1987).

The climatic responses to the enhanced greenhouse effect are evaluated by means of highly complex General Circulation Models (GCMs). Data resources on climate are relatively good, extending back to the last century in many cases; however, the predictions of the GCM are subjects to so many variables that the predictions will almost certainly change as the climate and the greenhouse systems are further understood. Most models do not adequately take into account sea-atmosphere interactions, changes in ocean circulation patterns, changes in snow cover or most important changes in cloud cover and precipitation

patterns (Milliman and Haq, 1996; Robin, 1996). In particular, less developed countries often have very sparse climate networks, short and badly broken data series and insecure undigitised database (Basher, 1999).

The brief history of published estimates of greenhouse induced sea level rise through the year 2100 shows that even though many uncertainties remain in existing climate prediction models, the trends in climate change are becoming increasingly apparent (Haq and Milliman, 1996). The uncertainties in estimates about future global sea level rise by 2100, made since 1983 by several authors, range from 0 to 350 cm (Titus and Narayanan, 1995). The range of uncertainty, while relatively stable since 1990, is markedly smaller than it was just 10 years ago (Figure 2.23, Yohe and Neumann, 1997). If there are not any surprises, future trajectories of gradually rising seas are likely to become less and less dramatic and therefore, to be among the most predictable of the physical impacts of global change (Bruce, 1999).

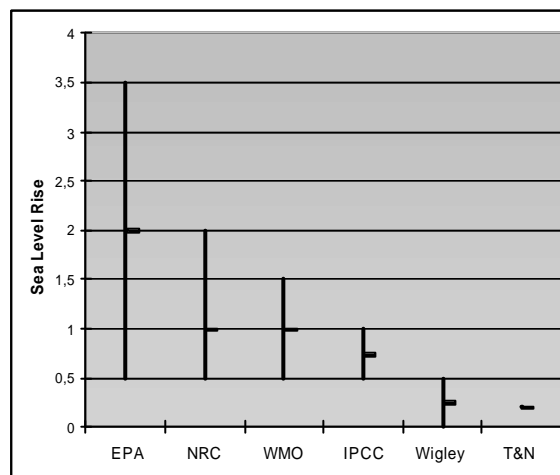


Figure 2.23 Ranges of anticipated sea level rise through the year 2100 in meters from selected sources published since 1983. (Source: IPCC, 1992b; NRC, 1985; Titus and Narayanan, 1995; Wigley, 1995; WMO, 1985).

Future socio economic development projected on the coasts is equally difficult to predict accurately mainly since it does not only depend on technical and economic viability factors, but also on the many times not comprehensible and very variable local, regional and international political reasons.

While there is certain confidence in the broad predictions at global and continental scales, there still are many uncertainties about detailed model predictions for regional or local scales, which are more interesting for individual communities (Pirazolli, 1996; Basher, 1999).

Predictions are always difficult to make considering the general uncertainty of natural and social environments; however, in spite of all the uncertainties, a review of possible sea-level change and socioeconomic development 50 to 100-years scenarios, considering pressures on the coastal system, has been formulated.

In spite of the existent uncertainties at global level, the lack of historical records, and more realistic climate and sea-level change predictive models on the Northern coast of Brazil, it is certain that rises in sea level have been occurring and will probably continue to happen so long as global warming increases. Both old and new climate models predict the sea level will nonetheless continue to rise for hundreds of years, even if greenhouse gas concentrations have been stabilised in the next few decades (Basher, 1999) (Figure 2.24). This long term effect is a result of a) the long residence time of the GHG in the atmosphere and b) the time lag caused by the thermal inertia of the oceans due to water mixing and retarded heat distribution (Sterr, 2000a).

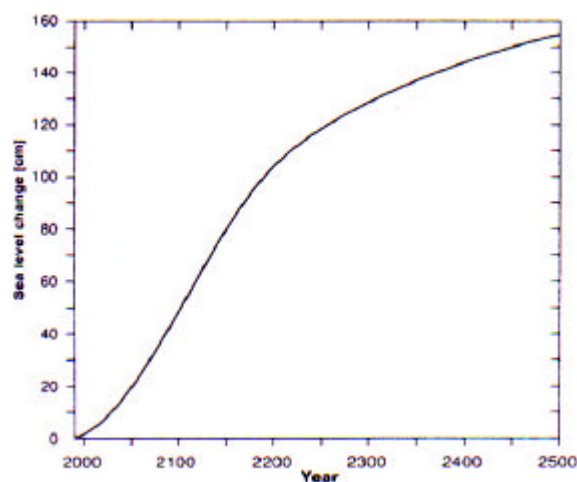


Figure 2.24 Projection of the long-term sea level rise to 2500, assuming the IS92a scenario until 2100 and a complete reduction of all greenhouse gas emission by 2200 (IPCC, 1996).

Nevertheless, it seems clear that, in the low-lying NE coastal areas of the State of Pará, the risk resulting from projected sea-level rise should significantly increase because federal and, principally, state strategies that are impelling more people and different kinds of human development activities to establish on the coastal zone, exposing them to natural hazards.

On this basis, a “wait for more information and see” attitude is not rationally acceptable. Then, considering the possible consequences of sea-level rise on the coast of Pará and despite the government’s tendency to neglect problems presumed to be distant, preventive actions must be taken now. The large uncertainty about future sea level and socioeconomic

development must be taken into account when considering possible impacts and possible responses, but it should not overshadow primary goals of ICZM-natural hazards issue, vulnerability and adaptation and mitigation response strategies analysis (Hoozemans et al., 1993b; Nicholls and Hoozemans, 1996).

CHAPTER 3

VULNERABILITY ANALYSIS TO NATURAL HAZARDS AND SEA-LEVEL RISE

Natural disasters are often perceived as events that are totally beyond human control. In these cases, people only complain and depend on others humanitarian aid to rebuild their normal life and belongings. However, sometimes is what humans do that frequently worsen the communities' vulnerability (Confort et al., 1999). In coastal areas, expansion of economic activities, urbanization, increased resource use and population growth may lead not only to unsustainable use of both the living and non-living resources, but also to the increase of coastal zone vulnerability to natural hazards.

Nevertheless, it is possible to do something if the people affected, knowing some aspects of the risks, act in a different way. After being aware of the nature and the implications of the threat, the next step in effectively managing a disaster consists of the understanding of the vulnerability of people, their values and the environment to the potential impacts of this threat (Vellinga and Klein, 1993). To reach this final objective, the areas that are most vulnerable must be identified (IPCC, 1990).

Definitions of vulnerability to environmental stress vary considerably. These different views regard, amongst other things, levels of certainty and disciplinary focus. Vulnerability must always be linked to a specific hazard or set of hazards and its definition shows a clear separation between the *Biophysical or Natural* dimension and the called *Socio-economic* dimension. In terms of the first one, vulnerability or the exposure to the hazard is defined as "*the susceptibility of resources to negative impacts from hazard events*" (NOAA, 1999) and "*the area or region liability to respond adversely to a hazard*" (Gornitz, 1991). The second dimension is defined as "*the state of individuals, groups or communities characterized in terms of their capacity or ability to (i) be physically or emotionally wounded or hurt (Kelly and Adger, 2000) and (ii) anticipate, cope with, resist, and recover from the impact of natural hazards or unexpected changes placed on their livelihoods and well being*" (Adger, 1999; Adger and Kelly, 1999).

Although vulnerability is defined, in this classic sense, by the prior damage (the existing wound) and not by the future stress (any further attack), it is possible to observe that in many places and over long term, coastal vulnerability is enhanced by climate variability and change, particularly by extreme weather events (Klein and Maciver, 1999). Therefore, at present, the vulnerability concept also embraces the physical and socio-economic susceptibility to future pressures, as potential global climate change and global sea-level rise, and the ability to cope with or adapt to their consequences (Bryan et al., 2001;

Nicholls and Hoozemans, 1996; Kelly and Adger, 2000). Sea-level rise is an ubiquitous hazard facing coastal areas and has great economic and ecological significance considering the intensive nature of both biological and human activity in the coastal zone. The impact of sea level rise involves, among others, increase and changes in inundation and erosion coastal processes, as well as landward ecosystem migration.

3.1 Vulnerability Assessment

The concept of vulnerability supports a policy-relevant framework construction that aims to improve the coastal capacity to respond to stress and therefore, the likely sensitivities, in terms of a limited capacity, must be identified.

Although there are diverse methods of coastal zones vulnerability (natural and socioeconomic) assessment, most of them coincide in the following points: (i) the coastal zone doesn't behave homogeneously; (ii) there is a necessity to integrate several different kinds of information; (iii) the definition and quantification of vulnerability should not be associated to subjective elements and constraints imposed by the availability of data; and (iv) the results have to provide a valid instrument for the proper planning and management of the coastal zone.

Even adjacent coastal areas behave in quite different ways, varying according to social, economic and environmental conditions. The recognition of this variability prompts efforts to classify the coastline and subdivide it into stretches and groups, on the basis of their characteristics (Dal-Cin and Simeoni, 1994). In the literature, there are many studies on the classification and assessment of coasts, based either on descriptive geomorphology (Fisher, 1982), on tectonic and morphological concepts (Inham and Nordstrom, 1971) or on coastal processes. Once the coastal area is subdivided; many different approaches have been employed in quantifying its vulnerability to natural hazards, most of them using multidisciplinary and multivariate data (LOICZ, 1995). The need of easily understanding the complex data sets has given rise to the development of numerous indices, in order to assess the sensitivity of the areas to threats from various hydrodynamic, climatic or anthropogenic perturbations, and presenting information in a format that can be understood by non-specialists (Cooper and McLaughlin, 1998). The definition of the indices of vulnerability can be determined, for example, as a function of coastal erosion (Ricketts, 1986), a variation of sea level (Gornitz and Kanciruk, 1989) or an ecological and cultural context (Ricketts, 1989; Dal-Cin and Simeoni, 1994).

Considering the importance that coastal vulnerability indices have as management tools for implementing preventive strategies, diverse efforts have been carried out in order to apply them in several studies at local, regional, and international spatial scales. At local scale, several indices have been developed, which were intended for application over small coastal stretches (El-Raey, 1997; El-Raey et al., 1997; Hughes et al., 1992). In such studies the effects of macro-scale climatic variability and hydrodynamic force are reduced or negligible.

At international and interregional scale level, the Commission of the European Community has sponsored an Europe-wide study, the CORINE, aimed at the assessment and identification of potential and current coastal erosion (Queilenec, 1989). Jelgersma et al. (1993) were commissioned by the UN Food and Agriculture Organization (FAO) to study the potential effects of rising sea level on areas of the Developing World. Gornitz and Kanciruk (1989) and Gornitz (1991) have developed a large-scale coastal hazards database to identify areas of the US coast in danger of inundation and/or erosion due to a future rise in sea level. Results on the vulnerability to accelerated sea-level rise in selected countries and regions from around the world, such as Argentina (Lanfredi et al., 1998), Germany (Behnen, 2000), South Africa (Hughes and Brundrit, 1992), Poland (Zeidler, 1997) and Mozambique (Chemane et al., 1997), the Mediterranean Sea (Nicholls and Hoozemans, 1996) and the South and Southwest coastal area of England (Bainbridge and Rust, 1995) have also been completed.

Much of those first-order assessment studies apply the *Intergovernmental Panel on Climate Change (IPCC)¹ Common Methodology* to assessment of coastal vulnerability to climate change. This “*Common Methodology*” comprises seven consecutive analytical steps that allow for the identification of priority coastal regions for the identification of populations and resources at risk (Klein and Nicholls, 1999).

It would be foolish to suggest that any particular approach to the concept of vulnerability is more or less appropriate (Kelly and Adger, 2000), neither is there a single “correct” method for conducting a vulnerability assessment. However, whatever approach is used, the assessment of vulnerability is an indispensable step for identifying risks and priorities for further study and improved management (Capobianco et al., 1999).

¹ The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP).

Experiences with several methodologies have described not only successful results, but also many problems and deficiencies when they are applied (Kay et al., 1996; Klein and Maciver, 1999). Considering the natural and socio-economic characteristics of the coastal zone of the State of Pará, rather than the use of some of these methodologies, the development of a methodology for vulnerability assessment which is more adapted to local needs is suggested. In order to achieve this objective, two aspects should be analysed. First, the vulnerability assessment activities already done on the Brazilian coastal zone and second, the availability of data and information.

In general, relatively few publications have dealt specifically with the risk and vulnerability assessment of the Brazilian coast to climate change and sea level rise (Mascarenhas and Augusto Filho, 1997). At global scale, Brazil carried out some steps of the IPCC's Common Methodology for assessing the vulnerability of their coastal areas (IPCC, 1994; Kay et al., 1996). Some results of the application of this methodology, called Global Vulnerability Assessment (GVA), ranks the Brazilian coastal area as a region of medium socioeconomic and ecosystems vulnerability (Hoozemans et al., 1993) (Figure 3.1). At national scale, the Ministry of the Environment (MMA, 1999) elaborates a diagnosis of the coastal zone of Brazil (spatial scale 1:1,000,000) which classifies it using several parameters (proportion of the service of potable water and sewage, population growth, number of conservation units, etc.) (Figure 3.2). Schnack (1993) has assessed the vulnerability assessment of the east coast of South America (Brazil, Uruguay and Argentina), and has analysed some potential adjustment strategies. Muehe and Neves (1995a, 1995b) have conducted pioneer works on the comprehension of the potential effect of sea level on the Brazilian coast on a local and regional scale. Extensive shore erosion along the Brazilian coast has been reported. Since there is still insufficient evidence to relate these observations to sea-level changes, these authors have recommended intensive monitoring of certain coastlines identified as vulnerable. The Recife metropolitan region (State of Pernambuco) has been a case study on local scale. For the North coast (Amapá, Pará and Maranhão States) they have suggested the Salinópolis region (State of Pará).

The current and future coastal processes' effects and vulnerability are strongly determined by local, regional and sometimes global conditions. Therefore, a good understanding of the physical and biological processes, the topography and social system, as well as a foundation of data on the climate (past, present and future) are required in order to forecast impacts and implement adaptations to climate change on low-lying coastal zone (Basher,

1999, IPCC, 1990). In spite of its significance, developing countries, as Brazil, often lack the most basic scientific information and, in case the data are present, problems with acquisition, storage and accessibility frequently occur.

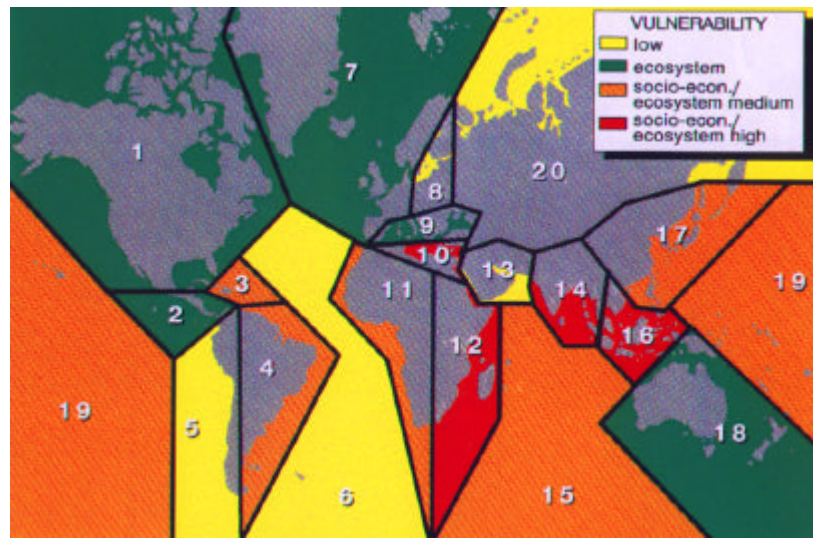


Figure 3.1 Brazilian vulnerability to accelerated sea level rise, according to the Global Vulnerability Assessment (GVA) (source Hoozemans et al., 1993).

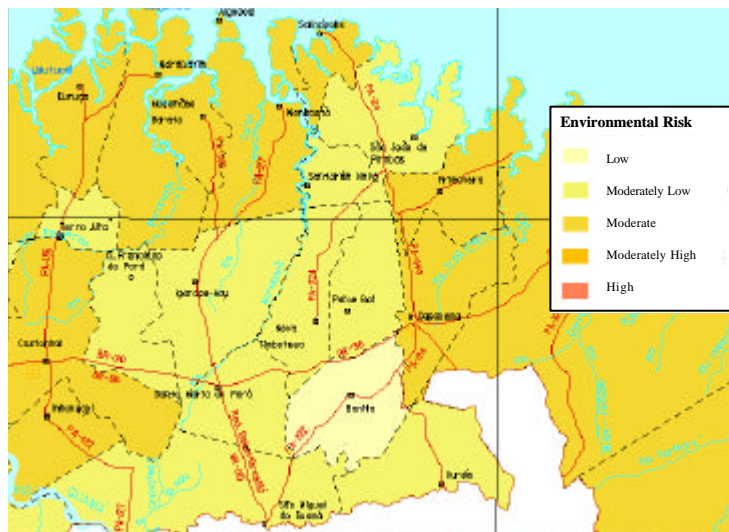


Figure 3.2 Environmental Risk classification of the coastal zone of Brazil (spatial scale 1:1,000,000). In this case an example of the NE coastal zone of Pará (source: MMA, 1999).

Data gathering is a neglected and under-resourced activity, principally because it must compete with other economic and social development priorities. The costs involved in this process are immediately obvious every year, while the benefits are usually diffuse and long term, without an immediate result to attract political and funding agency support. Data gathering problems result in a very sparse climate networks, and short and discontinuous data series, as well as in errors and inconsistencies due to the diverse instruments or

methodologies used in different periods. Data sets are often not readily available in digital form due to pre-computer era data sets, inadequate data acquisition and wrong database practices, which makes their effective use hard. Data and information accessibility is often constrained because of the economic cost, and security and property issues. Although the data problems mentioned are described in the whole country, they are more evident in the Amazon region. This could be related to the great area extension, the difficult access to several areas, the low demographic density and the lack of economic and scientific resources existent there.

3.2 GIS-Based Composite Vulnerability Index for the NE coastal Zone of the State of Pará.

Considering the few vulnerability assessment works on the Brazilian coastal area, almost all on national or international spatial scale, the Amazon region data problems - absence or poor quality - and the incipient development of the Coastal Zone Management program of the State of Pará, lead to the conclusion that there is a real need for firstly assessing regional-scale (coastlines in the order of hundred of kilometres) vulnerability to current and future natural hazards. This kind of assessment does not have intensive data requirements, and can identify vulnerable areas to sea level rise within coastal regions, setting them for future fine-scale studies and management (Bryan et al., 2001).

In this context, an interdisciplinary Composite Vulnerability Index (CVI) is developed for the NE coastal zone of the State of Pará providing a reliable measure of differences among regions and communities that are exposed to similar ranges of hazards. This should allow the partition of the coastal zone into units that exhibit similar attributes or characteristics, and a particular response or range of responses to future events may be designed for each of these coastal sections. In the following sectors, the general methodology and the evaluation of the individual parameters used to calculate the CVI are exposed.

3.2.1 General Methodology

A Composite Vulnerability Index could be defined as a means to combine a number of separate variables to create a single indicator. In this case, these selected parameters reflect natural and socio-economic characteristics that generate coastal vulnerability to natural hazards - flooding and erosion. Once selected, these parameters are combined or aggregated according to an appropriate set of weights. Such summary of all the information and coastal classification have been greatly aided by GIS capability for

integrating with remote sensing applications, and principally, for storing and examining, in a digital format, the relationships between multidisciplinary coastal data parameters and processes, generated on various scales (Burrough, 1986, Cooper and Mc Laughlin, 1998; Perillo et al., 1999). In this study, the SPRING-GIS program (version 3.6) of the Brazilian Institute of Spatial Research (INPE - *Instituto Nacional de Pesquisas Espaciais*) was chosen, with viewing, handling of the cartographic coverages, and space consultations carried out using Arc View GIS 3.2 (ESRI).

The GIS created to construct the CVI of the NE coastal zone of the State of Pará consist of four basic modules: (i) data gathering, (ii) data input and preprocessing, (iii) data storage and processing, and (iv) data output (Figure 3.3).

The first step includes gathering two types of data, *spatial* or *geographical* (e.g. satellite images, regional and detailed maps, etc.), and *Non-Spatial* (e.g. statistical records, socio-economic parameters, etc.). The spatial data are used to define where the features occur, providing geographical references for the non-spatial data, which record what the features represent using several characteristics (Maguire, 1991). The Spatial and Non-Spatial data can be classified as "Primary" and "Secondary". "Primary or Direct" data are those obtained by field and laboratory activities; the "Secondary or Indirect" ones are originated in the survey of scientific literature, data bases or another type of sources.

Some data result of the visual and digital interpretation and analysis of the cartography and remote sensing products (LANDSAT TM5 and airborne RADAR band X). Field work, carried out during 2001 and 2002, made if possible to obtain the georeference of natural or man-made elements using a GPS *Garmin 19 XL*, the identification of morphological features and processes, the confirmation of the results obtained in the remote sensing image analysis, and finally, the calibration of the CVI. Also, field interviews were conducted with government officials - like mayors and aldermen-, planners, and local population, permitting to obtain much information and collect examples, opinions and suggestions.

Although there are many data problems, some of the required data for vulnerability assessment and implementing adaptations already exists as a body of information that had been collected primarily for other purposes. It is important to highlight among the secondary information, the Infrastructure Georeferenced Information System of the State of Pará - SIGIEP (*Sistema de Informações Georeferenciadas da Infra-estrutura*

Paraense) of the Special Secretary of Infrastructure of the State of Pará. This system, GIS-based, has as an objective to facilitate the acquisition of information on several areas. At present, transport, energy, telecommunication and sanitation data are available. Table 3.1 shows the diversity of private and public data sources used to compound the index's variables.

Table 3.1 Secondary data, sources and types, used in the construction of the CVI of the Coastal Zone of Pará.

Data Source	Data Type
Brazilian Institute of Geography and Statistics (IBGE)	Census sectors maps and Statistic data. Topographic maps
Brazilian Institute of Spatial Research (INPE)	Remote Sensing Image LANDSAT TM5
Library of the Center of Geoscience (University Federal of Pará)	Geologic and Geomorphologic maps, RADAR photograph.
Tribunal of Financial Issues of the Municipal Districts of the State of Pará	Statistic data
"O Liberal" newspaper	Natural disasters and protection measures record
Civil Defense Coordination of the State of Pará	Natural disasters record and protection measures record
Special Secretary of Planning and Management of the State of Pará	Statistic data, infrastructure maps

Basher (1999) considers those original raw forms of data available, sometimes collected using diverse instruments or methodologies in different periods, not suitable for use, and suggests that it is often necessary to create new special data sets in which the raw data are assembled, corrected, transformed, summarized and aggregated into more consistent useful forms. Therefore, the data input and pre-processing phase covers (i) all aspects of transforming the data captured into a compatible digital form, using a wide range of computer tools which include digitizer, scanners and database software. Corrected and upgraded maps have been encoded using a high resolution-digitising tablet (*Summagrid V by Summagraphics, size A0*)²; (ii) the analysis of remote sensing images; (iii) the activities to remove data errors; and (iv) updating data.

The third phase consists of data storage - the way in which the data position and attribute of geographical elements are structured and organized - and processing. In order to process the data, two models have been adopted in this study for achieving the linkage between

² The digitalization activities were carried out at the Laboratory of Remote Sensing (LAGEOS) of the Department of Geology (University Federal of Pará).

geographical features and attribute information within GIS: the Geo-Relational Model and the Composite Map Model (Shepherd, 1991).

In the Geo-Relational Model, attribute information is associated with three basic concepts - the points, the lines or any kind of polygons that could describe features occurring in the real world, using a unique identifier (ID) assigned to each spatial element. Thus, a point, consisting of a single *XY* coordinate pair, locates features such as a locality that may be associated with information about budget and infrastructure. A linear feature, consisting of a starting *XY* coordinate and an ending *XY* coordinate, such as a river, might be associated with discharge, navigability, and fishing activities attributes. Finally, a polygon, consisting of a set of *XY* coordinates, could represent a census collection district that is linked to parameters as number and type of houses, population sex and age, etc. From database design point of view the model is characterized by simplicity, and the data are grouped together in two-dimensional tables - rows and columns (Healey, 1991). Sets of attribute information are stored in different tables linked according to the *relational* join where values in a column or columns, in one table, are matched to corresponding values in a column or columns in a second table (Frank and Mark, 1991). Relational databases have the advantage of having a very flexible structure and of being able to meet the demands of all queries that can be formulated using the rules of Boolean logic and mathematical operations.

The second method of linking spatial and attribute information, used in this work, is the Composite Map Model. This model is based on the "Overlay Concept", defined by the idea that the *Real World* is portrayed as a series of overlays (variables), each with one aspect of the reality recorded in (Burrough, 1986). The attribute information is related to some geographical feature, and it is stored on an individual layer. Data integration consists in combining attribute values for geographical features that lie above or below in a "stack" of superimposed layers. The combination or overlay of the layers results in the product of a new layer, and for every regions, a new attribute can be expressed.

Data output and presentation relate to the ways the data are displayed and the result of analyses are reported to the users. Data are presented as maps, tables and charts, or transferred to another computer system (Figure 3.3).

3.2.2 The evaluation of Natural and Socioeconomic Variables of the CVI

The general approach for model building is to think of NE coastal zone of the State of Pará as a linear combination of natural and socio-economic variables associated with its vulnerability. The variables are selected considering their availability for the entire region and relative independence from one another; that is, they do not measure the same things. In this way, different aspects of vulnerability are represented in the Model.

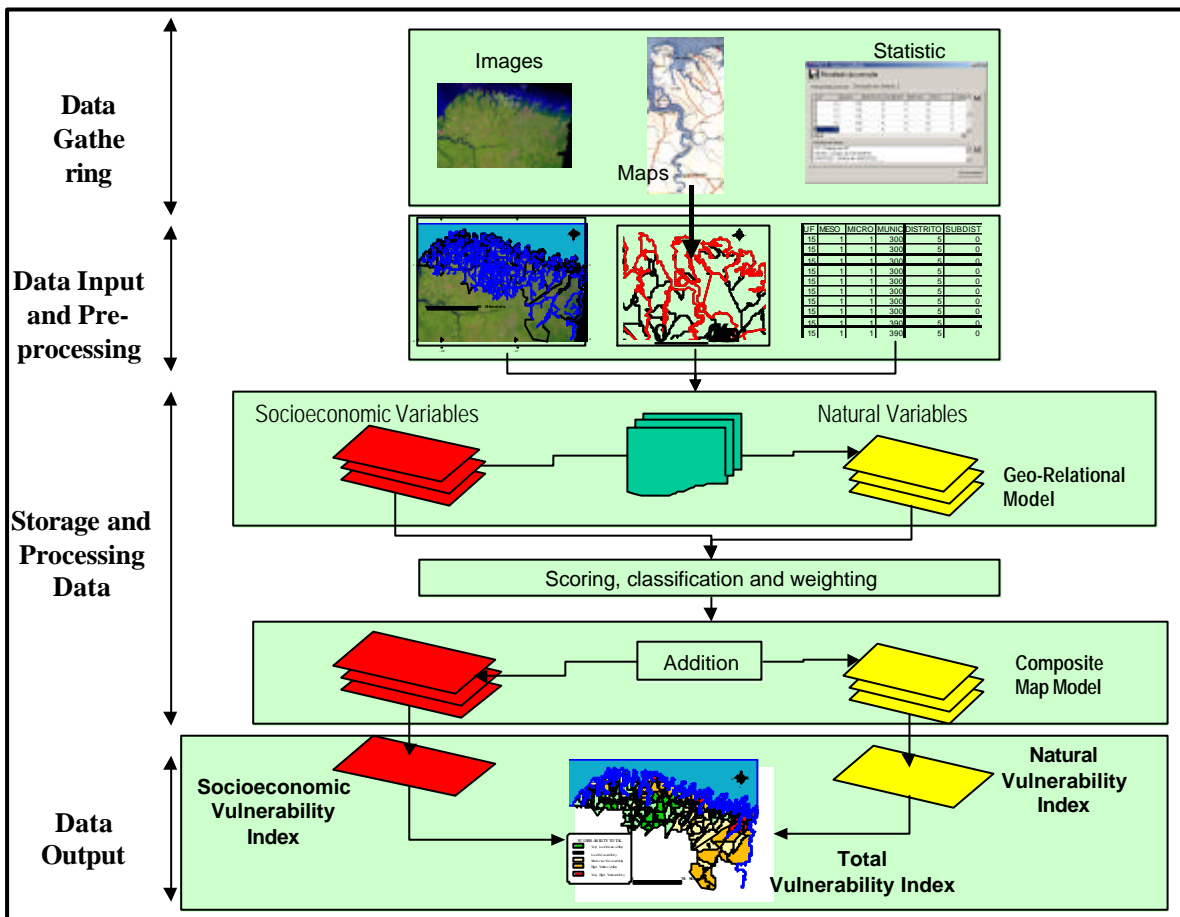


Figure 3.3 Scheme of Geographical Information System applied to elaborate the Composite Vulnerability Index of the NE coastal area of the State of Pará.

In order to facilitate the use of the CVI in planning, zoning and management of coastal area activities, all the attribute data of each one of the geographical features (point, lines, or area), are interpolated spatially and assigned to only two types of spatial polygonal elements, the municipal and the IBGE's census collection districts. The census collection districts are the geographical units used by IBGE in the complete (every 10 years) and sampling (every 5 years) demographic censuses. They are adopted since they represent the smallest unit, in the regional scale, defined by a government organism (Figure 3.4).

As far the two existent vulnerability dimensions, the parameters that characterize them can also be classified as natural and socioeconomic variables. The data of each variable are placed into groups or classes that have similar characteristics, assigning a rank between 1 and 5 according to their relative vulnerability, 5 being the most vulnerable. The classification method used, provided by the software ArcView, is the called “Natural Breaks”. This is the default classification method in ArcView that identifies breakpoints by looking groups and patterns inherent in the data. This method uses a rather complex statistical formula (Jenk’s optimization) that basically minimizes the sum of the variance within each of the classes (ESRI, 1996).

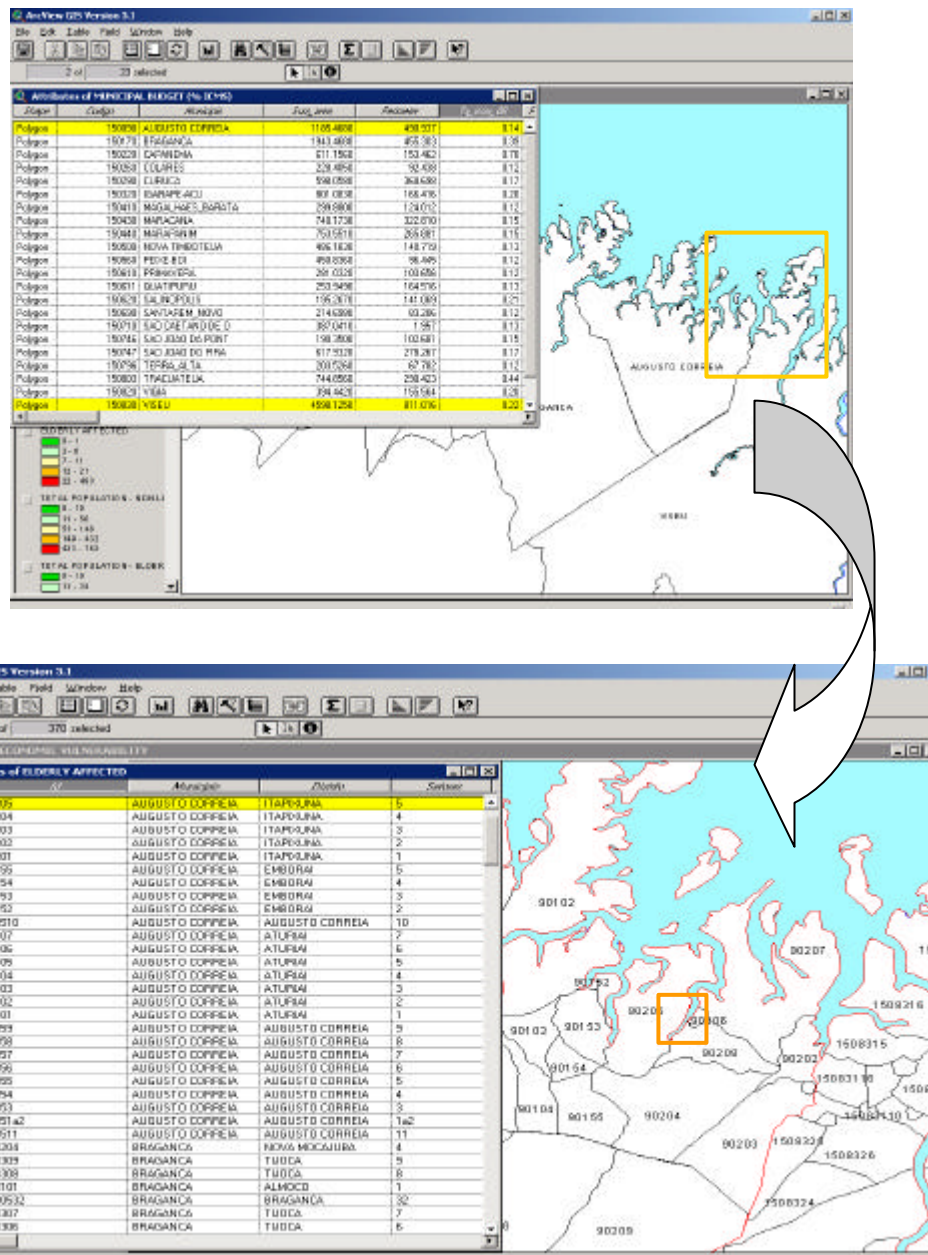


Figure 3.4 Polygonal features used in order to construct the CVI of the NE coast of the State of Pará such as the Municipal Districts (above) and the Census Collection Districts (below).

3.2.2.1 Natural Variables

Earth scientists have long recognized changes in the distribution of coastal hydrodynamic forcing mechanisms in the variety of coastal types (Kelletat, 1989). The degree of natural vulnerability of the coastal zone is composed by individual criteria that characterize the coastline, such as length and complexity (sinuosity and circularity), coastal geomorphic features, the municipal districts (continentality) and the spatial distribution of flooding areas. They also describe coastal protection measures and historic cases of emergency relief.

a. Coastline Length(km)

The longer the coastline is, the larger is the degree of exposition to erosive and flooding processes and potential effects of sea-level rise. Then the municipal districts are classified by the coastline length in kilometers, including their insular sectors (Figure 3.8). The coastline length measurement was carried out based on the existent cartography (scale 1:250,000).

b. Continentality

This parameter classifies the municipalities considering their dependence on the coast; in other words, the relative importance of the coastal area in the municipal context (Figure 3.8). The total area of each municipality is provided by the Special Secretary of Planning and Management of the State of Pará.

$$\textit{Continentality} = \textit{Total coastline length (km)} / \textit{Total municipal area (km}^2\textit{)}$$

c. Coastline Complexity (Sinuosity and Circularity)

The configuration or complexity of the shoreline can play an important role in increasing or reducing the intensity of various coastal processes, and thus coastal hazards (Bush et al., 1999). Sinuosity and circularity are parameters that are adapted from fluvial and basin morphometry (Summerfield, 1991). The sinuosity or tortuosity, which represents the irregularity of the coastline, is a morphometric parameter that allows classifying the municipal districts considering their exposure to the impacts of coastal processes and sea-level rise. The circularity is a parameter used in the insular sectors of the municipalities with the same objective of the sinuosity. The municipal district extreme-point's distance and the island area and perimeter are measured using GIS tools (Figures 3.5 and 3.8).

$$\text{Sinuosity} = L / D$$

Circularity = Island area / Area of a circle having the same perimeter as the island

L = Total coastline length (km) and D= Distance (km²) between the start and end points of the coastline

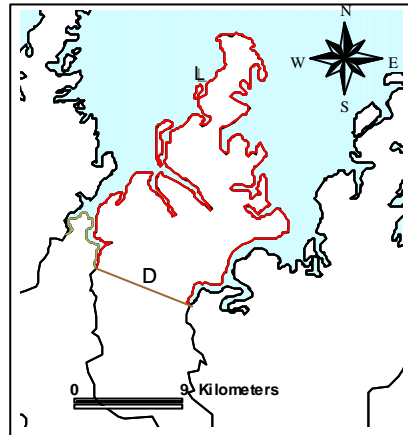


Figure 3.5 Example of Coastline Complexity - Sinuosity in the Municipality of Quatipuru defined as L/D , where L = Total coastline length (km) and D = Distance (km²) between the start and end points of the coastline.

d. Flooding Areas

Numerous works use high-resolution topographical maps (e.g. 1 or 1.5 m contour level) to define the extension and frequency of the flooded areas (Titus and Richman, 2000). Unfortunately, there are no high resolution topographical maps on the low-lying coastal zone of the NE of the State of Pará. The 50-meter-contour-level topographic maps of this area (spatial scale 1:250,000) can not be used for the delimitation, as an example, of the 20-60 cm sea-level rise estimated for the year 2100. Consequently, in order to delimitate flooding areas in the context of the present study, another method should be adopted.

Some topographical maps of the State of Pará (Soure-SA22-X-B, Salinópolis/Baía do Emboraí-SA23-V-A/B, Belém-SA22-X-D, Castanha-SA23-V-C, and Turiaçu INC-23-V-D), are the result of the works developed by the project RADAMBRASIL that analysed aerial photographs by RADAR sensor (band X). This analysis, besides field validation, allowed the identification of areas called "Alagadas" (flooding areas) (Lima, 1995). On the other hand, along low-lying coasts, mangroves develop only on very low elevation where such salt-tolerant vegetation flourishes and indicate past, present as well as future floodable areas (Bush et al. 1999). Therefore, the limits of this vegetation covering, visually interpreted by LANDSAT TM5 (RGB543) satellite images - scale 1:100,000 - support the boundary adjustments to the topographic maps' flooding areas (Figure 3.6).

The total flooding area (km²) per each census district, as well as the percentage flooded of each district are parameters used to classify different sectors of the coast considering their vulnerability to flooding and sea-level rise processes (Figure 3.9).

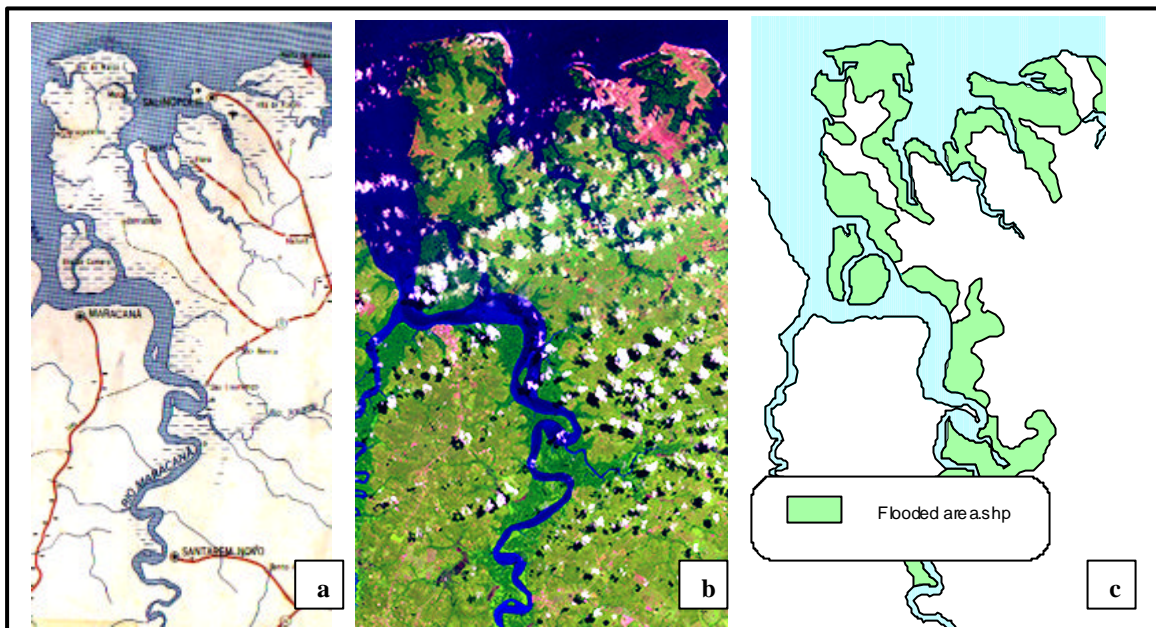


Figure 3.6 Flooding areas near Salinópolis (c) defined through (a) topographical map and (b) mangrove covering.

e. Coastal Features

Certain coastal geomorphic settings are more vulnerable than others. The estuaries and bays, although being vulnerable to the sea advance due to their relatively low gradient, are a low-energy environment and are more protected than the seafront beaches and cliffs as well. It means that, other things being equal, water front property on restricted bodies of water is at risk from fewer hazards than a property on a shoreline facing a large expanse of open sea (Nicholls and Hoozemans, 1996; Bush et al., 1999). Therefore, the municipalities are classified considering the ratio of open sea (*marine*) and estuarine coastal length. The delimitation of the open sea or estuarine areas is carried out by visual interpretation of the coastal morphology using LANDSAT TM5 (RGB 543) satellite images - scale 1:100,000 - and field works (Figures 3.7 and 3.10).

$$\text{Marine/Estuarine Ratio (\%)} = (\text{Estuarine-coast length (km)} / \text{Marine-coast length (km)}) \times 100$$

f. Coastal Protection Measures

In most cases, the shoreline is the least stable component of the coastal zone, and thus some special parts receive the greatest management attention because of potential real estate loss and property at risk. Coastal engineering structures are intended to halt shoreline

erosion or protect buildings and infrastructures (Bush et al., 1999). The presence of coastal engineering measures permits the classification of the census collection districts considering their degree of protection against the impacts of coastal natural hazards (Figure 3.10). These measures were inventoried on field trips (2001-2002) and records of the Civil Defense Coordination of the State of Pará.

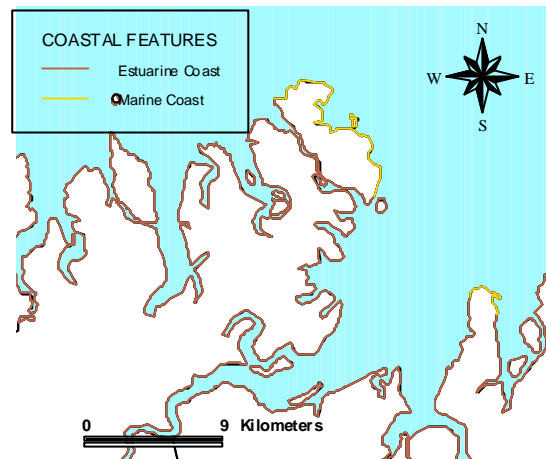


Figure 3.7 Definition of estuarine and marine coastal's types (Municipality of Bragança) through the analysis of satellite image.

g. Emergency Relief - Historic Cases

History may not be the guide in viewing how adaptation becomes manifest according to future changes in the definition of “hazardous change”, but it certainly is an appropriate one that should not be ignored (Yohe and Dowlatabadi, 1999). Cases recorded on newspapers, emergency relief organizations and local population remembrance are not only a clear indication of past and present problems, but also a likely indication of future problems. Historic cases of natural disaster emergency relief are used to classify the census collection districts (Figure 3.10). The data are collected from the record of the Civil Defense Coordination of the State of Pará.

h. Fluvial Drainage

In low-lying coastal areas, slight increases in sea level have the potential to inundate large areas permanently or periodically and deteriorate significant areas of wetland (Capobianco et al., 1999). Muehe and Neves (1995a) highlight the importance of the low gradient of the rivers in North Brazil, which favor tidal propagation, to increase the vulnerability of the coastal zone. In consequence, the fluvial systems and their floodplains can be considered some of the potentially most sensitive areas and the main "access" for the natural hazards to very distant regions of the shoreline.

Fluvial systems are a type of network; they consist of a series of links which connects nodes. The basic element of a stream network is the *Stream segment*. This is a section of a stream channel between two channel junctions or for “fingertip” tributaries, between a junction and the upstream termination of a channel (Summerfield, 1991).

The *total length of the fluvial system*, the *drainage density* which means the length of the stream channels per area unit, and the *split ratio* which is the total number of stream segments divided by the total length of the fluvial network are some morphometric properties that permit classifying the municipal districts according to their vulnerability to flooding and sea-level rise processes (Figure 3.11). The fluvial network data are extracted from topographical maps (Soure-SA22-X-B, Salinópolis/Baía do Emboraí-SA23-V-A/B, Belém-SA22-X-D, Castanhal-SA23-V-C, and Turiaçu INC-23-V-D), and modified using visual analysis in LANDSAT TM5 (RGB543) satellite images in scale 1:100,000.

The Table 3.2 resumes the scoring for the Natural Vulnerability criteria applied to each variable.

The analysis of the data of each one of the variables that characterize natural vulnerability indicates that:

- The coastline of the NE of the State of Pará has a longitude of approximately 2,625 km. Considering this parameter; it is possible to define three areas (Figure 3.8). The eastern area composed by the municipalities of Viseu and Augusto Corrêa, with the biggest extent (406 km and 394.7 km, respectively). The western area characterized by municipalities with little coastline length (Colares, Vigia, São Caetano de Odivelas and São João da Ponta), and between both, a third area with intermediate extent. Although two municipalities, Viseu and Augusto Corrêa, represent 30% of the total coastal length, other ones have very small extent as Primavera (8.7 km) and São João da Ponta (36 km).

- The coastal zone of Pará shows municipalities where the coastal area has a great relevance - continentality - as Curuçá, Salinópolis and Quatipuru. On the other hand, we could highlight the municipalities which present larger influence of the “non-coastal” area, either for the small extent of the coastline as Primavera, or for the great magnitude of the municipal area as Viseu and Bragança (Figure 3.8). The municipalities that show higher values of coastline complexity are Bragança, Quatipuru and Viseu and some islands of the municipalities of Curuçá and Marapanim.

Table 3.2 Scoring for the Natural Vulnerability criteria.

	Natural Vulnerability - Rank				
	1	2	3	4	5
Coastline Total Length (Km2)	0 - 36,16	36,17 - 69,78	69,79 - 145,78	145,79 - 294,39	294,4 - 406,89
Continentality (Km/Km2)	0 - 0,031	0,032 - 0,142	0,143 - 0,233	0,234 - 0,343	0,344 - 0,526
Coastline Complexity - Sinuosity	1-3,36	3,37 - 5,32	5,33 - 7,33	7,34 - 12,11	12,12 - 14,35
Coastline Complexity - Circularity	0 - 1,19	1,2 - 1,32	1,32 - 1,51	1,52 - 1,8	1,81 - 2,83
Total Area Flooded (Km2)/Census Collection District	0 - 6,83	6,84 - 24,94	24,95 - 60,67	60,68 - 138,21	138,22 - 225,28
Proportion (%) of the Total Area Flooded.	0 - 7,8	7,81 - 25,7	25,71 - 49,87	49,88 - 77,64	77,65 - 100
Total Length of Fluvial System (km)	17,46 - 63,64	63,65 - 108,82	108,83 - 205,9	205,91 - 243,22	243,23 - 381,19
Fluvial Drainage Density (Km/Km2)	0,076 - 0,083	0,084 - 0,236	0,237 - 0,329	0,33 - 0,413	0,414 - 0,5
Split ratio (Number of Segments/Km)	0,127 - 0,177	0,178 - 0,217	0,218 - 0,267	0,268 - 0,308	0,309 - 0,358
Coastal Features - Marine/Estuarine Ratio (%)	1 - 8,36	8,37 - 12,2	12,21 - 16,6	16,61 - 25,54	25,55 - 44,51
Protection Measures (PM)	Non waterfront districts	-	Waterfront districts with PM	-	Waterfront districts without PM
Emergency Relief - Historic Cases	no	-	-	-	yes

- The "Areas Alagadas" (flooded areas) of the NE coast of Pará cover an area of 2,342 km², which represents approximately 14.15% of the study area - 16,215 km². However, this coast is not a homogeneous geomorphologic unit. On one hand, Franzinelli (1982) already subdivided the NE Pará region in two sectors: (i) West, where the active cliffs - Barreiras and Pirabas Formations, reach the shoreline and are eroded by wave and tidal action; and, (ii) East, constituted predominantly by mangroves developed seaward, reaching currently a width of 30 km and inactive cliffs, due to the coastal plateaus stretch out southward. On the other hand, considering the spatial distribution of the flooded areas (fig. 3.9), this study defines three sectors (i) West, from the municipality of Viseu to the

census collection district of Japerica in the municipality of São João de Pirabas, with 1,565 km² of flooding areas (66% of total); (ii) Central, from the municipality of São João de Pirabas to the municipality of São Caetano de Odivelas, with 796 km² of flooding areas (34% of total) and finally, (iii) East, composed by the municipalities of Vigia and Colares, without significant flooding areas.

- Taking into consideration the proportion of the total area of the census collection districts affected by the waters (Figure 3.9), 133 districts (35% of total 370 districts) are entirely or partially influenced by floods. Although the great majority of the districts are near the coastline, some distant ones are also affected (e.g. part of the municipalities of Viseu and Marapanim). This figure shows, with concern, that approximately a quarter of the affected districts (34) have more than 75% of their total area flooded.

- The low-lying coastal zone of the NE of Pará is extremely irregular and jagged with numerous bays and estuaries. Therefore, few municipalities present large sectors of their shore considered under the direct influence of the sea (e.g. Salinópolis and Viseu) (Figure 3.10).

- Taking into consideration the total census collection districts of the coastal zone in direct contact with marine or estuarine waters (156), only 14 (9%) have the coastline protected by some engineering stabilization measures (municipalities of Bragança, Colares, Curuçá, Salinópolis, Quatipuru, Magalhães Barata, Santarém Novo, Maracanã, Marapanim, Vigia and São João de Pirabas), and only one, the town of Crispim (municipality of Marapanim) has registered the action of the emergency relief and mitigation conducted by the Civil Defense of the State of Pará, in the period 1992-2001 (Figure 3.10).

- The morphometric analysis of the fluvial network which extends 3,632 km allows characterizing the coastal zone according to the total longitude of the drainage system, its density and the number of fluvial segments that form it. Regarding the longitude of the fluvial system, this region can be divided in three sectors (i) West, with high extension (municipalities of Viseu, Augusto Corrêa and Bragança), (ii) Central, with middle dimensions, located between the municipalities of Tracuateua and Curuçá, and finally, (iii) East, with small extent (municipalities of Colares, Vigia, São Caetano de Odivelas and São João da Ponta). As to fluvial drainage density, the central area also stands out for its high density (Figure 3.11).

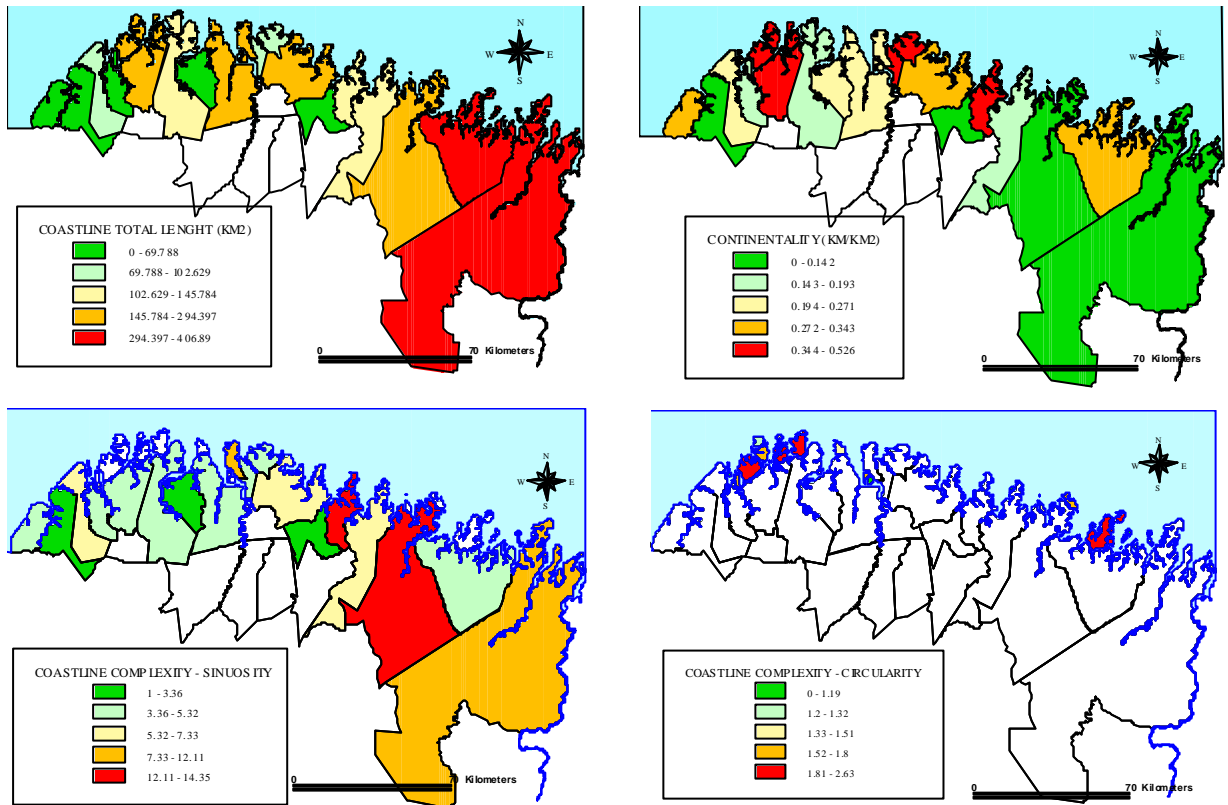


Figure 3.8 NE Coastline total length and complexity (sinuosity and circularity) as well as, Continentality of the Municipal Districts. No data is expressed as white Municipalities.

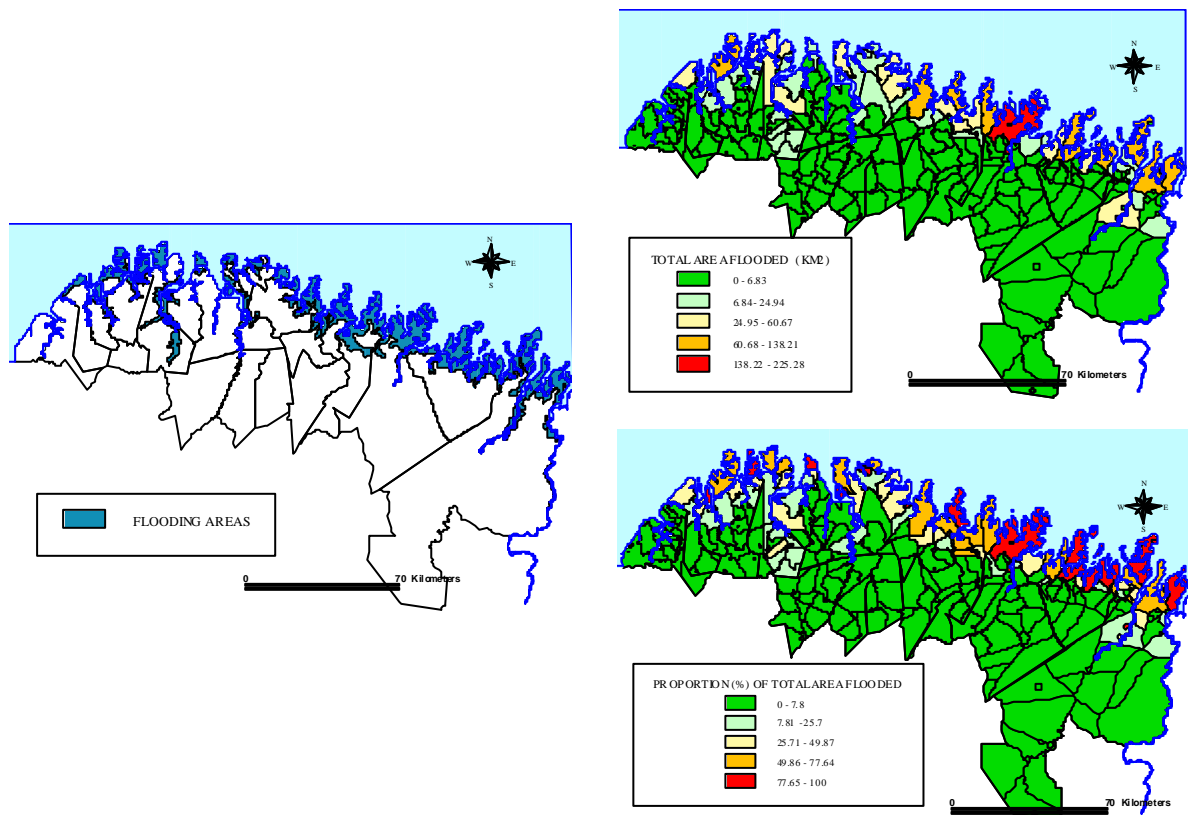


Figure 3.9 Flooded area per Census Collection Districts (total area and proportion).

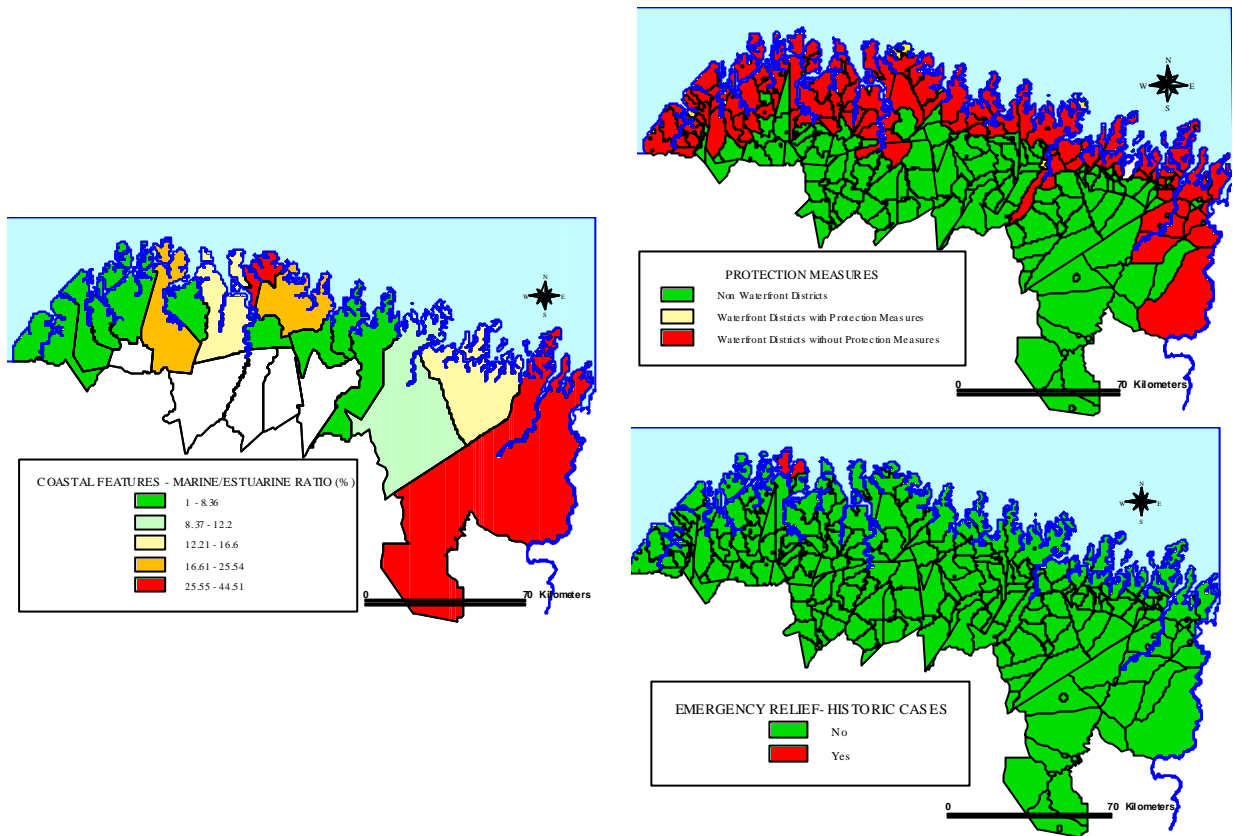


Figure 3.10 Coastal features (marine/estuarine ratio) per municipality. Census Collection Districts which have shore stabilization measures and which record Emergency relief activities. No data is expressed as white Municipalities.

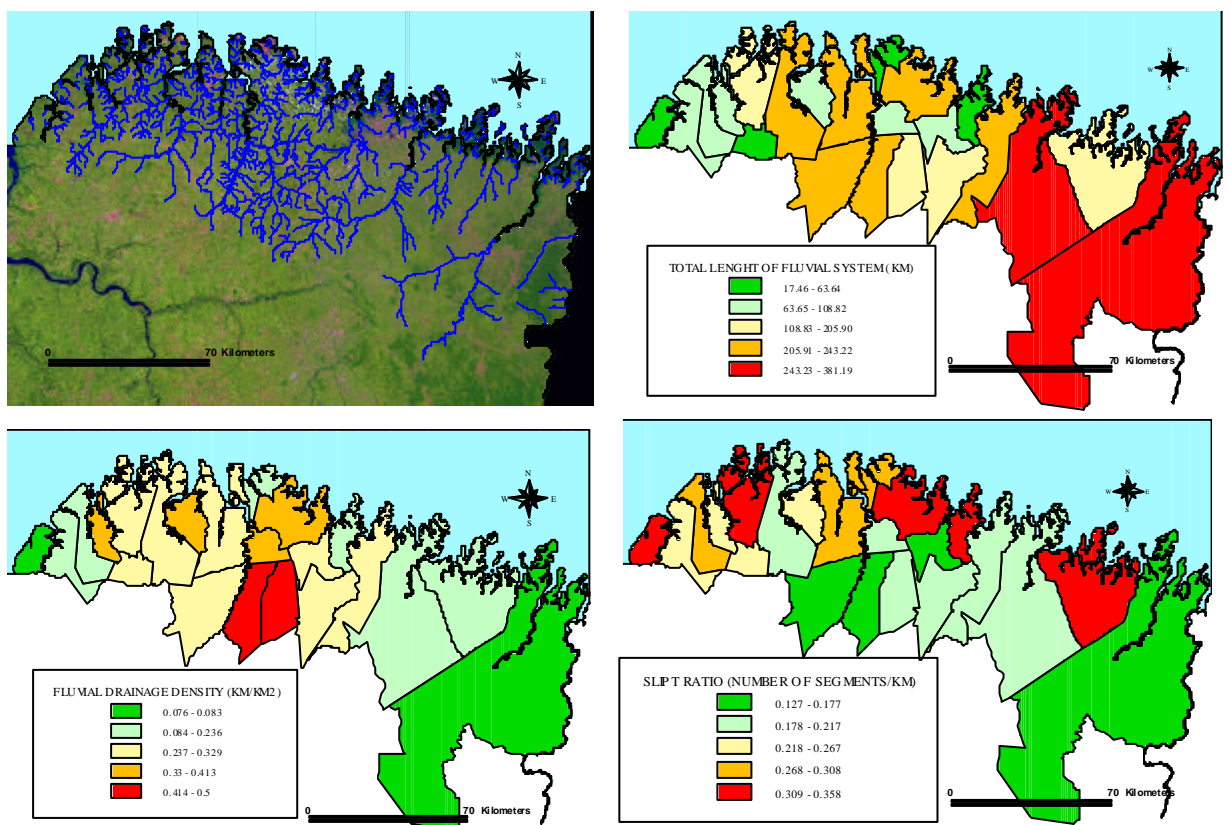


Figure 3.11 Characteristics of the fluvial system (total length, density and slipt ratio).

3.2.2.2 Socioeconomic Variables- Vulnerability Criteria

The central insight brought by social scientists to the process of adaptation is that vulnerability is socially differentiated (Adger, 1999). Griggs (1994) explains that because areas with exceptionally high population are likely to have heavier use of coastal resources and higher concentrations of coastal development, it is clear that the type, magnitude and distribution of coastal vulnerability will vary not only as a result of different physical conditions and geomorphic processes along the coastline, but also as a result of demographic variation. This contrasts with the predominant views on climate change vulnerability, which concentrate on its physical dimensions.

The social vulnerability is the exposure of population groups and values to unexpected changes and varies under different environmental conditions, social norms, political institutions and resource endowments, technologies and inequalities. Then, the degree of socioeconomic vulnerability of the coastal zone of the NE of the State of Pará is composed by individual criteria. The 11 variables include characterization of the population - total number, density; the most vulnerable groups - children, elderly and non-local; and economic aspects - poverty and municipal district wealth.

a. Total Population and Population Affected by Floods

Katayama (1993) suggests that if there is no human habitation in a given area, then the social vulnerability of the area will be null. Decisions to locate people in hazard prone areas increase society's vulnerability even when disaster reduction measures are adopted. Climate changes/sea-level rise will greatly amplify risks to coastal populations (Small, et al, 2000).

The statistic data are obtained from the Brazilian demographic census of the year 2000 (IBGE, 2001). Assuming a homogeneous distribution of the population in each census districts, the population affected by coastal floods can be calculated, allowing the classification of the districts considering their degree of vulnerability (Figure 3.12).

$$\text{Total population affected by floods (2000)} = \text{Total population} \times \frac{\% \text{ of the inundated area of the census collection district}}{100}$$

$$\% \text{ of the inundate area of the census collection district} = (\text{flooded area} / \text{total area}) \times 100$$

b. Population Density

The population density of coastal counties represents a rough measure of historic and present urban development pressures in the coastal zone (Good et al., 1999). The statistic data are obtained from the Brazilian demographic census of the year 2000 (IBGE, 2001) and permit the classification of the municipalities considering their degree of vulnerability (Figure 3.12).

$$\text{Total population density (2000)} = \frac{\text{Total population per municipal district (2000)}}{\text{Area of municipal district}}$$

In every society, principally in developing countries, it is quite clear that disasters do not impact all social groups to the same degree. A certain category is especially at risk, namely those persons who would be considered fragile also in a “normal society situation”. The most vulnerable groups often include: women, children, elderly, foreigners, poor, etc. (Parker, 1993; Szlafsztein and Yamamura, 1995; Tobim, 1999).

c. Children Population - Total and Affected by Floods

Natural disasters create devastating consequences, both direct and indirect, that greatly affect the children population. They suffer disproportionately and are usually among the first casualties in every emergency. The effects of natural disasters range anywhere from physical (i.e. loss of life and injury), to psychological trauma caused by panic and uncertainty associated to the evacuation to inadequate shelters (UNDRO, 1992; Swenson et al, 1996). Locke (1988) and Allen and Rosse (1998) state that the first marks of dysfunction in children appear within a few hours of the catastrophe and only rapid and specific intervention can help to avoid those problems.

“Children” are defined as the 0-4 years-old population³ and the statistic data are obtained from the Brazilian demographic census of 2000 (IBGE, 2001). Assuming the homogeneous distribution of the population in each census district, the children population affected by coastal floods can be calculated. This allows the classification of the districts considering their degree of vulnerability (Figures 3.13 and 3.14).

$$\text{Children population affected by floods} = \frac{\text{Children population (2000)} \times \% \text{ of the inundated area of the census collection district}}{\text{census collection district}}$$

$$\% \text{ of the inundated area of the census collection district} = (\text{area flooded} / \text{total area}) \times 100$$

³ The Brazilian Demographic Census groups the population each 5 years old, and then the youngest group is 0-4 years old.

d. Elderly Population - Total and Affected by Floods

The elderly, who make up an increasing proportion of the Brazilian population (O Liberal, 2002e), suffer when their houses having to be evacuated and find difficulties to recover from property and other economic losses (Quarentelli, 1994). Considering that Brazilian population life expectancy is 68.5 years, for women, in this study “elderly” is defined as population older than 70 years old. The statistic data are obtained from the Brazilian demographic census of 2000 (IBGE, 2001).

Assuming the homogeneous distribution of the population in each census district, the elderly population affected by coastal floods can be calculated. This allows the classification of the districts considering their degree of vulnerability (Figure 3.13 and 3.14).

$$\text{Elderly population affected by floods} = \frac{\text{Elderly population (2000)} \times \% \text{ of the inundated area of census collection district}}{\text{collection district}}$$

$$\% \text{ of the inundate area of the census collection district} = (\text{flooded area} / \text{total area}) \times 100$$

e. “Non-Local” Population - Total and Affected by Floods

Many people from different regions have been attracted to the coastal zone in the last years. There are three fundamental reasons for the migration of families and individuals from their areas of origin (i) the lack of basic life-elements (potable water, food, and jobs), (ii) the necessity of new areas for fishing activity development due to the decrease of natural resources and (iii) the tourism activity. Therefore, an increasing number of “non-local populations” are now living in the coastal zone, permanent or temporarily, constituting a vulnerable group to natural disasters because they are not familiar with the local hazards they must live with, and then often settle in risk prone areas (Plate, 1994).

The statistic data are obtained from the Brazilian demographic census of 2000 (IBGE, 2001) ⁴. Assuming the homogeneous distribution of the population in each census district, the non-local population affected by coastal floods can be calculated. This allows the classification of the districts considering their degree of vulnerability (Figure 3.13 and 3.14).

$$\text{“Non-local” population affected by floods} = \frac{\text{“Non-Local” population (2000)} \times \% \text{ of the inundated area of the census collection district}}{\text{census collection district}}$$

$$\% \text{ of the inundate area of the census collection district area} = (\text{flooded area} / \text{total area}) \times 100$$

f. Poverty - Human Development Index

Poverty is an important aspect of vulnerability to natural hazards and the impacts of future changes in climate extremes are expected to fall disproportionately on the poor (Pelling, 1999; IPCC, 2001). It can be directly related to social marginalization and lack of access to resources. Therefore, the poor population is considered the most vulnerable group to natural disasters (PAHO, 1994; Szlafsztein, 1995).

In the past, human progress was measured using only the Gross Product (GP); however, in the last years, many people have looked for a better, more comprehensive socio-economic measure. Nowadays, the concept of human development focuses on the creation of an enabling environment for people to be educated and to enjoy long, healthy and creative lives. Additional choices include political freedom, guaranteed human rights and self respect.

According to UNDP (2002), the first human development report, in 1990, introduced a new way of measuring development - by combining indicators of longevity, knowledge and standard of living into a Composite Human Development Index - HDI (scales-expressed as a value between 0 and 1). Longevity is measured by life expectancy. Knowledge is calculated by a combination of adult literacy (2/3 weight) and mean years of schooling (1/3 weight). Standard of living is measured by purchasing power, based on real GDP per capita adjusted for the local cost of living. The HDI facilitates the determination of priorities for policy intervention and the evaluation of progress over time.

This study adopts the HDI, as an expression of poverty, and uses it to classify the municipalities considering their degree of vulnerability (Figure 3.15). The statistic data (2000 - 2002) have been obtained from the Special Secretary of Planning and Management of the State of Pará.

g. Municipal Budget

Although the biggest concentration of financial resources in a region can imply a larger adaptation capacity to the natural hazards impacts, this is not applied to the study area. In the coastal zone of the State of Pará, the municipalities' wealth is related to higher economic activities, properties, and infrastructure works exposed to these potential impacts, which means higher vulnerability.

⁴ The Brazilian Demographic Census considers as *Non-Local*, the people that born in a different place that they live now.

Not all municipalities meet the deadline for surrendering their budgets to the Justice (*Tribunal de Contas dos Municípios*), hindering their utilization as a variable in the CVI. Then, in this study, the ICMS's Tax is used as an expression of municipal wealth. The tax on "Circulation of Goods and Services supply" (ICMS - *Imposto sobre Operações relativas à Circulação de Mercadorias e sobre as Prestações de Serviços*) is applied to the circulation of products as food, domestic appliances, among others, and also to services of interstate and inter-municipal transport and communication. Article 158 of the Brazilian Constitution (Brasil, 1991) establishes that 25% of the collection of the ICMS product belongs to the municipal districts, following criteria as area, population, value of the goods that enter and exit the municipality, in every calendar year. Therefore, the ICMS Tax classifies the municipalities considering their degree of vulnerability. The statistic data for the year 2000 have been obtained from the Treasury of the State of Pará (*Secretaria Especial de Estado de Gestão; Secretaria Executiva da Fazenda*) (Figure 3.15).

The Table 3.3 resumes the scoring for the socioeconomic vulnerability criteria applied to each variable.

The analysis of the data of each one of the variables that characterize socioeconomic vulnerability indicates that:

Table 3.3 Scoring for the Socio-economic Vulnerability criteria.

	Socio-economic Vulnerability – Rank				
	1	2	3	4	5
Total Population - 2000	20 - 1,205	1,206 - 3,759	3,760 – 8,647	8,648 - 25,418	25,419 - 47,769
Total Population - Density 2000	1 - 477	478 - 1,505	1,506 - 3,361	3,362 - 5,821	5,822 - 10,854
Total population affected by Floods	0 - 320	321 - 1,350	1,351 – 3,707	3,708 - 7,902	7,903 - 19,083
Total Population - Children	2 - 391	392 - 1,256	1,257 – 3,249	3,250 - 5,886	5,887 - 11,690
Total Population - Elderly	0 - 10	11 - 38	39 - 94	95 - 225	256 - 561
Non-Local Population	0 - 10	11 - 50	51 - 148	149 - 432	433 - 762
Total Population Children Affected (Floods)	0 - 64	65 - 254	255 - 542	543 - 1176	1177 - 2372
Total Population Elderly Affected (Floods)	0 - 1	2 – 6	7 - 11	12 - 21	22 - 493
Non-Local population affected (Floods)	0 - 11	12 - 38	39 - 89	90 - 203	204 - 380
Poverty (HDI)	0.463-0.481	-	0.428-0.462	-	0.427
Municipal Budget (% ICMS)	0.12 - 0.13	0.14 - 0.15	0.16 - 0.17	0.18 - 0.22	0.23 - 0.7

- The total population of the year 2000 in the NE coastal zone of the State of Pará, 539,324 inhabitants, represents approximately 8% of the total population of Pará. The spatial distribution of the population is not homogeneous in the whole region, major concentrations being observed in urban areas. 171,548 people, 31% of the total population of the coastal zone, resides in the capital cities of the municipalities of Bragança, Capanema, Vigia, Salinópolis, Viseu and Igarapé-Açu. The coastal zone has a very low demographic density (33 inhabitants/km²); however, there are sectors where this parameter exceeds the number of 3,000 inhabitants/km² reaching almost 10,000 inhabitants/km² as the localities of Primavera, Bragança, Emborai (Augusto Corrêa), Caratateua (Bragança), Colares, Vigia, Viseu, Salinópolis and Fernando Belo (Viseu) (Figure 3.12).

- The total population of children younger than 4 years old is of 114,348 children, 21% of the coastal zone's total population, however, about 30% of them (31,229 children) are concentrated in only the urban areas of the Municipalities of Bragança and Capanema as well as in some districts of the Municipality of Viseu (Viseu, São João do Piriá and Fernando Belo). The total population of elderly, over 70 years old, is only 3,913 people, 0.72% of the total population of the coastal zone, and 47% being concentrated in the districts of Salinópolis, São João de Pirabas, Marapanim, Viseu, Maracanã, and Fernando Belo (Viseu). Finally, 5,095 people have been registered as "non-local population" - 0.95% of the coastal zone's total population. 61% concentrate in industrial (Capanema), tourist (Salinópolis), agricultural (Igarapé-Açu), and port (Vigia, Bragança, São João de Pirabas and Augusto Corrêa) districts (Figure 3.13).

- Approximately 85,172 people live in flooding areas, 40% of them (33,495 people) being concentrated in the urban areas of only three municipalities (Salinópolis, São João de Pirabas and Marapanim). 16,775 children are living in affected areas; however, 45% of them (7,587 children) are grouped in six districts - Salinópolis, São João de Pirabas, Viseu, Marapanim, Quatipuru and Fernando Belo (Viseu). 91.4% of the elderly affected, 618 people, are concentrated principally in the urban area of Salinópolis and coastal districts of the municipality of Viseu (Viseu, Fernando Belo and São João do Piriá). 907 people coming from different areas are affected (17% of the total non-local population), living mainly (82%), in few coastal districts like Salinópolis, São João de Pirabas, Quatipuru and Marapanim (Figure 3.12 and 3.14).

- Very low numbers of the Human Development Index of the coastal zone of the State of Pará are shown for every municipality, being possible to highlight the lowest

indices of the municipality of Viseu. The economic resources distributed by the State of Pará to the different coastal zone municipalities (% ICMS), used as a tool to analyse municipal wealth, show that the municipalities have scarce economic resources, standing out Capanema, Tracuateua and Bragança as the municipalities with more participation in the resources distribution (Figure 3.15).

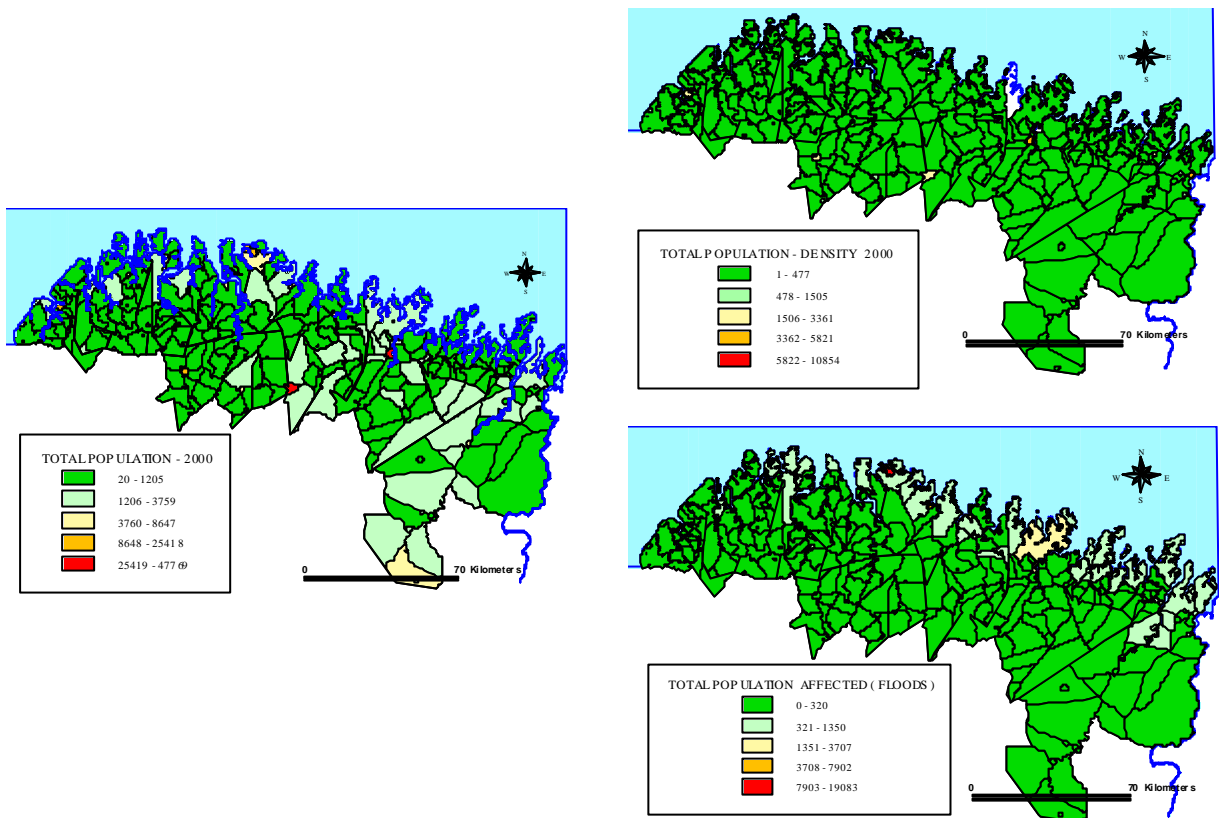


Figure 3.12 Demographic data per Census Collection Districts (Total population 2000; total population density and population affected by floods).

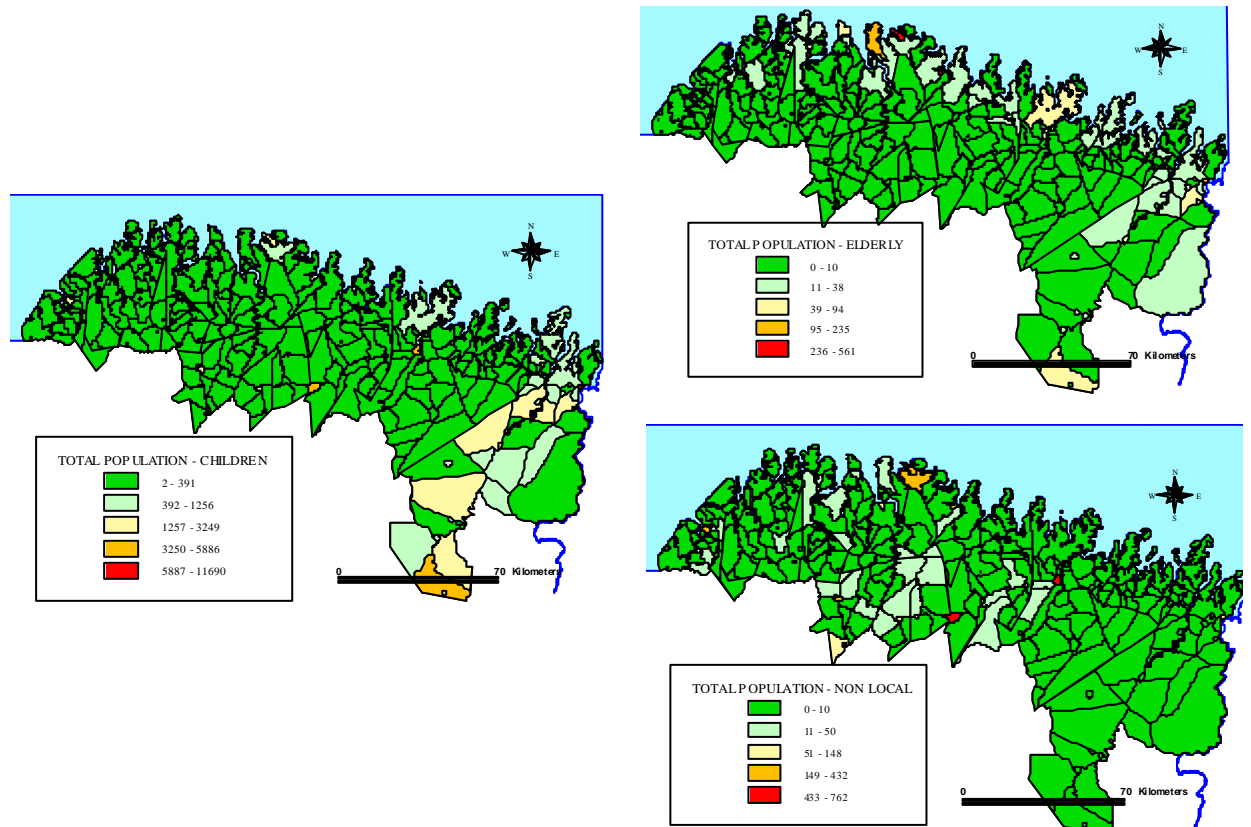


Figure 3.13. Demographic data per Census Collection Districts (Total children; elderly and non-local populations).

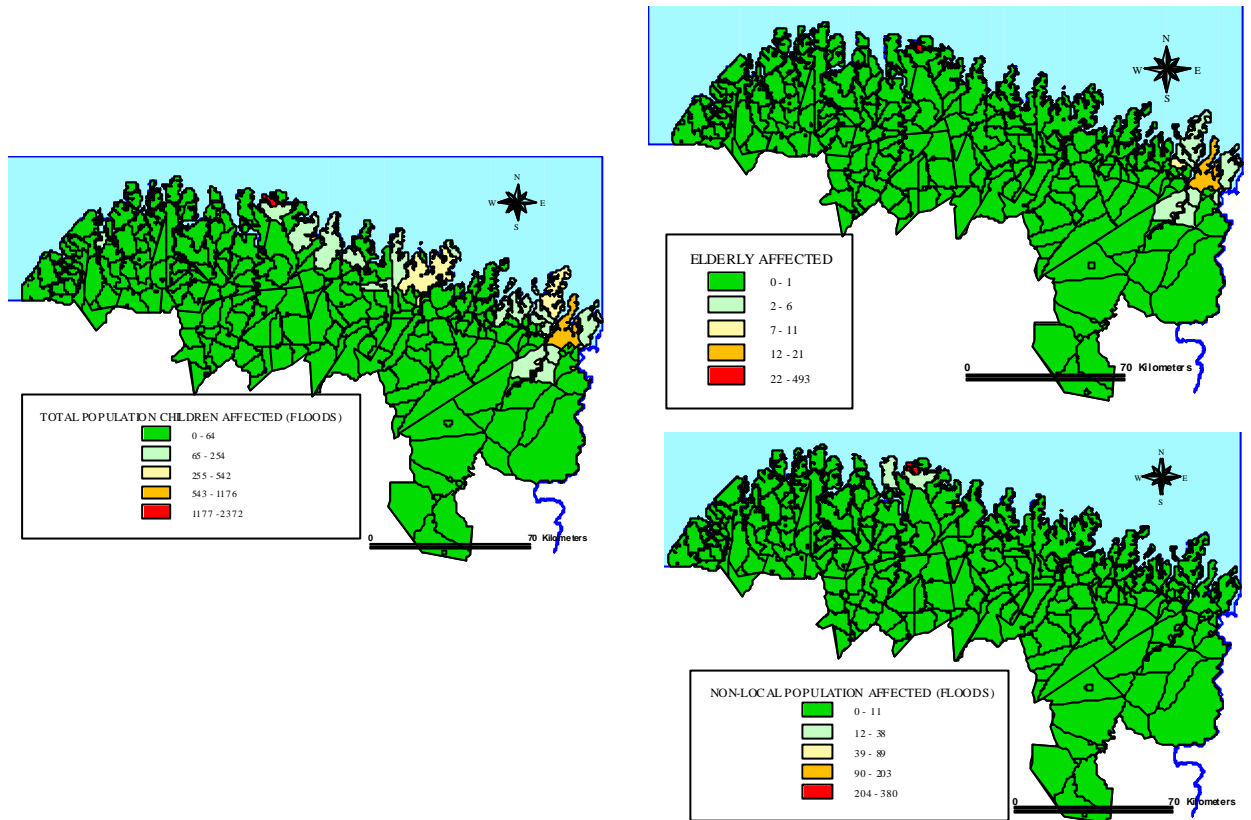


Figure 3.14 Demographic data per Census Collection Districts (Total children, elderly and non-local population affected by floods).

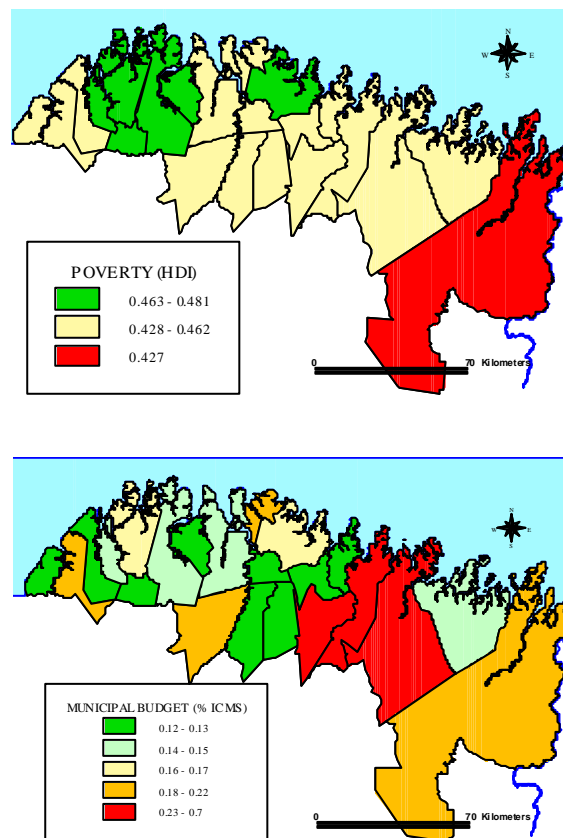


Figure 3.15 Poverty (expressed by HDI) and Municipal budgets (expressed by proportion of the ICMS) per Municipal districts.

The selection of number and types of variables used vary greatly according to the aims of the study (Cooper and Mc Laughlin, 1998). However, not all data used have the same relevance for this purpose. Some of them are chosen because the desirable data do not exist or are too expensive to collect, and others are a variable derived from the combination of two or more data. Therefore, each of these variables is weighed according to its importance in determining the vulnerability of coastal areas to natural hazards and sea level rise. In this study, the established weight for each variable is called "Dependence Degree". The Table 3.4 shows the variables used, their dependence degree and the weight assigned. Once classified and weighed, these coverages are then overlaid and the variable scores combined into Natural and Socio-Economic Coastal Vulnerability Indices. Total Vulnerability Index is defined as the combination of the Natural and Socio-Economic Vulnerabilities (Figure 3.16). All of these Composite Vulnerability Indices rank coastal sectors in a 5-level scale based on the degree of susceptibility, classifying them as: very low, low, moderate, high, and very high vulnerability.

Table 3.4 Classification of each variable considering their relevance in the construction of the CVI, expressed by their Dependency Degree and factor of weight.

	Variables	Dependence Degree (a)	Weight
Socio-economic vulnerability	Total population affected (flood); Non-local Population affected (flood); Children affected (flood) and elderly affected (flood).	1	1
	Population Density	2	0.5
	Non-local Population, Children, Elderly	3	0.25
	Total population 2000; Municipal Budget 2000; Poverty.	4	0.125
Natural Vulnerability	Coastline length, Flooding area; Protection measures, emergency relief historic cases; total length of fluvial system.	1	1
	Coastal features	2	0.5
	Continentality; coastline complexity; proportion of flooding area; drainage density; split ratio.	3	0.25

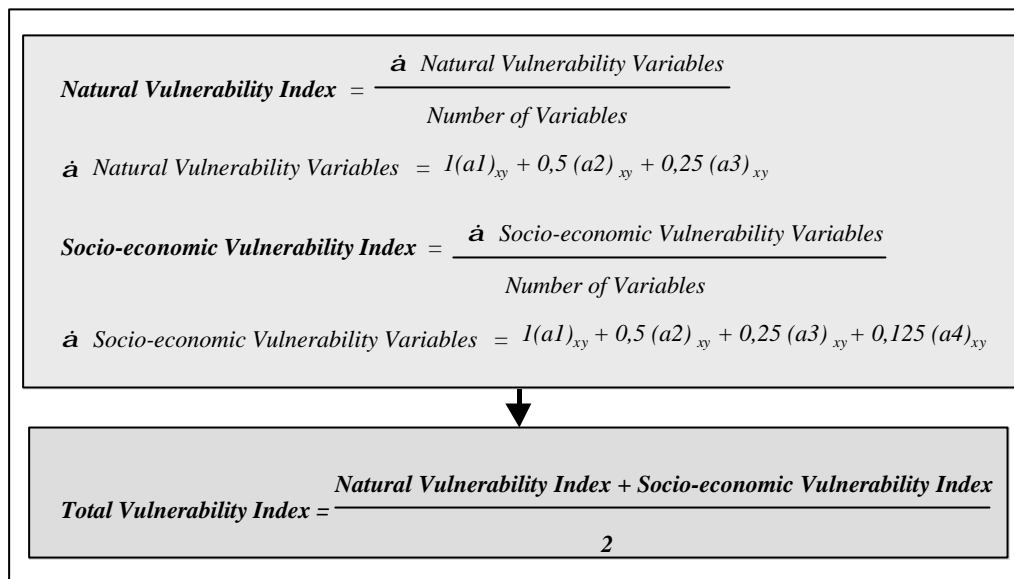


Figure 3.16 Definitions of Natural, Socioeconomic and Total vulnerability indices.

3.2.3 Results

From the analysis of Geographical Information Systems and statistical records the following conclusions have been reached:

Considering the values of the CVI - Socioeconomic dimension it is possible to identify two regions (i) near from coastline, with moderate to very high vulnerability values and (ii) distant from coastline, with very low to low vulnerability values (Figure 3.17). The first region consists of 51 districts (14% of the total) and an area of 1,909 km² (12% of the total area). The district that corresponds to the urban area of the municipality of Salinópolis is the only one characterized as very highly vulnerable. The others (high and moderate vulnerability) are the urban areas of the municipalities of São Caetano of Odivelas, Salinópolis, São João de Pirabas, São João da Ponta, Marapanim, Quatipuru, Maracanã, Bragança, Viseu, and Augusto Corrêa, as well as the districts of Fernandes Belo and São José do Piria (Municipality of Viseu), Caratateua and Bragança (municipality of Bragança), Emborai and Itapixuna (municipality of Augusto Corrêa), Japerica (municipality of São João de Pirabas), Murajá (municipality of Curuçá), and Cafezal (municipality of Magalhães Barata).

Considering the values of the CVI natural dimension, it is possible to identify three regions that are characterized by (i) high and very high vulnerability, (ii) moderate vulnerability, and (iii) very low and low vulnerability (Figure 3.18). The first region, located near from the coastline, is a continuous area of 5,357 km² (33% of the total area - 22% very high

vulnerability and 11 high vulnerability) integrated by the urban areas of the municipalities of Viseu, Marapanim, Maracanã, Curuçá, Bragança, Augusto Corrêa, Tracuataeua and, Quatipuru, as well as the districts of Fernandes Belo and São João do Piria (municipality of Viseu), Japerica (municipality of São João de Pirabas), Ponta de Ramos, Lauro Sodre and Murajá (municipality of Curuçá), Aturai and Itapixuna (municipality of Augusto Corrêa), Maruda (municipality of Marapanim), São Roberto and Boa Esperança (municipality of Maracanã), and Caratateua and Tijoca (municipality of Bragança). The second sector - 5,581 km² or 35% of the total area - is concentrated in the SE area and some discontinuous districts on the NW area of the coastal zone. Finally, the third sector, which presents very low and low values of vulnerability, is defined at SW and W area of the coastal zone. In this category the municipalities of Vigia and Colares deserves special attention due to their geographical position near to the coastline and their low natural vulnerability.

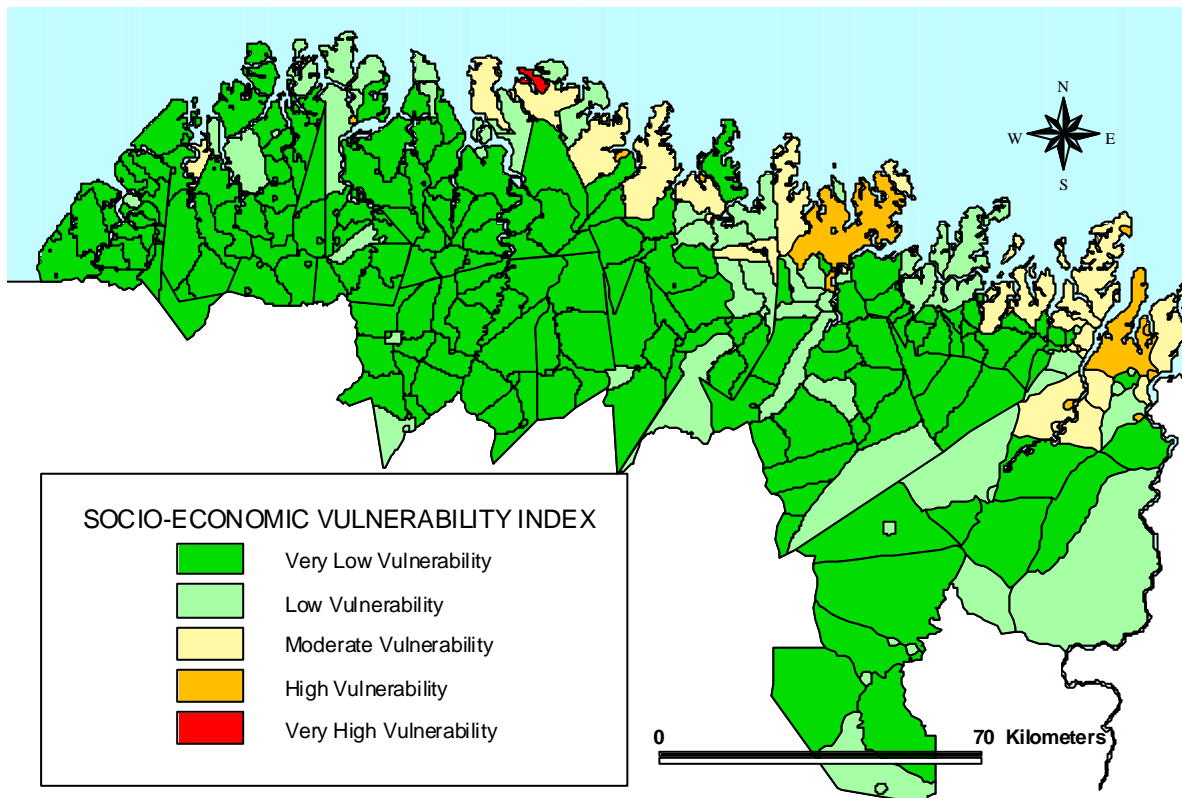


Figure 3.17 NE coastal zone of the State of Pará: Spatial distribution of the Socio-economic Vulnerability Index.

The analysis of the total vulnerability of the NE coastal area of the State of Pará (Figure 3.19) indicates that in this region, as a result of its socioeconomic and natural vulnerability characteristics, it is possible to define two regions with (i) moderate to very high vulnerability, and (ii) very low and low vulnerability (Table 3.5). The area of the first region (8,614 km², 54% of the total) is distributed among 158 Census Collection Districts (42% of the total) most of them near from the coastline. This sector, where around 270,600

persons live (50% of the total population), is integrated by the urban areas of the municipalities of Viseu, São João de Pirabas, Salinópolis, Marapanim, Maracanã, Bragança, Tracateua, Quatipuru, Curuçá, Augusto Corrêa, São João da Ponta, and São Caetano de Odivelas, as well as the districts of Fernandes Belo and São João do Piria (municipality of Viseu), Japerica (municipality of São João do Pirabas), Caratateua, Nova Mocajuba and Tijoca (municipality of Bragança), Aturai, Emborai and Ipixuna (municipality of Augusto Corrêa), Boa Esperança and São Roberto (municipality of Maracanã), Ponta de Ramos, Lauro Sodre and Murajá (municipality of Curuçá), and Marudá (municipality of Marapanim). In most districts, the variables related to natural vulnerability dimension prevail, while in few sectors, mainly in the urban areas and/or capitals of the municipalities (e.g. Salinopolis, São João de Pirabas, Marapanim, Quatipuru), those which prevail are the variables of socioeconomic vulnerability dimension.

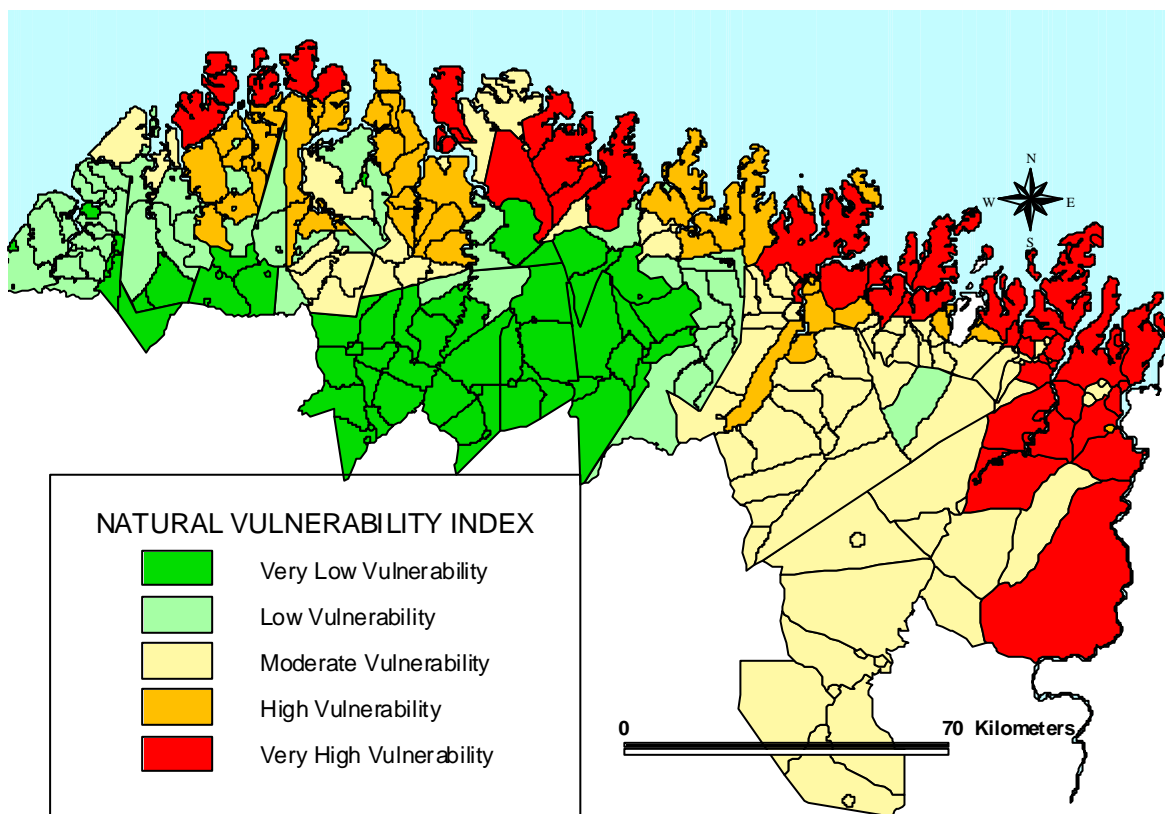


Figure 3.18 NE coastal zone of the State of Pará: Spatial distribution of the Natural Vulnerability Index

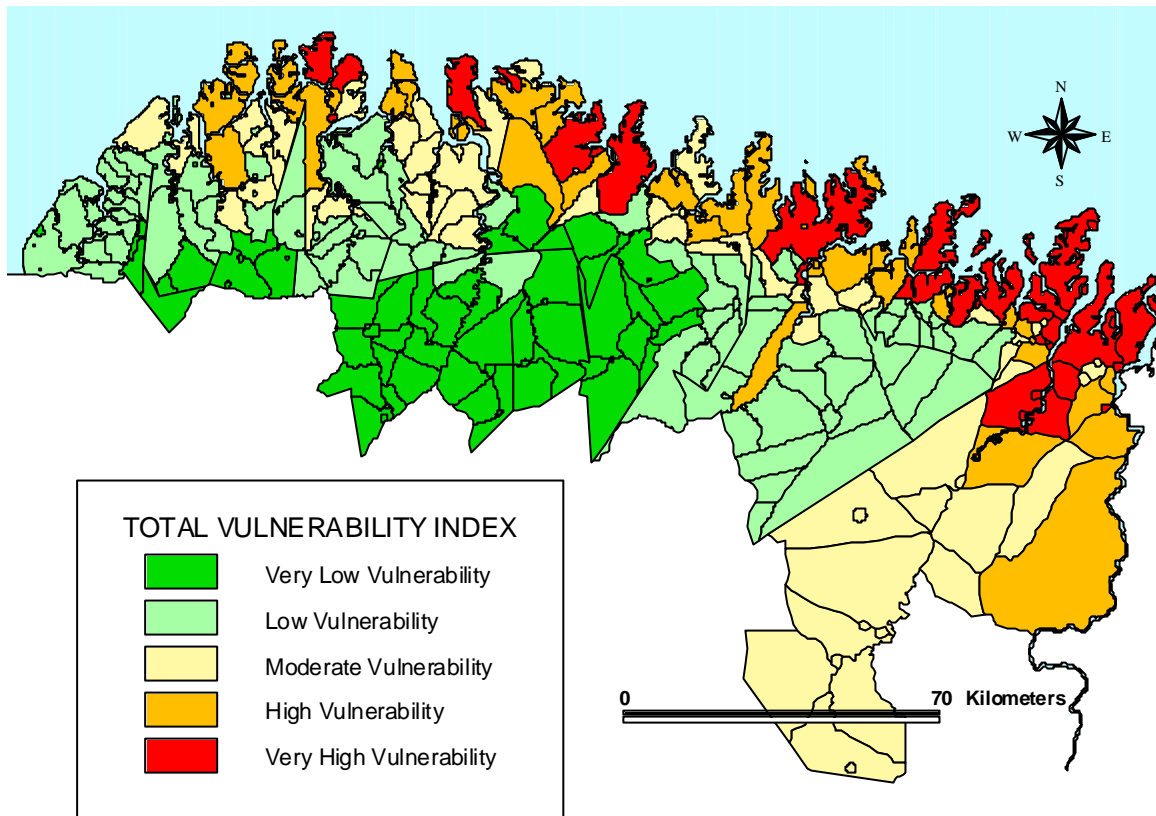


Figure 3.19 NE coastal zone of the State of Pará: Spatial distribution of the Total Vulnerability Index

Table 3.5 Total Vulnerability of the coastal zone of the NE of the State of Pará – some statistical data.

	Vulnerability	Census Collection Districts	Area (km ²)	Population
Sector i	Very High	31	1,759	87,504
	High	45	2,703	41,074
	Moderate	82	4,151	142,028
Sector ii	Low	124	4,568	121,022
	Very Low	88	3,032	147,696

3.3 Final Considerations

A broad interest in the development of coastal vulnerability indices is reflected in the variety of institutions that have worked on or founded research on them. Such organizations’ willingness to support the development of coastal vulnerability indices suggests an appreciation of their potential values (Cooper and McLaughlin, 1998).

The results obtained in this study have a high confidence in the observations and descriptions made in various regions. However, these results and conclusions should be carefully considered, always remembering that they are the result of a “reality model” and not of the reality itself. This is not to say that this kind of study is not important, but that its weakness must be recognized. The validity of the results obtained through this method is limited to:

- The Study Area: In fact, changing the area examined, the values of the variables can be dilated and/or notably reduced, thereby modifying the characteristics of single classes.

- Degree of system understanding: The variables chosen and their relative significance (weight) depend on a subjective analysis or it is derived from the system understanding. Therefore, other factors than the accounted among the chosen variables and discrepancies between the CVI Values and the observed scenario can be expected.

- GIS errors: several factors govern the errors that may be associated with the Geographical Information Systems, which are related to the age of the data, density observations, classification systems, position accuracy, and the problem of interpolating points or linear data into polygon boundaries that do not have the same dimensions.

It cannot be trusted that all the processes that determine vulnerability can be reliably identified; then the proposed method allows flexibility for utilizing a wide range of data. The CVI can be condensed to focus on fewer vulnerability factors or can be expanded to include more in-depth analyses according to data availability and needs of the research. In this study, it is recognized that many other factors could be used as components of the CVI, such as:

- Women population: They suffer disproportionately from natural hazards impacts; however, women problems in disaster and emergency broad context have only recently been addressed. Women vulnerability is based on those that are pregnant or nursing, have a high responsibility for dependent children, and are the head of household (UNDRO, 1991). Their vulnerability stems from cultural, political and economic conditions, not from biological or physiological differences (Wiest et al., 1996). Unfortunately, the census data per collection district available does not make any reference to the female population.

- Population growth: It is the cause of many, if not most, coastal problems (Kay and Alder, 1999). As the population grows, the competition for property, land and natural

resources also increases along with the exposure to coastal hazards (Griggs, 1994). In spite of that, people appear to be moving to many areas which are not only highly hazardous, but also likely to become even more hazardous with climate change. Statistic data are obtained from the Brazilian demographic census from 1991 and 2000; however, in the late 80s and early 90s, the municipalities in Pará suffered many changes in number and boundaries, hindering comparisons between censuses, which can only be possible if boundaries are recognizable and constant meanwhile (King, 2001). For example, the municipality of Quatipuru, which was dismembered from the municipality of Primavera (State Law 5859/94), the municipality of Tracuateua, dismembered area from the municipality of Bragança, and the municipality of São João da Ponta, dismembered area from the municipality of São Caetano de Odivelas (State Law 5920/95). Also, the boundaries of the census collection districts have been changed along the time.

- High-resolution elevation data: the site altitude is a primary determinant of susceptibility to inundation in low lying coastal areas; therefore, a high-resolution topographic mapping is necessary (Bryan et al., 2001; Titus and Richman, 2000). The lack of this kind of map makes it difficult to quantitatively assess people and property at risk of flooding and potential sea level rise. There have been some attempts to improve the precision of the topographical cartography on the NE coast of the State of Pará, through the elaboration of a 20-meter contour level map (Pereira, 1995) and a 1-meter contour level map (Cohen et al., 2000) but unfortunately they are limited to only few coastal sectors.

- Climatic and oceanographic data: The oceanographic setting of the adjacent continental shelf, and the regional coastal configuration will influence the distribution of energy reaching the shoreline (Bush et al. 1999). In spite of their importance, they have not been employed as a variable in the characterization of the vulnerability natural dimension in the NE coastal zone of the State of Pará due to their unavailability; also when they already exist, they are applied over a large area, lacking the detail required in order to differentiate coastal types and responses.

- Erosion rates: Although coastal erosion is relatively easy to document qualitatively, there is also the need for a more quantitative documentation on the rates of cliff retreat in order to compare coastal morphological change rates in different areas over different time periods, and to quantify the intensity or magnitude of shoreline processes (Griggs, 1994). These rates are typically determined through the measurement on sequential aerial photographs and/or historic maps. Unfortunately, only one study has been developed in

this sense, on a small sector of the coast of Pará (Cohen and Lara, 2003) over a span of 25 years, which limits reliability of the morphological change rates.

- Resilience: Coastal wetlands appear to be threatened by loss or significant change in most areas, as their present location is intimately linked with present sea level although their ability to respond dynamically to such changes by sedimentation and biomass production needs to be carefully considered.

Even though the lack of data imposes some limits, and more indicators perhaps could be added as the information becomes available, sometimes more indicators would not necessarily be better. On the one hand, some might overlap with existing indicators (e.g.: infant mortality is already reflected in IDH); on the other hand, more variables could confuse main trends picture.

Considering the limited validity of the obtained results, the absence of some important variables, and the uncertainty of climate change debates, why is it so important to make an assessment of coastal zone vulnerability to natural hazard impacts (potentially increased by sea-level rise), and for this reason to create a CVI? In order to support the ICZM program, it is crucial start basic research on vulnerability parallel with the implementation of coastal zone management guidelines and the development of disaster policies (Nicholls and Leatherman, 1995). On the one hand, some response options to natural hazard impacts, both technical and institutional, take decades to become fully effective, being necessary then to implement adaptation and mitigation activities as quick as possible (IPCC, 1990; Haq and Milliman, 1996; Vellinga and Klein, 1993). On the other hand, the lack of full scientific certainty should not be used for postponing measures that respond to natural hazards and climate change impacts (Adger and Kelly, 1999). Awaiting the necessary time in order to obtain **all** the information and knowledge or to let the existent uncertainties diminish is not possible; the decisions about the future will always be made in some degree of ignorance (Handmer et al., 1999).

Considering the present circumstances, this vulnerability study indicates that significant areas of the NE coastal zone of the State of Pará, principally near from the coastline, have a relatively high vulnerability to natural hazards. Vulnerability is explained by the combination of social and environmental factors, therefore, taking into account that these aspects could change in short and long term, the current vulnerability values should not be considered as constant; they may change through time. Adger (1999) states that changes in

the social causes of vulnerability often happen at much more rapid temporal scales than many environmental changes (e.g. 30 years). Some studies have also intended to evaluate and predict temporal scales from decades to a century of possible changes in coastal morphology (Leatherman, 1990; Woodroffe, 1990) and mangrove ecosystems (Ellison and Stoddart, 1991; Ellison, 1994). For these reasons, in Brazil, considering the potential scenarios of global climate change and regional and local human development described before, future changes in the spatial distribution, and on increase in the magnitude of coastal vulnerability to natural hazards could be expected.

It is important to highlight that the identification of vulnerable sectors, the predicted low rate of sea-level rise, and the socioeconomic development long-term scenario offer the possibility to implement the necessary response strategies and measures (mitigation and adaptation) in a well-planned way.

CHAPTER 4

HUMAN ADAPTATION MEASURES TO COASTAL PROCESSES AND CLIMATE CHANGE

Human societies are immensely adaptable, being constant adaptive behavior a characteristic of social, political and economic activity (Handmer et al., 1999). Adaptation is defined, in this work, as a kind of human response to the direct and indirect effects of coastal processes and their potential modifications, particularly as a result of climate characteristic, change and variability, for the purpose of lessening detrimental consequences or enhancing beneficial ones.

“Adaptation” refers to both the process of adapting (to make more suitable) and the condition of being adapted (Smit et al., 1999) and includes a wide range of behavioural adjustments that households and institutions take, consisting also of changes in laws, programs, and policies (Learly, 1999). Excluded from this definition are the physical, biological and behavioural responses of living organisms other than humans. The intent is to focus attention on individual or collective human responses that may be involuntary responses or deliberate adaptive strategies (Adger and Kelly, 1999).

People have always adapted to climate and many policies and practices are already in place. These policies generally treat climate as though it were constant over decades. The new challenge is to take the vast array of adaptation to climate and make them appropriate for climate change (Burton, 1996).

According to IPCC (2001), adaptation is a necessary strategy at all scales to complement climate change mitigation efforts. However, adaptation measures have been a neglected component of the climate change debate comparing with other elements (e.g. natural and human causes, economical and biological impacts) (Basher, 1999). This is possibly due to the following reasons. First, the school of thought about climate change “Preventionist” - which argues that the ongoing increase of atmospheric greenhouse-gas concentrations could be catastrophic and that a drastic action is required to reduce emissions. They fear that increased emphasis on adaptation will weaken society’s willingness to reduce emissions and thus delay or diminish mitigation efforts (Kates, 1997). Second, adaptation measures must take place in a context not only of a great lack of regional, national and site specific knowledge and data on coastal and marine processes, future technology and lifestyles but also of an enormous uncertainty of climate forecasts (Handmer et al., 1999).

These facts make the selection and implementation of adaptation options extremely difficult. Then, one possibility is to opt for making anything while expecting more information that can allow the decrease of these uncertainties. Considering local economic and political situations and the rate of progress of science and technology, to reach more certainties would take long time. Therefore, in spite of the large uncertainty and lack of knowledge involved, anticipatory adaptation strategies must be developed.

The selection of adaptive strategies and measures depends on factors such as physical (e.g. coastal processes), social (e.g. education level, information skills), economic (e.g. infrastructure, wealth), political (e.g. access to resources) and environmental characteristics of the affected areas and population (Charlier and DeMeyer, 1997; IPCC, 2001). Adaptation strategies and measures research and planning need to begin with an understanding of natural, social and economical vulnerability¹, especially considering human behavior and institutional capacity (Handmer et al., 1999). A decision-making process in order to opt for a response strategy and measure should include as a fundamental element a “cost-benefit” assessment to weigh the life cycle costs and economic returns of the various alternatives (Boyles Jr., 1993; Heather, 2001), however not all the important factors are totally quantifiable in monetary terms - particularly, those that are related to cultural, environmental and social issues. Nevertheless, these non-quantifiable aspects must be evaluated and given due consideration in order to formulate and implement an acceptable adaptive strategy and measure (IPCC, 1990). Finally, the relating historical experiences and the strategies and measures adopted in similar circumstances should also be considered.

4.1 Classification of adaptation strategies and measures

Although adaptation strategies are not a new subject, the possibility of climate change poses new challenges for adaptive management and adaptation options. They are classified using several parameters:

- i) The system to be adapted (Smithers and Smit, 1997).*
 - Natural
 - Socio-economic
- ii) The degree of self-determination of the affected population (Klein and Maciver, 1999).*
 - “Autonomous” adaptation: takes place without intervention of authorities
 - “Planned” adaptation: requires strategic actions, based on the awareness that climate is changing and that some action is needed to better respond to such changes.
- iii) The implementation time of strategies and measures (Klein and Maciver, 1999).*
 - “Reactive” adaptation takes place after impacts have occurred,
 - “Pro-active” adaptation takes place before impacts are apparent.

¹ See chapter 3.

Autonomous adaptation is reactive by definition; while planned adaptation in human systems can be both reactive and proactive.

iv) The deal with economic and non-economic loss (El-Raey et al., 1999).

- Preventing loss; which involves anticipatory actions to reduce the susceptibility to the impacts of climate change.
- Tolerating loss, where adverse impacts are accepted in the short term because they can be absorbed without long term damage.
- Spreading or sharing loss, when actions distribute the burden of impact over a larger region or population beyond those directly affected by the climate event.

4.2 Adaptation Strategies and Measures in the Coastal Zone of the State of Pará

The coastal zone of the State of Pará registers several evidences of environmental, social and economic impacts that result of human activities and erosion and coastal flood processes (Souza Filho, 2001; Franzinelli, 1982; Carvalho, 2000). The potential changes in natural phenomena characteristics as a consequence of global climatic changes and sea-level rise, together with the effects of disordered development are factors that will be able to raise this record of negative events. These impacts differ spatially considering not only the magnitude and frequency of the natural phenomena but also the vulnerability of the different coastal sectors and populations.

Some strategies and measures aim to reduce the emission of greenhouse gases as a form of mitigating climate change (MCT, 2003). Others, as adaptation measures, seek to decrease coastal vulnerability to the impacts of sea-level rise. However, the vulnerability of any individual or social grouping to some particular form of natural hazard is determined primarily by their already existent capacity to respond to that hazard, rather than by what may or may not happen in the future (Kelly and Adger, 2000). Therefore, a description and an evaluation of the performance of the response measures already employed or not, in Brazil and in the coastal zone of the NE of the State of Pará, are necessary. In this sense, some pressing research questions are:

- Which adaptation strategies and measures by the population and the authorities facing the action of natural coastal processes have been recently adopted?
- Considering their performance, which are the causes of success or failure of the adopted strategies and measures?
- Will these strategies and measures be suitable to face extreme events in consequence of global changes? What other adaptation strategies and measures can be used?

- Are there institutions or people already thinking of adaptation strategies and measures to a future scenario of climatic change? Which institutions or populations will be able to adapt quickly and which ones will not?

The main task for the analysis of response measures in the NE coast of the State of Pará involves the compilation of a detailed list of adaptive responses currently used, a description of their characteristics, and measure implementation success. Also, it assesses the possible alternative strategies that could be used to cope with the effects of climate change. The pieces of information have been picked up in diverse bibliographical sources, statistical data of the different government levels, field surveys and interviews with relevant experts, authorities, and local populations. The results of the evaluation process are described and analysed in order to provide policy advisers and decision-makers with some information to support coastal management using the best available adaptation options.

It is possible to identify and propose a wide spectrum of possible strategies and measures for coping with coastal erosion and flood damages associated or not with a rising sea level (IPCC, 1990; Bruce, 1999). At one end of the spectrum are policies that completely “protect” coastal development and valuable resources against natural processes and sea-level rise. The construction costs for these are relatively easy to quantify, but the biological costs are not. At the other end of the spectrum are a “no-action” and the “retreat” policies with unknown economic and social costs. In the first case, nothing is done, letting the natural and socio-economic processes continue as they are. In the second case, people abandon the land and structures in vulnerable areas and settle in other regions. Between these extremes are many other strategies and measures called “accommodation”. Many of these response measures can be adopted simultaneously or progressively in a certain region. Each possible adaptation strategy and measure would have different impacts on coastal biodiversity and would also pose quite different legal, economic, and political problems (Reid and Trexler, 1992, Gornitz et al., 2002).

4.2.1 No Action

This strategy means nothing is done to address the problem; letting things continue as they are. This kind of policy implies not to interfere in the action of erosion, flood and migration of ecosystem processes. It is only indicated in sectors of the coastal zone that neither show any kind of socio-economic activity, high-value ecosystems or geoforms that can be affected, nor show any impediments for the development of the natural processes.

4.2.2 Coastal Protection

The perception of coastal hazards varies widely among different segments of the population. Early man respected the power of the sea, and then the ancient harbors and coastal villages were established on protected areas or inland of estuaries, refuges from the fury of the powerful coastal elements. But as populations increased and changed their habits, society began to challenge coastal forces.

Problems appear when people put structures too close to the shoreline (Clark, 1995). The precarious houses of old fishermen, easily adaptable to hazardous events, are giving way to better quality houses and infrastructure such as roads, piers, electric services, etc. in the estuary and sea coastal areas. The new population's desire for unobstructed ocean views and convenient beach access lead to constructing these properties literally within a stone's throw from the water. For many people, the prestige and value of owning oceanfront property reduces the perceived threat from natural hazards.

As a result, repeated storm events produce total or partial loss of houses, lands and roads close to the shoreline, inciting the residents and the authorities to look for means to contain the water's action using stabilization measures. Consequently, these measures become one of the most employed alternatives for the protection of densely populated with valuable infrastructure areas.

Unfortunately, this "human/sea interactions" conflictive scenario can worsen considering sea-level rise and human development scenarios. Haq and Milliman (1996) state that building and utilizing coastal defenses against rising sea level should be viewed with particular caution. However, based on the existent experience in the region, it is conceivable to consider that these devices would integrate a response measures set in a coastal management program that considers the impacts of future scenarios of global climatic changes and sea-level rise. Thus it is worth having detailed analyses of the existent structures, which describe and classify the diverse types of them, measuring the economic impacts of their construction and analyzing causes of the success or failure of these protection measures in the coastal zone of Pará.

4.2.2.1 Inventory of Stabilization Structures on the NE Coast of the State of Pará

Measures for protecting the shoreline fall into two general categories: *Soft Stabilization* or non-structural approaches to shoreline stabilization, and *Hard Stabilization*, which relies on engineered structures. Here is a brief description of the main different kinds of measures (Clark, 1995; Marcomini and Lopez, 1993; Heather, 2001; Murck et al., 1996).

The *Soft Stabilization Measures* refer primarily to the process of beach "nourishment"; in which sand is dredged offshore and deposited onto an eroding beach as slurry via pipelines or dump

trucks. Widely used, nourishment or replenishment add new sand to the beach providing a wider buffer that removes the immediate threat to structures located too close to the water. These measures raise several concerns such as its high cost, the durability and the disruption of shoreline ecosystems. Another approach is the stabilization of dunes by planting certain types of grass.

The *Hard Stabilization Structures* are dependable methods of halting shoreline retreat and protecting coastal properties and infrastructure. These structures involve two main types: parallel to the shoreline structures, which interrupt the force of the waves (e.g. *seawall*, *bulkheads*, *breakwaters* and *revetments*) and shore-perpendicular structures, which interrupt the flow of sand along the shore (e.g. *groins* and *jetties*).

i. Seawalls: Seawalls are protective devices made of wood, steel, rock or concrete. They armour the shore and deflect wave energy away from the protected property or installations. Seawalls are not intended to block storm waves; they are generally used to attenuate wave energy and to fix the shoreline, that is, to halt the retreat of the shoreline into the line of the structures. They have three basic shapes: (1) *vertical*: resists the wave attack poorly, and is considered “very unstable”. Normally used in sedimentary coastal cliffs, it has not been useful, for being widely undermined and for not preventing the backward motion of the cliff front; (2) *Concave*: used when high-energy waves are more common and structural strength is required, and (3) *Sloping*: dissipates wave energy and allows simple access to the beach, but can be easily overtopped by wave action. However, these structures can actually accelerate loss of beach sand on the ocean side, making the beach steeper and narrower until it is finally destroyed.

ii. Bulkheads: Vertical structures composed of steel, timber or concrete piles that serve as shoreline retainers of fill. Their main purpose is to hold back land from slumping or eroding into the sea, not to absorb wave energy.

iii Breakwaters: Semi permeable offshore devices built with blocks of quartzite or waterproof stones, cement, and metallic girders. They are designed to reduce wave energy and shelter a portion of the shoreline. The effect of breaking the wave energy offshore is to interrupt the long shore transport of sand, which causes its accumulation behind the structures.

iv. Revetments Relatively inexpensive and causing less damage than other hard measures, these structures generally consist of interlocking stone or concrete in conformance to the contour of the shore. These armoured slopes dissipate wave energy because as waves break against revetments, much of the water is absorbed in the spaces between the rocks, reducing the erosion-causing backwash. The proper design of revetments requires carefully placed heavy and wave-resistant material for the structure, which has to be properly angled and backed by filter cloth.

v. Groins and jetties Semi permeable or impermeable devices that block the long shore flow of sand, holding and trapping the sediments. Groins are made of rock, wood, or steel. They are useful to retain the sediments already on the beach or new sand deposited from a nourishment project. Although in some cases groins and jetties rebuild eroding beaches, they could trap sediment on one side and intensify erosion on the other, depending on the net littoral drift direction, widening up drift beaches and “starving” of sand down drift beaches.

Hard stabilization measures become the most employed strategy and measure in the NE coast of the State of Pará. In order to adapt methodologies used at other places on the Brazilian coast (Esteves et al. 1999) to the particularities of this study, urban areas of different coastal localities have been visited, to register and characterize their hard protection structures. They have been classified considering several parameters (coastal type and morphology, origin of economic resources, protected element, type of hard protection measures and material employed), and a photographic registration has been made. Length and height measurements of the structures have been accomplished, registering their conservation state (good, precarious, destroyed).

Table 4.1 shows 34 different examples of engineered protection works that are being used in all kinds of coastal environments (estuarine, fluvial and marine). Although areas naturally protected by lateritic rocks (Fm. Barreiras) could be found, in most of the cases the shoreline is sheltered by structures built with public and private funds. The public ones, used principally in estuarine areas, aim to protect the existent infrastructures (roads, ports, energy posts, etc.) and the fund of coastal residents are exclusively applied to the protection of their own houses and lands. Among all the structures, seawall is, without any doubt, the most commonly used. They protect the whole cliff or only its base, with varied inclinations (vertical and sloping) and frequent use of buttresses. The materials employed in public works are concrete (armed and stone-mortar) and bags of hardened cement. The structures erected with private resources utilize a great variety of materials that includes wood and local-area stones, often used together. The selection of the materials used in private works depends on its availability in near areas (e.g. stones) and the proprietor's wealth. In the region of Salinópolis, there are evidences of the construction, with public resources, of other types of hard structures such as groins of bags of hardened cement and revetments with non-local stones (quartzite), many times fixed by rectangular steel wire mesh (gabion)² (Figure 4.1).

² Gabions consist of rock-filled rectangular steel wire mesh cages piled one on the top of the other to form a wall (Heather, 2001).

Table 4.1 Hard protection structures used in the NE coast of the State of Pará classified by several parameters (the numbers in the last column refer to the pictures of figure 4.1).

Coastal area	Morphology	Part of the cliff protected	Monetary funds	Element Protected	Type of protection measures	Materials employed		Position	Buttress	Localities
Sea	Sea cliff	Complete slope	Public	Roads and sea walk roads	Sea wall	Concrete	Armed	Vertical	No	Salinas (1)
							Stones and mortar	Sloping	Yes	Salinas (2)
			Private	Buildings	Sea wall	Concrete	Armed	Vertical	Yes	Atalaia (3)
								Sloping	No	Atalaia
							Stones and mortar	Sloping	No	Maruda (4)
		Wood and local-area stones				Mocooca (5)				
		Base	Public	Roads sea walk roads	Sea wall	Concrete	Armed	Vertical	Yes	Salinas
							Stones and mortar	Vertical	No	Salinas
					Sloping		Salinas			
					Cement bags			Maruda (6)		
					Groins	Cement bags		Salinas (7)		
			Revetments	Non-local area stones	With steel net		Salinas			
					Without steel net		Salinas (8)			
			Houses	Revetments	Local-area stones	With steel net		Salinas (9)		
			Private	Houses	Sea wall	Concrete	Stones and mortar	Vertical	No	Maruda
							Wood and local-area stones		Vertical	No
		Local-area Stones						Vertical	No	Maruda (10)
		Wood and cement bags								Atalaia (11)
		Natural	Houses		Local-area stones				Salinas Atalaia	
	Dunes	Private	Buildings on pillars	Sea wall	Wood				Ajurateua (12)	
						Wood and local-area stones				Atalaia (13)
						Cement bags				Crispim
	Estuarine	River cliff	Complete Slope	Public	Roads sea walk roads	Sea wall	Concrete	Stones and mortar	Vertical	Yes
Armed								Vertical	Yes	Boa Vista (14)
No					No	Cafezal (15)				
Base			Public	Roads sea walk roads	Sea wall	Concrete	Stones and mortar	Vertical	No	Maracana
									Yes	Maracana
Natural			Roads sea walk roads			Local-area Stones			No	Pirabas Maracana
										Boa Vista
No cliff	f		Public	Roads sea walk roads	Sea wall	Concrete	Armed	Vertical	No	Vigja
							Stones	Vertical	Yes	Vigja



Figure 4.1 Examples of the several and different types of hard protection measures in the NE coast of the State of Pará (the numbers on the pictures are related with table 4.1).

4.2.2.2 The Economic Cost of Hard Measures Construction

The decision to maintain a shore is an investment with economic benefits and costs to the nation, region and local community. In many coastal towns of the NE of the State of Pará, much of the public infrastructure (roads, utilities, and public beaches) is exposed to rising seas (Figure 4.2). Unfortunately, losses are relatively high and the federal, state and municipal governments have to spend increasingly limited funds on the maintenance, protection and replacement of this infrastructure. The costs of governmental actions are supported by the public taxpaying, implying a distribution of the responsibilities also among people that live far away from the coastal area.

The poor municipal budgets have scarce resources to invest in infrastructure, since most are destined for the payment of employees' wages and expenses as health and primary education. On the NE coast of the State of Pará, since 1995, only the municipality of Bragança has had own monetary resources to construct part of an engineered work against erosion. Therefore, in most cases, hard measures to protect public infrastructure are implemented with federal and state financial resources. The budgets of Brazil and the State of Pará, between 1995 and 2000, show the destination of about US\$ 5,000,000 for the construction of 46 works to combat fluvial and coastal erosion in the State; that represents approximately US\$ 108,500 for each work.



Figure 4.2 “Pracinha” leisure area, one of the most popular tourist points of Salinópolis (municipality of Salinópolis), built in 1992 and destroyed 4 years later.

Exact information (official and unofficial) on the cost of constructing a linear meter of protection work doesn't exist for the State of Pará, due to the diversity of types used and local characteristics (e.g. foundation depth, wave energy, etc.). In spite of these limitations, using existent data about the budgets of Pará and Brazil (Table 4.2), a value of about US\$ 1,155 per linear meter is estimated.

Boyles Jr. (1993) considers that a more efficient means of managing coastal erosion would be to force the property owners to internalize all the costs of their actions in such a way that they face the high costs of development rather than having some of those costs supported by the taxpaying population. This is the situation in several localities of the NE coastal zone of Pará where

affluent shorefront property owners have additional expenses to save beaches and principally, private possessions. The structure type used and their cost depend on the value of the object that will be protected, often reaching extremely high values in the regional context. On Atalaia beach (municipality of Salinópolis), where most of the defence works are executed with private resources, the municipal government has calculated the existence of 25 non-constructed areas and 23 residences with a total value of about US\$ 1,285,714 (Salinópolis, 2002). Unfortunately, in the interviews carried out with some of these property owners, it was not possible to obtain any information about monetary investments in the construction of the defense works.

Table 4.2 Data on hard protection structures extracted from the budgets of the State of Pará and Brazil (1995-2000) (source: Diarrio Oficial da União and Diarrio Oficial do Estado do Pará).

Municipal District	Total Value (US\$)	Length (Meters)	Linear Meter Value (US\$)
Acará	229,166	215	1,065.88
Aurora do Pará	159,250	100	1,592.5
Baião	36,000	150	240
Breves	275,000	270	1,018.51
Chaves	75,000	150	500
Curuçá	229,166	170	1,348.03
Magalhaes Barata (Cafezal)	229,166	160	1,432.28
Santarém Novo	267,666	170	1,574.50
São Domingos do Capim	309,833	185	1,674.77
Total	1,810,247	1.570	1,153.02

4.2.2.3 The Problems of Hard Stabilization Measures

To define the viability of future use of engineered works as a coastal protection method in Pará, it is essential to analyse the degree of success of the already existent works, identify their potentialities and vulnerabilities. The success of structural measures can be defined as the achievement of the initial objectives for which the engineered work was built, that it means the cessation or decrease of the coastal area erosion and flood processes.

The effects on beach stabilization are rarely rewarded with success (Clark, 1995). Although erosion and floods have largely diminished in some urban areas in diverse sectors of the State of Pará, in many others they still happen. Evident examples of the reduced success of these measures can be exemplified by the following situations:

- Several structures of similar type in the same area. The protection works have been not able to contain the erosive action causing cliff setback. Some years later, a similar or little modified structure type is built trying to reach the same objectives. In the town of Boa Vista (municipality of Quatipuru), the rests of a 10 year-old vertical stone-and-mortar seawall is a passive witness of a vertical reinforced-concrete seawall constructed about 7 m away behind the old one in 2001 (Figure 4.3(1)).

- Several structures of different types in the same area. The protection of shorefront private properties shows a series of attempt carried out with diverse types of structures in different times. On Atalaia beach (municipality of Salinópolis) old and unsuccessful wood-and stone-structures are standing in front of the rest of a stone-and mortar-concrete seawall and a new reinforced concrete seawall (Figure 4.3(2)).

- Isolated structures. The measure's failure in the protection of coastal areas is suggested by the presence of partial or complete structures isolated from the natural features and infrastructure that they should preserve. In Salinas (municipality of Salinópolis), a stone-and mortar-concrete seawall was built to protect a hotel and a square located near a cliff that, as old residents describe, has been suffering erosion for more than 100 years. As the protection structure was being overcome and the erosion was progressing, on the first part of the decade of 1990, a new structure had also to be constructed to defend the seawall. In its front, a sequence of groins of hardened cement bags was built, perpendicular to the coastline, 15 meters long and about 25 meters far from each other. A revetment of angular stones contained in a metallic net was also placed among the groins. Unfortunately, the waves' energy persisted in their erosive action and all the stones were removed. Many of them joined the waves in the erosive action, overcoming the seawall and causing cliff erosion. As a result, there are isolated parts of the structure having no function (Figure 4.3(3)).

- Structures that protect limited areas: As a consequence of the lack of an integrated coastal zone management and planning, the protection of engineered works is commonly limited to the central areas of the towns and the seafront richest properties. Then, as in Maracanã (municipality of Maracanã), some energy is deflected along the protection measures to the adjacent unprotected properties and areas, eroding the shoreline (Figure 4.3(4)). This way, coastal defenses often simply transfer the problem elsewhere, rising the vulnerability of poor populations that live in the non-protected periphery.

- Disproportionate Structure. Works that present any kind of structural defect however do not respond to the magnitude of natural phenomena. The port seawall of the city of Salinas

(municipality of Salinópolis) illustrates this situation. In spite of the good condition of the structure, high tide levels rise above it and provoke several economic losses.



Figure 4.3 Examples show the reduced success of hard structures on the NE coastal area of the State of Pará. (1) Several structures of similar type or little modified in the same area; (2) several structures of different types in the same area; (3) isolated structures, and (4) structures that protect limited areas and increase erosion in adjacent ones.

The principal vulnerabilities of the engineering works, most of them reinforced concrete seawalls, as a result of the action of increased wave energy erosion in front of the structures, and the build-up of water pressure on the landward side (Heather, 2001), can be summarized as (a) rupture (b) collapse; (c) inclination; (d) basal and back erosion (Figure 4.4).

At regular intervals scientists and the media expose major coastal events, such as cliff falls that threaten people's homes, and publicize the demands of those involved for having their properties protected. Therefore, some of the coastal problems of the NE region of Pará (e.g. Salinas) have been rather well known by the government and population. Despite such familiarity, the age of the structures (younger than 10 years old) and the important disbursement of money on their construction, little appears to have been successful in terms of effective defense construction. Many reasons explain the "no success" situation of the protection measures:

- Lack of an integrated coastal zone management: Without a global vision of the natural processes and their impacts, several protection measures are taken in an isolated and independent way, following attitudes defined by Gornitz et al. (2002) as "*each man for himself*". That means each seafront municipality or proprietor tries to be protected using hard structures that they believe appropriate, but not taking into consideration the full effects on the environment and their neighborhood.



Figure 4.4 Principal types of structural problems found in protection works, (a) rupture; (b) collapse; (c) inclination; (d) back erosion and (e) basal erosion.

- Lack of planning structures: Hard stabilization structures are dependable methods of protecting the coastal properties when appropriately designed (Heather, 2001). However, many works, mainly the private ones, are carried out without technical specification. One of the main seafront proprietors' complaints refers to the absence of any kind of technical attendance and inspection on behalf of the authorities for the construction of the protection works. The municipalities don't have economic or human resources for the elaboration of projects. When the resources come from the State, the Secretary of Transports (SETRANS) is responsible for the execution of the projects. However, the money usually comes directly from the federal budget to the municipalities that commend the projects to private companies. In these cases, a fragile inspection occurs.
- Structures not adapted to local conditions: The coast of Pará, many public protective structures have been approved and built by planners, engineers and contractors without previous experience of natural local conditions (e.g. strong storms).
- Data and information problem: For projects that intend to use data of natural parameters, there is a lack of detailed or/and up-to-date scientific information. Considering a significant time

lag between the collection on coastal process data by scientists and their utilization, engineers make an effort to obtain information in the brief periods that precede the beginning of the structures construction, paying no attention to the variability of coastal and climatic processes.

- Conservation lack: To conserve their good operation conditions, all engineering works, mainly those exposed to climatic changes and natural phenomena pressures, should have appropriate and frequent maintenance and defect correction tasks. Unfortunately, these activities that would avoid or diminish the possibility of problems are not carried out due to the lack of financial resources, and the usual administrators' indifference.

4.2.3 Accommodation

There are some other options to the "No-Action" and "Protection" strategies and measures. This policy implies the permanence in areas considered vulnerable, adapting the population's socio-economic activities and legal framework to the current and potential natural hazards. The accommodation strategies and measures require advanced planning and the acceptance that some coastal zone features could be lost.

The accommodation strategies include options as to discourage growth in population or additional development in vulnerable areas, providing information to the affected population or insure them against possible damages or loss. The following response strategies and measures are particularly analyzed:

- Land use legal framework
- Building style;
- Natural disaster management – relief programs;
- Natural Disaster Insurance System
- People and authorities knowledge

4.2.3.1 Land use Legal Framework

Shortsighted beachfront development interests frequently see increasingly higher property values with decreasing distance from the beach. The higher amenity values of building closer to the beach pressures many property owners to build as close to the water as possible (Boyles Jr., 1993). Thus, in areas with high population density and property value, it will be necessary to protect the coastal areas to respond to coastal geomorphologic processes.

However, hard defense measures will not be a practical option for the entire coastal zone. One of the main means to reduce coastal zone vulnerability to the impacts of erosion and flooding is to

establish new land use laws or only apply the existing ones. These laws look for (a) preventing, discouraging or restricting development, (b) prohibiting redevelopment in hazard-prone areas near the coast, and (c) allowing the existent development to take provided that it is abandoned if necessary (El-Raey et al., 1999; IPCC, 1990).

Natural resources and land use laws and regulations in Brazil and Pará coastal zone as a tool for preventing, discouraging, restricting or prohibiting human activities and development at regional and local levels have been analyzed. Among them, the *Brazilian conservation units system* and *urban zoning and setbacks regulation*.

a. The Brazilian Conservation Units System.

A well-preserved mangrove area that covers approximately 2,350 km² (Figure 4.5), located between the shoreline towns and the rest of the coastal zone, represents a region that for its characteristics, has historically, always become an impediment or restriction to the socio-economic regional development. In this sense, besides the mangrove areas natural characteristics (regular floods, difficult access and transport of goods, poor soil conditions for construction, etc.), the existence of a legal framework that conserves, protects and defines the possible uses of these ecosystems should be added.

The Brazilian Federal Constitution of 1988 (art. 225) recognizes that there are ecosystems and their components which need special protection (Brasil, 1991). However, in 1965, the Federal Forestry Code (Art.2, Law 4771) had already established the forests and other vegetation forms in the coastal zone, which contribute to dune fixation or mangrove establishment as “areas of permanent preservation” (IBAMA, 1992). Later, the “National Environmental Policy” (law 6938, Art. 18), in 1981, and the 4th regulation of the National Environmental Council-CONAMA (IBAMA 1992), in 1985, had transformed the forests and other areas of permanent preservation into “Biological Reservations” or “Ecological Stations”.

The “Biological Reservations” and the “Ecological Stations” are part of the National System of Conservation Units (SNUC) that integrates the Environmental National System (SISNAMA). The SNUC is one of the primordial strategies for the conservation of biological, cultural and scenic diversity in Brazil, the protection of threatened of extinction species and water and soil resources. Also, it motivates the sustainable use of natural resources and activities of scientific research on environmental issues, through the creation, implementation, and management of special areas (Milano, 1989).

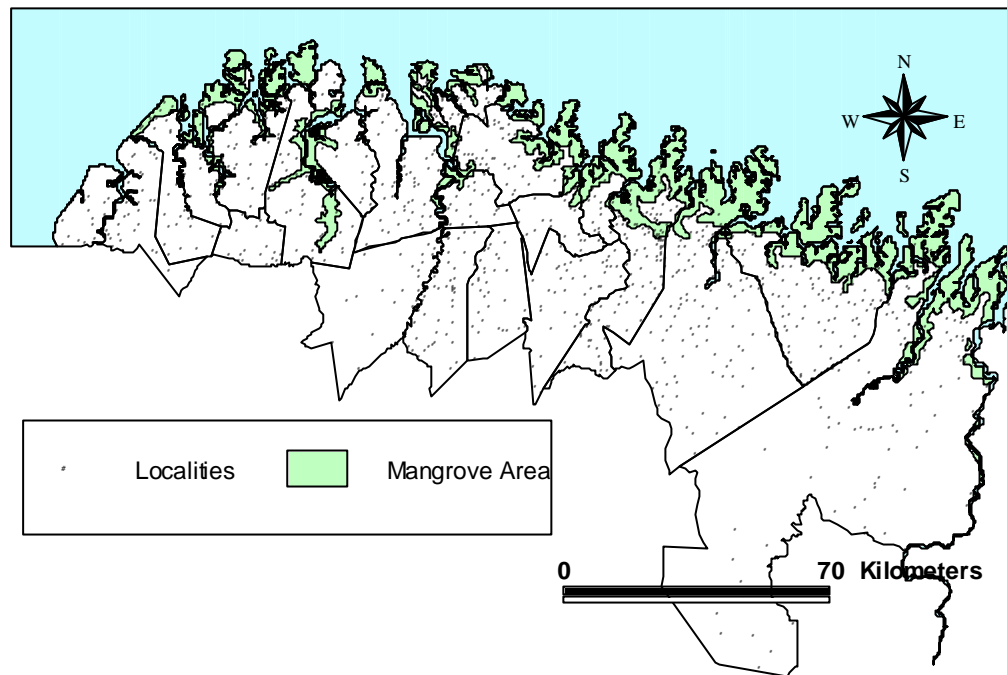


Figure 4.5 Mangrove areas that separate the localities (beachfront and inland) in the coastal area of Pará.

Given the multiple objectives of the SNUC, it is necessary that several types of conservation units exist, managed in differentiated ways:

i) *Conservation Units of Indirect Use or Integral Protection*: the exploration or the use of natural resources is totally restricted (e.g. national parks, biological reservations and ecological stations).

ii) *Conservation Units of Direct or Sustainable Use*: planned and regulated exploration and direct economic use of the area are allowed (e.g. areas of environmental protection, national forest and marine extractive reservations).

iii) *Special Units*: such as areas of relevant ecological interest, private reservations of the natural patrimony, areas of permanent preservation and legal reservations.

Biological Reservations are units designated to the integral preservation of the biota and other natural attributes within their limits, without direct human interference or environmental modifications. It is acceptable to carry out recovery measures for altered ecosystems and necessary management actions to preserve the biological diversity and the natural balance of ecological processes. The educational and scientific visits depend on authorization from IBAMA.

The Ecological Stations are units destined to the integral preservation of the biota and other natural attributes in their limits and to the accomplishment of scientific research. Research that causes alterations in modified ecosystems; management of species in order to preserve the

biological diversity, and collection of ecosystems components with scientific purposes can be allowed there.

In terms of regulation of the land and natural resources use, the Conservation Units of Integral Protection are the most restrictive, strongly limiting, in consequence, the development of the coastal area of the NE of Pará. Despite the existent restrictions, the local communities of crab collectors and small-scale fishermen have always exploited the natural resources in a sustainable way. Unfortunately, in the last years the mangrove areas of the coast of the State of Pará are also affected by other human activities impacts. They are, as an example, consequence of the construction of paved roads crossing these sensitive ecosystems in order to motivate the development of tourist activities on the beaches, and to facilitate the transport of fish, crab and shrimp production for the consuming market by local communities, and particularly, people from other regions and states (Souza Filho, 2001; Manesch, 1988; Carvalho, 2000).

The IBAMA and the coastal zone communities are apprehensive about this situation and unable to control all the events that happen in this extensive region (O Liberal, 2001e; O Liberal, 2002f). Thus, the proposal to implement another category of conservation unit - the marine extractive reservations (*Reservas Extrativistas Marinhas*) in diverse sectors of the coast of the State of Pará is under study.

The Conservation Units of Direct Use try to reconcile the preservation of biological diversity and natural resources with the sustainable use of part of these resources. The alteration of the ecosystems for human action should be limited to a compatible level of flora and fauna permanent survival. As part of this group, the marine extractive reservations are composed of none or partially altered areas, inhabited by traditionally extractive populations that collect products from the native biota for their subsistence. Those populations live from the forest and river resources, complementing them with products from subsistence agriculture. Their activities are guided by their traditional knowledge of the environment and its resources (Milano, 1989).

The expected success of this kind of conservation unit is based on the activities regularization and on the possibility that smaller areas with well-defined limits would allow the local communities to execute the management plan of these areas and control the activities that do not have connection with this plan. On the Brazilian coast there is this type of conservation unit³ already. Currently the processes of authorization to nine proposals⁴ for the creation of new marine extractive reservations in the NE coast of the State of Pará (municipal districts of Augusto

³ Reservas Extrativistas Marinhas Pirajubaé (State of Santa Catarina), Arraial do Cabo (State of Rio de Janeiro), Baía de Iguape and Ponta do Corumbau (State of Bahia) and Soure (State of Pará). (IBAMA, 2002b).

⁴ At present (2002), the processes have only concluded the biological assessment. Still lacking the socioeconomic assessment, final definition of the perimeter, production of cartographic map and pronouncement of the National real state (regional agency) (O Liberal, 2002g).

Corrêa, Bragança, Curuçá, Maracanã, Salinópolis, Santarém Novo, São João da Ponta, Tracuateua and Viseu) are under way (Figure 4.6).

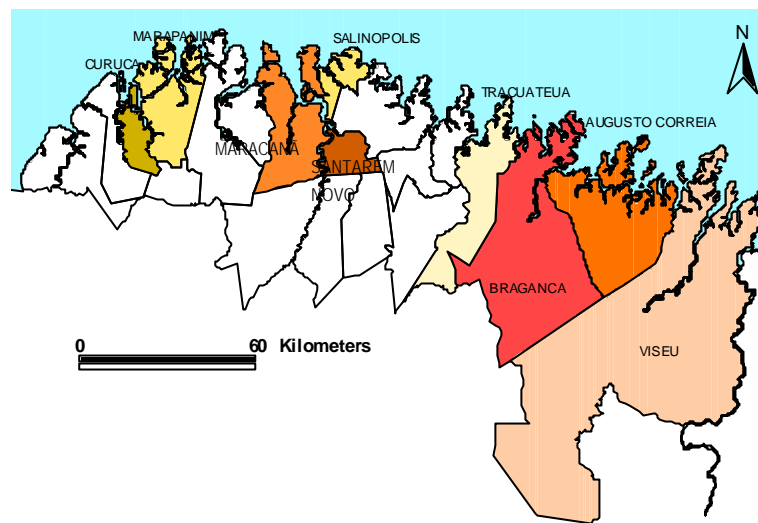


Figure 4.6 Municipal districts where the marine extractive reservations will be located.

b. Urban Zoning and Setbacks Regulation

The zoning and setback measures, very useful in coastal management, represent an attempt to combat development pressure excluding certain uses by the neighbourhood of hazard prone urban areas. The objectives of such setback zones include keeping structures away from the potential erosion of flooding damage, and protection of the public sight and access to the shore.

In Latin America several countries apply the concept of a “Zona Pública” (public zone), establishing shore land zones based on a specific setback from the shoreline, usually from mean high tide (Clark, 1995). In Brazil, the Federal Constitution of 1988 represented a great progress for the management of urban and environmental issues, delegating much of its competence to the municipal and state administrative levels (Santos Dias, 1996). In this sense, the Constitution of the State of Pará (art. 236) states that the urban policy, elaborated and executed by the State, and principally, by municipal districts, must aim for the complete operation of city’s activities and guarantee population well being (Brasil, 1991). At municipal level, the fundamental laws are included in the *Lei Orgânica* (organic law), which give a legal framework to diverse municipal policies. Among these, it is important to mention the guidelines on urban development strategies, where there are indicated requirements to create the “Building code” and “Urban Master Plan”. The latter is a group of norms and technical guidelines related to the physical, economic, social and administrative aspects of the municipal district (Meirelles, 1993). Every municipality with more than 20,000 inhabitants must have its own Urban Master Plan, but only few of them have elaborated it in the State of Pará, and only one in the coastal area - Belém. Although this municipal district is not included in the study area, some of the land-use regulations adopted by

its Urban Master Plan have such importance as adaptation strategies and measures that they will be described and analysed.

All these federal, state and municipal laws explicitly consider that all kinds of urban regulations must promote the people protection against the impacts of hazardous natural processes. To reach this purpose the urban regulations establish differential zones of land use and occupation that vary greatly in configuration and size depending on topography and tidal range. There are zones of variable and fixed dimensions.

Considering the zones of variable dimensions, the Urban Master Plan of Belém (art. 82) divides the city in two areas: “Highlands” and “Lowlands”. The first are situated above the topographical level of 4 m., being this point as high as the maximum level of water - tides amplitude and rainfall - historically recorded (3.86 m). The “Lowlands” are located below that topographical level and are affected by permanent or temporally inundation. The fragile character of the “lowlands” is taken into account by the law, calling them as “Zones of Special Social Interest”, and granting them special protecting urban rules (Belém, 1991).

Considering the zones of fixed dimensions can be divided in three groups, the “Non Aedificandi” areas, the “Terras de Marinha” (*marine lands*)/ the “Acrescidos de Marinha” (*marine reclamation areas*) areas, and the setback lines areas.

i) “Non Aedificandi” areas:

The Urban Master Plan of Belém (art. 88) defines the land use regulations near the channels and rivers. For natural rivers and channels, the “non aedificandi” areas cover the width of the channel plus 33 m. on each of its side, starting from its margins. For artificial channels, depending on the drainage basin, the width of the strips can vary from 20 m. to 120 m. In all these areas, occupation and construction is forbidden, and in the case the area is already occupied, it will be recovered through the removal of the existent structures, and a relocation program.

ii) “Terras de Marinha” (*marine lands*) and the “Acrescidos de Marinha” (*marine reclamation areas*):

The Federal Constitution of 1988 (art. 20) includes the “Terras de Marinha” and the “Acrescidos de Marinha” as part of the national real state establishing thus a federal land use regulation on the coastal zones (Brasil, 1991).

The “Terras de Marinha” are a 33m-wide strip of land horizontally measured landward from the position of the average high tide level of 1831⁵ (Figure 4.7) affecting the islands and the marine

⁵ The reason for using the year 1831 as a reference comes from the budgetary law of November 15, 1831 that stated that the collection of incomes

coast, river and lake margins, up to the place where tidal influence is observable. In both cases, tidal influence is defined as a periodic oscillation of the water level of at least 5 cm, occurring in any time of the year. The “Acrescidos de Marinha” reclamation areas are those formed natural or artificially at the side of the sea, rivers and/or lakes adjoining to the “Terras de Marinha”.

Since 1726 (Royal Orders of December 10), there have been definitions and regulations related to the ownership and use of these areas. However, at present, they show a disordered use and occupation. This situation could have been originated on years of numerous, varied and, some times, contradictory regulations and laws. The in force Ordinance-law 9760/46, called “The Patrimony Law”, definitively transferred to the Federal Heritage Institute (SPU) the administration of all the possessions of the Country (Santos, 1985).

The Instruction Normative 1 of 1981 regulates the use and occupation of the “Terras de Marinha” indicating that they can take place under two different frames (Ministerio da Fazenda, 1997). (i) By contract, the government attributes to a person the use right of the 83% of the requested area for an equivalent fraction of the current market value (CMV) of the land, persisting for the federal government the control on the remaining sector and, (ii) In fact occupation. The private right affects only the built infrastructure and not the land below it. In both cases the people who use these areas must pay some tax called *Aforo*. The Federal Heritage Institute (SPU) collects taxes of 0.6% of the land’s CMV per year from the leaseholder by contract and an annual tax of 2% to 5% of the land’s CMV from the occupants.

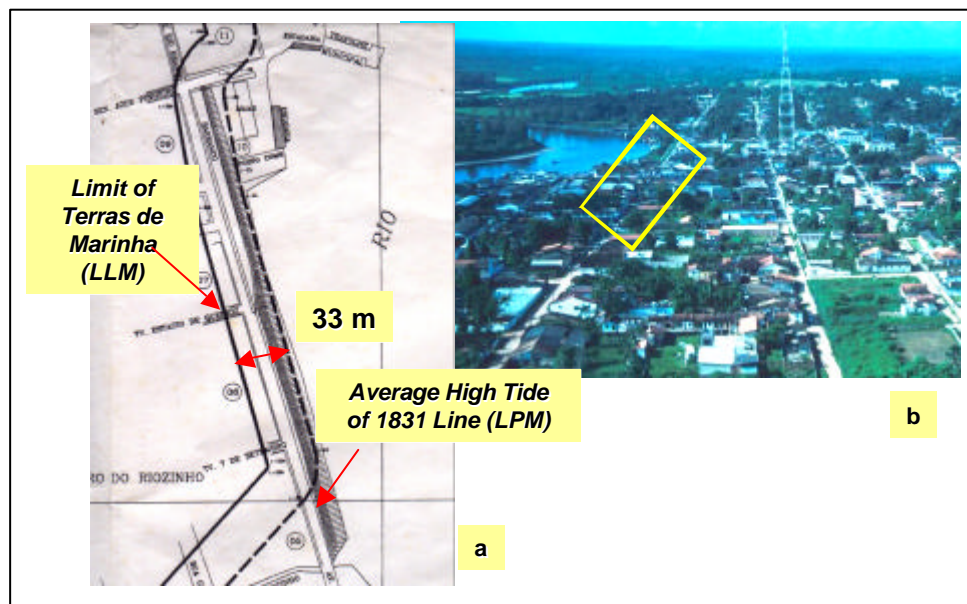


Figure 4.7 (a) Part of the map of the Bragança City Terras de Marinha, and (b) aerial view of the same area (yellow frame).

iii) Setback lines areas:

They are used to establish a protected buffer zone between the water and the land (Clark, 1995; Bird, 1993). The setbacks should be defined in the Urban Master Plan, but they are still not elaborated in the coastal municipal districts of Pará. However, considering the magnitude of the natural processes impacts in closest areas to the coastline, many of the Municipal Organic Laws have already established some of these setback lines (Figure 4.8).

The setbacks lines defined as a function of tidal range doesn't prohibit the development of these areas but rather regulates them, limiting the height of the constructions. The Organic Law of Marapanim (art. 176) prohibits the construction of buildings with more than 2 floors within a 200m-wide strip from the last annual high tide level in the marine, lake or fluvial coasts, and within a 300m-wide strip for buildings with more than 3 floors (Marapanim, 1997). In the municipal districts of Magalhães Barata and Maracanã, this second strip is modified (art. 123 of the Organic Laws) considering in this case a fringe of 500m-wide and buildings of more than 6 floors (Magalhães Barata, 1990; Maracanã, 1990). For some islands and beaches of the municipal district of Belém, it is allowed to construct buildings up to 8 m height within 200m-wide strip from the last annual high tide level, permitting up to 3 floors in the 600m-wide strip that follows the strip mentioned before.

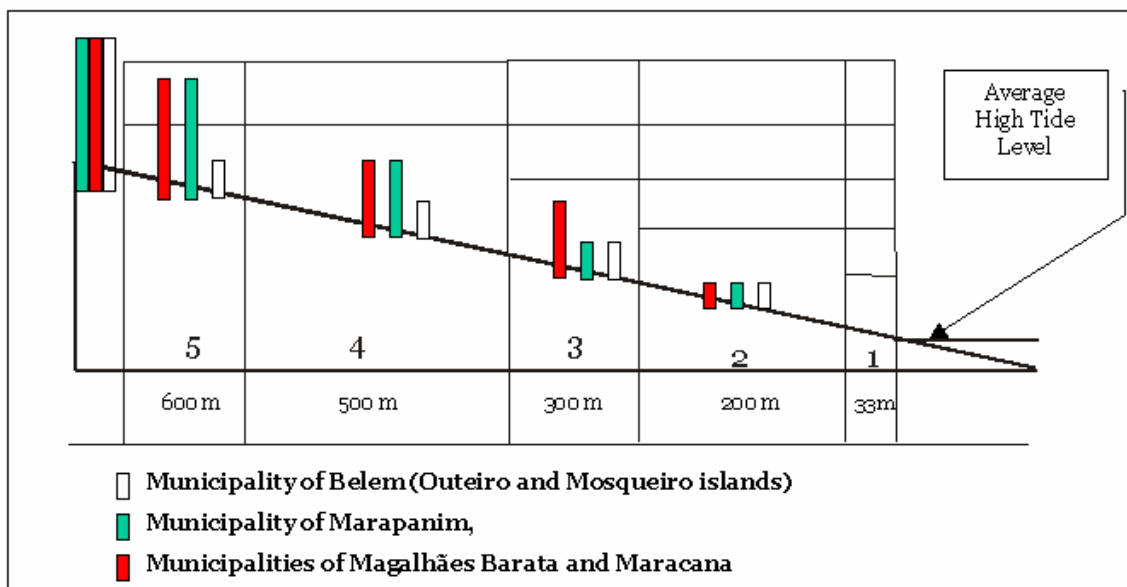


Figure 4.8 Land use regulations on some coastal municipal districts of Pará. The height of the rectangles is proportionate to the numbers of floors.

c. Sea Level Rise Potential Impact on Coastal Areas Land Use – Study Cases

i) The “Terras de Marinha”

Since 1919 have been evidences of the government difficulties to control the land use in the “Terras de Marinha”⁶. Nowadays, the federal administration continues to face problems to finish (a) the demarcation of these areas (strips are only delimited in more than a half of the Brazilian coastline (8,500 km) and in the coastal zone of the state of Pará, only in the cities of Belém, Salinópolis and Bragança); and (b) the inventory of buildings and structures (until the year 2001, only around 500,000 had been registered, paying U\$ 65 millions as annual tax (“aforos”) in the year 2000) (O Liberal, 2001f).

The position of the average high tide of 1831 line (LPM) is determined by the intersection of a horizontal plane, representing the position of the average high tide of 1831 in this area, to earth surface. As a consequence of the lack of data, it is possible to obtain information of closest time to 1831 from (a) old plants and documents and (b) tidal levels observations (Santos, 1985). The first one should fulfill some technical requirements (e.g. topographical contour levels, and indication of the marine border or old buildings) and could be found in public institutions and libraries, religious institutions or other sources of information. The observation of tidal levels is done using the charts elaborated by the Hydrographic National Observatory and the Secretary of Hydrography and Sailing (Ministry of the Navy). In absence of data for the considered area it could be used those referred to the closest locality of similar hydrologic situation. The limits of Marinha line (LLM) is a polygonal traced in a distance of 33 meters of the LPM measured horizontally landward (Figure 4.7a).

This is a complicated process; a lack of data (non existent or bad preserved) has caused an enormous delay in the delimitation of the “Terras de Marinha” in a large part of Brazilian coastal zone, as well as difficulties in coastal areas urban planning. Consequently, a proposed law⁷ is analysed at the National Congress that intends to maintain the strip of 33 m using as LPM the average high tide level line of the year 2000, easily calculated from tidal gauge data measured by the National Hydrographic Service.

According to Aubrey et al. (1988) and Mesquita (2000) the Belém tidal gauge station has documented subsidence at a rate of - 0.3 mm/yr to 2 mm/yr. Then, adapting this estimation, it is possible to assume that the average high tides level line of 2000, it is 5 to 33 cm higher than the 1831’s one. Therefore, in case of the 2000-year line project law will be approved, what would be

⁶ Budgetary law 3979 (31/12/1919) expressed "the government would try to turn faster the process of given privileges to people to use the “Terras de Marinha”, reforming the existent regulation".

⁷ Proposal of amendment to the Federal Constitution 40/99 elaborated by the Senator Paulo Hartung.

the effects on the coastal areas? The “Terras de Marinha” strip will migrate landward (1) affecting new areas and sectors nearer to the sea (3) will change their flooding regime, probably ceasing to be considered as “Terras de Marinha”. Depending on the land topography and the position on the 2000 line level, people could be affected more or less by floods or by payment of taxes (Figure 4.9). Also, the property rights could suffer some changes. The demarcation of the “Terras de Marinhas” would be retroactive, thus any property owner of the new areas considered “Terras de Marinhas”, even when there is a property contract, would be able to use it, only as a federal government's concession paying the annual “aforo”.

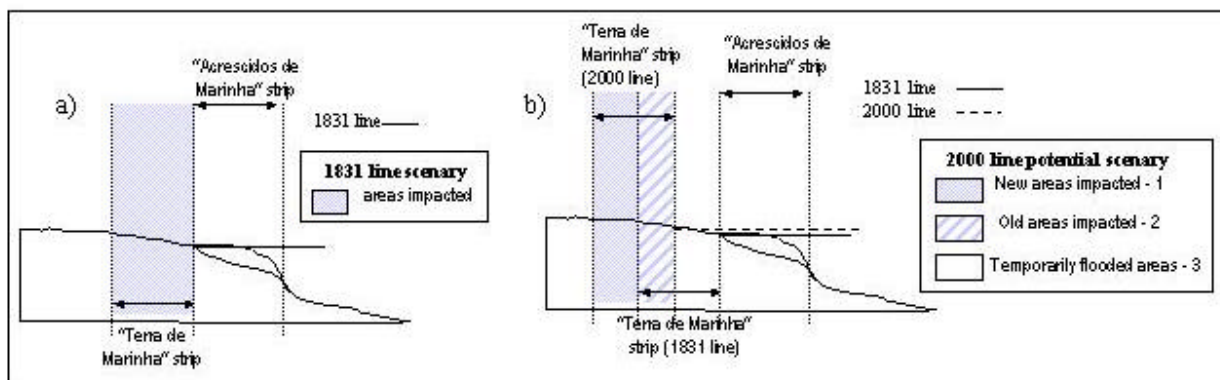


Figure 4.9 Schematic diagram of the current coastal land use “Terras de Marinha” strip delimited using the average high tide level of 1831 and the potential modifications considering the 2000-year line and a sea level raise scenario.

ii) The areas of “Permanent Ecosystem Conservation”

The extension of Brazilian mangroves makes their modification a globally relevant issue. Then, the effects of recent variations of the tidal inundation frequency in a mangrove ecosystem in the Bragança peninsula (municipality of Bragança), and its consequences on land occupation and use, focusing in potential conflicts between property rights and ecosystem protection is analysed. Previous work (Lara et al., 2002) examined field data and time series of remote sensing images⁸, focusing on the potential socio-economic impact of a changing environmental setting due to a rise in relative sea level. In a 25-year period (1972-1997), along the coastline of the Pará State vegetation changes indicate net losses of mangrove coverage and in the central part of the Bragança peninsula, a topographically higher herbaceous plain, constituting part of a farm, presents an active progression of mangrove forest into an area previously dominated by grasses and herbs (*Sporobolus virginicus*, *Cyperaceae Eleocharis geniculata* and *Fimbristylis spadicea*). This area consisted of 8.8 km² in 1972 and gradually decreased to 5.6 km² in 1997, being progressively replaced by a monospecific stand of black mangrove, *Avicennia germinans* (Figure 4.10). The farm exists since at least 1870 and has been used until recently as grassland for water buffalos and other bovines. Today, these activities are mostly abandoned. From oral

⁸ LANDSAT TM5 images and Mosaic of airborne RADAR Photographs.

communication of the 80-year-old farm owner, although this work presents quantitative data only for 25 years, there are evidences suggesting that this is a slow process that began several decades ago.

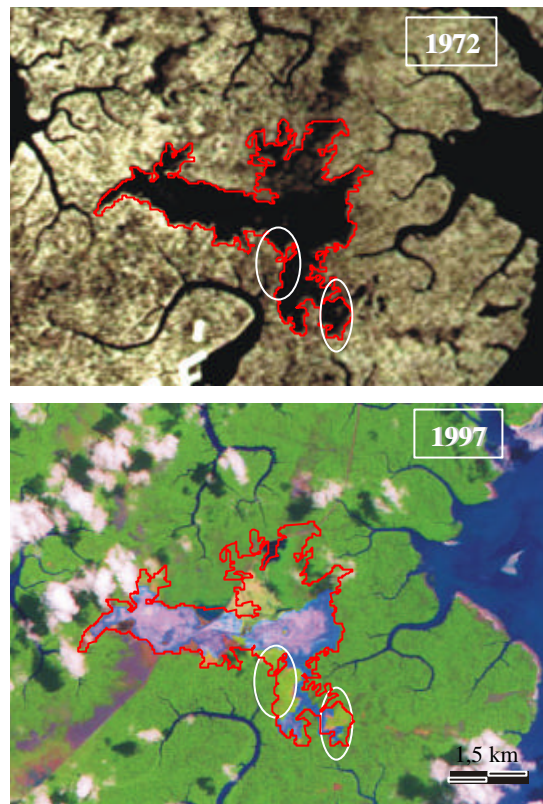


Figure 4.10 25 years images analysis showing a migration of mangrove vegetation landward on the peninsula of Braganca. Year 1972, RADAR image band X and year 1997, Landsat TM5, color composition RGB 543 (August 28). Adapted from Lara et al., 2002.

A linear extrapolation indicates that the elevated plain may be completely covered by mangrove in 2035 (Figure 4.11). This extrapolation is compatible with predicted estimates of sea-level rise. According to Titus and Narayanan (1995) there is a 1:1 possibility that greenhouse gases will have raised sea level by at least 15 cm in the year 2050. Thus, it seems realistic that the advance of mangrove forests towards higher locations might significantly influence land use in affected coastal ecosystems.

The Brazilian Federal Constitution (Brasil, 1991) declares *Property Right* (art. 5) not unrestricted but subject to a social function (art. 170). Public policies can circumscribe the right to private property in accordance with social interests as the “protection and conservation of the environment, including the preservation of ecological processes, biodiversity and genetic potential, as well as the protection of flora and fauna”. Brazilian states must identify and delimit the ecosystems and their components, which are in need of special protection (art. 225). One of them is the mangrove ecosystem that is protected by:

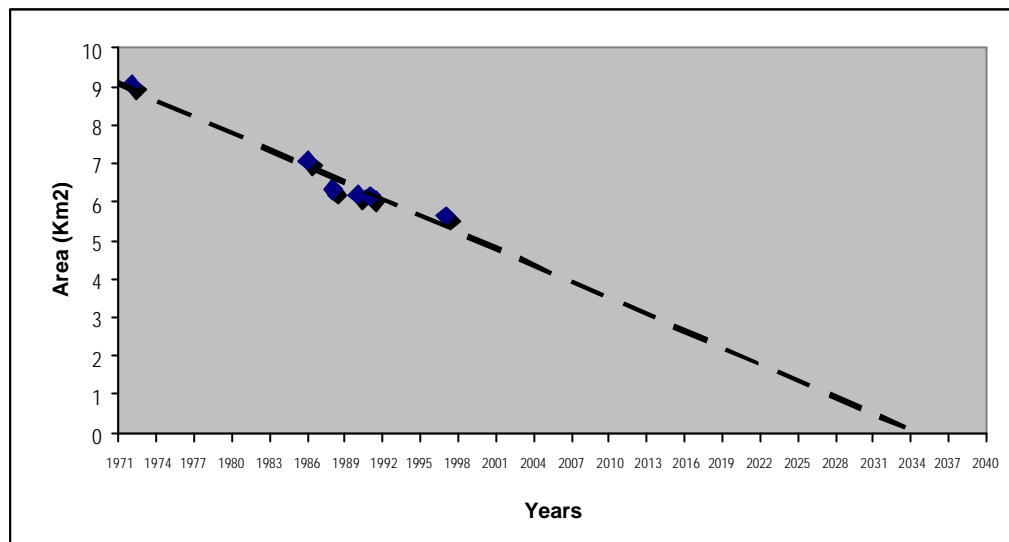


Figure 4.11 Linear relation *Km² of herbaceous vegetation/year* obtained from Satellite images (Landsat TM5 and Radar) of the period 1972-1997. Since 1998, an extrapolation of the trend line show that in 2035 all the area will be coverage by mangrove vegetation. Adapted from Lara et al., 2002.

- *The Federal Forestry Code (art.2, Law 4771/65)* that established the mangrove ecosystem, among others, as areas of “Permanent Preservation” (IBAMA, 1992).
- *The “National Plan for Coastal Management” (art. 2, Law 7661/88)* that elaborates criteria for rational resource utilization in the coastal zone giving priority in conserving and protecting estuarine ecosystems, coastal vegetation, “restingas”, dunes and mangroves (Leme Machado, 1993).
- *The Federal Environmental Crime’s Law (art. 38, Law 9605/98)* that prohibited destruction or damage to forest in permanent preservation areas, even if in the process of formation (MMA, 2000).
- *The law 6194/99 of the State of Pará* that declared illegally the extraction of mangrove plants or trees in all its territory, specifically naming several species (e.g. *Avicennia marina*) (art. 1). Its Article 3 also prohibits the extraction of these species in areas that in the *future* could be covered by mangrove. State law is thus considerably more restrictive on mangrove utilization than federal legislation.

The farm is in a topographical setting, which, under conditions of increasing inundation frequency, contributes to mangrove establishment and already contains new mangrove areas. Since the latter consist of monospecific *Avicennia* stands in high locations, the alternatives for commercial use are limited: crab density is very low in this kind of forest and fishery is not possible due to the absence of deeper creeks. Moreover, relevant legislation prohibits tree extraction.

Thus, with the current interpretation of relevant legislation, the unrestricted usable area of this private farm has fallen by about 40% in 25 years and will probably completely disappear in the next 35 years. Thus, it seems realistic that the advance of mangrove forests towards higher locations might significantly influence land use and property rights in affected coastal ecosystems.

4.2.3.2 Building Style

Accommodation is a more socially desirable option when applied in areas where there is a tradition of adapting to water. That is the case in the NE coast of the State of Pará where building design is one of the first and very used accommodation strategies, mainly among the poor populations. Many beach structures, vacation residences, small commercial buildings and particularly fishermen's houses called "ranchos" are elevated to protect them from floods, isolate from sand's heat and allow air circulation under the structures.

The elements used to elevate the buildings are bricks, concrete and, principally, wooden pillars (Figure 4.12). The elevation of the pillars, between 0,5 m and 2 m, as well as the foundation depth doesn't respond to any type of building code, being adapted to aspects as topography, proximity to the coastline, magnitude of coastal processes and available financial resources.

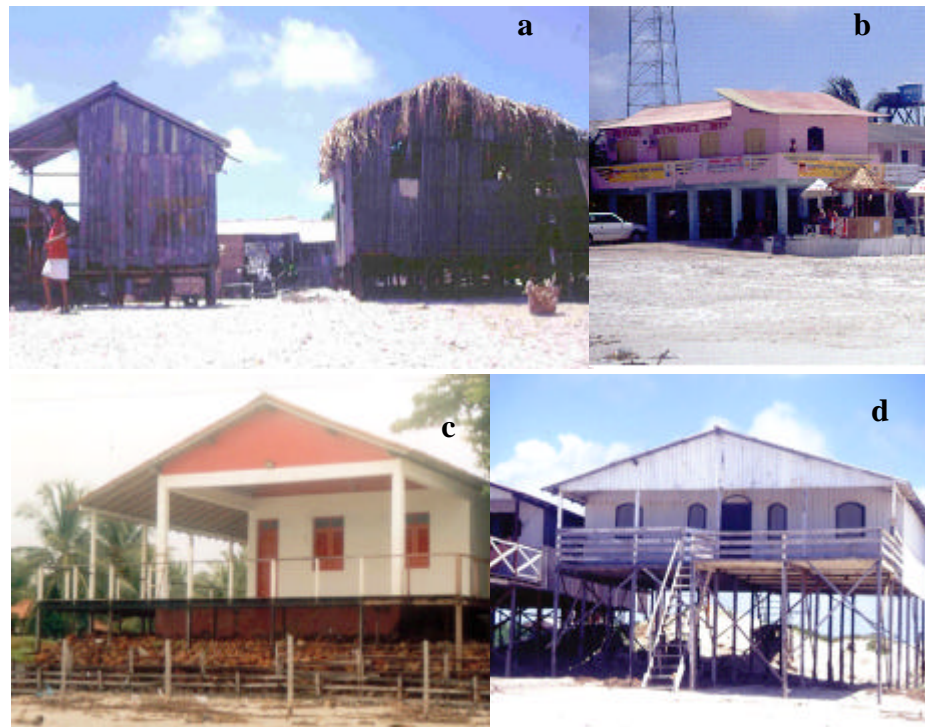


Figure 4.12 Different elements used to elevate (a) the fishermen's *ranchos* (wood), (b) commerce (concrete) and (c) residential house (brick) and, (d) vacation house (wood).

The process of building's adaptation is autonomous and continuous. The pillars should be replaced due to the action of the erosion processes in their base (considering also the unequal

exposition of the pillars to the wave's force) and the degradation of wood. The monetary costs of the pillar's recovery belong to the proprietors.

4.2.3.3 Natural Disaster Management – Relief Programs

Given the severity of many geophysical events, combined with limited resources, it is certainly not possible to eliminate all disasters, and many communities, because of their spatial location, will always remain hazard-prone (Tobim, 1999). The reality is that no matter how thorough are our investigations, hazards mitigation plans and adaptation strategies, some risk will always remain.

If the coastal communities want to face the threat and adopt accommodation strategies, they should receive some kind of help to prevent the risk and mitigate their consequences. This sort of help integrates the Emergency Management policies that in Brazil are conducted by 3 levels governmental organizations called “Defesa Civil” (*Civil Defense*). The organization, economic resources and implications of the Civil Defense Organizations activities are analyzed and a study case of the emergency management program in the coast (beach of Crispim) is described.

a. The “Defesa Civil” System

The Federal Constitution of Brazil of 1988 (art. 6) guarantees, as one of the called “social rights”, the life and patrimony protection facing the possibility of occurrence of natural disasters. Also it determines (art. 21) that is competence of the federal government to “plan and to promote the permanent defense against the public calamities, especially the droughts and the floods” and, to “legislate on territorial defense, aerospace defense, marine defense, *civil defense* and national mobilization” (art. 22) (Brasil, 1991). Natural disaster management is also a legal attribute of the state and municipalities. The Constitution of the State of Pará (art. 135) states that the Governor could order pertinent prevention and mitigation measures in case of natural disasters (Brasil, 1991). The Organic Law of several coastal zone's municipalities of Pará indicate that concerns them to plan and to promote permanent defence against public calamities and to accomplish activities, as combat to fires and prevention of natural accidents, in coordination with the federal and state governments (Maracanã, 1990; São Caetano de Odivelas, 1991; Curuçá, 1990; Magalhães Barata, 1990; Viseu, 1990).

Therefore, a system of appropriately organized emergency response measure, endowed with enough and very skillful human resources, as well as infrastructure and equipments is necessary. The National System of Civil Defense (SINDEC) was created and regulated (Federal Decrees 97274/88 and 895/93), consisting in a multi-level structure (Figure 4.13) where each level has its own objectives and activities (Table 4.3). The SINDEC has to plan and promote the permanent

defense against natural or man-made disasters, to act in disasters situation, to prevent or minimize damages, to help and to attend affected populations and to recover areas.

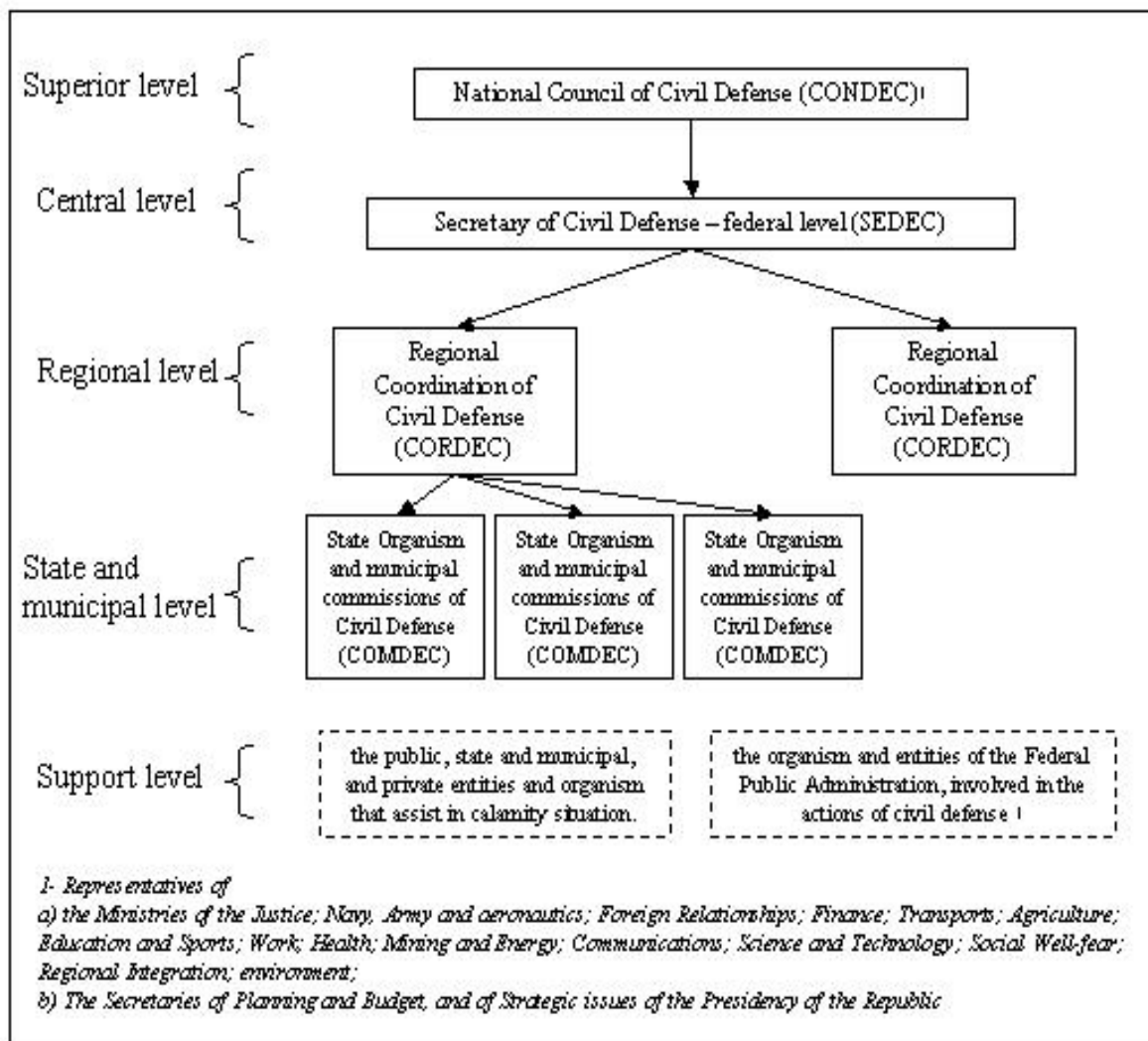


Figure 4.13 Schematic diagram showing the multilevel and multi-component characteristics of the Brazilian Civil Defense System (SINDEC).

One of their main tools is the right to declare “Emergency Situation” or “Public Calamity State” in a defined region affected by natural or man-made induced hazardous event. The “Emergency Situation” is defined as the governmental legal recognition of an abnormal condition, provoked by disaster, causing tolerable damages⁹ to a community. A “Public Calamity State” is declared when the disaster caused serious damages¹⁰, inclusive to people safety and life (Castro, 1999). Tolerable and serious damages can be classified in:

- **Human:** number of affected people (homeless, uncovered, missing, injured, sick, temporarily or definitively disabled, and dead);

⁹ Tolerable damages: Human, material and/or environmental damages not very important, intense and significant. They are usually of reversible character or of easy recovery.

¹⁰ Serious damages: Human, material and/or environmental damages very important, intense and significant. They are usually of irreversible character or of difficult recovery.

- **Material:** number of buildings and infrastructure facilities damaged and destroyed, as well as, probable cost of reconstruction or recovery;

Table 4.3 Activities and Competences of the components of each level of the SINDEC.

Level	Objectives and Activities
CONDEC	<p>To approve:</p> <ul style="list-style-type: none"> -The guidelines of civil defense's governmental action and procedures for cooperation with the activities of States, Municipal districts and private entities. -The technical criterion for analysis and approval of works destined to prevent risks, to minimize damages and to recover areas deteriorated by disasters; -The principles for declaration, approval and recognition of emergency situation or public calamity state.
SEDEC	<ul style="list-style-type: none"> -To promote and coordinate the civil defense activities at different levels and to systematize their information -To elaborate and to propose the policies and guidelines of the federal government activities of civil defense, defining areas and priorities for investments that contribute to minimize the vulnerability of the Country; -To motivate the creation and implementation of Municipal Commissions of Civil Defense (COMDEC); -To coordinate, in national level, technical training activities in disaster management pursuing objective of creation of groups to technically support the performance of organism or entities; -To propose to the CONDEC criteria for declaration, approval and recognition of emergency and calamity state; -To express opinion on reports proposing the recognition of emergency situation or state of public calamity.
CORDEC	<ul style="list-style-type: none"> -To coordinate, guide and evaluate, in regional level, the activities of the organism that integrate the SINDEC and the distribution of supplies to the populations affected; -To accomplish studies about the possibility of disaster occurrence; -To maintain up-to-date and available the information related to disaster management at regional level; -To make compatible the civil defense programs of the States for the elaboration of regional plans; -To coordinate, in regional level, technical training activities of training in disaster management.
CEDEC COMDEC	<ul style="list-style-type: none"> -To coordinate and execute relief activities as distribution of the supplies to the affected populations; -To maintain up-to-date and available the information related to disaster management at municipal and state levels; -To elaborate and implement plans, programs and projects of civil defense; -To obtain budgetary resources to recovery or preventive actions; -To coordinate, in state and municipal levels, technical training activities of training in disaster management; -To inform SINDEC about disasters events and propose the approval of emergency situation and state of public calamity.
SUPPORT LEVEL	<p><u>Ministries</u></p> <p><u>Justice</u>: to coordinate activities of the Public Security System and the performance of the Federal Police that seek to preserve the public order and people and patrimony safety in the affected areas.</p> <p><u>Navy</u>: to coordinate activities to reduce marine and fluvial casualties and damages, and support relief with personnel, material and transport means.</p> <p><u>Army</u>: to cooperate in rescue and reconstruction activities. Support relief with personnel, material and transport means;</p> <p><u>Aeronautics</u>: to coordinate search and rescue activities;</p> <p><u>Foreign Affairs</u>: to coordinate international relations (countries and organisms) related to logistic, financial, technical and scientific cooperation in disaster management;</p> <p><u>Finance</u>: to adopt financial measures and credits to assist populations and areas in calamity or emergency situation;</p> <p><u>Transport</u>: to adopt preservation and recovery measures of the federal road systems and terrestrial, marine and fluvial transport stations in areas affected by disasters,</p> <p><u>Agriculture</u>: to supply data and analyses relative to meteorological and climatic forecasts;</p> <p><u>Education</u>: to spread didactic contents related to the prevention of disasters through formal and informal education. The University of Brasilia accomplish seismic researches of interest of SINDEC;</p> <p><u>Health</u>: to supply medicines and control of water and food's quality. To supervise hospitals emergency activities and to teach, at community level, first aid techniques.</p> <p><u>Mining and Energy</u>: to promote floods control measures through the monitoring of basins hydrological conditions;</p> <p><u>Communications</u>: to adopt measures prioritizing the telecommunication services in the disaster areas.</p> <p><u>Science and Technology</u>: to determine risky areas and other scientific informations.</p> <p><u>Social Well-being</u>: to recover and reconstruct dwellings of the low-income populati on affected.</p> <p><u>Secretary of Planning and Budget</u>: to prioritize destination of monetary resources to assist populations, accomplishment of recovery and prevention works in affected areas.</p>

- **Environmental:** degradation of air, waters and soils (erosion and desertification), risk of biodiversity reduction and financial resources necessary for environmental rehabilitation.

The Figure 4.14 describes the complex schema established by the SINDEC that allows the recognition of “Emergency Situation” or the “Public Calamity State” at different governmental levels. At the local level, the Municipal Commission of Civil Defense (COMDEC) or in its absence, the population, after a field recognition in the affected areas sends the “Disasters Notification - Preliminary Report” (NOPRED) to the Municipal Prefect's knowledge. Proven the graveness of the circumstances, he could decree the “Emergency Situation” or the “Public Calamity State” in the region. This municipal decree only has significance if the Governor of the State homologates it. In order that this happens, the affected municipality should send the governor, in a smaller term to 12 hours, the NOPRED and the “Emergency Situation” or the “Public Calamity State” decrees. The Governor instructs the Civil Defense Coordination of the State (CEDEC) to check, in loco, the damages described in the municipal ordinance. Up to 5 days, the “Impact Assessment Report” (AVADAN) has to indicate the severity of the situation and suggest to the Governor about the homologation or not of the decree. Proven the graveness, the ordinance is published on the Official Gazette of the State.

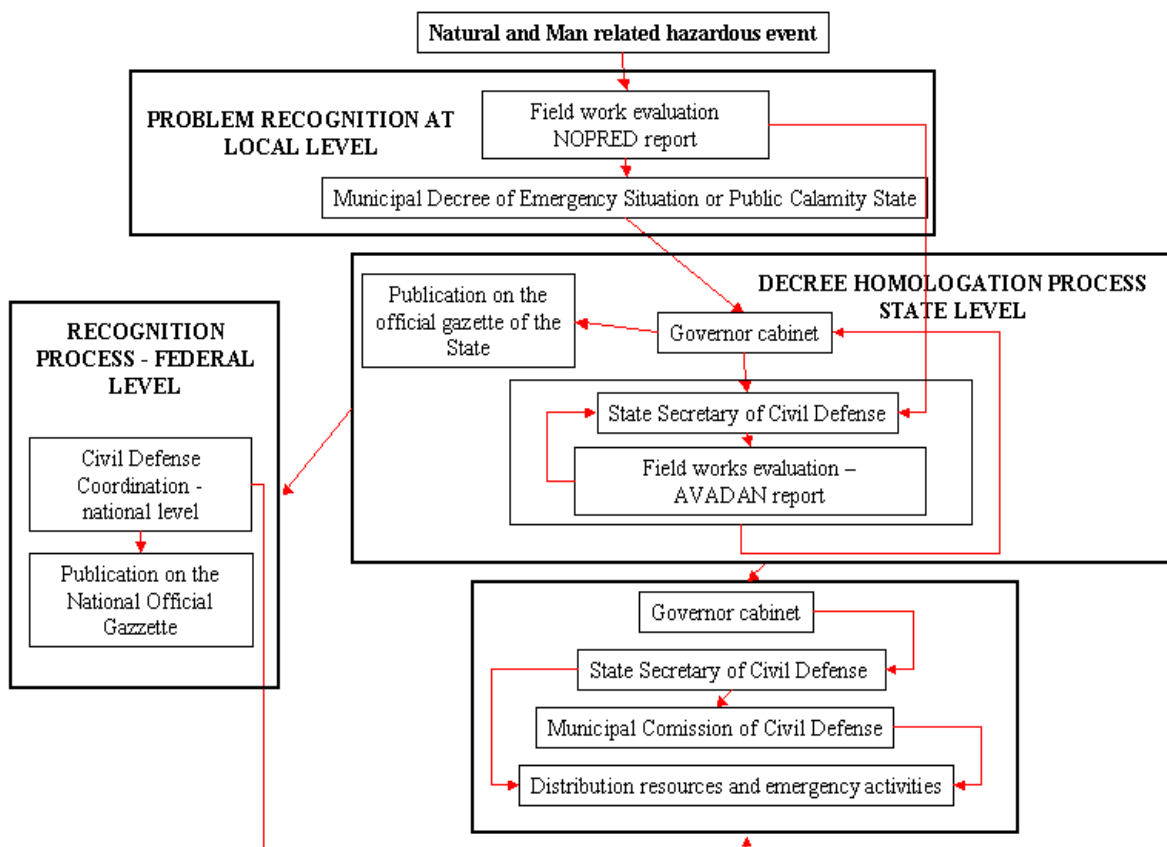


Figure 4.14 Schematic diagram indicating the proceeding form of SINDEC once happened a natural or man-made disaster.

The federal government’s assistance is necessary if the affected area has a great extension (e.g., several municipal districts) or/and the impacts overcomes the response capacity of the municipal and state governments. This aid only could be effective through the recognition of a disaster

situation made by the Civil Defense Secretary (SEDEC) and the subsequent publication of the decree in the National Official Gazette¹¹.

The kind of emergency relief not only depends on the type of natural hazard and the disaster magnitude but also on the State and Municipal response capacity. The main activities and tasks, which often require the contribution of the organism and entities that integrate the Support Level of the SINDEC, are (1) evacuation and assistance activities, (2) prevention measures, facing rapid recurrence of the events, and, (3) distribution of personal cleaning products and food (Table 4.3).

Besides the legal recognition of an abnormal situation and the beginning of the mitigation activities development, the declaration and approval of an “Emergency Situation” or “Public Calamity State” imply numerous and several legal and economic consequences defined in the Brazilian legislation. These implications are established in the Federal Constitution, the Brazilian Penal and Civil Law’s Codes, and in others federal laws and decrees.

The Brazilian Penal code (art. 61) considers the infraction made at times of fire, destruction, flood or any other public calamity situation as one of the circumstances that worsen the punishment (Ordinance-Law 2848/40). The Code of Civil Law (Federal Law 5869/73) determines that, in a lawsuit, the preemptory periods of the law could be exceeded for more than 60 days in case of disaster situation (art. 182). In case of calamity situation, the federal government could expropriate all possessions in whole national territory (art. 2) in order to facilitate the disaster response measures and reconstruction actions (Federal Decree Law 3365/41) and must assure the free distribution of necessary products¹² to the people consumption and of supplies to the agricultural, fishing and industrial activities (Federal Law 4/62, art. 1). Also, the vacation period of the civil servants of federal government, autarchies and public foundations can be interrupted (Federal Law 8112/90, Art.80), and the Minister of Regional Integration can request them, temporarily, to work in disaster mitigation, not implying any modification in their position, function, salary or others rights.

The declaration of abnormal situations could imply the reduction of tax collection or the generation of unexpected expenses. In one hand, the “Rural Territory Property” (*Imposto Territorial Rural* - ITR) could be mentioned. It is an annual tax that has to pay any continuous area, formed of one or more parcels of lands, located in rural area of a municipal district, unless it is located in an area declared and recognized under a state of calamity or emergency (Federal

¹¹ The presidential Decree of January 17, 1995 disposes about the competence of the Federal Government for recognition of public calamity state and emergency situation

¹² Nutritious products; clothes and footwears of popular use; medicines; agricultural machines; sanitary equipment and industrialized implements of domestic use and elements destined to the construction of popular houses and rural infrastructures.

Law 9393/96, Art. 10). On other hand, biddings are dispensed at public administration particularly those related to essential elements to the emergency assistance (Federal Constitution, art. 37 and Federal Law 8666/93).

Often, the necessary expenditure involved in disaster relief may place significant stress on budgets, especially in undeveloped regions. The financial resources for the activities of the civil defense organizations are provided by the “Special Fund for Public Calamities - FUNCAP” or the national, state or municipal budgets, representing a form of spreading or sharing losses not only among the affected populations (El-Raey et al., 1999). The federal government establishes the FUNCAP (Federal Law 950/69 and Federal decree 1080/94) as a tool to finance population assistance and rehabilitation of areas affected by calamities. However, this fund does not have any financial resource since 1996. The federal institutions, members of SINDEC, must accomplish their activities using their own financial resources that can be supplemented, if it is necessary, through extraordinary credits (Federal Constitution, art. 167). Besides the FUNCAP, emergency management activities have financial resources from federal, state and municipal budgets. Between 1996 and 2001, the Brazilian and State of Pará’s budgets allotted U\$S 508,816,868 (0.023% of total) and U\$S 2,589,563 (0.027% of total), respectively, to the organization and maintenance of the Brazilian Civil Defense System¹³ (Table 4.4). In the State of Pará, with the municipal district of Belém exception, there is no financial resource in the municipal budgets for emergency management.

In spite of the different public emergency and calamity situations that affect Brazil and the State of Pará (Szlafsztajn and Fonseca, 1998), it is very small amount of money for emergency management, indicating that natural disasters relief (prevention, mitigation and recovery) is not considered of great importance, mainly in a scenario of more urgent socio-economic necessities. This very small amount of money often is destined to other objectives, transforming a common practice to ask for budgetary reinforcements in case of natural disaster.

This would represent a worried situation. Considering the potential increase in extreme events induced by climate change, there are bigger possibilities of impacts and disasters occurrence, then more significant expenditures must be involved in disaster planning, prevention and mitigation. Once described the organization of the SINDEC, their financial resources and implications of their activities due to the recognition of “Emergency Situation” and “State of Public Calamity”, now, it is important to do a performance evaluation of the relief policies in case natural calamities in Pará.

¹³ Brazilian Budgetary topics related with Civil defense System: (1) Emergency procedures of civil defense, (2) Civil Defense System - qualification programs, (3) Coordination of the National System of Civil Defense and (4) Preparedness and prevention for emergencies and disasters events.

Table 4.4 Monetary found destined to Civil Defense System at federal and state levels (1996-2001), expressed in total values (US\$) and percentage (%) of the correspondent total budget (Source: ALEPA, 1996-2001; Brasil, 1996-2001).

	Years						
	1996	1997	1998	1999	2000	2001	Total
Federal Level							
Civil Defense - Total per year (US\$)	49,291,049	196,850,000	43,531,563	35,026,602	131,194,241	52,923,413	508,816,868
Brazil - Total Budget of the year (US\$)	277,896,705,610	455,256,906,654	485,531,747,292	253,964,755,113	414,006,272,442	381,665,789,068	2,268,322,176,179
Percentage of total budget (%)	0.017	0.043	0.008	0.0137	0.0316	0.0138	0.0234
State Level							
Civil Defense - Total per year (US\$)	341,666	394,342	749,067	341,776	555,600	207,112	2,589,563
State - Total Budget of the year (US\$)	1,790,373,435	1,995,065,193	2,473,856,710	1,195,821,154	1,192,152,529	1,280,751,046	9,928,020,067
Percentage of total budget (%)	0.019	0.019	0.03	0.028	0.046	0.016	0.0272

The opportunities that mitigation and reparation actions were executed after the establishment of an abnormal situation are used as a good indicator of the success of the SINDEC. Consequently, the performance of the Civil Defense Organizations in the State of Pará, particularly in the coastal area, is analyzed, in order to understand if the SINDEC could be an efficient response measure in the future scenarios of sea-level rise.

10-years daily issues of the State of Pará Official Gazette (*Diario Oficial do Estado do Pará*) (IOEPA, 1992-2001) were analyzed. Since January 1st of 1992 until December 31st of 2001, 126 decrees were established (Table 4.5). The Annex 1 characterizes these ordinances, ordering them chronologically and describing several parameters as: municipal district, localities and population affected, as well as, type of natural hazard that caused these abnormal situations. In this period,

there are others ordinances that do not have their origin in geomorphologic or climatic processes (e.g., lack of electric energy, malaria epidemics, etc.).

Table 4.5 Number of decrees establishing “Emergency Situations” and “Public Calamity States” on Pará (1992-2001).

	Number of decrees	Proportion (%)
Emergency Situations	99	78.5
Public Calamity States	27	21.4
Total	126	100

It is possible to recognize 8 groups of different types of natural events. Fluvial floods and inundation and heavy rainfall, with 44% and 37% respectively, were mentioned as the principal cause of natural disasters in the state of Pará (Figure 4.15), in 50 municipal districts (35% of total).

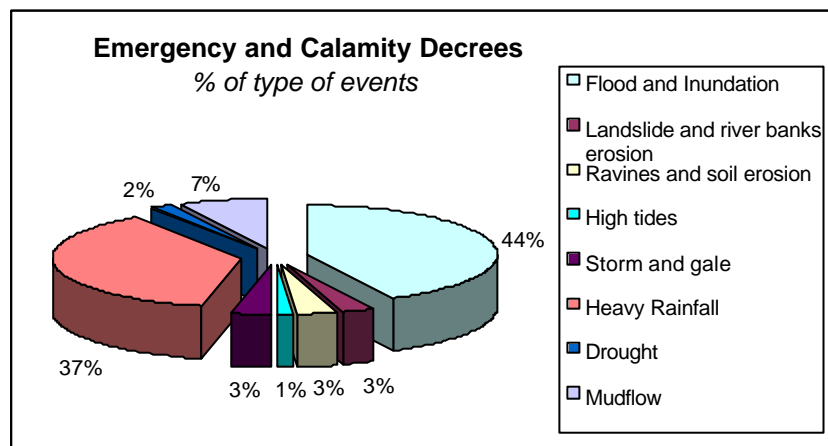


Figure 4.15 Types of Natural events (%) that cause the elaboration of disaster situation decrees in the State of Pará (1992-2001).

The figure 4.16 shows the spatial distribution of those municipal districts classified by the number of decrees, presenting a great concentration near the main rivers that cross the state (Amazon, Xingu, Tocantins, Araguaia) and the road (BR-230), called *Transamazônica*, where are located the poorest municipal districts of the State.

Although the great part of the SINDEC activities in the State of Pará are related to municipal districts closer to the margins of the most important rivers and roads, there are few records of their actions in coastal areas affected by high tides and beach erosion, particularly in the municipal districts of Chaves and Marapanim.

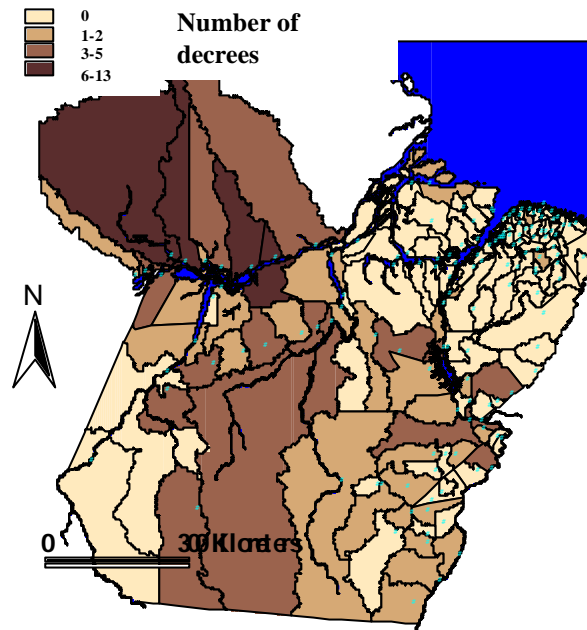


Figure 4.16 Municipal districts of the State of Pará ranked by the number of “Emergency Situation” and “Public Calamity State” (1992-2001). Higher concentration on those that are situated near the principal rivers and roads of the state.

b. The Performance of the Civil Defense System in Coastal Areas Disasters: A Study Case in Crispim.

The Crispim beach (Municipal District of Marapanim), 146 km far from Belém, is linked to Marudá (main city) by an 8 km-highway that crosses an extended mangrove area (Figure 4.17). On this beach, with dunes and clear ocean waters, there are few inns and bars. This area, considering its proximity to Belém, attracts many tourists on holidays (July and January) and weekends. However, few people inhabit Crispim the rest of the year, mainly fishermen.

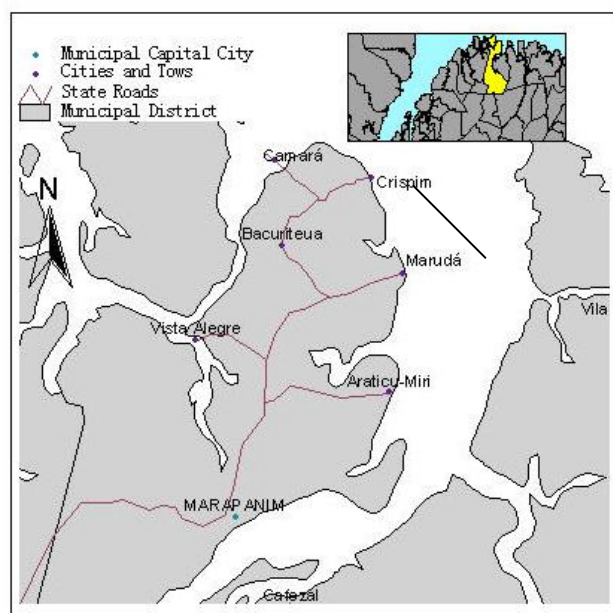


Figure 4.17 Location of Crispim beach on the NE coast of the State of Pará (Brazil).

There are evidences of wave action in the region and particularly on Crispim beach (Table 4.6). Big storms were registered on the first days of February 2001 with tide level ascending around 1 meter above the mean spring tide level of the month¹⁴.

Table 4.6 Data related to the hazardous occurrence in February, 2001 (DHN, 2002). The data are from the Port of Salinópolis.

2001	Mean high tide level
All of February	4,6 m
1 st -12 th February	4,9 m
9 th February	5,5 m

This hazardous event not only caused the death of a great extension of mangrove area, but also affected the building structures and the ending part of the paved road (PA-138) constructed to develop tourism activities at the beach (Figure 4.18). The NOPRED from February 14 (Figure 4.19) and the AVADAN reports by the Civil Defense State Secretary (CEDEC), classified the event as “coastal floods caused by the abrupt invasion of the sea”, a natural disaster of 3rd level (Castro, 1999).

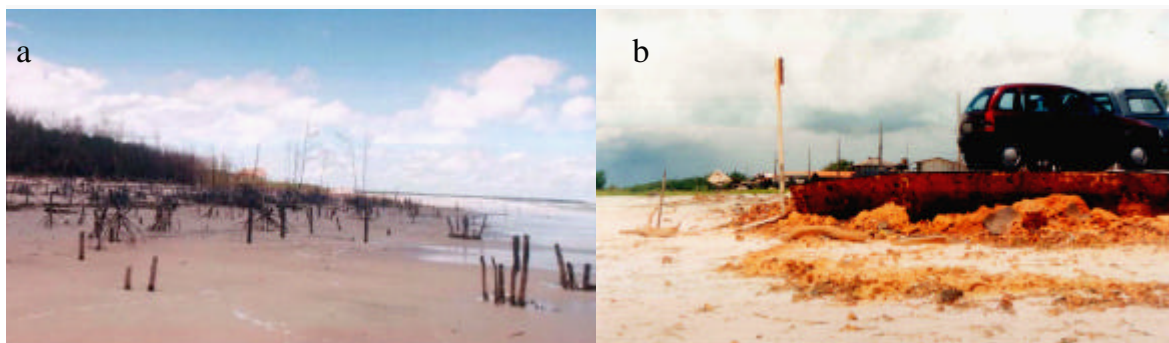


Figure 4.18 (a) Area affected registering evidences of wood pillars rests of local population houses and mangrove area destroyed by the storm event in February 2001 (b) Paved road (PA-138) that leads to the Beach of Crispim eroded around 15 m since its construction, as indicated by local population.

The NOPRED had initially informed that the number of affected people was 64, but later reports indicated that 46 families - around 217 people, and 25 buildings (15 damaged and 10 destroyed) - had been affected. Preliminary evaluation indicated material damage to popular houses (US\$ 42,000), and to artesian wells (US\$ 5,400), which together with the expenses for cleaning the affected area (US\$ 3,200), came to a total of US\$ 50,600. This disaster motivated the sanction of the municipality of Marapanim Emergency Situation decree 23/01. Although the affected population and the damaged material parameters seem to be of little importance, the natural disaster caused difficulties for the community economic development. Material damage

¹⁴ The month of February, 2001, registered averages of tides heights of 2,77 m, and of high tides of 4,6 m. Between the 1st and 12th of this month, the average of high tides is elevated at 4,9 m, arriving on the 9 February at 5,5 m (DHN, 2002).

represented 1.65% of the GDP of the municipality of Marapanim in the year 2000 (TCM-Pa, 2001) and about 40% of the region total population were affected¹⁵.


COORDENADORIA ESTADUAL DE DEFESA CIVIL - CEDEC						
 NOTIFICAÇÃO PRELIMINAR DE DESASTRE						
1 - Tipificação				2 - Data de Ocorrência		
Código	Denominação		Dia	Mês	Ano	Horário
NES12	12.304	Inundações Litorâneas provocadas pela brusca invasão do mar.	12	02	01	
3 - Localização						
MARAPANIM - (Praia do Crispim) - PARÁ						
4 - Área Afetada - Descrição da Área Afetada						
Orla marítima com edificações em madeira, destinados a moradia e comércio, vegetação em mangue.						
5 - Causas do Desastre - Descrição do Evento e suas Características						
Avanco do mar em direção a costa litorânea causando o acoreamento e destruindo a vegetação.						
6 - Estimativa de Danos						
Danos Humanos	Número de Pessoas	Danos Materiais		Número de Edificações		
			Danificadas	Destruidas		
Desalojadas	64	Residenciais	15	10		
Desabrigadas		Públicas				
Deslocadas		Comunitárias				
Desaparecidas		Particulares				
Mortas		Serviços Essenciais		Intensidade do Dano		
Enfermas			Danificadas	Destruidas		
Levemente Feridas		Abastecimento de Água	<input checked="" type="checkbox"/>	<input type="checkbox"/>		
Gravemente Feridas		Abastecimento de Energia	<input type="checkbox"/>	<input type="checkbox"/>		
Afetadas	64	Sistema de Transporte	<input type="checkbox"/>	<input type="checkbox"/>		
		Sistema de Comunicações	<input type="checkbox"/>	<input type="checkbox"/>		
7 - Instituição Informante						
CBM / CEDEC-Pa			Telefone			
Nome do Informante:	Cargo	Assinatura / Carimbo	Dia	Mês	Ano	
Norat	Cap QOBM		14	02	01	
8 - Instituições Informadas						
Coordenadoria Estadual de Defesa Civil - CEDEC		<input checked="" type="checkbox"/>				
Coordenadoria Regional de Defesa Civil - CORDEC		<input type="checkbox"/>				
COORDENADORIA ESTADUAL DE DEFESA CIVIL			Telefones - (091) 242 - 5155			
Rua João Diogo, 236						
Belém-Pa.						
CEP - 66015-160			Telefax - (091) 242-5159			

Figure 4.19 Copy of the NOPRED Report of the Civil Defense Coordination of the State of Pará about the natural disaster on Crispim of February 12, 2001 (source CEDEC-Pa).

Once the NOPRED and AVADAN reports had been analyzed, on February 16, the Civil Defense Coordination of the State of Pará advised the Governor to homologate the Decree 23/01. The Decree of the State of Pará 4524/01 from February 22 (published on February 23, in the Official Gazette of the State of Pará) (Figure 4.20), finally recognized the “Emergency Situation” in the locality of Crispim. Facing the seriousness and urgency of the situation, the civil defense distributed among the affected families, 61 baskets of foods and 20 mattresses provided by the “Executive Secretary of Work and Social Promotion” of the State of Pará (SETEPS).

¹⁵ Total population, year 2000, of the 6th census district of Marapanim, 568 inhabitants.

Belém, sexta-feira,
23 de fevereiro de 2001

DIÁRIO OFICIAL 100%
ELETRÔNICO

03 cadernos - 60 páginas

PODER EXECUTIVO
ESTADOS FEDERATIVOS DO BRASIL - ESTADO DO PARÁ

A HISTÓRIA NO DIÁRIO OFICIAL
ENÉAS MARTINS (XXVII)

✓ Através do Decreto nº 3028-A, de 20 de dezembro de 1914, o governador Enéas Martins regulamentou a cobrança dos impostos de consumo sobre o tabaco e bebidas alcohólicas de procedência nacional ou estrangeira.

Segundo o decreto, o imposto sobre o fumo recaria, não só sobre os preparados como charutos, cigarros, cigarrilhas, tabaco picado ou desfiado, como também sobre o manuseio em barra, melho e em bruto, quer fossem em folha, rolo ou cordão.

■ Os impostos sobre bebidas incidiriam nos líquidos que contivessem qualquer quantidade de álcool adicionados em vasilhames e expostos nas casas de comércio e outros estabelecimentos permanentes, temporários ou ambulantes. O decreto também determinava os casos que eram isentos de impostos e as medidas mais convergentes aos interesses locais do Estado.

Hoje
Hoje em dia
Online
www.ioepa.com.br
e-mail: diario@ioepa.com.br

Homologada situação de emergência no Crispim

Através do Decreto nº 4.524/01, o governo do Estado homologa a situação de emergência na localidade de Crispim, no município de Marapanim, em uma área de 500 metros de orla marítima. Segundo o decreto, a localidade tem sido atingida por fortes marés desde o início do mês de fevereiro, causando graves danos à economia, à segurança e à saúde da população local. Aproximadamente 46 famílias encontram-se em situação de risco e outras 15 estão desabrigadas por causa das fortes marés.

PONTO FACULTATIVO – O governo do Estado facilita o expediente nos órgãos estaduais da administração direta e indireta no dia 26 deste mês. No dia 28, as repartições estaduais funcionarão no horário de 12 às 18h. Para que a população não sofra com a falta de serviços, os órgãos estaduais das áreas de arrecadação, saúde pública e defesa social montarão escala de serviço.

(Caderno 1 - Pág. 3)

Concessão de descontos na anuidade da OAB só até dia 28

A Ordem dos Advogados do Brasil Seção Pará informa que a partir do dia 01 de março até 30 de abril, as anuidades devidas perante a OAB até o ano de 2000 deverão ser cobradas por seus valores históricos, acrescidos de multa penal de 10%, sem a incidência de correção monetária ou juros de mora.

A OAB informa, ainda, que os valores em débito poderão ser parcelados em até 10 vezes, prorrogáveis para até 20 vezes. Com relação às anuidades atrasadas até 1999, a Ordem dos Advogados comunica que o prazo para concessão de descontos encerra-se no dia 28 deste mês.

(Caderno 2 - Pág. 6)

Educação alimentar

A Lotepa assina convênio com a Ceasa para manutenção de um sistema de cooperação para implantar o Projeto Popular Educação Alimentar.

(Caderno 1 - Pág. 15)

Venda de bebidas

A Polícia Civil do Estado comunica, através da portaria nº 099/01, que será vedada a comercialização e a venda de bebidas alcohólicas, por ambulantes, nas imediações dos locais de realização dos eventos carnavalescos em vias públicas. A proibição é válida a partir das 19 horas do dia 26 até às 6 horas do dia 28 de fevereiro.

(Caderno 1 - Pág. 15)

Aviso

O Diário Oficial do Estado não circulará nos dias 26, 27 e 28 de fevereiro.

Figure 4.20 1st page of the Official Gazette of the State of Pará, informing about the homologation of the Decree that had declared Emergency Situation on Crispim (February 23, 2001). Headline *Ratified emergency situation in Crispim*.

4.2.3.4 Brazilian Natural Disaster Insurance System

Insurance policies are some of the “non-structural” adaptation strategies and measures to cope with the consequences of current and potential natural hazards. In many countries, insured property owners, who build in hazardous prone areas, determine the amount of risk that they are willing to take and, to offset this risk, purchase insurance to protect them against possible losses (Boyle Jr., 1993). However, insurance industry for natural hazards is facing a new challenge. According to White and Etkin (1997) if all the activities are based upon the assumption that the climate is constant, it is likely to be a serious problem. For this reason, the insurance industry should not simply use past experience as a guide for the future, it must adapted to climate change.

The insurance industry is concerned about the rapid increase in losses from natural catastrophes; most of them derive from extreme atmospheric events like windstorms, floods, droughts, and

hailstorms. The suspicion soon arose that this trend cannot be attributed entirely to growing economic development and increased populations exposed to the hazards. It has been influenced to a major degree by the environmental and climatic changes observed worldwide (Berz, 1999; Bruce, 1999).

All over the world there is a great diversity of insurance systems that cover natural catastrophes. Each market tries to have a kind of insurance that can respond to the challenges presented by natural hazards, considering its own economic development degree, structures and culture of insurance activities, casualty records and natural hazard vulnerability particularities. In some countries, the private insurance market offers protection against catastrophic natural risks; in others, there is a governmental participation in order to guarantee to the population the provision of protection instruments against catastrophic risks. In this sense, some aspects of the public and private Brazilian insurance system against natural disasters, particularly in the State of Pará and its coastal zone and, considering a probable scenario of sea level rise have been described and analyzed.

a. The Public System

In developed countries, the assistance to affected populations is summed up through indirect monetary loans (low or null interest and wide paying-off term) and other kind of donations. In some countries those kinds of help are enabled case to case, preparing “ad hoc” the measures and necessary resources. Others countries have specific mechanisms for these circumstances, with their respective operation and administrative rules that seek for distributing the budgetary help endowments within objective parameters. The *Small Business Administration* (USA); the *Accords d’Aide Financière en Cas de Catastrophe* (Canada); the Australian *Natural Disaster Relief Arrangements*, the *Statens Naturkadefond* (Norwegian) and the *Fond de la Calamités* in Belgium integrate this second class (Ibañez, 1999). In Brazil, there is also some federal mechanism to distribute the budgetary help endowments called *Fundo Especial para Calamidades Públicas* – FUNCAP (Special Fund for Public Calamities).

The FUNCAP was created in 1969 by the Federal Law 950 (Regulation Ordinance 1080/94) in order to finance population calamities relief activities according to the *National Plan of Permanent Defense Against Public Calamities*.

The condition for the allotment of monetary resources is the acknowledgment of an “anomalous” situation by the federal government, taking into consideration what had been established by the municipal and state governments. The allocation must follow some guidelines and priorities as:

- The immediate assistance to the populations hit by public calamities;

- The provision of food and drinking water; medicines, first aid material and supplies for personal care; clothes and coats; emergency shelters; fuel, oils and lubricants; equipments for rescue; cleaning and basic sanitation products; and burial material.

- The rehabilitation of affected areas

- The refund of expenses made by public or private entities related to the removal of debris, and the re-establishment of the essential basic services and transport.

These resources, originated from the annual budget of the Ministry of Regional Integration, are administered by a Deliberative Committee, headed by the Secretary of Civil Defense (Ministry of Regional Integration), and formed by representatives of the Ministries of Economy and Planning. In an emergency case, the president of the Deliberative Committee can authorize expenses *ad-referendum* of the committee.

Unfortunately, the natural calamities issues have not received a considerable attention from the federal government. Consequently, the FUNCAP does not have a permanent or own source of financial resources assured in the annual Brazilian budget. Other monetary resources that constitute the FUNCAP are obtained from the following sources: (a) subsidies and contributions from public and private, national, international or foreign entities, (b) still available balances of extraordinary credits for public calamity relief, and (c) other eventual resources. The federal budgets destined for FUNCAP, in the fiscal years of 1994 and 1995, were US\$ 101,272 and US\$ 210,400 respectively, and any other budget endowment since then (Brasil, 1996-2001). These amounts are clearly insufficient for any government action and have not been transferred by the National Treasury. Since 1994, FUNCAP has not received any kind of contribution from private, national or international entities.

Nowadays, several bills are being proposed at the Brazilian Federal Congress in order to provide FUNCAP with its own financial resources. The bill 183/96 by Senator Casildo Malader (State of Santa Catarina) proposes the contribution to a public insurance system and the change of the denomination FUNCAP into "Special Fund for Public Calamities and Civil Defense (FUNCADEC)". The Project proposes that every private insurances operation must contribute with 0.5% of the coverage total value. The insurance companies should be responsible for the collection, retention and withdrawal of the contribution that integrally will constitute the budget of FUNCADEC. The insurance operations linked to agricultural production, financing of rural activities, and exportation will be exempt of contribution. In consonance with the programs planning approved by the National Council of Civil Defense (Art. 7), at least 70% of the resources will be annually applied in loans to legal entities that have projects to invest in equipments and physical facilities for civil defense organizations (e.g. fire brigades). Up to 15%

can be annually destined to transfers and donations to civil defense entities, and also, up to 15% can be annually assigned for projects on development of the insurance system, especially the ones related to studies and technical research, personnel training and educational campaigns.

On the other hand, the bill 2500/00 by the Federal Deputy Vivaldo Barbosa (State of Rio de Janeiro) proposes the destination of 3% of the national lotteries total income for financial support of FUNCAP. The national lotteries, organized by *Caixa Econômica Federal* already contribute with part of the collected resources (approximately 48.5%) to several funds (e.g. Penitentiary Fund - FUNPEN; Culture National Fund - FNC), to the development of sport activities (Olympic and Paralympic Brazilian Committees, COB and CPB respectively), to educational credits, and mainly to the Brazilian Red Cross. The Commission of Urban and Regional Development (Federal Deputy Chamber) unanimously approved the bill on October 18, 2000, and now it is being evaluated by the Finances and Taxation, and the Constitution and Justice Commissions. Considering the period 1999-2002, when the resources collected by the national lottery were US\$ 1,091,959,400 per year (R\$ 2,729,898,500), if this law is passed FUNCAP would receive US\$ 32,758,782 per year (R\$ 81,896,955) (Caixa Econômica Federal, 2002).

b. The Private System

The Brazilian Private Insurance System (SNSP), created by Decree Law 73/66, has several levels of operation and control (Figure 4.21). On the top, the Ministry of Finance presides over the National Council of Private Insurance (CNSP) that establishes the guidelines for the Brazilian insurance policies. The Brazilian Reinsurance Institute (IRB) and the Superintendence of Private Insurance (SUSEP) execute them. IRB is the institute that executes the reinsurance operations, and SUSEP is the supervisory body that authorizes and inspects the performance of the insurance companies and brokers. The insurance companies and brokers operate at national, regional and local level. The company is authorized to practice the insurance, guaranteeing the patrimony compensation in case of a casualty foreseen in the contract. The broker is the person authorized, to analyze the risk, to elaborate the insurance proposal, and present it to an insurance company.

Private insurance could be described as a contract that imposed on the insurer, through the reception of the *premium*, an amount of money received by the insured, to pay him/her or other designated person in case if a future and uncertain event occurs as predicted in the contract. The Table 4.7 describes the several branches that compose the Brazilian private insurances system, the insured elements and the probable origins of the risks. Among these coverages, those that protect against natural hazards stand out – the several risk and multirisks.

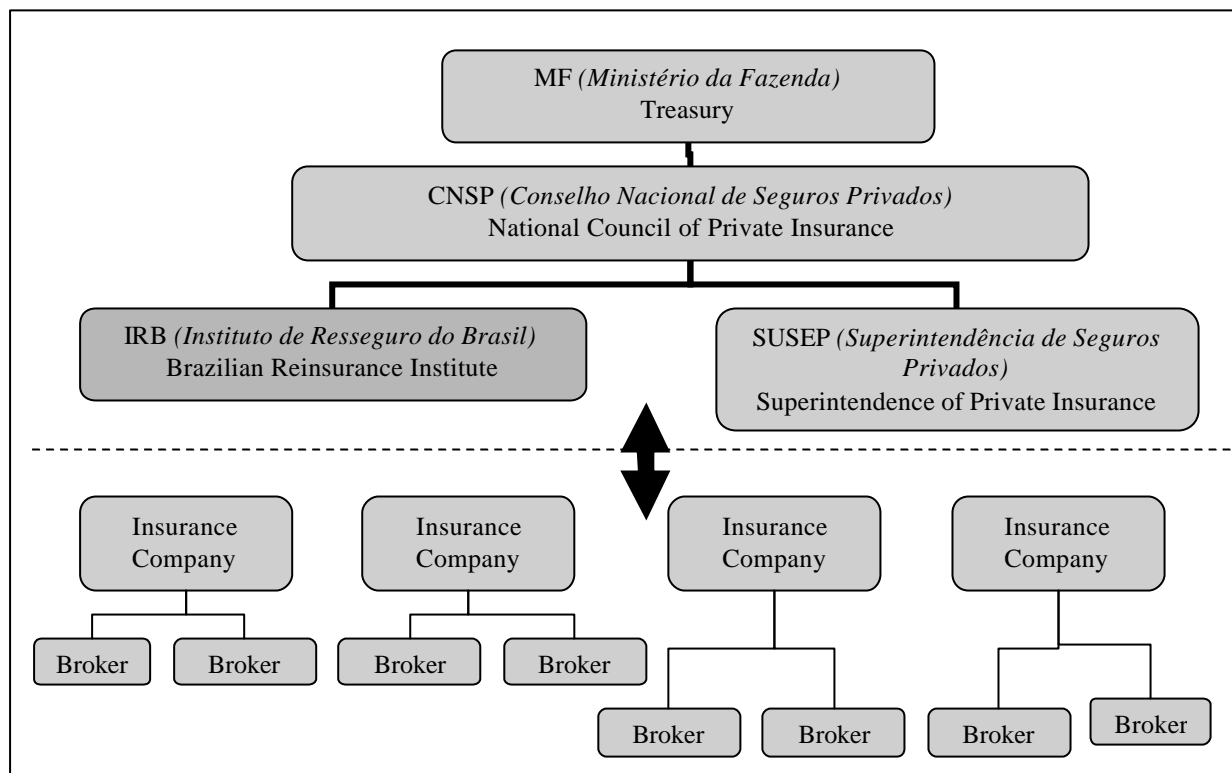


Figure 4.21 Diagram of the Brazilian Private Insurance System organization (Source: SUSEP, 2001).

The first policy of this type appeared in Brazil in 1951 and guaranteed, as part of the fire insurance, the protection against flood, earthquake, windstorm, hurricane, and hail risk among others. In 1992, the protection against natural hazards begins to be carried out for the insurance branches called “Several Risks and MultiRisks” (*Riscos Diversos and Multiriscos*) (Decree Law 605/92). They are special insurances because they include, in only one policy, different insurance modalities, and sometimes new ones; for instance, those that protect buildings and their content against damages of “external” cause, as natural hazards (Funenseg, 1998b). The “Several and MultiRisks” insurance are specifically related to the following natural hazards: floods, inundations, earthquakes, and wind and hailstorm.

For the Brazilian private insurance system, an event is defined as an inundation when water from rainfall or cloudburst or from pipe, canalization, or reservoir rupture (since it does not belong to the same building) go into buildings. Floods are described as the increase of water discharge by navigable rivers (defined by the Brazilian Ministry of Agriculture), and their tributaries. For the insurance system; windstorm is an event where the wind speed is equal or higher than 15 m/s.

Table 4.7 The main types of coverage in the Brazilian Private Insurance Market; the objects that are insured and the potential causes of the damage (source: Funenseg, 1998a).

Insurance Branches	Insured Objects	Potential Causes
Automobile	Propulsion engine terrestrial vehicles and their towing used to transport people, animals or things.	Collision, theft and fire risk.
Life	One person or groups of people.	Death or permanent disability.
Health	One person or groups of people.	Surgeries and illnesses.
Houses	Brick houses used strictly as dwelling.	<ul style="list-style-type: none"> - Fire, lightning fall to the insured area, and explosion. - Windstorm and hailstorm. - Collapse. - Pane break. - Electrical damages. - Domestic accidents.
Personal Accidents	One person or groups of people.	Accidents defined as external, sudden, or violent and involuntary incidents that cause corporal lesions, death, and partial or total ¹⁶ permanent disability.
Fire	Material damages or losses to the property belonging to the insured or under its responsibility.	<ul style="list-style-type: none"> - Fire action happened by any cause. - Lightning. - Explosion caused by domestic gas use.
Several Risks and Multirisks	<ul style="list-style-type: none"> - Houses. - Jewels. - Neon signs in exhibition or transport. - Musical instruments and works of art. - Cinematographic, photographic and television equipments. - Under-water operation equipments. 	<ul style="list-style-type: none"> - Natural hazards <ul style="list-style-type: none"> a. Earthquakes b. Floods c. Inundations d. Wind and hail storms - Risks that can be common to several insurance branches. - Risks that are not specifically foreseen by the other branches.

Some of the most important characteristics of these kinds of insurance are (Szlafsztein, 2001):

- **Contract Validity Term:** The insurance is usually contracted for one year, in order to inhibit the attempt to contract it for periods where there are great possibilities of casualty occurrence (e.g., flood insurance only for period of intense rain).
- **Compensation:** It allows to refund the insured by payment in money or by repair or replacement of the damaged material, in order to restore it to the same state that it was immediately before the hazardous event.

¹⁶ Partial: disability of one or more members or senses, without affecting the operation of the remaining corporal system. The insured could carry out elementary activities (e.g. loss of a finger). Total: the disability of members or senses affects the operation of the remaining corporal system, impeding the insured to carry out elementary activities (e.g. loss of both legs).

- Data Verification: In order to know the characteristics of the objects and people potentially at risk, the insurers can (a) consult the customers in personal interviews, (b) elaborate a “Field Inspection Report” together with specialized experts, and (c) compile the already existent information in risk or vulnerability maps (Augusto Filho et al., 2000; Chesnokova et al., 2000). Inundation and flood insurances are always subjected to previous field inspection. In these cases, environmental (e.g. proximity of a building to the river banks or to a steep slope) or historical (previous disaster events in the area) particularities can increase the values of the premium and “*Franquia*”¹⁷.

The insured elements are classified by the requirement or not of previous analysis. Buildings and their content are directly insured. On the other hand, energy towers and electricity transmission cables, animals, pastures, fences and walls, jewels or precious metals, money, checks and bonds; manuscripts and projects are subjected to previous study. Insurance against inundation, flood, and earthquake will particularly refund damages caused by deterioration of objects supposed to be kept in special environments and expenses for protecting them, as well as economical losses due to the interruption or disturbance of the activities. The insured values are specifically determined for each element, which is (1) buildings and engines: reconstruction costs considering the condition derived from use, age, and conservation; (2) equipments and goods: value of a new one at the damage date.

In spite of the relevant existence of a private insurance system sector related to protection against the impacts from natural hazards, no evaluation has still successful, in order to evaluate it as an adaptation strategy and measure. This way, aspects of the private insurance market against natural disasters in Brazil, and particularly in the coastal area of the State of Pará have been analysed.

The world’s most important insurance markets are concentrated in the populated and wealth North America, Europe and Asia continents (around 96% of the total), only 2% corresponding to Latin America (US\$ 40,757 millions in 2000) (Swiss Re, 2001) (Figure 4.22). In spite of this context and considering that Brazil is one of the most populated countries (172,860,370 people) and one of the greatest economies in the world (IBGE, 2001); high indexes of activity in the insurance market would be expected.

¹⁷ Franquia: rate defined by contract that restricts the responsibility of the insurer, exempting it from the payment of small compensations.

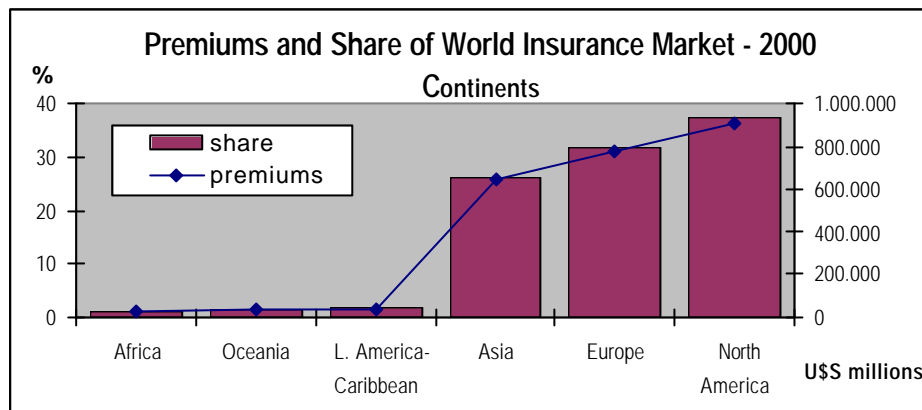


Figure 4.22 Distribution of total premiums (US\$ millions) and participation (%) per continent in the world insurance market in 2000. (Source: SwissRe, 2001).

However, the Brazilian private insurance market seems to be distant from the largest ones, even from countries with smaller population and GDP. In 2000, Brazil had only 0.51% of the world market (total premiums equivalent to US\$ 12,554,000), corresponding to 2.1% of its GDP and about US\$ 75 of premiums per capita (Figure 4.23) (World Bank, 2001; SwissRe, 2001).

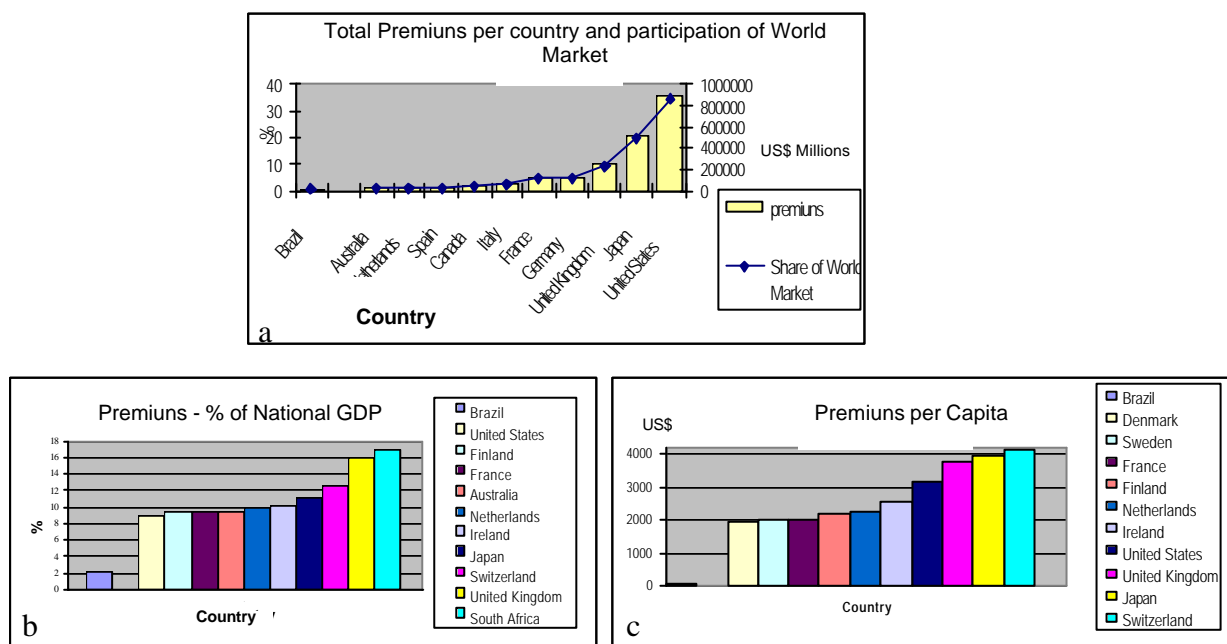


Figure 4.23 Brazilian and world private insurances markets in the year 2000, (a) total premiums per country and participation in the world market of private insurance; (b) percentage (%) of the total premiums in National GDP, and (c) total premiums per capita. Source: Swiss Re., 2001.

The total premiums of the Brazilian private insurance system, between 1994 and 2000, reached US\$ 80,471,880 (SUSEP, 2001), having had an increase of approximately 260% in local currency (Figure 4.24a). This increase could be related to an increase of the Brazilian GDP (total and per capita) since 1994, resulting from the political and economic reforms that started that year (Figure 4.24b) (BACEN, 2001)¹⁸.

¹⁸ In July a new currency called Real (R\$) was adopted as part of an economic policy that has hardly allowed to overcome years of very high inflation and no-growth economy.

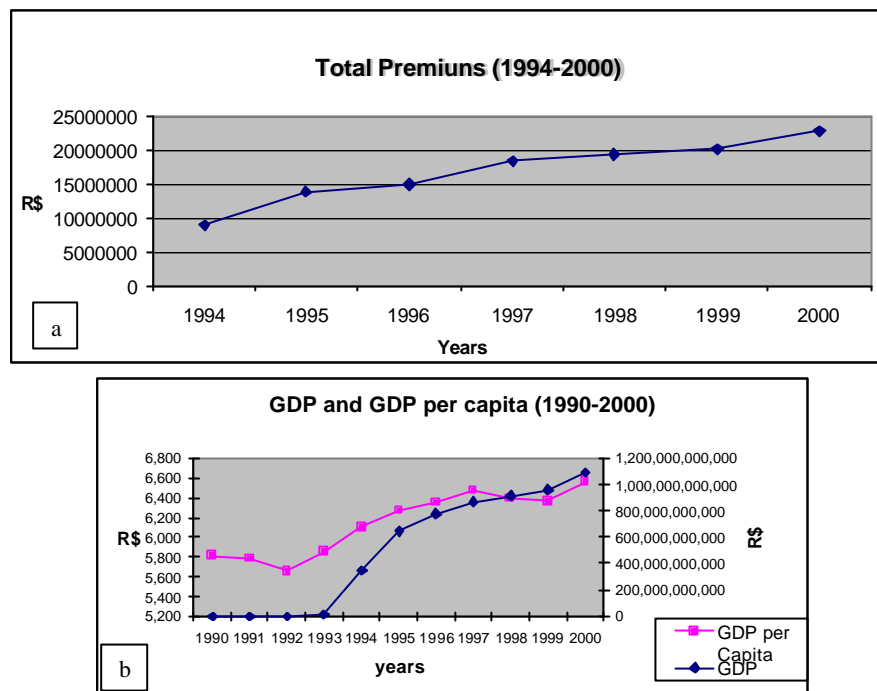


Figure 4.24 (a) Total premiums of the private insurance system (1994-2000) (source: SUSEP, 2001), and (b) the growing Brazilian GDP (total and per capita) since 1994 (source: BACEN, 2001).

Figure 4.25 shows several branches of the Brazilian private insurance system between 1994 and 2000. *Automobiles insurance* (33.96%), *life insurance* (16.41%), and *health insurance* (21.31%), can be mentioned among the most popular insurance types. In lower level, *fire*, *personal accidents* and *several risks* insurances can be mentioned. Several Risks insurance, with an average number of 5%, is the only coverage that presents a negative trend related to their market share. *Several Risks* and *Multirisk* insurances accumulated total premiums of US\$ 4,172,211 in the period 1994-2000 (SUSEP, 2001).

However, considering the huge territorial area, the diversity of natural environments, and the deep differences in economic and social development degree, the information and data should be carefully analysed.

The coastal states concentrated most of the Brazilian private insurance market, around 88% of the total premiums between 1996 and 2000 (SUSEP, 2001). They could be grouped in four regions, each one of them with its particular characteristics: (i) North (States of Amapá and Pará), (ii) Northeast (States of Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, and Bahia), (iii) Southeast (States of São Paulo, Rio de Janeiro, and Espírito Santo) and South (States of Paraná, Santa Catarina, and Rio Grande do Sul). There are profound differences among these regions. The SE and S regions, with a participation of 66.58% and 13.05% of the total premiums respectively, surpass the North region, whose coastal states only represent less than 1% of the insurance market activities (Figure 4.26). This would be

certainly related to the socioeconomic development of the SE and S regions that concentrate great part of the total population, the highest standard of living, and most economic activities in the country (IBGE, 2001).

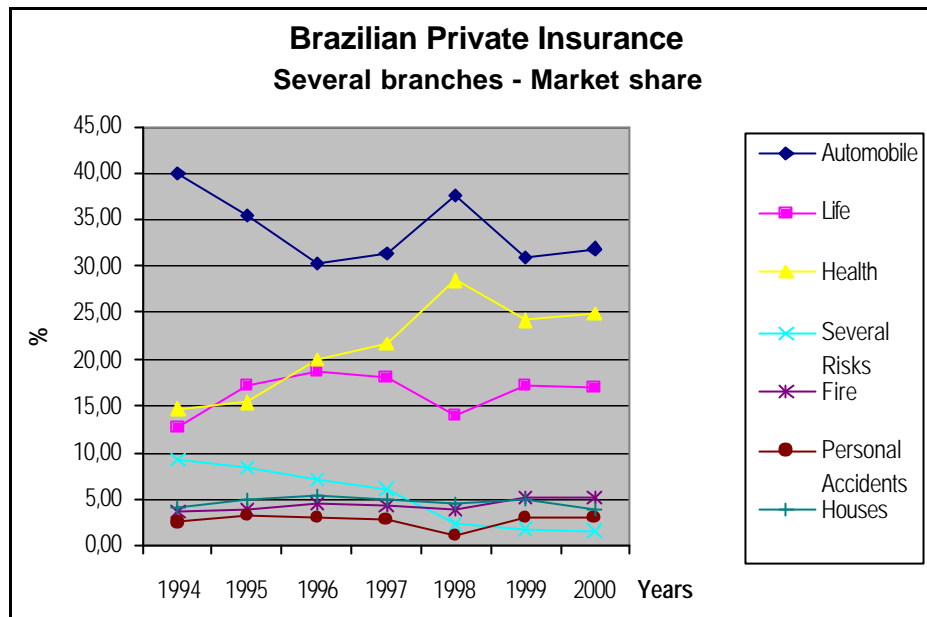


Figure 4.25 Market share of the main branches of the Brazilian Private insurance system (1994-2000). (Source: SUSEP, 2001).

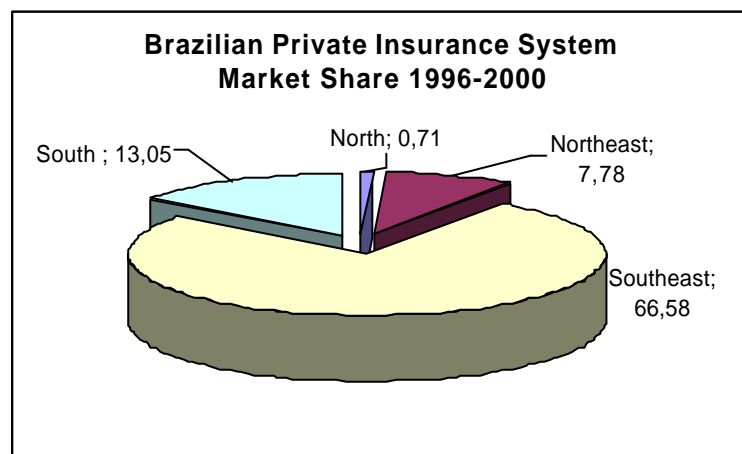


Figure 4.26 Coastal states (grouped per regions) share of the Brazilian private insurance market (1996-2000). (Source: SUSEP, 2001).

Unfortunately, there are not available economic data on the different types of insurance per State. Consequently, in order to analyse the behavior of the private insurance market against natural disasters in the coastal areas of Brazil, the coastal States' market share (1996-2000) has been adopted. According to it, "Several Risks" and "MultiRisks" insurance in the coastal states represent US\$ 2,220,258, and the State of Pará participates with less than 1% of the private insurance market, which means; only premiums about US\$ 18,000 are estimated by the *Several risk* and *Multirisk* insurances (Table 4.8).

Table 4.8 Estimation of “several Risks” and “multirisks” premiums (1996-2000) for each coastal State and region of Brazil.

Regions	Coastal States	Total premiums (1996-2000) – Market share of coastal states (%)						“Several Risks” and “MultiRisks” coverages Premiums (US\$)
		1996	1997	1998	1999	2000	mean	
North	Amapá	0.01	0.01	0.02	0.01	0.02	0.014	352.70
	Para	0.61	0.75	0.7	0.8	0.65	0.702	17,685.47
Northeast	Maranhão	0.26	0.26	0.26	0.21	0.2	0.238	595.93
	Piauí	0.06	0.1	0.08	0.12	0.09	0.09	2,267.36
	Ceara	0.73	0.72	0.79	0.73	0.74	0.742	18,693.19
	Sergipe	0.11	0.15	0.14	0.15	0.12	0.134	3,375.86
	Paraíba	0.17	0.16	0.2	0.22	0.18	0.186	4,685.89
	Rio Grande do Norte	0.17	0.25	0.25	0.25	0.25	0.234	5,895.15
	Alagoas	0.31	0.31	0.29	0.28	0.26	0.29	7,305.96
	Pernambuco	2.34	2.52	2.4	2.51	2.68	2.49	62,730.53
Bahia	3.19	3.4	3.13	3.34	3.83	3.378	84,900.36	
Southeast	São Paulo	47.58	47.87	48.11	47.97	49.33	48.172	1,213,596.60
	Rio de Janeiro	17.49	17.21	17.75	18.91	16.42	17.556	442,288.09
	Espírito Santo	0.75	0.86	0.94	0.86	0.85	0.852	21,464.42
South	Santa Catarina	2.51	2.64	2.71	2.4	2.33	2.518	63,435.94
	Paraná	5.39	5.4	5.4	4.88	5.07	5.228	131,708.93
	Rio Grande do Sul	5.85	5.35	5.26	5.45	4.63	5.308	133,724.37

4.2.3.5 People and Authorities Knowledge Level

Improving the capacities of the governments and communities that will be affected by coastal change so that they can understand the significance of the natural variability inherent in the systems that are changing and to appreciate that change, is inevitable. In this sense, the degree of awareness and knowledge about current and potential hazardous situations by local populations and decision makers is traditionally one of the main preventive adaptation measures that help to reduce the area vulnerability. The easily removable elements used by coastal populations to construct some of their houses, as well as the ability to periodically rise the structures over pillars according to the level of the water, are clear examples of adaptation measures based exclusively on the population autonomous knowledge, results of acquired experiences.

However, governments have to take the role of assuring that **all** inhabitants of potentially vulnerable areas have thorough knowledge about an expected sea-level rise, and its associated uncertainties through the provision of information about related risks (IPCC, 1990). In this sense, the Coastal Management Program of the State of Pará and its Municipal Districts collaborate establishing that the future development of the coastal area has to be based on a detailed knowledge of physical, urban and socio-economic characteristics. The Brazilian legislation also

establishes that it concerns to the States (Brasil, 1991) to guarantee the popular participation and its information about the decision made on environmental aspects (art. 253), and to promote environmental education and information in all levels (art. 255). Also, it clearly forces the municipal government to systematically inform the population on pollution levels, ecological disequilibrium and situations of risk (Maracanã, 1990; Marapanim, 1997). Unfortunately, as in the case of other laws, little has been done in order to implement them.

4.2.4 Retreat

Protection and accommodation measures prove to be the most viable adaptation options in extremely or rather densely populated and economically productive coastal areas. However, it is not always possible to use them as response strategies and measures. They are not usually chosen when these situations coincide in the same region: (a) natural hazard events of great magnitude and frequency that overcome the population's capacity of accommodation and protection, (b) areas of low population density and economic development, (c) the acknowledgement of the problem seriousness and the decision by the affected community and the government to abandon the area, and finally, (d) the existence of non-risky and unoccupied coastal or landward areas.

In those cases, the only possible strategy and measure is retreating. It consists of removing the structure from the waterfront moving it elsewhere, either in one piece or in sections, or demolishing the shoreline home, rebuilding it in a different place. Abandonment is also an economically sound option, especially where the cost of moving the building exceeds the building value. Retreats may be of two kinds according to (a) time: gradual and slow, or a sudden abandonment following a catastrophic storm, and (b) type of organization: autonomous, that arises in the own community, or a planned withdrawal at governmental levels.

4.2.4.1 Retreat Strategies - Study Cases

Although the retreat is not the most used option of adaptation strategy and measure, some cases are identified in the coastal zone of the north of the State of Pará, particularly, at the localities of "Vila dos Pescadores" (Municipality of Bragança), and "Praia do Crispim" (Municipality of Marapanim) (Figure 4.27).

a. Vila dos Pescadores

The town of "Vila dos Pescadores da Praia de Ajuruteua" is surrounded by mangroves and located in the mouth of a tide channel (furo Grande) close to the sea. There, as in other areas of the coast of Pará State, small communities of fishermen commonly settle down in close to the shore areas, which have precarious structures locally called "*Ranchos de Pescadores*" (fishermen

ranches). These one or two-room wooden huts (approximately 10 m² - 15 m²), are often the only place for fishermen and their families to live and work in (Figure 4.28).

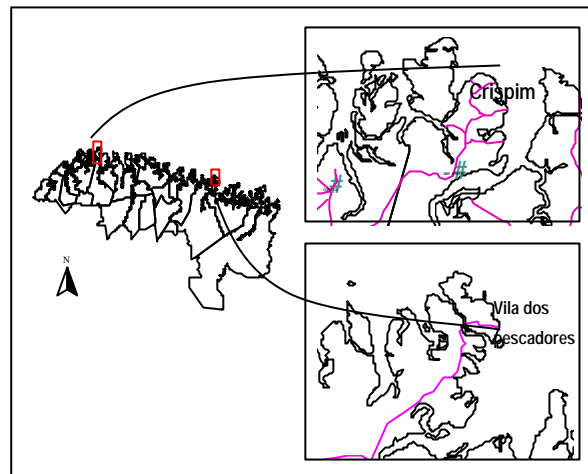


Figure 4.27 Study case areas of Crispim (municipality of Marapanim) and Vila dos Pescadores (municipality of Bragança).



Figure 4.28 Fishermen hut (*rancho*) in Vila dos Pescadores (Bragança).

As a strategy of autonomous accommodation, most of these “*ranchos*” are elevated on pillars for isolation from the sand heat, and mainly for the protection against the effects of high tides and surging water. However, in the last 30 years evidences of a growing process of marine erosion have been registered causing the loss of enormous beach areas in the region (Silva, 2001). Nevertheless, the adaptation measures used by the local population against the impacts caused by sea and wind action, have contributed not only to the destruction of the huts that are closer to the banks of “*Furo Grande*”, but also to the reduction of the town and work area (Maneschy, 1988; Santana, 2001) (Figure 4.29).

Consequently, for a long time, the fishermen and their families had repeated a cycle of small retreats and accommodations of their huts, in the same area of the island. However, in mid-1980, the local population of “Vila dos Pescadores”, due to the progress of the water, had to migrate to

other places (Nascimento, 2001). Maneschy (1988) reports that the residents, uncertain of how long the town would last, gathered together, talked about where they could move, and considered an area called *Ilha de Bonifácio*, about 4 km distant from the town. Up to that moment, the community had acted in an autonomous way¹⁹, referring to accommodation and retreat processes, but then they needed the government's help because the place where they intended to go had already had its juridical status changed being occupied by a great allotment project. The local population mobilization requiring the Government intervention for an agreement with the lot occupants guaranteed the relocation of the fishermen.



Figure 4.29 Position of the beach 10 years ago as stated by local people.

Currently, the following panorama could be described. The population is living in two towns; the remainder of population “Vila dos Pescadores” inhabitants, always aware of the likely necessity of lifting their houses, of repairing the damages or of deciding to abandon the area; and the inhabitants of the town of Bonifacio, far from the sea erosion, where the precarious "fishermen ranches" have given place to better quality wooden houses, provided with schools and health center, ice factory, electric power and other infrastructure facilities (Figure 4.30).



Figure 4.30 View of the main street of Vila Bonifácio, where electric power is supplied to houses, a school and a small hospital.

¹⁹ Autonomous adjustments are defined as responses to climate change and climate variability that households would choose when acting autonomously. It excludes responses that would require collective actions such as expenditure of public funds, changes in laws, public institutions, or programs, subsidies or tax policies (Learly, 1999).

b. Praia do Crispim

The Crispim beach, 146 km far from Belém, attracts many tourists on holidays and weekends; however, few people inhabit Crispim during the rest of the year, only fishermen. In the area, there are poor infrastructures (fishermen huts, inns, and bars).

There are evidences of wave action in the region, where the local population has taken accommodation measures (snack bars and houses built upon pillars), and in some cases, has used protection strategies (Figure 4.31). These measures turned out to be insufficient on the first days of February 2001 when big storms were registered at the beach of Crispim, with tide level raising around one meter above the mean high tide level of the month (Table 4.17). This hazardous event caused the death of a great extension of mangrove area, and affected the wooden constructions, more than 200 people, and part of a paved road. This disaster motivated the sanction of a decree of emergency situation (decree 23/01 of the municipality of Marapanim homologated by the ordinance 4524 from February 22).

Many relief programs strive to return communities to the status quo that is “*to get the community back to normal*”. Hence, communities are doomed to repeat the disaster-damage-repair-disaster cycle (Tobim, 1999). However, in this case, considering the seriousness of the situation and the unsuccessful protection and accommodation measures, the local population opted for implementing new adaptation measures against natural hazards. In consensus with the technicians of Civil Defense State Coordination of Pará, they decided to retreat the structures to an area located about 300 meters distant from the coastline, reusing the same material from the destroyed houses and bars (Figure 4.32).



Figure 4.31 Cement bags dispersed on the beach as an evidence of former protection measures accomplished by the local inhabitants. Behind them, new provisional construction.



Figure 4.32 Relocation area around 250 meters from the beach (arrow) surrounding the paved park area for tourists.

This planned retreat of the local population did not have a permanent character. Considering that the reconstruction efforts that only intend to restore the community to its level before the disaster often perpetuate conditions that create vulnerability (Confort et al. 1999), the residents committed not to establish structures immediately in the beach front for about three years. Time that they considered adequate to study behavior and variability of the coastal processes in the region (Figure 4.33).

c. Other Cases

The erosion processes have also happened on other beaches of the area, motivating the retreat of the residents or the definitive abandonment of several towns. In *Coroa Comprida*, at river Caeté bay, the population has been transferred by the municipal government to the town of *Peri Miri* in the Municipality of Augusto Corrêa (Santana, 2001); in *Vila de Tamaruteua* (Municipality of Marapanim), the inhabitants have had to move from the proximity of the shore to the center of the town; and in the community of Mocoóca (Maracanã), the fishermen have been retreating up to where they are able to, some of them moving to the *Fortalezinha* beach, and others, to the locality of *40 do Mocoóca* (Nascimento, 2001). In all these cases, the necessary costs for the migration and resettlement of the communities have been pay by the affected areas population.

4.3. Final Considerations

The possibility of climate change poses new challenges for adaptive management and adaptation options (IPCC, 1990). However, independently of the adopted strategies and measures, the predicted slow rate of sea level rise permits appropriate planning and incremental implementation of response options. Adaptive strategies may require decades of lead time to implement and tailor them to the characteristics of a particular coastal area in order to make the necessary analyses, train people, develop the plans, mobilize the public and create political awareness as well as support (Gornitz et al., 2002). Therefore, the adaptation processes should

begin today. It is evident that there is not only a single adaptation strategy and measure, but several of them are applied or can be applied in case of a natural disaster and/or sea-level rise scenario.



Figure 4.33 Temporary constructions with materials from the region used as bars for tourists.

Although some particular sectors of the coastal zone (huge areas covered by mangroves and wetlands, strongly protected by the legislation, with low demographic density, difficult access and lack of economic incentives for occupation) are favourable for the adoption of the “No Action” strategy, some other regions need to be protected.

In spite of the existence of small and little urbanized villages still unprotected, the municipal main urban areas have their shoreline protected against coastal erosion and flooding processes. Several types of walls are the main structures used by the residents and government in order to protect their properties, lands and infrastructures against the action of the sea. However, they have a limited success. The erosion and flood impacts continue in some coastal sectors as well as they begin and intensify in others. Coastal hazards not only destroy properties but also isolate and damage protection structures. However, property and infrastructure value is high, and, therefore, enormous sums of private and public money have been spent to stabilize inhabited water-front areas. These impacts and money expenses can be multiplied considering the global tendency toward a rising sea level, which is threatening to erode beaches and flood coastal areas (Clark, 1995).

The relative success of the engineered protection works in the coastal zone of the State of Pará do not stop them from making part of the adaptation measures set that will be adopted as part of the Coastal Management Program, even in a global change circumstances because (a) there are many urban nuclei that will hardly be removed, even at the evidence of imminent risk²⁰; (b) the high value of oceanfront property leads to extreme pressure on the government to allow development

²⁰ The Federal Constitution of 1988 (Brazil, 1991) allows the establishment of procedures for expropriation in the case of imminent public danger by fair and anticipated reparation (art. 5^o-XXV) in order to guarantee safety social right for the population (art. 6).

despite the presence of coastal hazards and risks; (c) considering their visibility or the lack of knowledge of other possible measures, the hard defenses are often regarded by people as being the ultimate saviour when land or properties are at risk, unfortunately creating a false sense of security; (d) they are measures of relatively fast execution; (e) to deny owners the right to protect their property might well be seen as unconstitutional, and finally (f) the politicians can show their supporters a concrete work whose construction gets important financial resources and creates job opportunities in undeveloped areas.

It is important to say that while the national and state coastal management programs (Federal Law 7661/89 and State Law 5.887/95) delegate most actions to the local government, little can be done due to insufficient budgets, and to the portion of the budget that represents the cost of the structures (Table 4.9). Considering the high cost of protecting selected portions of the coast, the municipalities seem to be in absolute dependence on state and federal monetary resources. This means they do not have complete control on the decisions about the response measure to be adopted, which often, gives more attention to political particularities than local needs.

Table 4.9 Construction cost of hard structures and their part in the municipal budget. (Source: TCM, 2001).

Locality	Value (US\$)	Municipal budget (US\$)	% of Annual Budget
Curuçá	110,000	1,978,723	5.56
Santarém Novo	128,480	1,168,172	11
Magalhaes Barata	110,000	385,855	28.5
Marapanim	40,000	3,060,000	1.3
Quatipuru	20,000	1,147,040	1.75
Maracanã	80,000	2,475,341	3.23

The estimated costs for protecting the whole shoreline of the NE coastal area of Pará, approximately US\$ 2,8 billions (about 2,400 km of coastal line at a cost of US\$ 1,153 km), and the existence of many areas little developed or even uninhabited are the biggest incentives to examine the possibility of using other response strategies. In many cases, a process of gradual and strategic retreat or accommodation as a quite reasonable alternative (IPCC, 1994).

Many of the adaptation options are likely to be influenced by prevailing social norms, or to be subjected to legislation, principally those that may encourage, restrict or totally prohibit the land use or occupation of coastal areas (El-Raey et al., 1999). In the NE coast of the State of Pará, a great part of the regional and urban land use and occupation is intimately related to natural environmental conditions, and much of its regulations in the coastal areas, are associated with tidal patterns.

The contents of the state and coastal municipalities' laws could be interpreted as the official authorities' awareness of erosion and flood hazards effects. Legal zoning or land-use policies and regulations established there enable an orderly and equitable occupation or pullback from the most vulnerable areas. However, this is clearly not enough to diminish risk for the population. Although there are already adequate institutions and legal frameworks to plan and implement these adaptive responses, they do not completely fulfil their objective. Two important aspects contribute to this situation (i) the land and natural resources appropriation in the coastal zone of the state of Pará and (ii) the non-implementation or monitoring of the already existent laws.

On the one hand, the Federal Constitution (Brasil, 1991) explicitly considers the coastal areas (maritime beaches, coastal and oceanic islands), the "Terras de Marinha" and their contiguous reclamation areas as part of the Brazilian national patrimony (art. 20). All the other coastal oceanic areas and islands that do not belong to the Nation or to private people are included among the property of the state and municipal districts (art. 26). Therefore, in practice, there is a complex framework of executive ministries, secretaries and organisms that regulate, manage, and control natural resources, land use, and human activities (Table 4.10). This circumstance frequently produces several legislation gaps and/or contradictions among federal, state and municipal levels, deeply hindering the elaboration and execution of adaptation response measures for the effects of natural processes.

Table 4.10 Levels and organizations that legislate and regulate coastal use and activities.

Administration Levels		
Federal	State of Pará	Coastal Municipal Districts
Congress	Legislative Assembly	Councilor Chamber
Treasury	State Treasury (SEFA)	Municipal Treasury
Environment ministry – federal Environmental Agency (IBAMA)	Science Environment and Technology Secretary (SECTAM)	Environment Secretary
Sports and Tourism ministry – Tourism Institute of Brazil (EMBRATUR)	Tourisms Company of Pará (PARATUR)	Tourism Secretary
Agriculture Ministry	Secretary of Agriculture (SAGRI)	Agriculture Secretary
Science and Technology Ministry (MCT)	Executive Secretary of Urban and Regional Development (SEURB)	
Transport Ministry – National Department of Roads (DNER)	Executive Secretary of Transport (SETRANS)	
The Federal Heritage Office (SPU)	Land Regulation Institute (ITERPA)	
Planning and Budget Ministry		
Navy Ministry		
Secretary of Urban Development		
National Integration Ministry		

On the other hand, enforcement of law is a crucial problem. According to Anann (1999), disaster and vulnerability reduction legislation is not sufficient and is useless if not effectively and impartially enforced. Studying the implications of global change in the Brazilian Amazon area, Laurence (2000) describes the weak enforcement of legislation as a “chronic” problem, a great problem that also extends to the put into effect of restrictions on coastal development (Figure 4.34). The municipalities in Brazil now enjoy significant territorial zoning and planning autonomy (Diegues, 1999), however, the weak enforcement of law can have origin in (i) political aspects as lack of coordination between government agencies in charge of coastal management, environmental protection or urban planning; (ii) economic characteristics such as the very strong pressure by the lobbies for tourism, land speculation, and construction, and (iii) cultural behaviour of the developing countries, where the rules are enforced only when the people agree to it and believe that it will bring them some benefit (El-Raey et al., 1999).



Figure 4.34 The problem of land use law enforcement in the coastal areas. Announcement by the Federal Heritage Office (SPU) indicating (in red) that the area belongs to the federal government and consequently, the occupation is forbidden.

In spite of these problems, in the coastal area of the State of Pará accommodation strategies based on the land use legislation; prohibition, limitation and/or restriction on vulnerable areas occupation have been observed.

It is certainly unwise to allow development of property that will probably be lost to the sea, especially when the security of buildings so often creates demands for private or public money to be spent on protective works. Therefore, coastal management programs and urban regulations should attempt to have structures located behind a setback line. However, it is important to highlight that, with the exception of the closest strips to rivers and channels in Belém (“*Non Aedificandi*” Areas), there is not any kind of legal prohibition from building in vulnerable areas or reconstructing in the same place, once affected. The setback line municipal regulations only limit the type of construction, generating a transition zone (buffer) between the water and upland

property, within which the natural processes may act causing small damage to properties, also anticipating some effects of sea level rise.

If some kind of development already exists in vulnerable areas of the coastal zone, private or not, all governmental levels have the authority to expropriate land and property, but only upon providing compensation to the owners of coastal land and property (Brasil, 1991, Maracanã, 1990; São Caetano de Odivelas, 1991. Curuçá, 1990, Magalhães Barata, 1990; Viseu, 1990, Bragança, 1990). Considering the lack of financial resources, these measures are difficultly carried out, with the exception of extreme emergency events. Consequently, this approach could be only implemented through the conversion of land ownership into long term or conditional leases which would expire when the sea reaches a certain level.

Another course of action is the establishment of protection and conservation units, as mangrove areas, is a way to prevent and restrict human development in coastal zones. For these kinds of area with low population density and little human development, the IPCC (1990) suggests that the adaptation strategy could be to leave the mangrove areas to their natural processes, enabling them to migrate inland as the sea level rises. This inland migration would possibly have many particular consequences on population (Figure 4.35).



Figure 4.35 Newspaper report informs about mangrove migration; headline “Mangrove takes revenge of the Maruda beach” (O Liberal, December 13, 2000).

Coastal management programs tend to adopt a short-term view, recognizing frequent changes, but are quite unprepared for medium to long-term changes (Pethick, 2001). However, considering the narrow relationship with environmental variables, the implications of a global change scenario, and potential relative sea level rise, land use regulations must have flexible limits, which may vary with time (Charlier and DeMeyer, 1997; Bird, 1993). Therefore, Gornitz et al. (2002) suggest that in vulnerable regions in New York City metropolitan area, new constructions would only be permitted landward from the area expected to erode within the next 30 or 60 years. Clark (1995) also states that the setback lines, for example, may need to be

recalculated every 5 to 10 years. The idea of a dynamic and evolutionary urban planning (Meirelles, 1993) is also supported on the Urban Master Plan of Belém (art. 2) that expresses that it should be successively adapted to the community demands and to the local progress, in a permanent process of planning.

Development in vulnerable areas would not presumably occur if authorities and population were not willing to accept the risks. However, if people continue to live there, the government must be prepared to take the necessary actions to ensure public safety. SINDEC is a frequently used tool for natural disaster prevention and mitigation in the State of Pará; therefore, it should be fully considered in the implementation of governmental plans for adapting to potential impacts of sea-level rise on the coastal zone. Unfortunately, up to the present, research and interviews in the three levels of SINDEC indicate little or no concern to adapt and get ready to face the potential impacts of climatic change and particularly of sea-level rise.

SINDEC is a complex system that regulates the elaboration, approval and recognition processes of emergency situations. Some operational problems could have the origin in the fact that it has been created in order to assist the necessities of the whole country, paying no attention to regional characteristics. Due to the Amazon region particularities - enormous areas with lack of communication services and difficult access - to fulfill all the steps and deadlines established for SINDEC, so it has become a difficult task, even worse in natural disaster periods.

Repeated emergency and calamity ordinances provoked by similar natural hazards in the same region indicate, among other things, that prevention activities in order to diminish the vulnerability are little used. The high percentage of emergency situations decrees (78.5%) in the state of Pará (1992-2001) suggests that most disasters have caused “tolerable damages”, that is, damages of reversible character or of easy recovery. At least more than 200,000²¹ people have been affected by natural hazards impacts - a high number of people as compared to economical damages. These data must be carefully analyzed because sometimes loss estimates are inflated to qualify for disaster assistance.

For the near, much research foresee global climatic changes that will affect the type and the geographical distribution of the natural processes, increasing their frequency and magnitude. Consequently, mitigation measures should be adapted to this new reality. The relationship between the insurance systems and the potential changes are being studied by several institutions (Berz, 1999; Brauner, 1998; SwissRe, 1996) and researchers (Hudgens, 1999; White and Etkin, 1997; Leigh, 1998). Among the main conclusions, they highlight the exceptional ability of the

²¹ The decrees indicate 16,229 people and 47,631 families (average of 4 persons per family) affected. Not all the ordinances indicate the number of affected people.

insurance industry to adjust the new circumstances and to respond to the menaces of climatic changes in reactive ways (increasing prizes, leaving areas of high risk, transferring risks to reinsurance companies) and in pro-activate ways (distributing educational pamphlets, developing products that encourage disaster mitigation measures and investment in efficient energy generation, promoting the execution of an appropriate construction code and zoning in currently vulnerable areas). In Brazil, there are not any references to the theme.

Although considerable uncertainty surrounds the details of the impacts of climate change, some considerations can be expressed about insurance as an adaptation measure.

Considering that governments facing financial inadequacies are unable to invest in natural disaster emergency and relief as desirable, FUNCAP has a very important purpose; it is a public insurance system that supports the civil defense system and helps post-disasters mitigation activities. However, the federal government has demonstrated little interest in contributing to this fund, what makes other possible financing sources imitate this behaviour.

In order to get an appreciation of how increasingly Brazilians are using the private insurance system to protect them against natural hazards impacts, one must look at historical and current data. Unfortunately, compilation of reliable national or even regional disaster loss statistics is a notoriously difficult task. Much of this information is not well documented or available, and it is also grouped with other data hindering the statistical analysis of SUSEP's information.

IPCC (1990) recommends private insurance coverage in vulnerable areas as an important way to compensate injuries and damages caused by natural disasters. It forces people to consider whether risks are worth taking and provides the necessary funds to repair damages and compensate innocent victims. However, access to private insurance, as a means of adaptation to natural hazard impacts and climate variability and change, is severely limited for most Brazilian population. Possible reasons that explain this situation could be (a) the non-planning future population's culture; (b) the lack of wide information diffusion about insurance benefits, (c) the idea that characterizes Brazil as a country with low-level risk, and (d) the basic needs of the society, still not supplied, indicating other priorities for monetary resources.

Other great obstacles for the Brazilian private insurance system against natural hazards relate to:

- The lack of qualified personnel and consultation sources of information (e.g. vulnerable maps) to allow the assessment inspection on the site and items to be insured. These data should be permanently updated and carefully consider the climate change impacts predictions.

- The certainty of receiving of public help after a disaster often inhibits responsibility from potentially affected people for protection of their belongings, neglecting the adoption of prevention measures and rejecting insurance acquisition.

Nowadays, the population autonomously adopts most of the response measures, based fundamentally on the practical knowledge of the local conditions. Direct governmental work is barely observed for lack either of administrative structure or employees that many times act without technical training and/or necessary scientific information. However, the present characteristics of natural processes (beach erosion and coastal flood) are bound to suffer important modifications according to global climatic changes, invalidating much of the experimental knowledge obtained in the past. Therefore, more scientific research on climate change scenarios and impacts, as well as directing awareness is needed, because they have extreme importance in order to overcome future adverse impacts of sea level rise. It doesn't mean having to choose between autonomous or technical/scientific kind of knowledge, but combining both. Although experts and decision makers could have great technical skill and enough amount of information, it is particularly important that members of the affected communities are consulted and participate in the decision to adopt appropriate options as their involvement in implementing response options is also essential for the success of adaptive responses.

Although little used as a planned strategy, retreat has become in a fundamental policy and based on the socioeconomic and land occupation characteristics of the coastal zone of Pará it could be adopted among the spectrum of adaptation responses in case of sea-level rise. This way some considerations about current and future use of these instruments should be carried out.

Most of the fishermen that inhabit the coast of Pará choose the moment to migrate to new areas considering the availability of natural resources and, principally, the capacity to cope with natural processes. The statement of a fisherman from *Vila dos Pescadores* (municipality of Bragança), "*I will stay here until the moment that the sea determines*"²² (Nascimento, 2001), reinforces the idea that in the local population's conception, few things could be made against natural phenomena and therefore, the option is to retreat from these areas.

Heather (2001) describes that the obvious advantages of relocation are that the beach is preserved, and the property owner and community save costs when moving in a one-time expense, whereas hard and soft stabilization approaches are a continuous expenditure. However, all retreat options have been identified as having potentially significant social and cultural implications, particularly when individual or community's identity is closely associated with a specific piece of land or access to a resource, as in most subsistence economies. In spite of the

²² "*Fico aqui enquanto o mar determinar*"

low population density, for the low-income local population of Pará, the greatest implications of retreat may lie on the difficulty to find, nowadays, “free” areas to resettle whole population, next to the natural resources (most of the areas are private or public properties). This problem is clearly expressed by a fisherman from *Vila dos Pescadores* (Santana, 2001), “*While there is space on the beach, we will stay at the beach, because my work is here, and I am not going to move to an other area inland because all the places already have owners, and the one that remains is far away from my work*”²³. If nothing is done, people may choose not to abandon even vulnerable coastal areas if there is strong population pressure in adjacent areas and/or if they have to migrate far from their natural habitat, certainly to the periphery of urban areas. Consequently, there will be some social problems in case of future scenarios of climate change impacts and development on the coastal zone.

²³ “*Enquanto houver espaços na praia, a gente fica na praia, pois o meu trabalho é aqui e não vou a mudar para a terra firme, porque todos os lugares já têm dono, e o que resta é longe do meu trabalho*”.

CHAPTER 5

CONCLUSIONS AND PROPOSALS

The present study aimed to analyze how the natural hazards and relative sea-level rise issue can be incorporated into broader contexts of a *long-term* integrated coastal management program for the NE of the State of Pará in order to support, with scientific and methodological basis, planning of state and municipal governments.

The methodological approach is based on: (i) review of the scientific literature, on historical and journalistic records about disaster events, and their consequences, and on planning and management strategies, and other government information, (ii) analysis of the regional vulnerability to natural hazards as erosion and flood, through the elaboration of a GIS-based index, and (iii) collection of data on field works and interviews with local populations and different decision-makers.

Based on this review, analysis, and activities, it may be concluded that:

- Among other conflicts, the problems related to natural hazards, particularly erosion and flooding are already significant in many parts of the NE coastal zone of the State of Pará. Their impacts, although not economically quantified yet, are evident in the main urban centers (e.g. Salinas, Marudá).

- Although launched in 1995, the Coastal Zone Management Program of the State of Pará has only accomplished the preliminary stages, and consequently, there is still a clear need to determine the priorities for action at local and regional levels. A conceptual framework of “*relative constancy*” - socio-economic and environmental (climate and other physical aspects) variables are relatively “stable” - has lead to the elaboration of *short-term* coastal management.

- Clearly, the gaps in the present knowledge on coastal zone natural and socioeconomic processes and the uncertainties of current global change models do not completely enable a clear definition of present and potential effects. However, evidence is enough to recognize the following factors as producing increasing pressure factors on the coastal zone. The sea level rise (global and relative) impacting on a low lying coastal topography, the growing human population and development scenarios - based on large-scale socioeconomic parameters, changes in the production strategies, and new and better infrastructure - are considered as pressure factors on the coastal zone system of Pará for the next 50 to 100 years.

- In general terms, the coastal zone of Pará has a relatively high vulnerability to natural hazards, being large in some coastline regions such as the urban areas of the

municipalities of Viseu, São João de Pirabas, Salinópolis, Marapanim, Maracanã, Bragança, Tracateua, Quatipuru, Curuçá, Augusto Corrêa, São João da Ponta, and São Caetano de Odivelas, as well as the districts of Fernandes Belo and São João do Piria (municipality of Viseu), Japerica (municipality of São João do Pirabas), Caratateua, Nova Mocajuba and Tijoca (municipality of Bragança), Aturai, Emborai and Ipixuna (municipality of Augusto Corrêa), Boa Esperança and São Roberto (municipality of Maracanã), Ponta de Ramos, Lauro Sodre and Murajá (municipality of Curuçá), and Marudá (municipality of Marapanim). Considering the potential scenarios of global climate change and regional and local human development, future changes in the spatial distribution, and an increase in the magnitude of coastal vulnerability to natural hazards could be expected.

- Despite the limitation in the data availability in the region, the GIS-based index allowed the identification, confirmed by field validation, of more sensitive regions in order to bring them to the attention of the state and federal governments, and for data storage and management in a friendly GIS environment. Further a data base was created.

- Most of the fishermen that inhabit the coast of Pará have chosen *retreat* as an important strategy. Migration to new areas depends on the availability of natural resources and, principally, on the capacity to cope with natural processes in the original settlements. In spite of the low population density, for the low-income local population of Pará, the greatest implications of retreat may lie on the current difficulty in finding “free” areas to resettle whole populations, next to natural resources (most of the areas are private or public properties).

- In spite of the existence of small and little urbanized villages still unprotected, the municipal main urban areas have their shoreline protected against coastal erosion and flooding processes. Several types of walls are the main structures used by residents and government in order to protect properties, lands and infrastructures. They have a limited success, thus erosion and flood impacts continue in some coastal sectors, and begin or intensify in others.

- Natural processes knowledge and possible adaptation response to the impacts by the local population are mainly based on their own experience, not taking the possibility of potential climatic changes and sea-level rise into consideration. The scientific and technical knowledge is not often used in the implementation of concrete adaptation measures.

- Prevention and principally mitigation activities by the public emergency relief system (SINDEC) is considered one of the main strategies employed in the region in order to coexist with natural hazard problems. Among the total number of States of Emergency and Calamity ordinances in the last 10 years, those happened on the coastal zone of Pará were in the Municipalities of Soure, Marapanim, and Augusto Corrêa.

- There are already adequate institutions and legal frameworks to encourage, restrict or totally prohibit land use or occupation of coastal areas in the State of Pará. However, the complex structure of ministries, secretaries and organisms that regulate, manage and control natural resources, land use, and human activities, as well as the enforcement of the laws are crucial problems in the region.

- Insurance system against natural disasters is an accommodation strategy and measure in spite of being little used in Brazil, particularly, in the North region. On the one hand, the public system (FUNCAP) does not have the necessary financial resources to develop its activities, on the other hand, the population has a great difficulty in accessing the private insurance system due to ignorance, high costs, or the own companies lack of interest.

On the base of these conclusions, some proposals for the coastal zone management program of the State of Pará are recommended. An important challenge is related to the possibility of establishing propositions that can function in the presence of gaps in information and understanding. It would be clearly unrealistic to delay the utilization of coastal zones and their resources until all data have been obtained. However, decisions must be avoided which could have irreversible consequences, or seriously threaten the resource base over a long term, or exclude options for future generations to utilize coastal and ocean resources. Therefore, it is suggested that the following elements are required:

- To integrate the *natural hazards* issue to the coastal management of the State of Pará

Although, it has been stated that important consequences are not expected due to the low density human occupation in the North coastal area of Brazil (Muehe and Neves, 1995), several evidences of natural hazard impacts are described in the present work. Considering potential scenarios of sea-level rise and human development, these impacts, now affecting economic activities, houses, and infrastructures, can significantly worsen. Therefore, an important aim of the coastal zone management of the State of Pará should be to

definitively integrate the knowledge on coastal hazards and risks into planning guidelines for the region.

- To transform the *short-term* coastal management into a *long-term* coastal management

It is important to define when the best moment to adopt adaptation strategies and measures is. Although each strategy and measure has its own characteristic, in general terms, a strategy of *preventive adaptation* should be preferred. Preventive adaptation usually depends on the level of public and scientific awareness of possible future changes in climate and human development; however, even if there is considerable consciousness, interest conflicts may oblige policy-makers to choose between climate change adaptation policies and other public policies. Clearly it is necessary to consider the climate change issue and its potential consequences in the context of other problems that affect people's lives in the coastal region. This could be achieved by transforming the *short-term* coastal management in a *long-term* coastal management that can consider 50-100 years future scenarios.

- To use smaller analysis and territorial planning units

At present, the coastal management program of Pará is based on municipal limit units. However, considering the large extension and the diversity of natural and socioeconomic characteristics in some of these municipalities, as well as the results obtained from the vulnerability analysis, the adoption of smaller analysis and territorial planning units (e.g. Census Collection Districts) is suggested.

- To incorporate new variables to the Composite Vulnerability Index (CVI)

The GIS-based Composite Vulnerability Index allows flexibility for using a wide range of data. Therefore, it can be condensed to focus on fewer factors or can be expanded to include deeper analyses according to the data availability and needs of the research. In this study, it is recognized that many other factors could be used as components of the CVI, such as women population, population growth, high-resolution elevation data, climatic and oceanographic data, and erosion and resilience rates.

- To intensify the use of the GIS-based Composite Vulnerability Index (CVI)

The results obtained by CVI are confirmed by field validation. Therefore it is possible to plan to use these indices for (i) identifying vulnerable sectors in areas previously classified as non-vulnerable on a large scale analysis, (ii) adapting the index to detailed studies, (iii) repeating the vulnerability assessment process in all municipalities that integrate the Coastal Zone Management Program of the State of Pará, and (iv) developing predictive impact models (e.g. assessment of the population at risk using trends of population change).

- To implement adaptation response strategies and measures

In the study area, adaptation response strategies and measures to natural hazards and sea level rise impacts have been described and analyzed according to the IPCC classification: *no action*, *protection*, *accommodation*, and *retreat*. In order to subsidize the Coastal Zone Management Program of the NE of the State of Pará, it is important not only to make proposals that permit implementing new strategies and measures, and modifying and improving those already existent, but also to indicate the best places (by Census District) to implement these strategies and measures. Among the proposal related to adaptation response measures can be mentioned:

- To improve the design and construction of hard stabilization measures

At present, most of the engineered work built principally by the own residents and sometimes by the governments, lack many technical specifications and result in ineffective protection measures. It is necessary not to repeat the same mistakes. Thus a more active presence by the State in work design, construction or inspection stages, independently of the origin of the resources, is fundamental. An important point, in consequence of the territory extension and of the difficult access to many regions, refers to the possibility of gradually transfer knowledge, responsibilities and budget from the federal and state governments to the municipal Secretaries of Public Works.

- To use soft stabilization measures – beach nourishment techniques

Some of the properties in dune areas on Atalaia (municipality of Salinópolis) and Ajuruteua (municipality of Bragança) beaches periodically suffer the consequences of wave energy. In many occasions, the water “path” is facilitated due to the illegal

removal of sand and lateritic stones (Barreiras group) from the front of the properties in order to be used in local constructions. The adopted measures relate to the construction of buildings far from the shoreline, and to the use of natural berm as a protection means. However, they still suffer the impacts of spring tide events (Figure 5.1 a-b). For these areas, it is possible to propose the use of soft-engineering measures as beach nourishment, artificially adding sediment to the top of the beach profile and/or to the base of the cliff, allowing the constant rearrangement of this material.

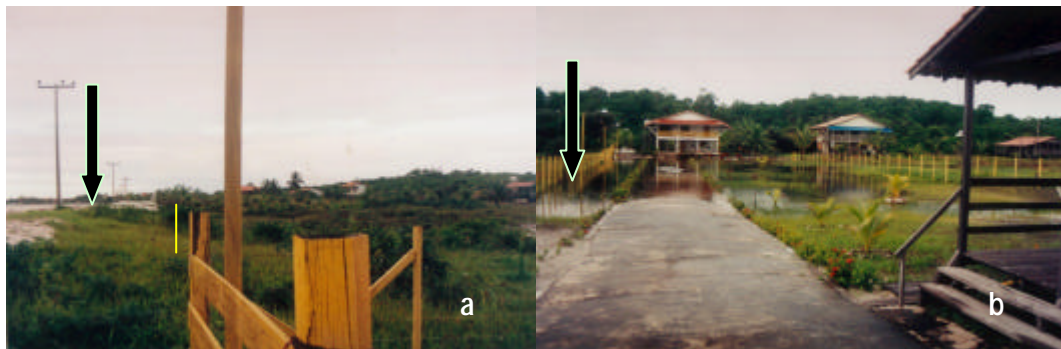


Figure 5.1 Adopted measures against the water action as houses setback and the use of the berm as protection (a) black arrows indicate the berm and properties position, and the yellow arrow, the difference of height between them. (b) Unfortunately, a view from the berm shows that they are not adequate in periods of storm and potential sea-level rise.

- To define a “*transition zone*” in the conservation units

Although many populations located on the wetland limit and their property rights would be affected by mangrove landward migration as the sea level rises, the pressure on these sensitive ecosystems will be larger considering the regional development scenario, and the now closer contact with human settlements and activities (e.g. tourism and fishing). Therefore, the protected areas must be buffered, delimiting a “*transition zone*” or a less intensively used area between mangroves and neighbouring populations (Wehrhahn, 1998). A “*transition zone*” is part of the Brazilian System of Conservation Units (SUC), and is defined as the portion of territory and jurisdictional water adjacent to a conservation unit, which are subject to restrictions on use with the purpose of reducing impacts on the protected area, as a consequence of human action in the neighboring areas (law 2892/92). The boundaries of the transition area should be established simultaneously with the creation of the conservation unit, or during the development of the management planning. In 1990, the 13th resolution of

CONAMA (National Environmental Council) already determined the creation of an area of 10 km² around conservation units. Figure 5.2 shows an example of the proposed transition zone for the NE coast of the State of Pará.

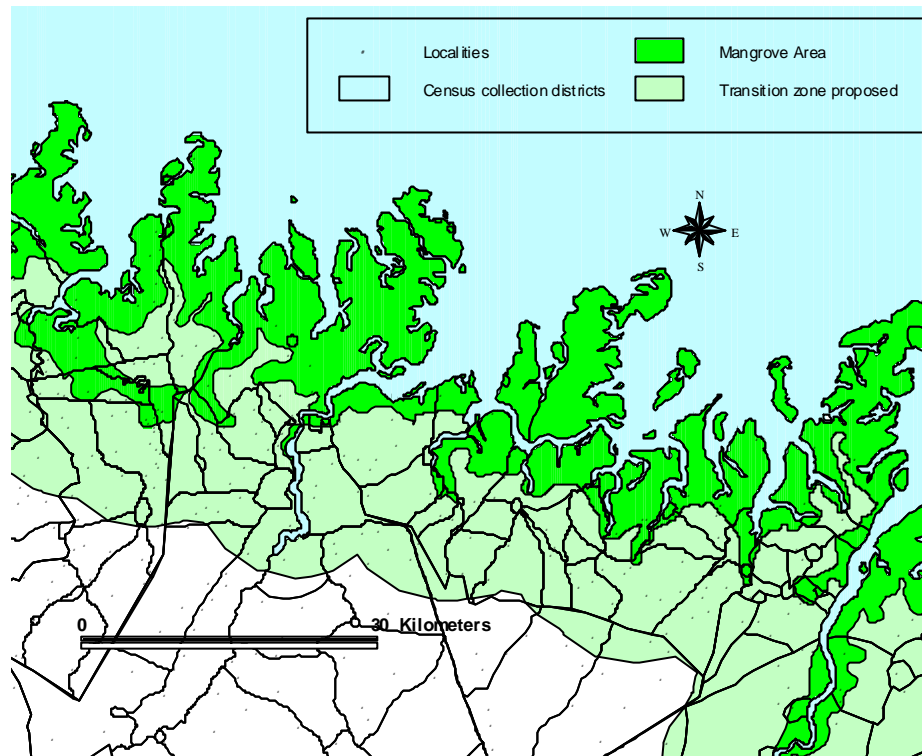


Figure 5.2 Considering the possible conflicts “human activities-mangrove ecosystems”, it is proposed the creation of “Transition Zones” next to conservation units .

- To improve the Emergency and Relief System

SINDEC is a frequently used tool for natural disaster prevention and mitigation in the State of Pará; therefore, it should be fully taken into consideration in the implementation of governmental plans for adapting to potential impacts of sea-level rise on the coastal zone. In order to improve the emergency and relief system in the State of Pará, some measures should be considered, such as to motivate the government to (i) implement more preventive measures (information for the population, alarm systems, etc.) to the detriment of mitigation ones. These measures still have great significance considering a scenario of low rate relative sea level rise; and (ii) create a larger number of civil defense municipal or inter municipal commissions (COMDEC)¹. Considering the territorial extension of the State and the lack of appropriate transport and communication means, this would

¹ 24 % of the municipal districts of the State of Pará only have a municipal commission of civil defense (COMDEC) (Source. Ministerio de Integração Regional, 2002. available at web: www.integracao.gov.br).

allow the members of the municipal commissions to be closer to vulnerable areas, and to better know about the reality and necessities of the local population. Therefore, they could improve the execution of prevention and mitigation activities. At present, in most cases, the commissions are created temporarily, only for the period when the recuperation activities are going on.

- To increase the financial resources

Although the lack of economic resources is well known in all government levels, in order to prevent and to mitigate natural hazard impacts in the coastal zone, it is fundamental (i) to look for a permanent supply of financial resources for FUNCAP, and (ii) to increase the portion of the national and state budgets destined to civil defense systems, and federal and state coastal management programs.

- To adapt the Insurance Private System

The Superintendence of Private Insurance of Brazil (SUSEP) has the competence to implement new insurance modalities, as well as to suppress and/or modify existing ones according to the society and market requirements. This SUSEP's capacity has capital importance in changing scenarios. Therefore, it is necessary to consider the possibility to (i) incorporate other natural hazards as origin of damages (e.g. storm surge, frost and low temperature processes), and (ii) revise some articles of the contract, as the "Replacement Clause", which compensates suffered damages in order to restore the property to its previous condition, mostly in a endangered place.

- To adjust technical parameters of the laws to the new scenarios

The coastal management of the NE of Pará must be prepared for medium to long-term changes and for the probable occurrence of natural catastrophes that can be unprecedented in their severity and frequency. Therefore, the possibility of periodical revision - 10 to 15 years - on the environmental parameters of the land use zoning legislation (e.g. setback lines) and insurance norms (e.g. the wind velocity that indicates a *windstorm*) must be contemplated. A good example is the changes in the delimitation of *Terras de Marinha*, already in development, that will allow a better implementation of land use regulations in the coastal area.

- To improve people and authorities knowledge

It is essential to carry out a real program for population and decision-makers education regarding the impacts of sea level rise and ongoing activities so that everyone understands the risks of development in coastal areas and tries to adopt the necessary adaptive measures. There are several types of formal and informal education. They involve a spectrum that goes from traditional school education, community meetings, and technical visits to local areas, distribution of brochures and notes, and even the specification of technical aspects.

The technicians' building capacity to transfer existing coastal adaptation technologies, and to provide training on coastal zone management, engineering and environmental monitoring is very important. Such training might also include technological advisory committees, research on development, conferences, as well as pilot projects to enhance technology transfer. Many times this help can be offered by more developed regions in Brazil.

- To modify the “retreat concept”

Although at present, most of the small-scale processes in coastal zones have been described as “autonomous” and “spontaneous”, this status must be changed into governmentally coordinated planned measures. In other words, if the government opts for a “retreat policy”, it will have to consider ownership and land use measures in the proximity of the coastal area that assure the most similar or best conditions to those that have existed previously (e.g. Vila Bonifácio, in Bragança).

- Spatial distribution

As a final result of the present study and one of the most important contributions to the Coastal Management Program of the State of Pará, the following spatial distribution is suggested for the implementation of strategies and measures (Figure 5.3). In this map, the most suitable strategies and measures for each one of the planning and management units (Census Collection Districts) are indicated, without excluding other strategies and measures cannot be implemented, simultaneously or not.

In the regions that are next to the coastline or flooding areas, poorly inhabited (less than 600 people), with difficult or nonexistent terrestrial access, and where the

natural vulnerability index is higher than the socioeconomic one, the **non action** strategy (not to interfere in the action of the natural processes) is suggested. Some exceptions are indicated in areas with important tourist activity (e.g. Algodual Island, municipality of Maracanã).

In the regions that are next to the coastlines or flooding areas, moderately inhabited (total population over 600 people and under 1500 people), with difficult terrestrial access, and where the natural vulnerability index is higher than the socioeconomic one, the recommended option is to implement planned **retreat** strategies and measures.

The implementation of a **protection** instrument (hard and soft stabilization measures) is suggested in the highly inhabited capital cities and important urban nuclei with high degree of natural and socioeconomic vulnerability, and where hard-stabilization measures already exist, or natural hazard impacts are already evident.

Accommodation measures and strategies are recommended for the sectors that fulfill some of the following requirements (i) bordering a capital city or important urban nuclei where hard-stabilization measures already exist, and (ii) integrating the *transition zone* (10 km buffer) of the conservation units to be defined in the region.

The remaining sectors, distant from the coastline or flooding areas, and not belonging to the *transition zone*, have been classified according to their total vulnerability index values as moderate to very low vulnerability areas. For these areas, any kind of adaptation strategy and measure are indicated.

The results of this proposal (Figure 5.4) show that although only 1% of the total area (117 km² and 16 units) is indicated to implement protection measures, these would be affecting 28% of the total population (approximately 149,081 people). On the other hand, the large extensions where no action is suggested (2,388 km² and 96 units) or the retreat strategy is indicated (1,383 km² and 36 units) are poorly inhabited - 40,770 and 32,415 people respectively. The 122 units where the accommodation strategies and measures prevail have the largest area (5,283 km²) and population (149,455 people).

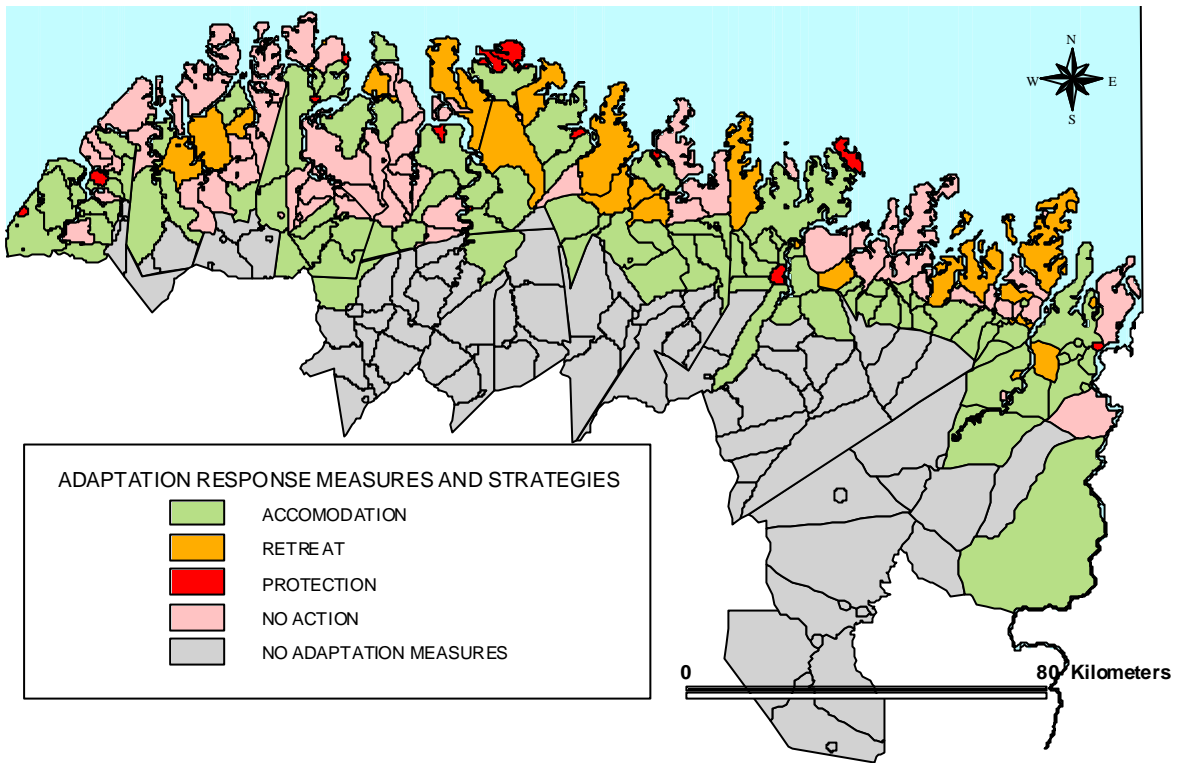


Figure 5.3 Map showing the recommended localization for the implementation of different adaptation strategies and measures.

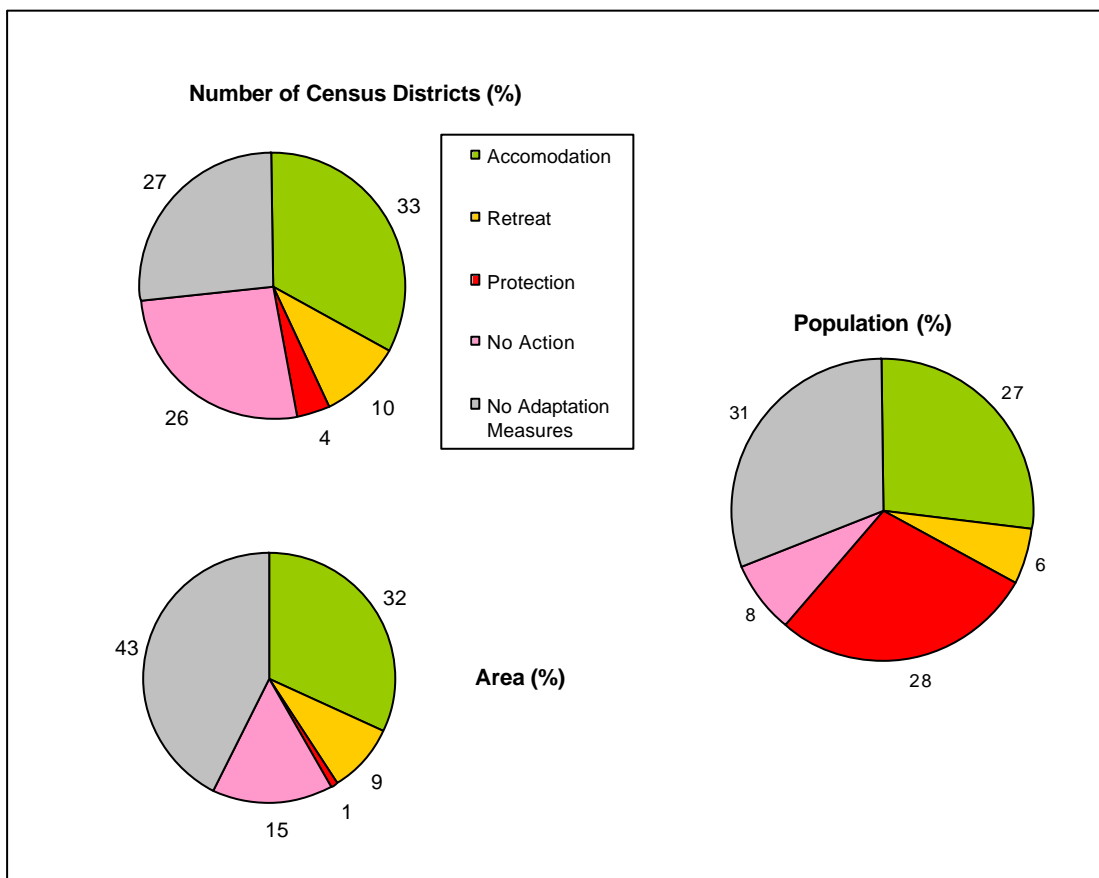


Figure 5.4 Sectors, area and people affected by recommended different kinds of strategies and measures.

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ANNEX 1
Record of Natural Disaster Situation Decrees – State of Pará 1992-2001

Decree	Date	Municipality	Areas and People Affected	Type of Event	Type of Decree
1	20.02.1992	Marabá	No description	Inundation	Emergency Situation
2	24.02.1992	Tucuruí	No description	Inundation	Emergency Situation
3	01.06.1993	Jurutí	No description	Inundation	Emergency Situation
4	01.06.1993	Alenquer	No description	Flood- Amazon River	Emergency Situation
5	01.06.1993	Monte Alegre	No description	Flood- Amazon River	Emergency Situation
6	01.06.1993	Óbidos	No description	Flood- Amazon River	Emergency Situation
7	20.04.1994	Jurutí	No description	Flood- Amazon River	Emergency Situation
8	20.04.1994	Monte Alegre	No description	Flood- Amazon River	Emergency Situation
9	03.05.1994	Terra Santa	No description	Flood- Amazon River	Emergency Situation
10	03.05.1994	Almeirim	No description	Flood- Amazon River	Emergency Situation
11	03.05.1994	Faro	No description	Flood- Amazon River	Emergency Situation
12	31.05.1994	Praíha	No description	Flood- Amazon River	Emergency Situation
13	31.05.1994	Oriximiná	No description	Flood- Amazon River	Emergency Situation
14	31.05.1994	Óbidos	No description	Flood- Amazon River	Emergency Situation
15	11.05.1995	Chaves	Settlements at margins of Cururu, Jurucupu, Jurará and Mocoões Rivers	High tides, Inundation	Emergency Situation
16	24.04.1996	Monte Alegre	No description	Storm and gale, landslides and river banks erosion, mudflow	Public Calamity State
17	20.05.1996	Rurópolis	No description	Heavy rainfall	Public Calamity State
18	20.05.1996	Brasil novo	No description	Heavy rainfall	Public Calamity State
19	20.05.1996	Uruará	No description	Heavy rainfall	Public Calamity State
20	20.05.1996	Altamira	No description	Flood - Xingu River	Public Calamity State
21	20.05.1996	Novo Progresso	No description	Heavy rainfall	Public Calamity State
22	20.05.1996	Trairão	No description	Heavy rainfall	Public Calamity State
23	20.05.1996	Pacajá	No description	Heavy rainfall	Public Calamity State
24	12.06.1996	Oriximiná	127 settlements on rural area	Flood- Amazon River	Emergency Situation
25	12.06.1996	Óbidos	35 settlements on rural area. 400 families	Flood- Amazon River	Emergency Situation
26	12.06.1996	Alenquer	Rural area and settlements at margins of Curuá River. 2 deaths	Flood- Amazon River	Emergency Situation
27	12.06.1996	Jurutí	22 settlements on rural area. 712 families	Flood- Amazon River	Emergency Situation
28	25.06.1996	Rurópolis	No description	Heavy rainfall	Public Calamity State
29	25.06.1996	Pacajá	No description	Heavy rainfall	Public Calamity State

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30	25.06.1996	Novo Progresso	No description	Heavy rainfall	Public Calamity State
31	25.06.1996	Brasil Novo	No description	Heavy rainfall	Public Calamity State
32	25.06.1996	Trairão	No description	Heavy rainfall	Public Calamity State
33	25.06.1996	Uruará	No description	Heavy rainfall	Public Calamity State
34	26.07.1996	Altamira	No description	Flood- Xingu River	Public Calamity State
35	26.07.1996	Monte Alegre	51 settlements. 100 families evicted. 348 homeless.	Storm and gale, landslides and river banks erosion, mudflow	Public Calamity State
36	07.08.1996	Xinguara	Settlements 9 and 10 of road PA-150. Jaguatirica I and II, Mata Azul, Itaipavan, and others towns.	Heavy rainfall	Emergency Situation
37	07.08.1996	Água Azul do Norte	Nova Canada, Água Azul and Xinguara Towns	Heavy rainfall	Emergency Situation
38	07.08.1996	Conceição do Araguaia	Honesta and Bela Vista Towns. Colony São Jacinto	Heavy rainfall	Emergency Situation
39	07.08.1996	Eldorado do Carajás	Água Fria, CIB, Sereno, Rio Vermelho, Boca do Cardoso, Grotão dos Cabocloes e do Linhao, Eldorado colonies	Heavy rainfall	Emergency Situation
40	07.08.1996	Itupiranga	Mangueira, Jurunas, Planaltina and Panelinha towns	Heavy rainfall	Emergency Situation
41	07.08.1996	Jacunda	Céu Azul, N. S. Aparecida, Sta. Maria, Boa Esperança, Sta. Rosa, Porto Novo and Placa da Moram towns	Heavy rainfall	Emergency Situation
42	07.08.1996	Marabá	No description	Heavy rainfall	Emergency Situation
43	07.08.1996	Medicilandia	No description	Heavy rainfall	Emergency Situation
44	07.08.1996	Novo Progresso	No description	Heavy rainfall	Emergency Situation
45	07.08.1996	Paraupébas	Rio Branco and Palmares rural projects. Paulo Fontelles colony. Palmares town. 4800 families	Heavy rainfall	Emergency Situation
46	07.08.1996	Redenção	State roads PA-Capitinga and PA-Arraiaporá	Heavy rainfall	Emergency Situation
47	07.08.1996	Rio Maria	Rio Maria city. Jussama, João Canuto and Jacira II rural projects.	Heavy rainfall	Emergency Situation
48	07.08.1996	Santana de Araguaia	Mandi and Propasa towns. Mandi gold claim. 2500 people	Heavy rainfall	Emergency Situation
49	07.08.1996	São Domingos do Capim	No description	Heavy rainfall	Emergency Situation
50	07.08.1996	São Felix do Xingu	Canaã settlement and Tancredo Neves rural Project.	Heavy rainfall	Emergency Situation
51	07.08.1996	São Geraldo do Araguaia	Fortaleza, Elgura, Vitalino, Abóbora and Sete Barraca towns.	Heavy rainfall	Emergency Situation
52	07.08.1996	São João do Araguaia	No description	Heavy rainfall	Emergency Situation
53	07.08.1996	Vitória do Xingu	No description	Heavy rainfall	Emergency Situation
54	27.08.1996	Aveiro	Rural area	Heavy rainfall	Emergency Situation
55	27.08.1996	Uruará	Rural area	Heavy rainfall	Public Calamity State
56	27.08.1996	Novo Progresso	No description	Heavy rainfall	Public Calamity State
57	27.08.1996	Rurópolis	No description	Heavy rainfall	Public Calamity State

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58	27.08.1996	Trairão	No description	Heavy rainfall	Public Calamity State
59	27.08.1996	Pacajá	No description	Heavy rainfall	Public Calamity State
60	27.08.1996	Monte Alegre	No description	Storm and gale, landslides and river banks erosion, mudflow	Public Calamity State
61	11.09.1996	Brasil Novo	No description	Heavy rainfall	Public Calamity State
62	24.01.1997	Ourilandia do Norte	Águas Claras, Abelha, Caracol, Cabano, Calça Amarela, Campos Altos, and others rural communities. 1800 families	Storm and gale	Emergency Situation
63	02.04.1997	Marabá	Low-lying areas of Velha Marabá and Nova Marabá city. 1600 families.	Flood- Tocantins and Itacaiunas Rivers	Emergency Situation
64	04.04.1997	São Geraldo do Araguaia	1650 peoples	Flood - Araguaia River	Emergency Situation
65	04.04.1997	Tucuruí	Low-lying areas of Tucuruí city. 220 families.	Flood- Tocantins River	Emergency Situation
66	07.04.1997	Bannach	No description	Heavy rainfall	Emergency Situation
67	10.04.1997	Marabá	City of Velha Marabá and part of the city of Nova Marabá. 8000 families.	Flood- Tocantins and Itacaiunas Rivers	Public Calamity State
68	10.04.1997	Rondon do Pará	settlements at margins of Pratinha, Marcelino, Pebas and Surubiju rivers	Heavy rainfall	Emergency Situation
69	10.04.1997	Itupiranga	200 families	Flood- Tocantins and Itacaiunas Rivers	Emergency Situation
70	10.04.1997	São João do Araguaia	2100 families	Flood - Araguaia River	Emergency Situation
71	15.04.1997	Baião	Stá. Maria Andirobal, Castanheiro, Rua do Fogo, Acatinga, Xininga, Joana Peres, Mararia and others settlements	Flood- Tocantins River	Emergency Situation
72	17.04.1997	Mocajuba	Rufino, Santana, Camaleão, Fariseu, Tatuoca, Tauarezinho, Tauare grande, Rosário, and others. 876 families.	Flood- Tocantins River	Emergency Situation
73	12.05.1997	Alenquer	Communities at margins of rivers and urban area. 1500 families.	Flood- Amazon and Surubiu Rivers	Emergency Situation
74	12.05.1997	São Geraldo do Araguaia	No description	Heavy rainfall, Flood - Araguaia river	Public Calamity State
75	12.05.1997	Monte Alegre	Floodplain and river margins communities. 400 families.	Flood- Amazon River	Emergency Situation
76	14.05.1997	Prainha	River margins communities of Puru, Ipanema, Uruara, Itanduba, Paranaquara and others settlements. 500 families	Flood- Amazon River	Emergency Situation
77	14.05.1997	Obidos	River margins communities. 5000 people	Flood- Amazon River	Emergency Situation
78	23.05.1997	Oriximina	River margins communities of Boto, Trombetas and Nhamundá rivers, Cachoeiry and Currais streams. 1000 families.	Flood- Amazon River	Emergency Situation
79	23.05.1997	Almeirim	River margins communities of Bacabal, Vila Pinhel, Fé em Deus, Livramento, Boa Vista, and others. 516 families.	Flood- Amazon River	Emergency Situation
80	23.05.1997	Juruti	River margins communiites	Flood- Amazon River	Emergency Situation
81	23.05.1997	Porto de Moz	River margins communities of Lui, Peiturú, Aquiqui, Guajará, Costi, Majari and Macacos. 1200 families.	Flood- Amazon and Xingu Rivers	Emergency Situation

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82	26.05.1997	Terra Santa	Communities at margins of Nhamunda river and Bom Jardim and Pirarucu - Piraruacá and others lakes. 200 families.	Flood- Amazon River	Emergency Situation
83	26.05.1997	Altamira	Brasília, Aparecida, Tufi, Sudam I, Centro and Boa Esperança neighborhood. 426 families.	Flood- Xingu River	Emergency Situation
84	26.05.1997	Prainha	73 river margins communities. 2280 families	Flood- Amazon River	Public Calamity State
85	26.05.1997	Curua	river margins communities	Flood- Amazon River	Emergency Situation
86	26.11.1997	Santarém	No description	Drought	Public Calamity State
87	25.11.1998	Obidos	Mamaurú, Jacaré Puru, Castanhanduba, Silencio da Mata, Mata de Baixo, São Jose, Buiucu, and others settlements	Drought	Emergency Situation
88	22.03.1999	Monte Alegre	Urban area. 30 families	Storm and gale, landslides and river banks erosion	Emergency Situation
89	22.03.1999	Obidos	Urban zone and Santa Terezinha, Fátima, Cidade Nova and Centro neighborhoods	Mudflow	Emergency Situation
90	30.03.1999	Rondon do Pará	Rondon do Pará city and federal road – BR-222	Mudflow	Emergency Situation
91	09.04.1999	São Geraldo do Araguaia	State roads PA-477 and PA-275 and bridges.	Heavy rainfall and inundation	Emergency Situation
92	28.04.1999	Almeirim	State road PA-473. Nova Vila, Palhal and Buritizal neighborhoods	Heavy Rainfall and flood - Amazon River	Emergency Situation
93	30.04.1999	Medicilandia	Federal road BR-230	Heavy rainfall	Emergency Situation
94	11.05.1999	Prainha	Purus, Uruara, Guajara, Vira Sebo, Anema, Jauari and Ipanema rivers. 10350 people	Flood- Amazon River	Emergency Situation
95	11.05.1999	Pacajá	Federal Road BR-230	Heavy rainfall	Emergency Situation
96	13.05.1999	Monte Alegre	Urban zone	Heavy rainfall, Mudflow	Emergency Situation
97	28.05.1999	Irituia	São Francisco town	Ravine and linear soil erosion	Emergency Situation
98	31.05.1999	Alenquer	river margins and urban areas	Flood- Amazon, Surubiu and others Rivers	Emergency Situation
99	10.06.1999	Terra Santa	Rural zone	Flood - Nhamundá River	Emergency Situation
100	10.06.1999	Oriximina	Rural zone. 1000 families	Flood- Amazon River	Emergency Situation
101	10.06.1999	Monte Alegre	Floodplain and outlying neighborhoods. 450 families	Flood- Amazon River	Emergency Situation
102	18.06.1999	Altamira	Urban area. 1405 families	Heavy Rainfall	Emergency Situation
103	18.06.1999	São Domingos do Araguaia	Rural area	Heavy rainfall, Mudflow	Emergency Situation
104	22.06.1999	Obidos	Communities living in flood plain. 300 families	Flood- Amazon River	Emergency Situation
105	24.06.1999	Placas	Communities near Federal road BR-230	Heavy rainfall, Mudflow	Emergency Situation
106	29.06.1999	Porto de Moz	Several communities near rural and urban floodplains. 573 families	Flood- Xingu River	Emergency Situation
107	29.06.1999	Curua	No description	Flood- Amazon River	Emergency Situation

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108	29.06.1999	Anapu	communities near the federal road BR230	Heavy Rainfall	Emergency Situation
109	08.09.1999	Santa Maria das Barreiras	Novo Horizonte and São João Batista settlements. 450 families	Drought	Emergency Situation
110	20.09.1999	Monte Alegre	Urban area	Heavy rainfall, Mudflow	Emergency Situation
111	29.03.2000	Altamira	Tufi, Açaizal, Jardim Independente I, Olaria, Peixaria, Boa Esperança, Aparecida, and others neighborhoods	Flood- Xingu River	Emergency Situation
112	29.03.2000	Marabá	Sta. Rosa, Francisco Coelho, Marabá Pioneira, Amapá, Folha 33, Sta Rita and others neighborhoods. 653 families.	Flood- Tocantins and Itacaiunas Rivers	Emergency Situation
113	13.04.2000	Tucuruí	Matinha and Centro neighbourhoods. 500 families	Flood- Tocantins River	Emergency Situation
114	10.05.2000	Monte Alegre	Outlying neighbourhoods and rural area	Heavy rainfall, mudflow, Ravine, Inundation	Emergency Situation
115	10.05.2000	Bannach	Rural area, Dom Manuel and Campo do Triunfo towns and communities near state road PA-Muriçoca. 4500 people.	Heavy rainfall, Mudflow	Emergency Situation
116	18.05.2000	Alenquer	Several communities	Flood- Curua River	Emergency Situation
117	18.05.2000	Almeirim	Several communities	Flood - Jari and Paru Rivers	Emergency Situation
118	02.06.2000	Rondon do Pará	River margins communities of Surubiju River and Prata, Pebas, Abacate, Binoca, and others Streams. 3600 people	Flood -	Emergency Situation
119	09.06.2000	Oriximina	Urban and rural areas. 695 families.	Flood - Trombetas and Amazon River	Emergency Situation
120	29.09.2000	Oriximina	Rural area and indigenous Wai-wai settlements.	Flood - Trombetas and Amazon River	Emergency Situation
121	23.02.2001	Marapanim	Crispim Beach. 281 people	High tides	Emergency Situation
122	07.05.2001	Monte Alegre	Several neighborhoods, airport and rural area.	Heavy rainfall, mudflow, Ravine and linear soil erosion	Emergency Situation
123	22.05.2001	Obidos	1035 families.	Heavy rainfall, mudflow, Ravine and linear soil erosion	Emergency Situation
124	23.05.2001	Prainha	Floodplain and river margins communities. 1630 families	Flood- Amazon River	Emergency Situation
125	05.07.2001	Monte Alegre	Several neighbourhoods, airport and rural area.	Heavy rainfall, mudflow, Ravine and linear soil erosion	Emergency Situation
126	06.08.2001	Prainha	Floodplain and river margins communities. 1630 families	Flood- Amazon River	Emergency Situation