

Changes in mangrove extension along the Northeastern Brazilian coast (1978-2003)

Mangroves dwell at the land-ocean interface and are thus encroached upon by competing land use at the coastal zone. They are also subject to impacts from catchments developments. As a result, mangroves worldwide are having their extension changed (Spalding *et al.*, 1997). Worldwide it is well accepted that mangrove extension is decreasing mostly due to conversion to other uses, in particular aquaculture, urbanization and tourism development (ITTO, 2002). In many coastal sites, however, regional environmental changes have resulted in an expansion of mangrove area. Erosion of upland soils has increased sedimentation in coastal areas of Thailand, Bangladesh, Mozambique, Venezuela and New Zealand, resulting in augmenting of mangrove area (Perez *et al.*, 2002; Aizpuru *et al.*, 2000; Schwarz, 2003). In other areas, global climate change may result in rising sea level with increasing saline intrusion and mangrove expansion inland. The rapid response of mangroves to regional and global environmental changes and their huge ecological importance for coastal ecology and for the millions of people dwelling along tropical coasts, makes the continuous mapping of this vegetation a fundamental tool for coastal management plans and the sustainability of coastal areas.

The northeastern Brazilian coast is a semi-arid sector of the country's littoral where watershed management has resulted in intense environmental changes. River damming and water withdraw for human use and agriculture have resulted in decreasing freshwater and sediment supply to the coastal zone. More recently, an accelerated development of tourism and shrimp aquaculture have also resulted in significant changes in the coastline. Erosion of seaward mangrove fringes, increasing saline intrusion and increasing wind driven sand transport, resulted in significant changes in mangrove cover along that part of the Brazilian coast (Lacerda & Marins, 2002; Maia & Lima, 2004).

The International Society for Mangrove Ecosystems, through its Brazil Chapter (ISME-

BR) together with the Institute of Marine Sciences of the Federal University of Ceará (LABOMAR/UFC) and with support from the National Research Council of Brazil (CNPq) through its Institute of the Millennium Program and the Brazilian Association of Shrimp Producers (ABCC), triggered an effort to map the overall impact of regional environmental changes on mangrove extension along the NE Brazilian coast. The present paper summarizes major findings and discusses potential impact of these changes on the environmental sustainability of the coastal zone.

Methodology

Mangrove area was mapped from the Parnaíba River, Piauí State (Lat. 03° 15'S; Long. 41° 45'W) to the Una River Estuary in Pernambuco State (Lat. 08° 45'S; Long. 35° 15'W) (Figure 1). This roughly corresponds to the semi-arid coast of Brazil, where annual rainfall is generally less than 1,000 mm and total freshwater flux to the ocean is less than 1,000 m³.s⁻¹. Along this area we analyzed satellite images from 51 estuaries. Most of the recent images were from LANDSAT 7 ETM+. Other satellite sources, Quikbird and IKONOS, were used when more detailed mapping was. Images were treated using ArcGIS software.

We used the map produced by Herz (1991), based on 1978 RADAR images, which is considered a landmark in mangrove mapping in Brazil, as a starting point of our comparisons. Also, we used for comparison the results by Freire & Oliveira (1993), reviewed by Lacerda (2002), which were based on local sources, in particular state environmental agencies. Whenever available, images from any date between 1978 and 2003 were also used and mapped in this study. A full description of the methods and procedures as well as images and maps of the 51 estuaries can be found in the ISME-BR publication "Mangrove Atlas of the Northeastern Brazil", which Portuguese version will be available soon through the Brazil Regional Center of GLOMIS (www.gломis.com).

Overall changes in mangrove cover from 1978 to 2003

Figure 1 shows present day mangrove distribution along the NE coast of Brazil, whereas Table 1 summarizes major overall changes of mangrove extension along the mapped coastline. The comparison of the data showed large changes in mangrove area in all states. Mangrove area expanded steadily from 1978 to 2003 compared to Herz (1991) data, overall expansion reached about 37%. Largest expansion occurred in Pernambuco state (+67%) and the smallest in Rio Grande do Norte (+19.9%). The fastest mangrove expansion occurred between 1978 and 1990. Most of the expansion during this period occurred in abandoned salt pans. Salt production, a major economic activity in the region during most of the 20th century, was drastically reduced by 1970's; today being restricted to the Rio Grande do Norte coast.

From the early 1900's to 2003 mangrove expansion reached about +17% when compared to

Freire & Oliveira (1993). During this period mangrove extension occurred mostly as a result of saline intrusion and changes in sediment deposition along river margins, as can easily be seen by the different generations of mangrove growth along many estuaries along the mapped area. These changes in estuary's morphodynamics were mostly due to the increase in rivers damming and freshwater withdrawn due to increasing irrigated agriculture and coastal human population during the two last decades of the 20th century. For example, the Jaguaribe River, the largest basin of this sector of the Brazilian coast (about 72.000 km²), had its flow reduced from the historical average of about 200 m³.s⁻¹ to about 22 m³.s⁻¹ (Marins *et al.*, 2002). These changes have resulted in drastic alterations of mangrove distribution in that area (Lacerda & Marins, 2002).

Local and recent changes in mangrove distribution

Although the general trend observed in the

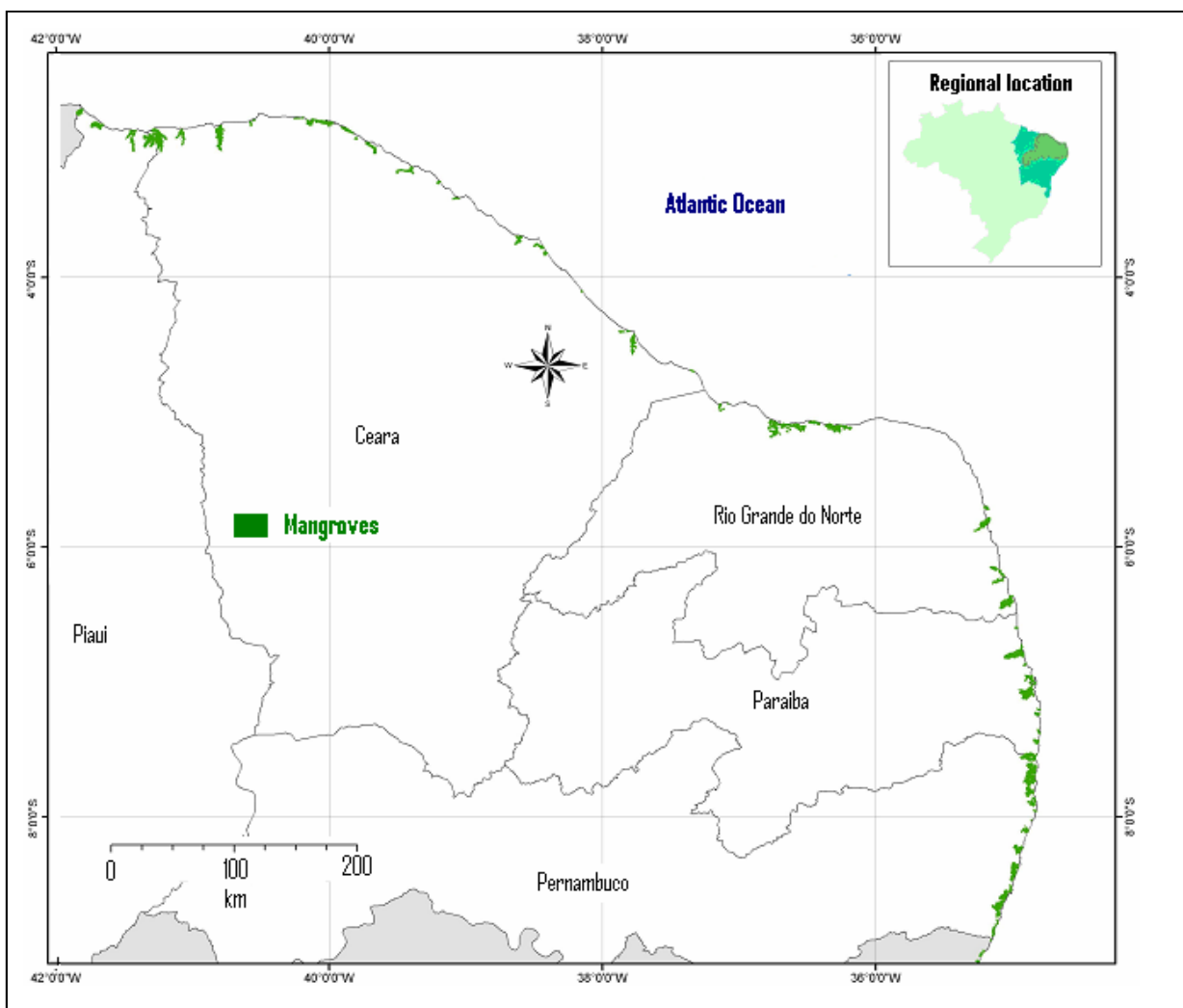


Figure 1. Present mangrove distribution along the NE Brazilian Coast.

Tabela 1. Mangrove area along the Brazilian northeast (km²). Comparison between Herz (1991) (A), local and regional inventories summarized by Freire & Oliveira (1993) (B) and the results obtained in the present study (C).

State	Herz (1991)	Freire & Oliveira (1993)	This study (1999-2004)	Variation (km ²)		Variation (%)	
	A	B	C	(C-A)	(C-B)	(C-A)	(C-B)
Piauí	29.94	43.70	40.40	(+10.46)	– (-3.30)	(+34.9)	– (-7.6)
Ceará	140.43	229.40	180.64	(+41.82)	– (-47.15)	(+29.8)	– (-20.6)
R. Grande Norte	108.19	69.90	129.71	(+21.52)	– (+59.81)	(+19.9)	– (+85.6)
Paraíba	68.88	100.80	96.31	(+27.43)	– (-4.49)	(+39.8)	– (-4.5)
Pernambuco	96.61	78.10	161.38	(+64.77)	– (+83.28)	(+67)	– (+106)
Total	444.04	521.90	610.05	(+166.00)	– (+88.15)	(+37.4)	– (+16.9)

study was a significant mangrove expansion throughout the region, in many specific sites, and in particular after the aquaculture boom, which occurred after 2001, mangrove area has been reduced. Although shrimp farms are strongly regulated by local and federal environmental agencies, which consider mangroves as permanent protection areas, at least 600 to 800 ha of mangrove forests were converted to shrimp ponds between 2001 and 2004. For example, in the Guaraíras Lagoon, Rio Grande do Norte State, although a striking increase in mangrove area occurred due to the enhancing seawater flow to the lagoon by permanently opening of a canal, tracks of mangrove forest converted to shrimp ponds are clearly visualized in the map based on the satellite imagery (Figure 2). Similarly in many estuaries of Ceará State opening of access roads and adduction canals for shrimp farms resulted in loss of mangrove forests (Figures 3 B and C). Urbanization and tourism development has also caused mangrove area reduction in specific locations.

Apart from direct anthropogenic impacts, pressures from natural phenomena due to global climate changes have also resulted in mangrove area decrease. In areas where mobile dune fields exist, increasing dune displacement is occurring due to drier conditions, in particular during El Niño events (Maia *et al.*, 2005). In such areas mangroves have been covered by the advancing dunes (Figure 3A).

Conclusions

The present summary based on a detailed analysis of remote sensing data, shows a significant increase in mangrove areas along the NE Brazilian coast, although specific mangroves

areas have been converted to other uses, mostly during the first years of the 21st century. This general increase, also registered in other coastal sites worldwide, however, rather than being indications of better conservation practices, is a result of regional and global environmental changes induced by anthropogenic drivers. The positive or negative impact of such changes in mangrove extension is still to be evaluated.

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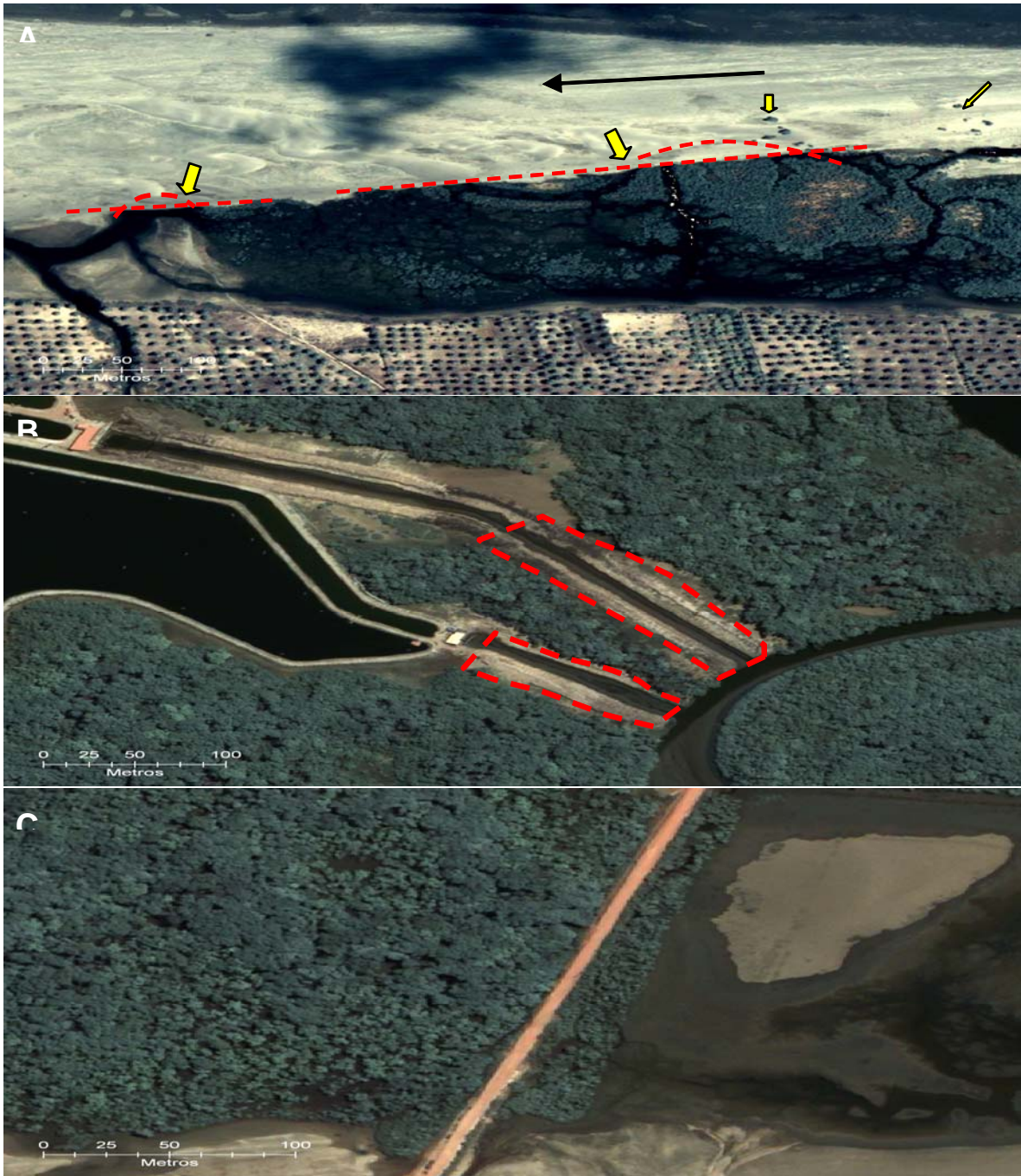


Figure 3. Sand dune advance on mangroves (A), cutting of mangroves for opening of adduction canals (B) and access roads (C).

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