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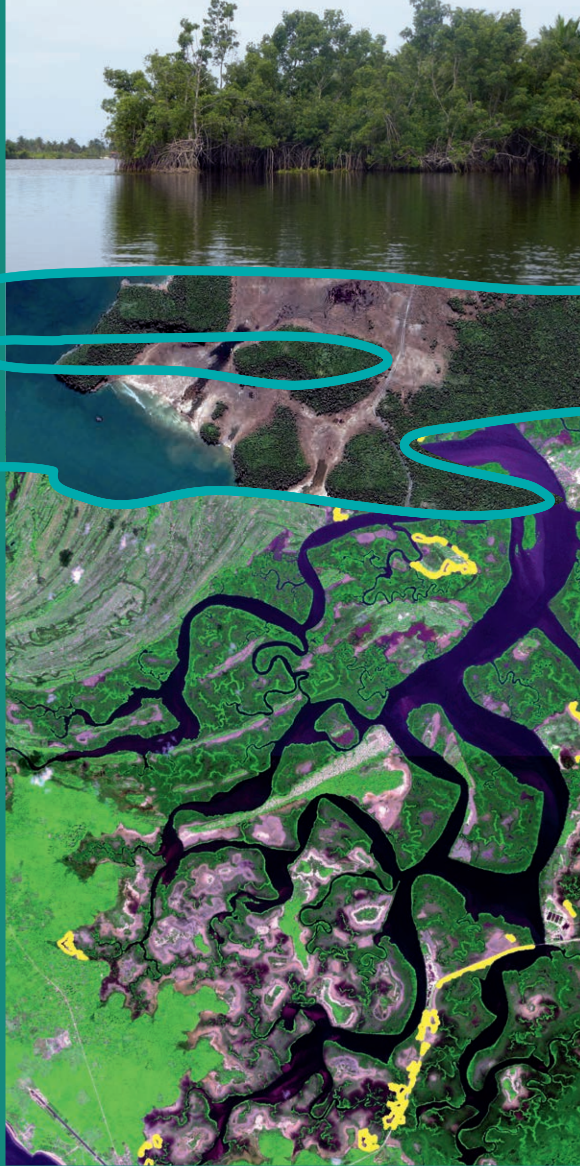

Monitoring The Restoration of Mangrove Ecosystems from Space

REPORT - NOVEMBER 2014

UNIGE/GRID-Genève
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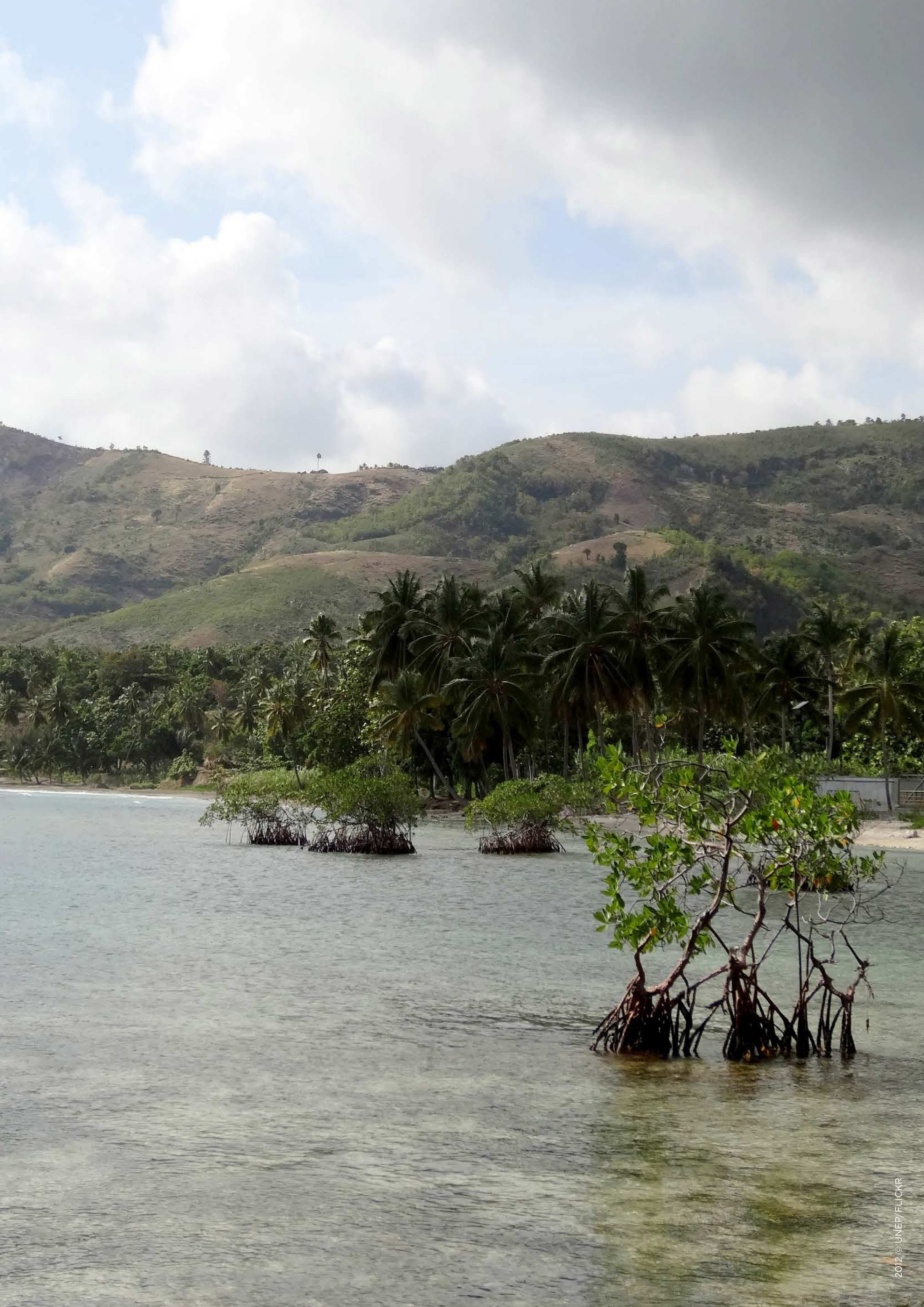
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Executive summary

Mangrove establishment and rehabilitation projects have had varying levels of success at different locations around the world. Given the money that has been invested in restoring mangrove coverage, it is useful to map, monitor and compare results and experiences in different parts of the globe to compare the success of such projects. This study conducted temporal analyses for 24 mangrove sites from 10 different projects in six different countries (Senegal, the United Arab Emirates, Madagascar, Kenya, Solomon Island and Indonesia) using satellite imagery and GIS technology to map and monitor their status. Given that many of the sites were small, very high-resolution satellite imagery (0.45, 0.6 and 1 metre resolution from Worldview, Quickbird and Ikonos, respectively) was used.

Compared with ground surveys, remote sensing provides a synoptic view and, using ancillary data, makes it possible to look at historical data. However, it may preclude gaining a clear understanding of reasons for failure and successes of projects.

Given the time and financial resources for this project, it was not possible to conduct ground surveys. However, the results were sent to the mangrove recovery project managers. As it turned out, results were mostly unchallenged. The results provided include a quantitative evaluation of the mangroves restoration (in both absolute number of ha and in percentage of the total). An analysis of the change in other vegetation coverage was also included where relevant. Additionally, the results show a range of various degrees of success. Half of the projects were very successful, 20 per cent were successful, 20 per cent show limited or no change, and in one project a decline of mangroves was observed.

Several limitations for detecting mangrove recovery from space have been highlighted, the main one being that the satellite images should be taken at least three to four years after the complexion of the mangrove recovery, as the size of the mangrove canopy would otherwise not be large enough to be detected. It also has to be noted that mangroves and tropical vegetation can be easily confused, and such distinction from space therefore remains challenging. Overall, the study showed that remote sensing is a good tool for monitoring mangrove recovery.

1. Introduction

Mangrove establishment and rehabilitation projects have been given increasing attention in recent years. The general impression is that the level of success for replanting of mangroves has varied significantly. However, until now there has been little effort to map, monitor and compare results and/or experiences throughout the world and to analyse what makes a sustainable mangrove (re-)development succeed or fail.

This study conducted temporal analyses for 10 projects (24 sites in six countries (the United Arab Emirates, Madagascar, Kenya, Senegal, Solomon Islands and Indonesia) to assess mangrove recovery after the implementation of restoration projects. It was conducted to map and monitor the loss and/or increase of mangrove forest areas via satellite imagery and GIS technology, and tries to assess the potential benefit of these methods.

1.1 Literature review

Mangrove ecosystems

The term mangrove is both used for the tree itself, and the overall habitat. Mangroves are small to medium evergreen trees or shrubs (Kuenzer et al., 2011) usually with a complex root system. They grow in the intertidal zone of marine coastal environments and estuarine margins between approximately 30° N and 30° S (Giri et al., 2011). Mangrove habitats are forests of mangrove trees. They grow in high salinity, high temperature and extreme tidal zones, which have high sedimentation rates and muddy anaerobic soils (Giri et al., 2011). In this report, the word "mangrove" refers to the habitat, but it has to be kept in mind that in the literature it can be also referred to as a "tidal forest" or a "mangrove forest" (Giri et al., 2011).

Mangrove ecosystems are represented by a large variety of plant families that are salt tolerant and found in brackish waters (Field, 1998). "Mangrove" can also refer to the ecosystem itself; a differentiation that will be used in this publication.

The importance of mangrove forests

Globally, mangroves are among the most productive of coastal ecosystems. About 75 per cent of all tropical commercial fish species and associated ecosystems, such as seagrass meadows and coral reefs, depend on mangrove forests as nurseries, and for shelter and food. Additionally, mangroves protect coasts from waves and wind—helping to reduce the risk of flood damage and erosion—and support soil stabilization, nutrient retention, filtration of sediment and pollutants, and the sequestration of carbon dioxide. For people living in coastal areas, mangroves provide firewood, medicine, fibres and dyes, food and building material.

Mangroves are influenced by tidal levels, salinity, and rainfall, and are threatened by human pressure, (through wood/timber extraction, pollution, and reclamation), global warming, and rising sea level.

Mangroves have recently been recognized as a key component of the global carbon cycle. They are the most carbon-rich forests in the tropics and are able to sequester carbon at a faster rate than terrestrial forests (Donato et al., 2011; Ray et al., 2011; Matsui et al., 2012; Kauffman et al., 2014). If their overall coverage is combined with that of marshes and seagrass meadows, they only account for approximately 0.5 per cent of the seabed area but for more than 50 per cent of the earth's blue carbon sinks, and for 71 per cent of all carbon storage in ocean sediments (Nellemann et al., 2009). The annual economic value of coastal wetlands (mainly based on mangrove ecosystems) is estimated to be between US$2,000 and US$200,000 per hectare (Van der Ploeg et al., 2010).

Current status of mangroves

Giri et al. (2011) made the most recent comprehensive, global survey of mangrove coverage (using Landsat archives to estimate the total surface of mangroves in the year 2000 for 137,760 km^2), including data from 118 tropical and subtropical countries. Approximately 75 per cent of this area is concentrated in 15 countries[1]. While there are no accurate estimates of the original cover, there is a general consensus that it would have been over 200,000 km^2 and that considerably more than 50,000 km^2 or one quarter of original mangrove cover has been lost as a result of human intervention (Spalding et al., 2010), with at least 35 per cent disappearing within the past two decades (Valiela et al., 2001). This rate is four times greater than the loss of terrestrial rainforest (Duarte, 2009) and it is expected that it will further accelerate (Waycott et al., 2009).

The destruction of mangroves is closely linked with human activities such as urban development, aquaculture, mining and overexploitation for timber. The greatest threats come from the development of fish and shrimps farms, and overexploitation of fisheries. Alteration of hydrology, pollution and global warming are also contributing to the loss of mangroves, but to a lesser extent (Alongi, 2002).

Mangrove restoration

The definition of the term "restoration" is generally restricted to the process of assisting the recovery of an impaired ecosystem (Clewell and Aronson, 2007). In this document, the term has been broadened to encompass all associated components of the ecosystem, including hydrology, soils, water quality, and all plant and animal species (Lewis, 2011). Planting mangroves in bare areas where there were no previous mangroves is "afforestation", whereas planting in other vegetated surfaces is referred to as "habitat conversion" (Erftemeijer and Lewis, 1999).

In mangrove restoration projects, the following parameters need to be assessed for the whole watershed during the site selection: stability of the site, siltation rate, soil characteristics (i.e. salinity, pH, nutrients and grain size), exposure to waves and currents, tidal height, height of water table, water salinity, availability of fresh water, presence of pests, availability of propagules, and signs of natural regeneration (Field, 1996; Venugopal et al., 2008). An understanding of the causes of ecosystem degradation of the selected sites (i.e. past use as a shrimp farm or paddy field) is compulsory, as they will differentially affect soil quality and other parameters and potentially affect the success rate of a restoration