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This article provides the first comprehensive scientific data on land-use and land-cover change in the coastal zone of Tanzania over the 1990 and 2000 time periods. The research was part of an African region initiative to demonstrate the practical application of geographic information for sustainable development. Remotely sensed images from close to 1990 Landsat Thematic Mapper (TM) sensor and 2000 Landsat-7 Enhanced Thematic Mapper Plus (ETM+) sensor and geographic information system (GIS) technologies are applied to discern changes in land cover and land use along the mainland Tanzania coast. Change detection results show that urban land area has increased dramatically. Mangrove forest area declined modestly, but field verification shows severe deterioration of their conditions near urban areas. While the area of dense woodland decreased, the area of open woodland and the area of woodland interspersed with agriculture increased. This study demonstrates how geospatial information science and technologies provide critical information and tools for coastal resource managers who work at the crossroads of resource use, land-cover change, poverty alleviation, and environmental management.

Keywords coastal land-cover change, integrated coastal management, remote sensing and GIS, Tanzania

Introduction

Science has always played a major role in coastal resource management worldwide. A central tenet underlying the integrated coastal management (ICM) concept is that ICM decision making is based on the use of the best information and science available (Tobey & Volk, 2002; Lowry, 2002). In Tanzania there are eleven marine protected areas and coastal management programs, in addition to a national ICM program. Each of these efforts require reliable knowledge and understanding in order to guide the wise use of coastal resources, resolve human-induced problems, and improve governance systems. Sustainable development requires access to data about the environment and natural resources, human patterns of land use, and infrastructure development.

The need for reliable information and understanding is becoming more evident as the complexity of the relationships among the environment, resources, and the economic and social well-being of resident coastal people, are fully recognized. The linkages between poverty, the environment, and the use of natural resources were dominant themes of the World Summit on Sustainable Development (WSSD). Decision makers need data and tools to monitor and assess natural resource inventories, environmental change, and social change.

This study of coastal land-cover change in Tanzania is part of the Geographic Information for Sustainable Development (GISD) initiative that was introduced in 2001 by the United States Agency for International Development (USAID). GISD is an international alliance which shares the goal of increasing local capabilities to apply earth observation data and geographic information technologies in Africa for improved decision making on sustainable development problems such as food security, environmental health, natural resource management, disaster mitigation, and poverty alleviation (NRC, 2002).

The Tanzania GISD effort and this case study contribute to an understanding of how applied technology and local knowledge are being integrated into improved decision making in coastal zone management. In this article we describe the geospatial information and techniques used, such as remote sensing and GIS, the use of local experts, and the land-cover change results obtained. We also describe the policy environment in Tanzania for the use of coastal geographic information and explore the human causes of coastal land-cover change and their policy implications.

The Rise of Science in Integrated Coastal Management in Tanzania

In November 2002, the government of Tanzania formally adopted a National ICM Strategy (United Republic of Tanzania, 2002). It is the second national ICM policy framework in Africa (after South Africa). The need for better coastal data on resource status, trends, and uses is one of six priority issues identified in the National ICM Strategy, and one of the strategies highlighted in the document calls for systems that allow available scientific and technical information to inform ICM decisions. The National ICM Strategy document mandates the National Environment Management Council (NEMC) to establish a Science and Technical Working Group that facilitates scientific inputs into national and local coastal programs.

The Tanzania GISD effort was specifically designed to support the need for scientific and technical information identified in the National ICM Strategy. Prior to the GISD effort, NEMC lacked coastal maps with geographically referenced data on coastal resources and land use for analysis and planning. In Tanzania, there is minimal in-country capacity in spatial information technologies and limited infrastructure for storing and sharing GIS data. The benefits of geospatial information for future decision making and implementation of the National ICM Strategy include the following:

- Provide accurate information regarding development trends, woodland change, and mangrove distribution.
- Help identify geographic areas of concern and assist in preparation of special area management plans.
- Support district coastal action planning.
- Visually connect resource use and/or degradation with management to expand commitment for resource management.
- Determine status and trends for components of the ecosystem to be managed.
- Help obtain scientific consensus on the nature of conservation problems and increase the legitimacy and acceptability of management actions on contentious issues.
- Provide a baseline for future land cover and land use assessments and a framework for integration with social and economic data in order to connect with human concerns such as poverty alleviation and food security.

Geospatial Technologies and Information

Remote sensing is well documented as an effective tool for mapping and characterizing cultural and natural resources (Holz, 1985; Lo, 1986; Jensen, 1996; Campbell, 1997). The multispectral capabilities of remote sensing allow observation and measurement of biophysical characteristics, while the multitemporal and multisensor capabilities allow tracking of changes in these characteristics over time. A common use of satellite data is production of land-cover maps that indicate landscape patterns and human development processes (Turner, 1990; Baker & Cai 1992). These capabilities also make remote sensing very useful for land management (Quattrochi & Pelletier, 1991). The advantages of satellite images over aerial photographs or videography for change detection include cost effectiveness, extent of coverage, and ability to reveal landscapes at large scales (Wang & Moskovits, 2001).

Satellite remote sensing has been applied in Tanzania for general vegetation and land cover mapping since the 1980s. A 1984 map of Tanzania vegetation types was compiled from the interpretation of 1974 Landsat Multispectral Scanner images at a scale of 1:2,000,000. Detailed information on coastal natural resources, such as mangrove forests, is not available in this early map. Two recent efforts in the application of satellite remote sensing for general land cover mapping in Tanzania include the United Nations Africover project and a natural resource mapping project executed by Hunting

Technical Services (HTS) of the United Kingdom. The HTS land-cover map was published at a 1:250,000 scale, which corresponds with existing topographic maps. The thematic maps were generated from interpretation of scale-controlled images. The mosaics of Landsat TM and SPOT (*Système pour l'Observation de la Terre*) satellite images used by HTS were acquired between May 1994 and July 1996. The HTS classification scheme has 34 land-cover categories. The United Nations Food and Agricultural Organization (FAO) hosted the Africover project. A goal of the Africover project is to establish a digital georeferenced database of land-cover for African countries (Alinovi, Gregorio, & Latham, 2001). Africover's product for Tanzania was produced by visual interpretation of Landsat and SPOT images acquired between February 1995 and June 1998. Land-cover categories were complied using an internationally adopted Land Cover Classification System (Di Gregorio & Jensen, 2000). The final map product is at 1:200,000 scale. The above two map products are good references for Tanzania but not suitable for the purpose of this study. In this project, we developed land-use and land-cover maps at 1:50,000 scale of the coastal districts of Tanzania over two time periods using Landsat remote sensing data. The generated maps were in digital format and managed within a geographic information system (GIS) database. The land-use and land-cover datasets were used to analyze rates of change in resource and land-use patterns.

Methodology

Study Areas and Data Sources

This study focused on Tanzania's fourteen mainland coastal districts and the nearby districts, which consist of Bagamoyo, Ilala, Kibaha, Kilwa, Kinondoni, Kisarawe, Lindi, Mkuranga, Mtwara, Muheza, Pangani, Rufiji, Tanga, and Temeke (Figure 1a). To produce the land-use and land-cover maps and quantify the changes, we used Landsat TM images acquired between 1986 and 1993 and Landsat-7 ETM+ images acquired between 2000 and 2001. Each Landsat scene covers a 185 × 185 square kilometer area. Table 1 lists the paths and rows of the Landsat scenes and the times of image acquisitions. The majority of the study area is covered by Landsat Path 166/Rows 64-66, and Path 165/Row 67. These four major scenes of TM images were acquired in 1987 (P166/R64), 1989 (P166/R65), 1989 (P166/R66), and 1991 (P165/R67), respectively. We refer to these TM scenes as the 1990 time period images. All the Landsat-7 ETM+ scenes were acquired in 2000 except the P167/R64 scene, which was acquired in 2001 (Table 1). Since only a very limited area (less than 2 percent) of the P167/R64 ETM+ scene is within the study area and was used by the project, we refer to the ETM+ scenes as the 2000 images.

The TM and ETM+ images possess 30-meter spatial resolution with multispectral coverage ranging from visible lights to the middle infrared portion of the electromagnetic spectrum. We did not use the TM and ETM+ thermal band data in this study. All images were orthorectified and georeferenced to the Universal Transverse Mercator (UTM) map projection and coordinate system.

The land-use and land-cover classification scheme we used was consistent but different from the land-cover categories defined and used by the Africover project, for the reasons that the classification system used by the Africover project was designed for generic multiple-country land-cover mapping, while our project was specific to the Tanzania coastal region. Our classification scheme consists of nine general categories, with twenty-one imbedded subcategories (Table 2). Among the land-use and land-cover types, urban and settled areas, mangrove forests, woodland categories and cultivated land were the primary categories of interest.

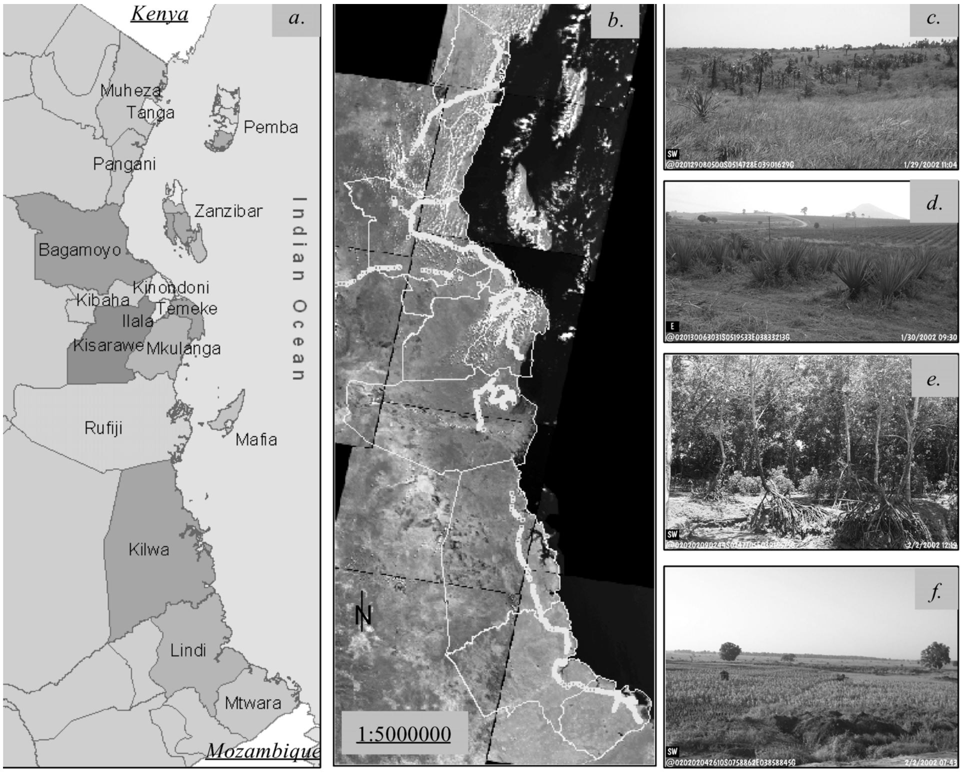

Figure 1. Study area includes the districts along the mainland coast of Tanzania (a). Ground truthing locations are illustrated on top of the mosaic of Landsat TM images (b). Each ground truthing location has corresponding GPS spatial and attribute records, as well as georeferenced photos. Examples of the georeferenced photos show the land-cover types of open woodland (c), sisal plantation as cultivated trees (d), mangrove forest (e), and agricultural area (f).

Field Observation and Ground Verification

We conducted field investigations in January, February, and August 2002, and March 2003 for the Tanzania coastal districts. The fieldwork supported TM and ETM+ image interpretation of land-cover types defined in the classification scheme. The field observations provided essential independent reference data for identifying land-use and land-cover types within the Landsat scenes as well as for accuracy assessment. Since the ground truth data were intended for interpretation of the two time periods Landsat TM and ETM+ images, special attention was given to the locations where the landscape had been altered and land use had changed over the past ten years.

We visited Regional and District management offices to seek advice and guidance. District natural resource officers reviewed laminated hardcopies of the satellite imagery with us and identified areas of interest. This helped us to ensure effective differentiation between different types of coastal forests, shrub lands, and mangrove forests. For example, mangrove officers helped in identification of specific sites where mangrove management actions, such as replanting or conversion from coconut plantations and rice farms to mangroves, had been conducted. The local knowledge also greatly helped in identification of critical locations where land-use and land-cover types had changed since 1990.

We used a Trimble® GeoExplorer® 3 Global Positioning System (GPS) unit to

Table 1
Landsat TM and ETM+ data acquisition

Path/row	Landsat TM	Landsat ETM+
165/66	June 12, 1993	May 22, 2000
165/67	June 7, 1991	May 22, 2000
166/64	May 15, 1986; January 26, 1987	January 22, 2000
166/65	December 9, 1989; May 29, 1991	June 30, 2000
166/66	June 8, 1989	June 30, 2000
166/67	May 18, 1993	May 29, 2000
167/64	January 1, 1987	March 4, 2001
167/65	June 5, 1991	July 7, 2000

Table 2
Classification scheme of the land-use and land-cover types

Land-cover types	Code	Subclasses
Urban/settled	U	1. Urban/settled Areas
Cultivated land	Ca	2. Cultivated agriculture (maize, rice)
	Ct	3. Cultivated tree (sisal, coconut, spice tree)
Forest	Fn	4. Natural forest\
	Fp	5. Forest plantation
	Fm	6. Mangrove forest
Woodland	Wc	7. Closed woodland
	Wo	8. Open woodland
	Wcr	9. Woodland with crops
Bush land	Bd	10. Dense bush land
	Bo	11. Open bush land
	Bcr	12. Bush land with crops
Grassland	G	13. Grassland
	Gtf	14. Grassland; temporarily flooded
	Gcr	15. Grassland with crops
Barren land	BS	16. Bare soil
	Sc	17. Salt crust
	Sb	18. Sandy beaches
Water	IW	19. Inland water
	O	20. Ocean
Wetland	Sm	21. Swamp/marsh

record the locations of field transects and points of interest. We recorded general characteristics of the landscape and associated information using a data dictionary uploaded to the GeoExplorer® 3. Items in the GPS data dictionary included site and transect identification information, date, time, and a description of the landscape by characterizing the land use, vegetation canopy and canopy density, and understory vegetation, in addition to other site-specific comments. We also referenced land cover types along the transects on the Africover and HTS maps.

Our field survey covered a total of 3,500 km by road. GPS locations and the recorded attributes were imported into a GIS database to facilitate integration of the data with the Landsat TM/ETM+ images. Figure 1b shows our field survey paths. As part of this effort, we recorded georeferenced site photos along the transects and the points of interest using a Kodak® DC265 Field Imaging System (FIS). The FIS consists of a twelve-channel Garmin® GPS III unit connected to a digital camera. The FIS photographs identify both their geographic location by latitude/longitude coordinates and their general compass bearings. We recorded over 1,500 georeferenced digital photographs which, when augmented with GPS data from the GeoExplorer® 3, effectively identified locations and characteristics of coastal land-use and land-cover types. Examples of the FIS site photographs illustrate the land cover types of open woodland (Figure1c), sisal plantation as cultivated trees (Figure1d), mangrove forest (Figure1e), and agricultural areas (Figure1f). The site photographs and GPS data effectively served as a virtual field reference database, helping in the verification and fine-tuning of the image interpretation to create the land-use and land-cover data.

Image Interpretation

We interpreted the Landsat images within a GIS environment to delineate land-use and land-cover types. We chose manual interpretation instead of digital supervised image classification for several reasons. First, the land-use and land-cover types are always mixed and the spectral signatures are not clear and unique in the study areas. For example, agriculture in coastal Tanzania is always interspersed with woodland or grassland areas, resulting in a landscape that makes supervised digital image classification of agricultural land very difficult. Rural settlements are typically constructed with natural, unmodified materials and are therefore often difficult to separate from their surroundings. Cultivated trees could be confused with other open and closed woodland and forested areas. Mapping the characteristics of land-use and land-cover types in this developing country requires a comprehensive understanding and interpretation of the landscape. Visual image interpretation and subsequent manual delineation can serve this purpose better. Second, the GIS infrastructure is weak in Tanzania. Therefore, conventional post-classification improvement using GIS data is almost impossible. Without postclassification improvement, the classification accuracy through supervised digital image classification would be challenged. Third, the local management officers prefer using hard copy maps generated from vector format GIS data, rather than maps produced from the raster data resulting from digital remote sensing image classification. Finally, the local professionals trained through the capacity building of this project felt more confident using manual interpretation in order to produce future updates of the land-cover and land-use data. Given these considerations, we chose manual interpretation to produce the land-use and land-cover maps and to conduct the subsequent change analysis. To reduce inconsistency that might be introduced in the image interpretation process, we had one expert conduct the image interpretation for both 1990 time period TM and 2000 ETM+ images.

As an accuracy assessment measure, we conducted a three-day workshop following the completion of the interpretation of the Landsat images. We invited natural resource officers from each of the districts, and other experts mainly from national government agencies, all possessing excellent knowledge of the landscape of the Tanzania coastal districts, to review the data. We asked all participants to bring to the workshop helpful information about land-cover in their respective districts, including information about vegetation types, agriculture and forestry activities, urban development statistics, and locations of mangrove replanting. Participants marked on the hard copy maps where errors or incorrect interpretations were found, and introduced their corrections. The results of the workshop were used to revise our land-cover interpretation. This verification gave added scientific credibility to the land-use and land-cover maps produced from the data at the conclusion of this effort. Figure 2 illustrates the produced land-use and land-cover maps. These maps provide a visual presentation of the identification of their respective geographic locations and change patterns.

On completion of the image interpretation, we calculated the total areas for each of the land-use and land-cover type from the two time periods for the entire study area (Table 3). We then used the administrative boundaries of the coastal districts to determine areas of the land-cover types within each district (Table 4). The last step was to calculate land-cover changes. The tabulated information is submitted for coastal resource management and development planning.

Results

Change detection results show that coastal areas experienced dramatic changes in urban land-cover. Urban and settlement areas increased from 38,877 hectares in the 1990 time period to 75,043 hectares in 2000, a 93% increase in about ten years (Table 3). Urban land-cover mostly increased surrounding major coastal cities, such as Dar es Salaam, Tanga, Kilwa, Lindi, and Mtwara.

Comparison of the resulting land-cover maps shows that mangrove forest areas declined by 3,828 hectares from 112,135 hectares in the 1990 time period to 108,307 hectares in 2000 (Table 3). This result is a little bit different from our previous report, which indicated that the mangrove forest was 109,593 hectares in 1990 and 108,307 hectares in 2000 (Wang, et al., 2003). We determined that the mangrove areas and changes summarized in this paper represent more accurate information. The data in this paper resulted from several improvements, including the acquisition of better quality orthorectified Landsat images, the enhanced experience in interpretation of land cover in Tanzania, and by incorporating the feedbacks from our accuracy assessment workshop. Although not dramatic, mangrove forest declined in most of the coastal districts except Tanga and Mtwara.

Conversion from closed or dense woodland into open woodland and woodland with scattered agriculture was one of the major changes in the coastal areas over the time period. The area of closed woodland declined 149,200 hectares, while the area of woodland with cultivation increased 78,285 hectares and the area of open woodland increased by 8,583 hectares (Table 3). Human impacts are the reasons for the change. For example, slash-and-burn agricultural practices were observed in several sites during our fieldwork. Conversion from open bushland to grassland was another change in land-cover. Open bushland declined by 25,851 hectares, while grassland increased in area by 137,196 hectares.

Discussion

Change of Urban Land and Settlements

The increase in urban and settlement areas coincides with a parallel increase in population. Census data shows that Dar es Salaam has gone from a city of 356,000 in 1967 to

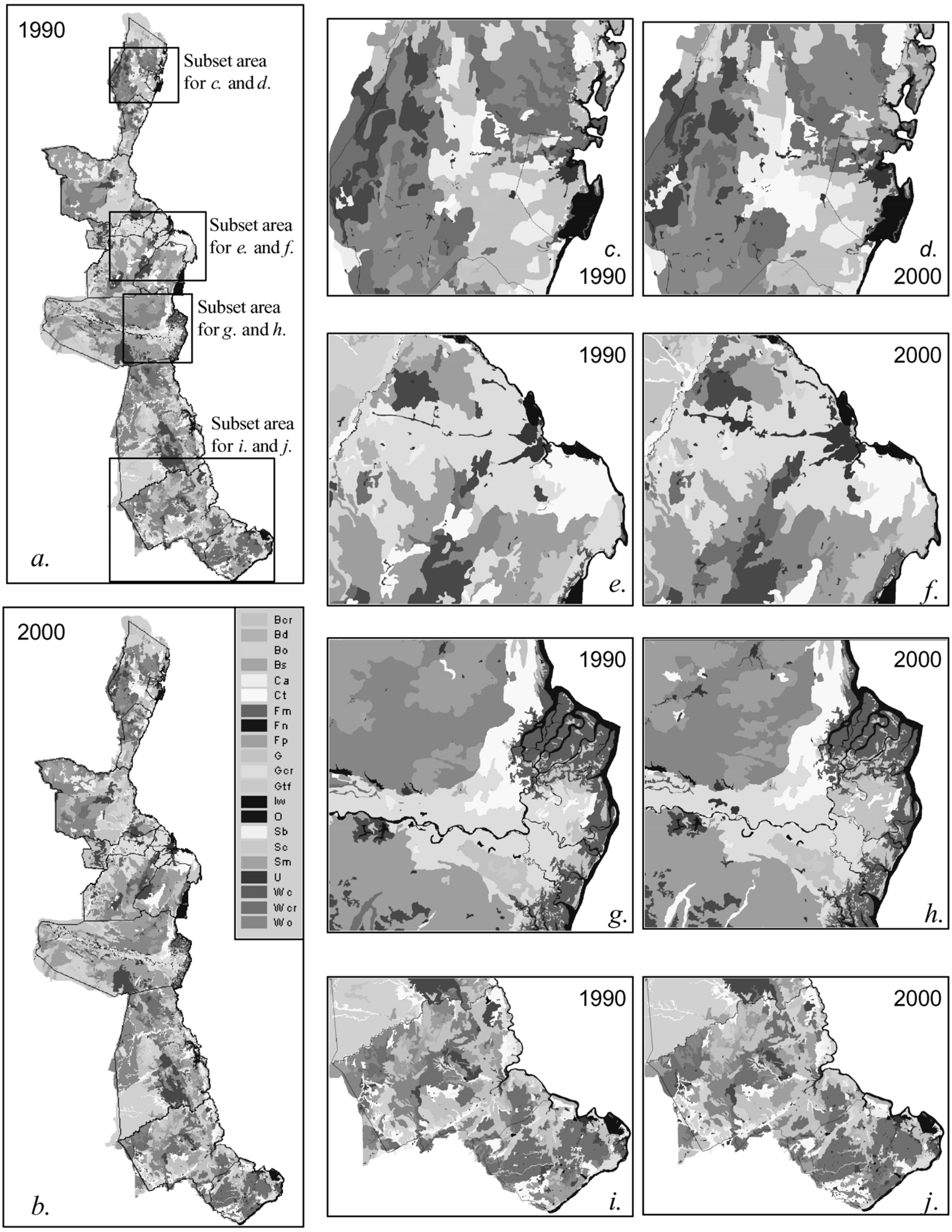

Figure 2. Land-use change of the Tanzania coastal districts between 1990 time period (a) and 2000 (b), and comparisons of the changes in the subset areas around the Tanga district ((c)–(d)), Dar es Salaam ((e)–(f)), Rufiji district ((g)–(h)), and Lindi and Mtwara districts ((i)–(j)).

a city of 2.5 million in 2002. Between 1988 and 2002, the population of Dar es Salaam grew 83% (Government of Tanzania, 2003).

Poverty and lack of livelihood opportunities are thought to be the key reasons for the rural-to-urban migration. For example, Lindi Region is among the poorest in the country. This has led to the large-scale migration of youths from this Region to urban areas, especially Dar es Salaam. This influx of youths to Dar es Salaam from Lindi and

Table 3
Land cover types in Tanzania coast districts between 1990 time period and 2000

Land-use and land-cover types	Area (hectares) 1990	Area (hectares) 2000	Change in area (1990–2000)	Percent change (1990–2000)
Bare soil	17,281	36,087	18,806	109
Urban/settled	38,877	75,043	36,166	93
Grassland	363,177	500,373	137,196	38
Grassland/flooded	108,189	136,647	28,458	26
Woodland with crops	571,163	649,448	78,285	14
Cultivated tree	419,491	425,767	6,276	1
Open woodland	1,012,068	1,020,651	8,583	1
Mangrove forest	112,135	108,307	–3,828	–3
Open bushland	930,941	905,090	–25,851	–3
Wetland	13,688	12,179	–1,509	–11
Cultivated agriculture	182,614	161,994	–20,620	–11
Closed woodland	1,189,373	1,040,173	149,200	–13
Grassland with crops	580,749	455,722	125,027	–22

Mtwara has created a distinctive social group known as "Wamachinga." With little education or money, most of the immigrants depend upon petty trading for survival. The policy implication evident in this ten-year trend in urban growth is a need to promote environmentally sustainable livelihood opportunities in rural coastal areas, and to strengthen infrastructure, education, and social programs in an effort to assist these rural communities in retaining their population base.

Change of Mangrove Forests

The resources harvested from mangrove habitat and their resulting products are an important economic and ecological resource in Tanzania. It is estimated that over 150,000 people make their living directly from mangrove resources (TCMP, 2001).

It was also recognized that the area of mangrove forest does not give a full picture of the health of mangrove ecosystems. Consequently, the NEMC Science and Technical Working Group conducted an assessment of mangroves in Rufiji District in 2003 and analyzed similar surveys from other districts in Bagamoyo, Kinondoni, and Kilwa along the coast, and the Dar es Salaam and Lindi Regions. Field assessments confirmed that the mangrove change data under-represents the threats to mangrove forests in Tanzania and the potential for future loss. Less accessible areas such as Rufiji appear to be in good condition, but the health of mangrove forests closer to urban areas and growing settlements is not as robust.

Wagner (2003) reported that the Rufiji mangrove forest is in the best health with respect to highest species diversity, height, and density of mature trees. The forests in coastal areas outside of the city of Dar es Salaam, on the other hand, are much degraded due to extensive overharvesting. Surveys taken in 2003 found the mangrove forests in Bagamoyo and Kilwa to be in good condition, although the forests in Bagamoyo primarily consist of very young trees, and both areas are under high cutting pressure. An indicator of cutting pressure is the number of stumps of cut trees per area of measurement. In three sites in Bagamoyo District five to ten stumps per 25 m^2 plot were observed (Wagner,

Table 4

Areas of selected land-cover types in coastal districts in 1990 time period and 2000 (hectares)

	Agriculture		Bushland		Forest/Woodland		Mangrove		Urban	
District	1990	2000	1990	2000	1990	2000	1900	2000	1900	2000
Bagamoyo	76,914	73,050	187,218	198,205	474,896	437,830	5,198	4,603	2,252	4,012
Ilala	0	0	0	0	578	764	0	25	2,868	5,102
Kibaha	16,943	13,016	6,536	5,529	55,010	47,992	0	0	2,365	7,814
Kilwa	120,515	109,038	384,036	418,826	645,313	641,591	22,454	21,777	2,070	4,438
Kinondoni	0	0	0	2,320	2,318	1,243	371	327	5,843	9,718
Kisarawe	35,150	19,915	128,739	95,558	256,233	273,389	0	0	1,319	3,054
Lindi	115,087	115,346	293,240	320,686	456,324	422,935	4,419	4,357	5,213	9,695
Mkuranga	34,607	43,494	15,051	4,496	142,104	157,996	4,940	4,242	492	1,436
Mtwara	48,200	51,563	87,299	83,669	209,850	206,397	9,486	9,643	6,551	12,412
Muheza	48,886	63,236	120,984	124,005	232,842	226,019	7,156	6,976	2,281	3,713
Pangani	16,342	15,558	22,543	19,557	59,791	69,572	2,335	2,259	352	580
Rufiji	45,863	45,579	209,488	198,102	673,224	630,957	51,121	49,032	2,054	5,292
Tanga	8,043	6,457	11,567	11,217	3,390	4,912	2,335	2,853	2,309	3,185
Temeke	35,555	31,509	2,188	3,826	2,153	419	2,320	2,213	2,908	4,592

2003). This is a significant number when compared in proportion to the number of trees per plot. Wagner also found that in general the largest trees had been cut, according to the circumference of the stumps within the plots that were measured.

An analysis of the loss and modification of marine ecosystems in Tanzania reveals that the major immediate causes of the degradation of mangrove forests are overharvesting of mangroves for firewood, charcoal-making, building poles and boat-making, and the clear-cutting of mangrove areas for agriculture, solar salt pans, road construction, urbanization, and commercial development (Francis et al., 2001). The production of charcoal is viewed as one of the main threats to the remaining mangrove forests, especially since all parts of the trees can be utilized and there is less incentive for selective cutting and sustainable harvesting.

Construction of evaporation ponds for solar salt production has resulted in the clearance of mangrove areas, especially in Bagamoyo and Kilwa Districts. Solar salt accounts for over 75% of the total salt produced in Tanzania (TCMP, 2001). The production of lime by burning pieces of coral harvested from reefs, is one source of coastal livelihood that is particularly destructive to both mangroves and coral reefs. Extraction of living coral for use in conversion into lime is widespread along the entire coast. Live and dead corals are extracted from reefs using pick axes, crowbars, and other implements. The corals are brought ashore where they are piled into kilns and burned to produce lime for local building and trade. This activity is very fuel intensive, and much of the wood is from mangroves. It is prevalent particularly in the Lindi, Mtwara, and Dar es Salaam regions.

Change of Woodlands

Conversion of closed woodland could be the result of increasing population in coastal areas and exploitation of wood resources. Without appropriate land-use management and sustainable agricultural practices, the loss of woodland will continue with associated consequences such as desertification, soil erosion, sedimentation, and the loss of coral and marine life resulting from sedimentation and turbidity in coastal waters. The implication of this study is that terrestrial land use, especially agriculture and forestry, is critical to sustainable coastal development and planning.

Concluding Comments

There is an increasing need for the use of science-based decisions for policy making in Tanzania. Information on land-use and land-cover change is critically important. Coastal and natural resource managers in particular have recognized the value of this type of information for resource management and sustainable development. This reflects the level of attention given to scientific and technological issues in general on the part of coastal management professionals.

The integrative quality of geographic information that links social, economic, and environmental data opens new opportunities for collaboration among natural scientists, social scientists, and decision makers at all levels. The intersection of resource use, land-cover change, poverty, and environmental management, with their attendant social and economic consequences, are at the forefront of coastal and marine management in Tanzania. Successful implementation of recent national priorities addressing poverty alleviation and integrated coastal management require objective scientific information to assist with developing policy priorities, understanding cause-and-effect linkages between human activities and ecosystem changes, formulating management strategies, and devising conservation measures. The results from this study demonstrate and encourage the use of geospatial technologies and information in environmental and natural resources monitoring in order to obtain information necessary to support decision making.

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