

Land surface dynamics and environmental challenges of the Niger Delta, Africa: Remote sensing-based analyses spanning three decades (1986–2013)



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A B S T R A C T

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The Niger Delta, the largest river delta on the African continent, is one of the most densely populated river deltas globally and hosts the world's third largest mangrove forest. It is a major biodiversity hot spot of our planet. At the same time the delta is home to Africa's largest oil reserves and responsible for a skyrocketing GDP development of Nigeria since the 1970s. Nigeria ranks 13th among all oil producing countries, but oil exploitation also brought with it severe environmental degradation, leading to the delta's nomination for a place on the top 10 list of the "World's Worst Polluted Places Report" in 2013. Despite the outstanding importance of the region for Nigeria, Africa, and the international community most studies published focus mainly on topics of geology, geochemistry, and environmental toxicology. Studies employing earth observation satellite data to assess Niger Delta dynamics are rare. This paper aims at contributing to an overview of Niger Delta geography and environmental threats and challenges, as well as to an understanding of Niger Delta land surface dynamics from 1986 to 2013. Covering the complete delta, we present results of land cover change analyses, results of an assessment of coastline dynamics, as well as the manifestation of oil exploitation activity as expressed via oil access canal dredging and gas flaring, monitored within the 27 year time span investigated.

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Introduction: geography of the Niger Delta and socio-ecological threats

Geography of the Niger Delta

The Niger Delta in Nigeria is Africa's largest river delta and covers an area exceeding 29,900 km² (Goudie, 2005) (see Fig. 1). The Niger River discharges on average over 30,000 m³ of water per second into the Gulf of Guinea. Currently, 20% of Nigeria's population – over 30 million people – live in the Niger Delta (National Bureau of Statistics, 2013). The largest city in the Delta is Port Harcourt, with a population exceeding one million inhabitants.

Delta genesis started in the Cretaceous (Short & Staeuble, 2004) and progressed according to marine transgressive and regressive cycles of differing durations in response to eustatic sea level changes. The horizontal sediment structure of the delta is

characterized by different marine and fluvially deposited layers composed of sand, silt, and clay (Abam, 1997). A most comprehensive and novel stratigraphy and sedimentology of the Niger Delta has recently been published by Reijers (2011). Geomorphologically, the recent Niger Delta can be categorized into three different regions: the continental part of the delta, the transitional area dominated by land and ocean interactions in the coastal zone, and the delta's marine territories (Ugbe, 2011). This humid region receives between 2400 and 4200 mm of precipitation per year, mainly during the rainy season.

Flora and fauna in the delta are very diverse. The largest mangrove forest of Africa – and the third largest globally – can be found in the delta and comprises an area between 5000 and 8600 km² depending on the literature source (Fatoyinbo & Simard, 2012; Isebor & Awosika, 1993; Ohimain, 2003). The Niger Delta region is characterized by an extraordinary aquatic and terrestrial biodiversity, above all related to the aforementioned mangrove forest areas, which also provide a substantial number of ecosystem services (Kuenzer & Quoc 2013; Prince & Arokoyu, 2010; Quoc, Oppelt, & Kuenzer, 2012). But not only the near-coastal areas are

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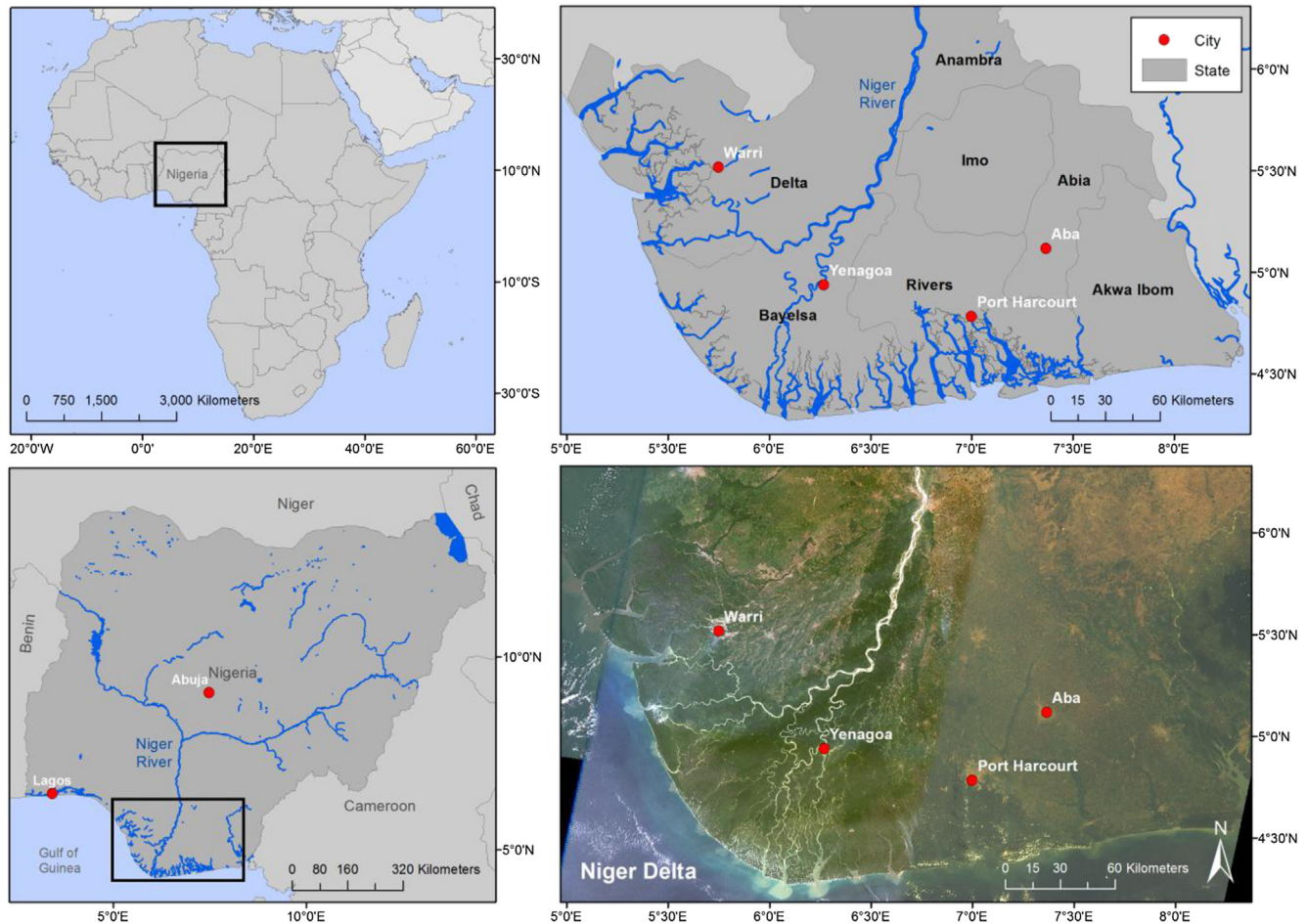


Fig. 1. Location of the Niger Delta in Nigeria. The Niger Delta consists of seven states: Anambra, Delta, Imo, Bayelsa, Rivers, Abia, and Akwa Ibom. The Niger Delta also hosts the large cities of Warri, Yenagoa, Aba, and Port Harcourt.

relevant biodiversity hot spots. Important wetlands and swamp forests, such as the Apoi Creek Forest Reserve, Lake Oguta, and the Upper Orashi Forest Reserve were all designated as significant wetland areas under the Ramsar Convention in 2008.

The seemingly most valuable natural resource in the Niger Delta is its enormous oil and gas deposit (Ajobade & Awomuti, 2009; Ikelegbe, 2005; Mbano, 2008; Osuoka, 2007; Oyegun, 1993). In 2012, over 853 million barrels of oil were exploited from over 5000 oil wells (NNP Annual Statistical Bulletin 2012, 72pp.). Further natural resources include, but are not limited to, timber and non-timber forest products, agriculture (raffia palm, banana, oranges, yam, pumpkin, to name just a few), aquaculture, and silica sand (Mbano, 2008; Okpara, 2004, 102pp.). In the Niger Delta, agricultural activities are characterized by traditional peasant farms. The largest portion of the GDP is generated by the oil industry (Abayomi, 1992; Mbano, 2008). Within the last decade alone, GDP grew from about 83 billion USD in 2000 to 178 billion USD in 2012. However, the profits generated from the oil industry could so far not help to alleviate the chronic poverty of this most densely populated country of Africa. Nigeria ranks 153rd of 186 countries listed in the human development index (CIA 2013).

Environmental and socio-ecological threats in the Niger Delta

Usually, river deltas globally belong to the most densely settled areas on Earth, as they are characterized by multiple benefits

offering a good livelihood for humans: a flat topography, fertile soils, access to marine and sweet water resources, access to harbors, numerous underground oil, gas, and salt deposits, as well as wetlands with extensive biodiversity (Kuenzer & Renaud, 2012). At the same time, numerous authors observe river delta resources exploitation in the Anthropocene with concern, discussing the concept of tipping points for socio-ecological systems (Renaud et al., 2013).

Several socio-ecological threats are prevalent in the Niger Delta. The greatest threat is environmental pollution with hydrocarbons. Most multinational oil companies, such as Shell, Agip, Total, or Chevron, are active in the region, and the growth of the oil and petroleum industry during recent decades led to several serious environmental problems as well as social conflicts. Oil spills caused by pipeline leakages, technical accidents, or illegal discharge, as well as the release of further toxic substances, have negatively impacted surface water, aquifers, soils, and vegetation and led to the destruction of large parts of the mangrove forests. According to Baird (2010) between 9 and 13 million barrels of oil were spilled in the delta since 1958. Next to these resources, agricultural land, all fauna, as well as human health (food chain effects), are also affected (Bayode, Adewunmi, & Odunwole, 2010; Emoyan, Akpoborie, & Akporhonor, 2008; Twumasi & Merem, 2006; Ugoschukwu & Ertel 2008). Frequent flooding in the rainy season aggravates the oil-exploitation-related threats. Floodwater disperses large amounts of sediment in the delta as well as further inland. These

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