Application of Landsat Data to the Study of Mangrove Ecologies Along the Coast of Ghana

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Abstract — Sustainable management of coastal mangrove systems requires up-to-date data on land use and land cover information. The objective of this study was to use Landsat Thematic Mapper (TM) and the Enhanced Thematic Mapper Plus (ETM+) remote sensing information to provide such management data and corresponding analysis. This study showed that the degradation of Ghana's mangroves was due primarily to agricultural activities and human settlements. The paper concludes by making policy recommendations which involves the local population in the decision making process and the integration of remotely-sensed data into the management process to maintain the integrity of mangrove systems

Keywords: Ghana, remote sensing, mangrove, degradation and management

1. INTRODUCTION

Mangrove ecosystems are highly important to most nations around the globe and serve a number of productive functions. In the tropical areas, mangrove vegetation is important in stabilizing coastal ecosystems. Mangrove forests are greatly valued as a medicinal source among both urban and rural dwellers, and plant medicines are widely traded in the rural and urban markets. Large leaves of many mangrove trees are used to wrap food, notably fresh vegetables and fish... The gathering and trade of these leaves provide an important source of income to hundreds of local people, mostly women, along the coast. Mangrove ecosystems provide protective habitat for fish, crabs, shrimps and nesting grounds for bird species. They also guarantees the soil and understorey foliage protection from the direct brunt of raindrops and rays of sunlight (Rasolofo, 1997; Adeel and Pomeroy, 2002).

Despite these benefits, mangrove forest vegetation is threatened by human and natural factors. According to FAO data, mangrove stands around the globe declined from 19,809 hectares in 1980 to 14,653 hectares in 2000 (FAO, 2004). Along the coastal areas in most developing countries especially Africa, population pressure has led to the conversion of many mangrove areas to other uses, including infrastructure development, aquaculture, rice production, and salt production (Rasolofo, 1997; Edyvane, 1999; Botero and Salzwedel, 1999; Yap, 2000; Adeel and Pomeroy, 2002). In Kuala Selangor, Malaysia, physical processes especially erosion and deposition, coupled with changing activity associated with human land-use, has had considerable impact on the mangrove ecosystem (Ghazali et al., 2001). Evidence of extensive mangrove degradation in KwaZulu-Natal, South Africa through sedimentation, and dredging is also reported in the work of Forbe et al. (1996). A study done in Thailand by Akosornkoae and Paphavasit (1996), has also documented an extensive damage to its mangrove ecosystem due to sea level rise. Related problems are also found by Nur et al., (2001) in Indonesia, especially at Jakarta Bay on the north coast of Java.. Their study revealed mangrove destruction from pesticide contamination, blast fishing, sand mining, and coral extraction. A recent study in Brazil, by Silva et al. (2003) has shown the effects of heavy metals use such as mercury on mangrove destruction. The study of Voravit and Piamsak (2003) in the Gulf of Thailand attributed the degradation of its coastal mangrove to excessive shrimp farming. Overall, the literature on mangrove degradation reflects only the early stages of our understanding of the rapid destruction of coastal habitats and the environment.

In Ghana, existing literature reveal that, urbanization, high population growth, and salt and sand mining are among the major factors threatening the mangrove ecosystems along its coast. It is also documented that any management effort is hampered by lack of of development of data inventories for sustainable management. This suggests the need to find tools appropriate for sustainable mangrove management.

Recent studies in the literature revealed a widespread application of remote sensing in mapping and assessing mangrove ecologies along the coastal regions of the world (Hardisky et al., 1986; Hurd et al., 1992; Scavia et al., 1995; Green et al., 1996; Perez et al., 2002). In the U.S.A, Kelly (2001) used sequential Landsat Thematic Mapper (TM) images to quantify changes in wetland habitat along the coast of North Carolina. Kelly's study also called for the need for management to integrate remotely sensed data in order to improve wetland management processes in the United States. Jayatissa et al. (2002) combined ground-truth survey, aerial photographs, and remote sensing data to assess vegetation species including mangroves in the Kalametiya lagoon in southern Sri Lanka. Results of the study showed a decline in mangrove species caused by irrigation. In Mexico, Kovac et al. (2001) used multi-date data to assess potential losses of mangrove forest of the Teacapán–Agua Brava lagoon system. Their results indicated a decline of the mangrove species between 1972 and 1999 due primarily to hurricane activity and widening of the canal in the 1990’s.

Despite the successes of the use of remote sensing as effective planning and management tool in some parts of the world this technology has not been effectively used in most African cities to address coastal ecological degradation especially. Studies aimed at integrating this technology into a planning process to improve the efficiency of coastal management in Ghana are lacking. Perhaps the most important missing element in the previous efforts to manage the mangroves along Ghana coast consists of baseline data on the ecology, land use, and land cover of the area which forms the basis for most management schemes.

The objective this paper is to use Landsat Thematic Mapper (TM) and the Enhanced Thematic Mapper Plus (ETM+) remote sensing data to provide such data and corresponding analysis in developing a coastal management plan for Ghana.

2. MATERIALS AND METHODS

The Study Area

Ghana, is a former British colony, and shares borders with Togo, Burkina Faso, and the Ivory Coast (Figure 1). For the purpose of this paper, the study will focus on the west coast of the country. The area lies in the dry equatorial climatic region. It has two rainfall maxima, but the dry seasons are more pronounced. Mean annual rainfall is between 74 and 89 centimeters. The average monthly humidity is higher in the rainy seasons than during the rest of the year (Dickson and Benneh, 1988). Mangrove forests interspersed with coastal shrubs are the principal vegetation along the coast. Since the 1970s, the west coast has come under intense pressure due to urbanization, and population growth because of economic opportunities found in the coastal cities such as salt and sand mining (Coleman et al., 2004). There is also lack of effective regulations and a good coastal zone management (CZM) plan has impacted greatly the mangrove ecosystems (Mensah, 1997; Figures 2 and 3). The area is also home to many fishermen and fishmongers. Wood is heavily used as building materials, and a source of energy for the household to smoke their fish. These activities have had a tremendous impact on the mangrove ecologies.

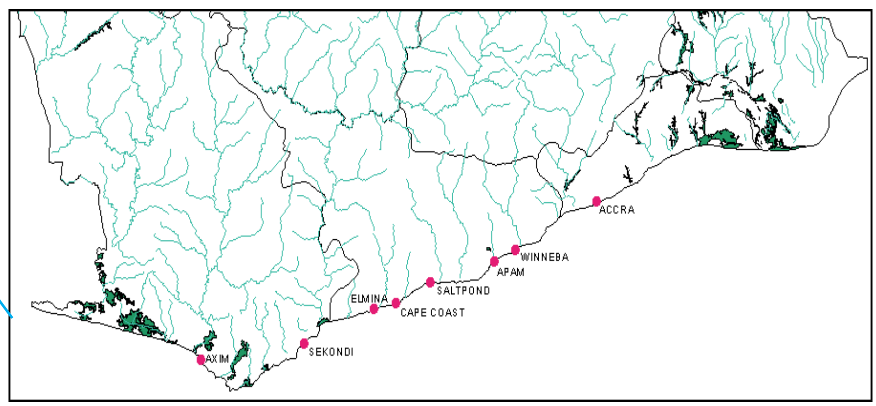

Figure 1: The Study Area. Insert shows the position of Ghana in West Africa.

Figure 2: Some of the mangrove ecosystems along the coast which has been depleted due to human disturbances.

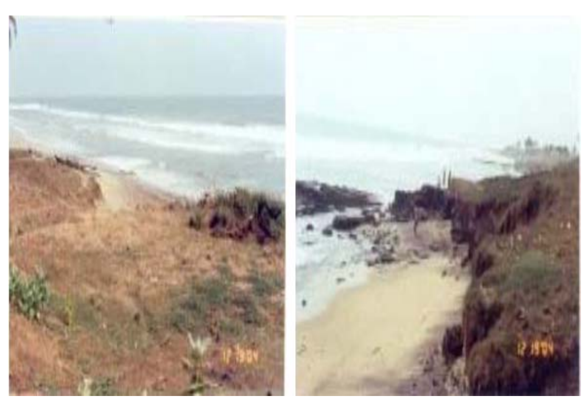

Figure 3: Degraded Mangrove along the Coast (east of Winneba) due to human and wave actions

Data Acqusition and Processing

Two near-anniversary Landsat TM and ETM+ images (20 June 1990; 14 June 2000) were obtained for the general study area. The Landsat TM and ETM+ satellite data were processed using ERDAS IMAGINE 8.7 image processing software. The images were imported into ERDAS using NLAPS importing format. Two steps were taken to process the data. In the first step, the images were imported into Erdas Imagine’s standard image format (.img). Since the images were in single bands, they were stacked together using the layer stack technique to form a floating scene. A subset of the images was obtained from the floating scene to identify the study area and then, later displayed as false-color composites using a band combination of red as band 4, green as band 3, and blue as band 1. In order to assure the map accuracy in terms of the relationship between specific pixels and map co-ordinates, the images were geometrically corrected using first order polynomial transformation. The final positional accuracy (root mean square error) for the transformation was within 1.00 pixel. The images were later resampled using the nearest neighbor techniques in order to preserve as much of the original details in the images as possible. The images were later enhanced using histogram equalization techniques, and classified using an unsupervised classification technique to identify land cover features within the study area.

3. RESULTS AND DISCUSSION

The classification results of the 1990 and 2000 images are provided in Figures 4 and 5, and Table 1.The results were compared to the ground truth data which provided an overall accuracy of 80 and 85 percent for the 1990 and 2000 images, respectively. Mangrove declined from an initial estimate of 2,605 hectare (ha) in 1990 to 1,905 ha in 2000 representing an overall decrease of 26.87 percent (Table 1). There was also a significant decrease in areas covered by coastal shrubs and grassland. For example in 1990, coastal shrubs vegetation declined from 27,884 ha to 21,181 ha in 2000, representing a decline of 24.04 percent. While there were declines in mangrove, coastal shrubs and grassland vegetation, agricultural activities and settlements in the area were increasing. For instance, between 1990 and 2000, agricultural activities increased from 15,363 ha to 20,450 ha representing a change of 24.88 percent. Settlements also posted an increase of 37.67% from 1,117 in 1990 ha to 1,792 in 2000. Water bodies also recorded an increase of (1.41%), but not significant as agriculture and coastal shrubs.

The decrease in mangrove and coastal shrubs may be partly due to the economic activities along the coast. Also, the increase in the agricultural activities along the coast may be attributed to the reduction in the mangrove and coastal shrub vegetation. Agricultural activities such as large-scale coconut plantations and other stable crops could have played a role in the decline of the mangrove and coastal shrub vegetation in the area. Furthermore, some of these coastal towns serve as district capitals.. These capitals with modern facilities serve as a pull factor for most of the migrants causing an increase in population at the same time putting a stress on the mangrove ecosystems.

4. CONCLUSION

This study has shown that the most significant factors affecting mangrove degradation are human settlements and agricultural activities. This calls for the need of the government of Ghana to integrate the local population into the decision making process. This process would be in the form of giving financial incentives to the local population and also educating them on the dangers of loosing mangrove resources. There is also the need for the government to integrate remote sensing data into the management planning process. This may provide baseline data for planning of mangrove resources and show existing spatial patterns of the area. Incorporation of remote sensing data may also assist the inventories of coastal resources over time. These measures would go a long way to help manage the coastal ecosystems including mangroves resources.

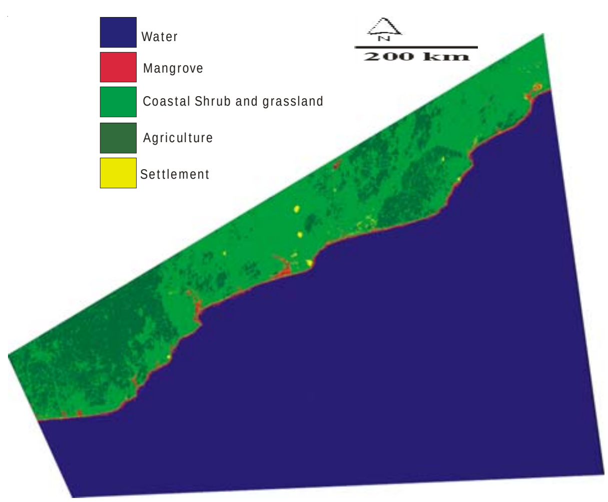

Figure 4: Classified image of Landsat TM image, June 20, 1990

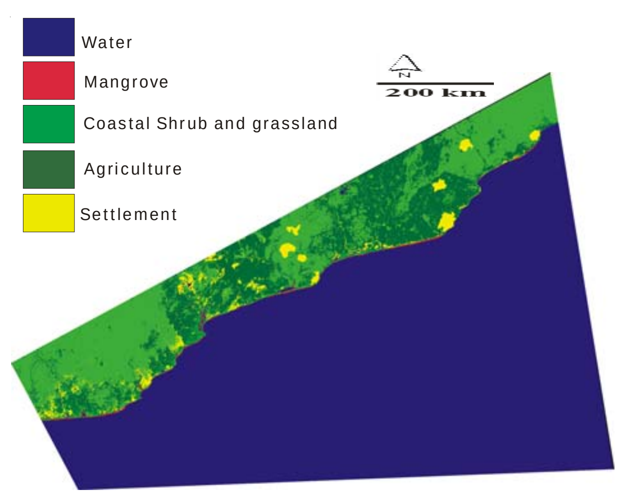

Figure 5: Classified image of Landsat ETM+ image, June 14, 2000

Table1: Results of the classified 1990 and 2000 images

Classes	Area (ha) in 1990	Area (ha) in 2000	% change (1990-2000)
Water	116,188	117,829	1.41
Mangrove	2,605	1,905	-26.87
Settlement	1,117	1,792	37.67
Coastal Shrubs	27,884	21,181	-24.04
Agriculture	15,363	20,450	24.88

5. ACKNOWLEDGEMENTS

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