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Degradation and conservation of Brazilian mangroves, status and perspectives

Alexander Cesar Ferreira*, Luiz Drude Lacerda

Instituto de Ciências do Mar (LABOMAR), Universidade Federal do Ceará, Avda. da Abolição 3207, Meireles, Fortaleza, CE, CEP: 60165 081, Brazil

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ABSTRACT

Mangroves are one of the most human-affected coastal ecosystems, despite their important social and ecological roles, and after decades of devastation these forests continue facing different processes of conversion, threatening their global future. Brazilian mangroves are not an exception, despite the existence of severe protection legislation. Conversions to aquaculture, industrial and urban development among others, have destroyed more than 50,000 ha (about 4% of the total mangrove area in the country) over the past three decades. Restoration efforts have somewhat minimized losses, but has recuperated only a 5% of the total degraded area. Despite criticized, monospecific plantings have demonstrated return of some ecosystem structure and functioning, and seems to be a starting point in mangrove restoration. Around 70% of Brazilian mangroves are today inside preserved areas, but the effectiveness of these advances continues impaired by bureaucracy, lack of conservation policies and economic interests. We estimate the status of Brazilian mangroves and review some restoration and conservation efforts, suggesting some management measures like restoration and community-based ecosystem management. Based in a reforested stand in Northeastern Brazil, we assess the environmental cost of mangrove clearing and reforestation results.

1. Introduction

Mangroves are highly productive ecosystems that occupy one of the most human-affected regions of the world, the continent–ocean interface. They cover around 170,600 km^2 of tropical and subtropical coasts worldwide (Lacerda, 2002). Brazil, with 7% of the world's mangroves, is the third country in mangrove extension on Earth (FAO, 2007). Worldwide, at least 35% of these forests have been destroyed in the past decades by human settlements, overexploitation, conversion into salt or aquaculture ponds and other aggressions, disregarding their important ecological and social roles (Alongi, 2002; Barbier et al., 1997; Diegues, 1999; Lugo, 2002; Manson et al., 2005; McLeod and Salm, 2006). Fish and mainly shrimp aquaculture practices were also responsible by nearly half of the total mangrove clearing, in particular in South and Central America and Southeast Asia (McLeod and Salm, 2006; Valiela et al., 2001). For example, nearly 279,000 ha of Philippine mangroves were converted to aquaculture ponds from 1951 to 1988, whereas in Indonesia a similar area (269,000 ha) was also converted between 1960 and 1990 (Primavera, 2000). Nearly 50% of Ecuador's mangroves were converted between 1980 and 2000 attributed to shrimp farm development (Lacerda et al., 2002). In the Gulf of Fonseca, Honduras, about 30% of the native mangroves were substituted by aquaculture facilities, with significant losses in the local fisheries (DeWalt et al., 1996) and conversion continues at an annual rate of 2000–4000 ha (Lal, 2002). Overexploitation of forest products and expansion of coastal human populations have been increasingly important vectors of mangrove destruction. Natural processes such as sea level rise, changes in estuarine hydrodynamics and tsunamis, also threaten mangrove endurance in the Planet (Alongi, 2002). However, effective official policies or strategies to integrally protect mangroves as national and humanity patrimony, despite site specific cases (see Alvarez-León, 2003), are still rare at regional and global scales.

Afforestation and replanting of mangroves carried on in all continents have partially decreased the speed of forest losses (Ellison, 2000; Ferreira et al., 2007; Field, 1996; Kairo et al., 2001; Magris and Barreto, 2010; Menezes et al., 2005; Walters et al., 2008). Some programs afforested areas by planting one or few species, and have been criticized by doing so (Ellison, 2000; Lewis,

* Corresponding author.
E-mail address: alexcrab90@hotmail.com (A.C. Ferreira).

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2005; Walters et al., 2008). However, monospecific mangroves can show rapid development and restore some ecosystem structural properties and functioning (Ferreira et al., 2015; Hong, 1996; Macintosh et al., 2002). A *community management* approach was applied in some restoration processes (Ferreira et al., 2007, 2015; Brown et al., 2014; see review by Datta et al., 2012), developing necessary collaboration for larger scale plantings, which are yet scarce due to logistical problems. Sometimes, self-recuperation of mangrove stands is possible, following specific management measures such as hydrological restoration (Lewis and Gilmore, 2007; Matsui et al., 2010; Turner and Lewis, 1997) or simply by protecting measures to avoid new impacts and to allow natural recovering (Field, 1996). On the other hand, several studies reports that mangrove extension has stopped decreasing and even augmented in some previously deforested or new mangrove areas (Benfield et al., 2005; Cavanaugh et al., 2014; Giri et al., 2011; Lacerda et al., 2007; Li et al., 2013; Maia et al., 2006; Martinuzzi et al., 2009; Ren et al., 2011; Schwarz, 2003). Unfortunately, global forests losses are still extensive. For example, between 1975 and 2005, in the tsunami-affected region of Asia, 12% of mangrove forests were converted into agriculture and aquaculture (Giri et al., 2008). This is much larger than afforestation efforts in this same area (Spalding et al., 2010).

The larger mangrove extension (around 80%) of South American Eastern margin occurs along the Brazilian coast (Fig. 1). Extensive mangrove areas have been destroyed by human pressure, mainly aquaculture, salt production and changes in sedimentary patterns, along the north and northeastern coast; and chemical and urban pollution, and urban expansion, in the southern coast (Diegues, 1999; Godoy and Lacerda, 2015; MMA, 2006). Despite the larger Brazilian mangrove forests (60–70% of the total area) being located in the Northern region (Fig. 1) and relatively preserved, Brazil has lost at least 50,000 ha of these forests (around 4%) over 25 years (FAO, 2007). Considering that all mangroves in Brazil are legally 'Areas of Permanent Protection' (APPs), this illegal deforestation is more serious and unacceptable. Poverty, difficult logistics and Governmental bureaucracy preclude more efficient mangrove conservation, a common feature with other underdeveloped countries (Primavera et al., 2014), and despite several preserved areas were created to protect mangroves, they were not as effective in stopping the degradation of these coastal forests throughout Brazil, mainly due to lack of surveillance on legislation observance. Plantings have been made, but most data on recuperation remains unpublished or reduced to planting techniques, lacking data of mangrove development from medium to long term monitoring (Rovai, 2012). Data from Northeast Brazil, showed high *Rhizophora mangle* propagules survival (70–90%) and aboveground biomass after 5 years planting, showing that planted mangroves (including monospecific stands) can have rapid development and restore some ecosystem functioning (Ferreira et al., 2015; Hong, 1996; Macintosh et al., 2002). Several mangroves are suffering a new wave of conversion, and shrimp ponds built on previously deforested mangroves for salt production and to a lesser extent to agricultural and cattle breeding, contribute to maintain or amplify environmental damage and makes difficult legal actions upon the new developments. Developing of harbors and Industrial facilities remain growing sources of impacts over forests (Lacerda et al., 2002), and continue blindly ignoring ecological (mainly as seedling furnisher), touristic and economical value of mangrove stands. Sometimes, the proper governmental enterprises impact mangrove ecosystems. While natural disasters are uncommon, and in spite of mangroves be substrate builders by efficiently accumulating sediments and therefore resist tidal washing and erosion, sea level rise due to global warming threats directly and indirectly mangrove stands unable to expand landwards, due to geographical constrains in some areas and anthropogenic activities located upstream watersheds (Godoy and Lacerda, 2015).

The conservation status of Brazilian mangroves and major drivers threatening their extension and functioning are mostly based on reactively old literature. Major changes in coastal development as well as on the proper environment legislation towards the management of the coastal zone occurred in the past two decades and updated figures of their impacts on Brazilian mangroves are still lacking (Kjerfve and Lacerda, 1993; Lacerda et al., 2002; FAO, 2007). Major threats such as those from aquaculture and global climate changes are still poorly documented (Godoy and Lacerda, 2015). In this work we update the current status of conservation of Brazilian mangroves, their level of degradation, and

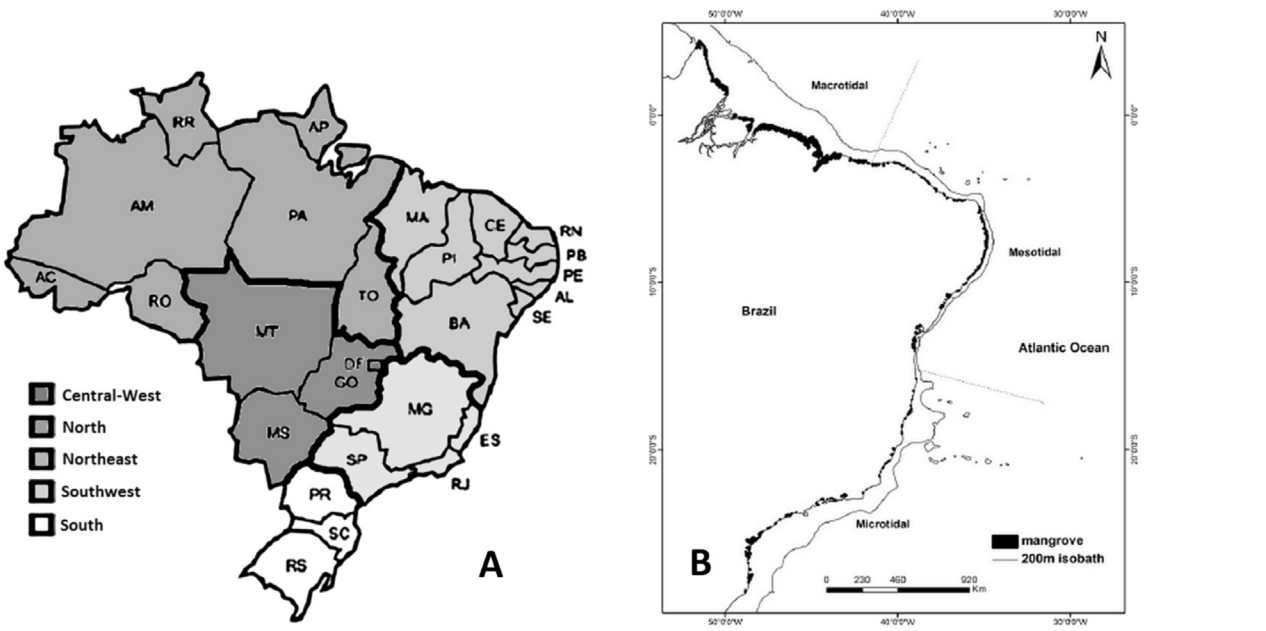

Fig. 1. A. Brazilian States and Regions. States are composed by Counties, almost 5.600 in the country. **B**. Mangrove areas at Brazilian coast (from Magris and Barreto, 2010).