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LAND COVER CHANGES ALONG THE COASTAL MARINE ECOSYSTEMS OF ZANZIBAR

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ABSTRACT

The coastal marine ecosystem of Zanzibar is experiencing a decline of natural habitats and biodiversity. due to the changes in land use and land cover caused by increasing human. This study investigates the changes that have occurred between 2001 and 2011. Landsat ETM+ images were used to locate and quantify the changes. The intensity analysis method was employed to get quantitative information at interval and category levels only. The interval level examined how the size and speed of change vary across time intervals, and the category level examined how the size and intensity of gross losses and gross gains in each category vary across categories for each time interval. Results show that between 2001 and 2011, mangrove, cultivated land/shrubs and bareland covers declined by 127.4 ha, 46.0 ha and 10.2 ha respectively while mixed trees, "jangwa la bahari" and water increased by 147.2ha, 35.8ha and 0.6 ha respectively in Kisakasaka. Between the same time, cultivated land/shrubs, mangrove and mixed trees covers declined by 262.2 ha, 86.3 ha, 49.4 ha respectively while rice pads, barelends, "jangwa la bahari" and water has been increased by 165.6 ha, 109.7 ha, 103.9 ha and 18.7 ha respectively in Bumbwini.

Keywords: Land cover, Land cover change, Biodiversity, Ecosystem Intensity analysis, Zanzibar.

1. INTRODUCTION

Marine ecosystems are among the largest of the Earth's aquatic ecosystems. They include oceans, salt marshes and intertidal ecology, estuaries and lagoons, mangroves and coral reefs, the deep sea and the sea floor. Marine ecosystems cover approximately 71% of the Earth's surface and containapproximately 97% of the planet's water [1]. Coastal ecosystems are important because they provide food source to both estuarine and coastal ocean consumers; serves as habitat for large numbers of living organisms; and they regulate important components of coastal chemical cycles. As coastal populations grows, the coastal lands, like any other land; have come under increasing pressures from a wide variety of factors, including encroachment and unsustainable harvesting of coastal products.

The coastal areas of Tanzania are subject to a number of threats which consequently may lead to biodiversity loss and degradation of the whole ecosystems. However, major driving forces of biodiversity loss are those associated with the use of natural resources at the local level. Threats to coastal ecosystem and their habitats include: clearing, over-harvesting, destruction of coral reefs, mining and exploration activities as well as urbanization, pollution and climate change [2] and climate variability.

Rapid population growth in Zanzibar island over the last three decades has created a significant challenge to land use development in the Island [3]. The growing population has led to a higher demand for settlements, agriculture and other infrastructure developments which in turn has an impact on the resource base, threatening the productive and protective capacity of the marine resources [4].

However, in Zanzibar the situation is somehow different from what is happening in Tanzania mainland; the coastal ecosystems have often been cleared to make room for agricultural land, human settlements and infrastructure (such as marinas), and industrial activities. More recently, clearing for tourist developments, shrimp aquaculture, and salt farms has also taken place. This clearing is a major factor behind ecosystems loss along the coastal areas of Zanzibar.

Understanding the status of the coastal ecosystems is important for strengthening stakeholders so that they can be able to use and manage the land resource sustainably. The objective of this study is, therefore, aimed to contribute to the understanding of land cover changes in the coastal ecosystems of Zanzibar, using intensity analysis approach, under scenario of climate variability and change in order to provide information for coastal marine ecosystem based management (CMEBM). Intensity analysis offers the opportunity to characterize land change patterns quantitatively, so that subsequent phases of investigation can focus efficiently on the important patterns and processes of change. It also accounts for the intensity of transitions of land cover change in the area [5].

In this study the change is analysed in terms of size and intensity at three levels; i.e. interval, category and transition levels starting from general to more detailed levels. At first level, (interval level); the total change in each time interval is analysed to examine how the size and annual rate of change vary across time intervals. At the second level, (category level); each category is examined to measure how the size and intensity of both gross losses and gross gains varies across space. At the third level, the “transition level”, a particular transition is analyzed to examine how the size and intensity of the transition varies among categories available for that transition.

2. METHODOLOGY

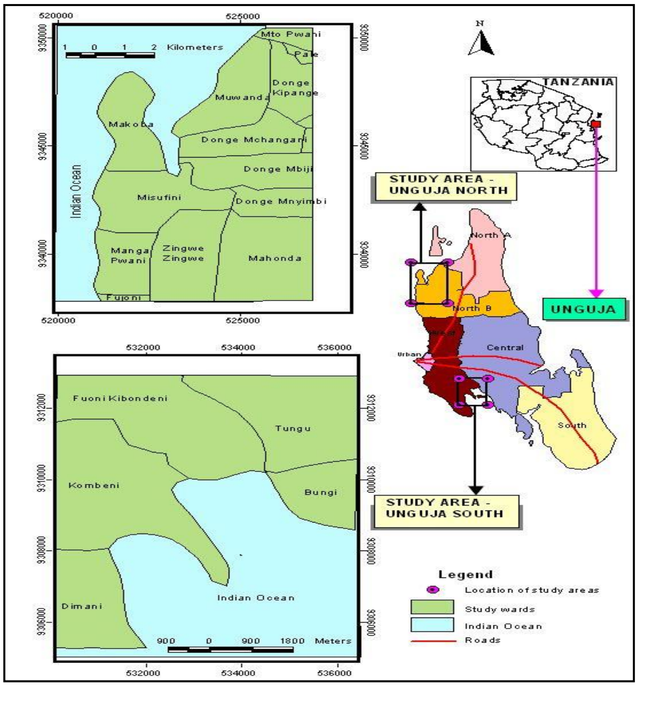
2.1. Description of Study Area

Zanzibar, which is part of the United Republic of Tanzania, consists of two main islands of Unguja and Pemba. This study uses the term Zanzibar referring to the island of Unguja, and therefore the data collected and analysed were based on Unguja, at Bumbwini and Kisakasaka mangrove ecosystems (Figure 1).

Bumbwini is located in the northwest of the Island, on a short peninsula immediately to the south of Tumbatu Island. The The Bumbwini Bay is host to the Bumbwini mangrove, a 1,507 acre forest that is an important ecological site which provides rich fishery grounds for the local community. The mangrove forest has faced increased environmental degradation from waste disposal, clear-cutting of mangroves, poor agricultural practices leading to increased erosion and sedimentation, overfishing and general lack of awareness among the local community. As a result, a number of community based organizations and village conservation committees, have come together to initiate efforts to conserve and manage the mangrove forest within Bumbwini Bay.

Kisakasaka is located on southern side of the Island along the Kiwani bay. With a population of 526 people relying entirely on 400 ha of mangrove for their livelihood, Kisakasaka was used as a site for a community-based management pilot project of forest resources in Zanzibar. For this reason Kisakasaka was also selected as one of the areas for this study.

Figure-1. A map of Tanzania showing location of the study areas



2.2. Data Collection

2.2.1. Satellite Data

Data sources were determined based on the objectives of the study. Landsat satellite images (for 2001, 2009 and 2011) used in this study were obtained from, Unites States Geological Survey (USGS) Data Interface from the Global Visualization Viewer (Glo Vis) at http:glovis.usgs.gov. Some of the constraints encountered are lack of cloud free data in the case of satellite imagery because Unguja being an Island is persistently covered by clouds.

2.2.2. Topographic Maps and Aerial Photographs

The latest set of aerial photographs (of 2005) covering the area of study were obtained from Unguja Department of Forests. Topographical maps at the scale of 1:50,000 were obtained from Sokoine University of Agriculture, Department of Soil Sciences.

2.3. Digital Image Processing

Remotely sensed data were processed using ERDAS Imagine 9.1 software. The Landsat imageries were rectified to the UTM projection, zone 37 on Clarke 1880 spheroid and Arc 1960 datum. An area of interest (AOI) was selected based on the criteria that the mangrove forests of Kisakasaka and Bumbwini are included as among other land covers along the coastal marine ecosystems. This AOI was used to subset the three Landsat ETM+ imageries of 2001, 2009 and 2011 for both study areas. Landsat imageries were processed (classified) to generate land cover types and also analyzed to determine changes that have taken place within the study areas between years 2001 and 2011. Aerial photos of 2005 year and topographic map of 1985 year, both at a scale of 1:50,000 were used to assist in image interpretation and the classification process.

2.3.1. Image Classification

The hybrid method was used forclassification processes; where the unsupervised classification tool was used to create isodata and signature files. The files were then imported for final supervised classification process. Seven classes for Bumbwini and six classes for Kisakasaka were formulated and confirmed through the use of ground-truth data. The classes of interest included water, mangrove, jangwa la bahari/cleared mangrove, mixed trees (including settlements), rice pads (for Bumbwini only), scrubs/crop (cultivated) land, and bare land.

2.3.2. Class Editing

Mixed trees includes forest, palm trees, mango trees and other varieties, were classified together with settlement because houses in the area are mostly covered with palm trees, therefore, to separate the two classes based on Landsat imagery was very difficult. The spectral reflectance for "*jangwa la bahari"* and cleared mangrove were also difficult to differentiate, hence accounted in the same classes. The same applied to cultivated (crop) land and scrubs. Other mixed classes were rectified through the process of class editing, where each pixel in the mixed classes is visited and labeled by its true class. The true class of each pixel is identified by visually interpreting the satellite image data using available ground truth information. The approach is based on generating binary masks or bitmaps over areas where mixed classes are identified. The masks are then used to either restrict the classification algorithm to a spectral range of pixels representing respective classes or transfer pixels from one category to another, or merge classes that are to form one class or delete undesirable classes falling under the mask.

2.4. Ground Truthing and Classification Accuracy Assessment Data

Reference points were collected simultaneously during the social economic survey. A total of 112 reference points were collected from Bumbwini area and 62 points from Kisakasaka based on the 2011 image. The 2011 imagery was selected for conducting accuracy assessment because it is the most recent image and close to ground observations. In literature it is sighted that if the overall classification accuracy is greater than 80% the classification is accepted [6]. In this study, the overall accuracy was greater than 80% and hence was acceptable.

2.5. Socio-Economic Survey

Socio-economic data was collected using a variety of participatory rural appraisal (PRA) techniques including focus group discussions and questionnaire survey. A cross-sectional study design was used to explore important information on rural economic activities, conservations, land tenure, people’s involvement in various land uses including agriculture, fishing, uses of coastal marine ecosystems and climate change awareness.

2.6. Images Analysis and Change Detection Analysis

The generated land cover maps for 2001, 2009 and 2011 were analysed following map overlay method. Recording were done following supervised classification, and then areas for each land cover category were calculated for both years. The change detection was done by post classification approach using image interpreter|GISanalysis|matrix tool in ERDAS software. The approach identifies quantitative changes by comparing two independent classified images pixel by pixel basis using a change detection matrix [5, 7]. The observed matrix was then processed in an intensity analysis program (Pontius matrix excel sheet). Analysis of transition matrix and quantitative change was done based on the definition adopted from Pontius, et al. [8] and Alo and Pontius [9]. The persistence is an area ($\mathrm{A_{ii}}$, given in a column for category i, or$\mathrm{A_{jj}}$, given in a row for category j in the matrix) which remained under the same land cover category over time, i.e. remain unchanged, which in a standard cross-tabulation matrix, is given in the diagonal.

The gross loss,L_i, is the area which experiences loosing by category *i* between initial time and subsequent time, given as a difference between total area $(\sum \mathrm{A_{i+}})$ and persistence in a column (equation 1). The gross gain is the area which experiences gaining by category *j* between initial time and subsequent time, given as a difference between total area $\left(\sum \mathrm{A_{+j}}\right)$ and persistence in a row (equation 2).

$$\mathrm{L_i} = \sum \mathrm{A_{i+}} - \mathrm{A_{ii}} \qquad 1$$

$$\mathrm{G_j} = \sum \mathrm{A_{+j}} - \mathrm{A_{jj}} \qquad 2$$

Net quantity change is the absolute difference between the gross gain and the gross loss (equation 3), and overall change for each category is given as the sum of the gross gain and gross loss (equation 4).

$$\text{Net quantity change} = |\text{Gross gain} - \text{Gross loss}| \qquad 3$$

$$\text{Overall change} = \text{Gross gain} + \text{Gross loss} \qquad 4$$

When a land cover experiences gross gain and gross loss simultaneously, a kind of this change is known as swap location change [9], and is given by equation 5.

$$\text{Swap location} = \text{Overall change} - \text{Net quantity change} \qquad 5$$

3. RESULTS AND DISCUSSIONS

3.1. Classification Accuracy Assessment

3.1.1. Accuracy Assessment for Bumbwini Image

Table 1 shows details of producer's and user's accuracy for Bumbwini. Mangrove had the highest producer's accuracy of 96.0% and thus it was assumed that this proportion had been correctly classified followed by mixed trees, cultivated land and rice pads with 94.7 %, 82.1 % and 80.0 % respectively. Classes of water, "*jangwa la bahari"* and bare land achieved less than 80 % of the producer's accuracy, which indicates that a considerable number of pixels belonging to these classes had been classified erroneously or in other words, there was an omission error of greater than 20 % for water, "*jangwa la bahari"* and bare land classes.

On other hand, Water had the highest user's accuracy (100 %) showing that all of the pixels labeled water on the classified image represented water. Although mixed trees had the highest producer's accuracy, only 78.3 % of the area labeled mixed trees was actually covered mixed tree on the ground. This means that 21.7 % of pixels classified as mixed trees were actually other information classes. The class mixed tree, therefore, has a commission error of 21.7 %. The same can be said for the cultivated land and rice pads. The number of pixels were considered to be correctly classified is 91 out of 112 which gives an overall accuracy of 81.3 %.

Table- 1. Accuracy totals for Bumbwini

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water	9	5	5	55.60%	100.00%
Mangrove	25	25	24	96.00%	96.00%
Jangwa	10	12	6	60.00%	50.00%
Mixed trees	19	23	18	94.70%	78.30%
Rice pads	10	12	8	80.00%	66.70%
Cultivated/shrubs	28	26	23	82.10%	88.50%
Bare land	11	9	7	63.60%	77.80%
Totals	112	112	91		
Overall Classification Accuracy = 81.3%					

3.1.2. Accuracy Assessment for Kisakasaka Image

Table 2 shows details of producer's and user's accuracy for Kisakasaka. Water, "*jangwa la bahari"* and mixed trees had the highest producer's accuracy of 100.0% and thus it was assumed that this proportion had been correctly classified, followed by bare land with 94.7 %, 83.3 %. Classes of mangrove and cultivated land achieved only 68.8 % and 60.0 % of the producer's accuracy, which indicates that a considerable number of pixels belonging to these classes had been classified erroneously or in other words, there was an omission error of 31.2 % and 40 % for mangrove and cultivated land classes respectively.

On the other hand, water, mangrove, cultivated land and bare land had the highest user's accuracy (100 %) showing that all of the pixels labeled water, mangrove, cultivated land and bare land on the classified image were real water, mangrove, cultivated land and bare land respectively. Although mixed trees and "*jangwa la bahari"* had the highest producer's accuracy of 100 %, only 63.6% and 62.5 % of the area labeled mixed trees and "*jangwa la bahari"* was actually covered mixed tree and "*jangwa la bahari"* on the ground respectively. This means that 100 % of mixed tree and 100 % of "*jangwa la bahari"* visited were correctly interpreted but only 63.6% of mixed tree and 62.5 % of "*jangwa la bahari"* interpreted were real. The class mixed tree and "*jangwa la bahari"*, therefore, have commission errors of 36.4% and 37.5 respectively. The number of pixels that were considered to be correctly classified is 51 out of 62 which gives an overall accuracy of 82.3 %.

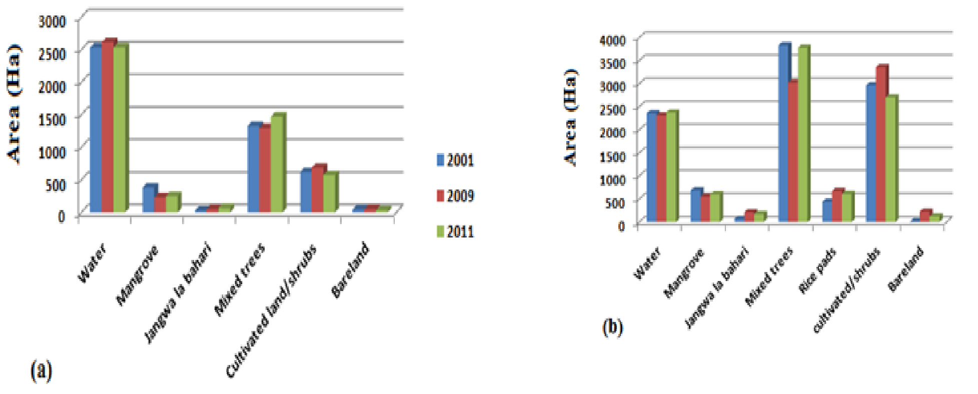
Table 2. Accuracy totals for Kisakasaka

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water	5	5	5	100.00%	100.00%
Mangrove	16	11	11	68.80%	100.00%
Jangwa la bahari	5	8	5	100.00%	62.50%
Mixed trees	14	22	14	100.00%	63.60%
Cultivated land	10	6	6	60.00%	100.00%
Bareland	12	10	10	83.30%	100.00%
Totals	62	62	51		
Overall Classification Accuracy =82.3%					

3.2. Land Cover Distribution

Figure 2 shows total area covered by each land cover class (category) at each epoch and for (a) Kisakasaka and (b) Bumbwini areas. Over 50% of area is covered by water, followed by mixed trees, cultivated land and mangrove at all time point and for both Kisakasaka and Bumbwini. It gives the quantity of each category, but doesn't give any details concerning individual transitions and stationarity between categories [5]. Persistence, gross gain and loss for each category are explained in tables 3 and 4 for Kisakasaka, and tables 5 and 6 for Bumbwini.

Figure-2. Distribution of land cover over (a) Kisakasaka and (b) Bumbwini for 2001, 2009 and 2011



The gross loss column shows the quantity of land cover that experiences a gross loss of land cover during 2001-2009 and 2009-2011 time interval, and the gross gain column shows the quantity of land cover that experiences a gross gain of land cover between the same time interval [9].

In order to budget the overall change for each category, the organized information is given in table 5 and 6 for Kisakasaka and Bumbwini respectively. Table 5 shows that the largest gross loss in 2001-2009 was experienced by Mixed trees (529.4 ha), followed by cultivated land (394.1 ha) and mangrove (211.7 ha), while net quantity change shows that mangrove and mixed trees are losing with 148 ha and 30.9 ha respectively. In 2009-2011, the largest gross gain was for Mixed tree (495.7 ha) followed by cultivated land (278.3 ha) and mangrove (78.8 ha).

Table-3. Cross tabulation matrix showing observed persistence (on the main diagonal) and observed land cover changes (off the main diagonal) for 2001-2009 time interval for Kisakasaka

		2009							
	Class name	**Water**	**Mangrove**	**Jangwa (cleared Mangrove)**	**Mixed trees**	**Crop land/ shrubs**	**Bareland**	**Total 2001**	**Gross Loss**
2001	Water	2508.5	4.32	0	15.66	3.33	0.18	2532.06	23.49
	Mangrove	72.36	167.85	28.71	85.86	24.75	0	379.53	211.68
	Jangwa/ (cleared mangrove)	1.71	5.49	1.35	15.03	6.3	0	29.88	28.53
	Mixed trees	23.76	39.78	15.21	796.14	421.38	29.25	1325.52	529.38
	Crop land/ shrubs	7.83	12.42	6.84	360.99	223.83	6.03	617.94	394.11
	Bareland	0.36	1.71	0.09	20.97	7.65	13.86	44.64	30.78
	Total 2009	2614.5	231.57	52.2	1294.6	687.24	49.32	4929.57	1217.97
	Gross Gain	106.02	63.72	50.85	498.51	463.41	35.46	1217.97	

The overall change, i.e. 2001-2011, in Kisakasaka (Table 5) shows that a total area of 127.4 ha, 46.0 ha and 10.2 ha of mangrove, cultivated land and bareland respectively was declined, and 147.2 ha of mixed trees, 35.8 ha of "jangwa la bahari" and 0.6 ha of water was increased. The overall change, i.e. 2001-2011, in Kisakasaka (Table 5) shows that a total area of 127.4 ha, 46.0 ha and 10.2 ha of mangrove, cultivated land and bareland respectively was declined, and 147.2 ha of mixed trees, 35.8 ha of "jangwa la bahari" and 0.6 ha of water was increased.

Table 6 shows that the largest gross loss in 2001-2009 was experienced by Mixed trees (1649.1 ha), followed by cultivated land (1135.4 ha), rice pads (285.6 ha) and mangrove (225.5 ha), while net quantity change shows that mixed trees, mangrove and water are losing with 807.9 ha, 134.0 ha and 42.1 ha respectively. In 2009-2011, the largest gross gain was for Mixed tree (1500.8 ha) followed by cultivated land (892.4 ha) and mangrove (132.3 ha). The overall change, i.e. 2001-2011, in Bumbwini (Table 6) shows that a total area of 262.2 ha, 86.3 ha and 49.4 ha of cultivated land, mangrove and mixed trees respectively was declined, and 165.6 ha of rice pads, 109.7 ha of bareland, 103.9 ha of "jangwa la bahari" and 18.7 ha of water was increased.

Table-4. Cross tabulation matrix showing observed persistence (on the main diagonal) and observed land cover changes (off the main diagonal) for 2009-2011 time interval for Kisakasaka

		2011							
	Class Name	**Water**	**Mangrove**	**Jangwa/ cleared mangrove**	**Mixed trees**	**Crop land/ shrubs**	**Bareland**	**Total 2001**	**Gross Loss**
2009	Water	2521.3	62.55	1.26	22.95	6.21	0.27	2614.5	93.24
	Mangrove	2.7	173.25	17.73	37.08	0.54	0.27	231.57	58.32
	Jangwa/ cleared mangrove	0	6.84	29.34	15.93	0.09	0	52.2	22.86
	Mixed trees	8.28	9.36	16.83	977.13	268.2	14.94	1294.83	317.7
	Crop land/ shrubs	0.36	0.09	0.54	388.2	293.4	4.32	687.06	393.5
	Bareland	0	0	0	31.5	3.15	14.67	49.32	34.65
	Total 2009	2532.6	252.09	65.7	1472	571.7	34.47	4929.5	920.3
	Gross Gain	11.34	78.84	36.36	495.7	278.2	19.8	920.34	

The kind of results given above explains only how much, where, and what type of land cover change has occurred. Figure 3 gives a graphical approach of intensity analysis to present results at interval level; in which, 2001-2009 was identified to be slow in terms of overall annual change for both study areas, while 2009-2011 was the fast in changing. The study also reveals that the uniform rate of changing at Bumbwini is higher than Kisakasaka. This could either be contributed by population, since Bumbwini is highly populated than Kisakasaka. The results of intensity analysis at category level are given in figures 4 and 5 for Kisakasaka and Bumbwini respectively. In figure 4, only water was dormant for both time intervals in Kisakasaka, while other classes were active.

"Jangwa la bahari" is mostly active followed by bareland and cultivated land in 2001-2009, while bareland is mostly active followed by cultivated land and hence "Jangwa la bahari" in 2009-2011. All cover classes are stationary since the intensity of both gross gains and losses are less than uniform line for water and are greater in other classes in all intervals.

Table-5. Cross tabulation matrix showing observed persistence (on the main diagonal) and observed land cover changes (off the main diagonal) for 2001-2009 time interval for Bumbwini

		2009								
	Class name	**Water**	**Mangrove**	**Jangwa/ cleared mangrove**	**Mixed trees**	**Rice pads**	**Crop land/ shrubs**	**Bareland**	**Total 2001**	**Gross Loss**
2001	Water	2204	58.0	61.4	19.9	2.5	9.9	0.0	2356	151.7
	Mangrove	61.4	459.9	65.6	66.9	4.9	26.8	0.0	685.4	225.5
	Jangwa/ (cleared mangrove)	2.5	7.7	43.4	8.8	0.6	5.5	0.1	68.6	25.2
	Mixed trees	43.4	24.9	28.2	2180.8	195.4	1314	42.9	3830	1649.1
	Rice pads	0.0	0.0	3.7	73.6	154.6	165.2	43.1	440.2	285.6
	Crop land/ shrubs	2.3	1.0	11.8	667.4	312.7	1831	140.3	2966	1135.4
	Bareland	0.0	0.0	0.0	4.6	2.5	5.2	0.8	13.1	12.3
	Total 2009	2314	551.4	214.0	3021.9	673.2	3357	227.3	10359	3484.7
	Gross Gain	109.5	91.5	170.6	841.1	518.6	1527	226.4	3485	

At Bumbwini (Figure 5) again shows water and gain in mangrove were dormant in 2001-2009, while other classes were active. Bare land is mostly active followed by gain in "jangwa la bahari", rice pads and slight active in cultivated land and loss in mangrove for 2001-2009.

Otherwise, in 2009-2011loss in bare land was mostly active followed by rice pads, jangwa la bahari, cultivated land and gain in mangrove. Loss in mangrove followed by water, are dormant cover classes over the others. Only mangrove is not stationary since the loss intensity of 2001-2009 is greater than uniform line while in 2009-2011is less than uniform line and vice-versa is true for mangrove gain.

Generally, there is variation in cover coverage between the two time intervals. It is important to note that all land cover categories changed but with varying magnitudes. Variations on results from change detection analysis are unavoidable, and these could impair the interpretability for the detected changes.

Table-6. Cross tabulation matrix showing observed persistence (on the main diagonal) and observed land cover changes (off the main diagonal) for 2009-2011 time interval for Bumbwini

	Class Name	2011								
		Water	**Mangrove**	**Jangwa/ cleared mangrove**	**Mixed trees**	**Rice pads**	**Crop land/ shrubs**	**Bareland**	**Total 2001**	**Gross Loss**
2009	Water	2303.0	10.3	0.4	0.2	0.0	0.0	0.0	2313.8	10.8
	Mangrove	38.0	466.8	29.3	14.7	0.5	2.2	0.0	551.4	84.6
	Jangwa/ cleared mangrove	1.1	61.7	92.9	20.8	16.2	17.1	4.2	214.0	121.1
	Mixed trees	31.3	43.6	31.5	2279.5	73.5	541.1	21.4	3021.9	742.4
	Rice pads	0.0	2.1	3.1	168.2	229.5	265.5	4.9	673.2	443.7
	Crop land/ shrubs	1.3	14.7	15.3	1281.1	205.3	1811.4	28.4	3357.4	1545.9
	Bareland	0.0	0.0	0.1	15.9	80.7	66.5	64.0	227.3	163.3
	Total 2009	2374.7	599.1	172.4	3780.4	605.8	2703.8	122.9	10359.0	3111.8
	Gross Gain	71.6	132.3	79.6	1500.8	376.3	892.4	58.9	3111.8	

By looking closely in the cross tabulation matrix (Table 3 and 4), one could be identifies that some of the changes were unrealistic (e.g. a change from mangrove to mixed trees or cultivated land cover). According to Geist and Lambin [10] and Lambin, et al. [11] land-use/cover changes are driven by a complex of underlying causes, rather than by often claimed single factors such as ‘shifting cultivation’ or ‘increasing population’ pressure.

It is observed that in Zanzibar; ecosystem dynamics response is multi-directional (not linear) and depends on many factors, mostly on the variation in climate variables pattern and distribution. Trend analysis of rainfall in the Zanzibar revealed that there was significant decrease in rainfall amount between recent years, and temperature rise statistically.

The aim of this paper was to find out the quantity and intensity of land cover that has experienced changes in a given time over Kisakasaka and Bumbwini by measuring the size and stationarity of land cover changes in interval and category level; and not to identify drivers of change within the study area.

Table-7. Quantitative change over Kisakasaka between 2001-2011

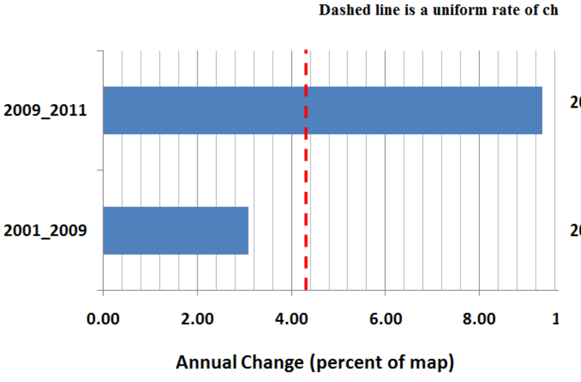
Years	Land cover classes	Gross Gain	Gross Loss	Sum	Net Quantity change	Absol.Net quantity	Swap location
2001 - 2009	Water	106.0	23.5	129.5	82.5	82.5	47.0
	Mangrove	63.7	211.7	275.4	-148.0	148.0	127.4
	Jangwa la bahari	50.9	28.5	79.4	22.3	22.3	57.1
	Mixed trees	498.5	529.4	1027.9	-30.9	30.9	997.0
	Cultivated land/shrubs	463.4	394.1	857.5	69.3	69.3	788.2
	Bareland	35.5	30.8	66.2	4.7	4.7	61.6
2009 - 2011	Water	11.3	93.2	104.6	-81.9	81.9	22.7
	Mangrove	78.8	58.3	137.2	20.5	20.5	116.6
	Jangwa la bahari	36.4	22.9	59.2	13.5	13.5	45.7
	Mixed trees	495.7	317.7	813.4	178.0	178.0	635.4
	Cultivated land/shrubs	278.3	393.6	671.9	-115.3	115.3	556.6
	Bareland	19.8	34.7	54.5	-14.9	14.9	39.6
2001 - 2011	Water	46.3	45.6	91.9	0.6	0.6	91.3
	Mangrove	70.7	198.2	268.9	-127.4	127.4	141.5
	Jangwa la bahari	63.8	28.0	91.8	35.8	35.8	56.0
	Mixed trees	580.3	433.2	1013.5	147.2	147.2	866.3
	Cultivated land/shrubs	395.5	441.5	836.9	-46.0	46.0	790.9
	Bareland	27.7	37.9	65.6	-10.2	10.2	55.4

The results at category level can be summarized as: At Kisakasaka most of the categories were identified to be active and stationary; only water category is dormant, and at Bumbwini; again water is stationary and dormant. Mangrove was active in loosing for 2001-2009 and active in gaining at 2009-2011, and very dynamic, i.e. not stationary. This could be contributed by awareness campaign in which mangroves are being replanted and also employment of conservation measures. Otherwise, other remaining classes are active and stationary.

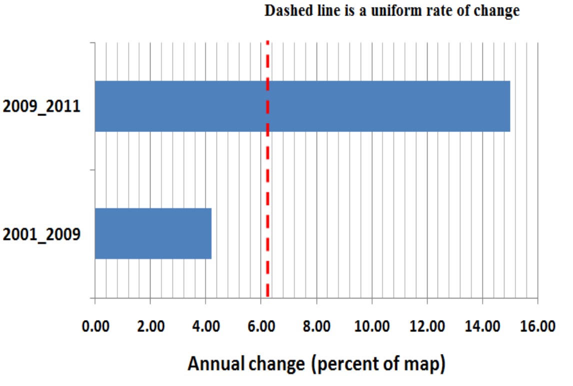
Table-8. Quantitative change over Bumbwinibetween 2001-2011

Years	Land Cover classes	Gross Gain	Gross Loss	Sum	Net Quantity change	Absol.Net quantity	Swap location
2001 - 2009	Water	109.5	151.7	261.2	-42.1	42.1	219.1
	Mangrove	91.5	225.5	317.1	-134.0	134.0	183.1
	Jangwa la bahari	170.6	25.2	195.8	145.4	145.4	50.4
	Mixed trees	841.1	1649.1	2490.2	-807.9	807.9	1682.3
	Rice pads	518.6	285.6	804.2	233.0	233.0	571.1
	cultivated/shrubs	1526.9	1135.4	2662.2	391.5	391.5	2270.7
	Bareland	226.4	12.3	238.8	214.1	214.1	24.7
2009 - 2011	Water	71.6	10.8	82.4	60.8	60.8	21.6
	Mangrove	132.3	84.6	216.9	47.7	47.7	169.2
	Jangwa la bahari	79.6	121.1	200.7	-41.6	41.6	159.1
	Mixed trees	1500.8	742.4	2243.3	758.4	758.4	1484.8
	Rice pads	376.3	443.7	820.0	-67.4	67.4	752.6
	cultivated/shrubs	892.4	1545.9	2438.3	-653.6	653.6	1784.7
	Bareland	58.9	163.3	222.1	-104.4	104.4	117.7
2001 - 2011	Water	161.9	143.2	305.1	18.7	18.7	286.4
	Mangrove	118.9	205.2	324.1	-86.3	86.3	237.8
	Jangwa la bahari	143.0	39.2	182.2	103.9	103.9	78.3
	Mixed trees	1261.3	1310.7	2571.9	-49.4	49.4	2522.5
	Rice pads	475.4	309.8	785.2	165.6	165.6	619.6
	cultivated/shrubs	1111.9	1374.0	2485.9	-262.2	262.2	2223.7
	Bareland	122.5	12.8	135.3	109.7	109.7	25.6

Figure-3. Time intensity analysis for two time intervals: 2001-2009 and 2009-2011 for (a)Kisakasaka and (b)Bumbwini

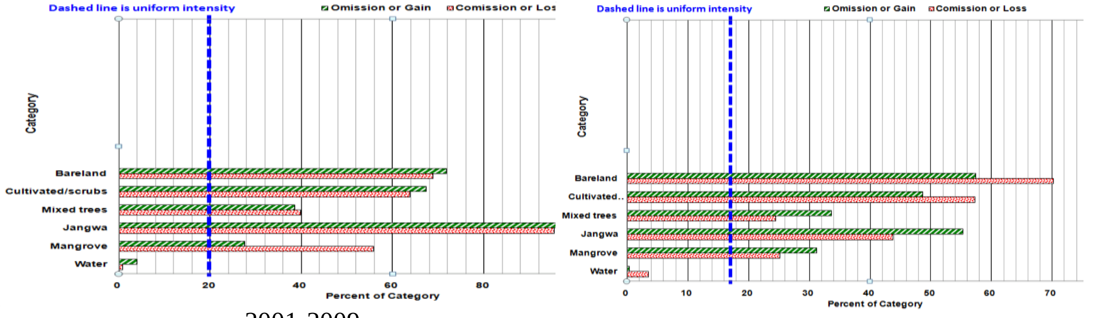


(a)



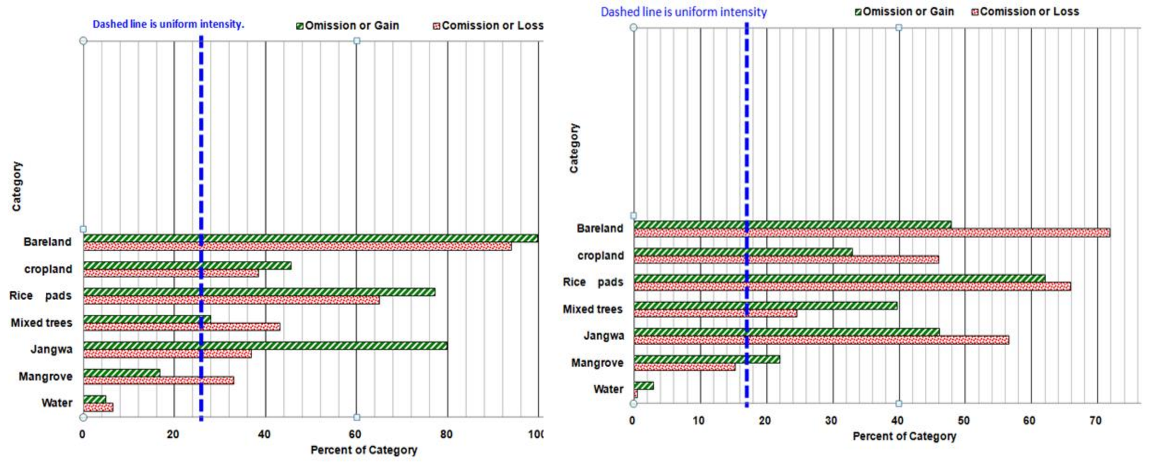
(b)

Figure- 4. Category intensity analysis forKisakasaka



2001-2009 2009-2011

Figure- 5. Category intensity analysis for Bumbwini



2001-2009 2009-2011

5. CONCLUSION AND RECOMMENDATION

It can be concluded that at the interval level, where it measures variation in overall change across each time interval in a manner that accounts for the number of years in each time interval; the rate of change is slower at initial interval and is faster at the later. At the category level, where it measures variation of gross loss and gross gain by category in a manner that accounts for the initial and subsequent areas of the categories; it was revealed that water cover is the most dormant and stationary class, while mixed trees, cultivated land, bareland and rice pads classes are stationary but active. The mangrove class is active and little stable over Kisakasaka, but active and not stable at all over Bumbwini; is the most dynamic cover. It is recommended that highly and strict measures have to be taken to ensure sustainability of coastal ecosystems. The coastal management team should be strengthen through increasing human resource and equipped with working tools for more safety.

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