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Cover change analysis of mangrove forest and surrounding land cover of Mtwapa creek, Kenya

J. Kiplangat[1], A. Mbelase[2], J.O Bosire[3], J. M Mironga[1], J.G. Kairo[2], G. M Ogendi[1], D. Macharia[4] and N. W Nyamao[1]

[1]Egerton University, P.O. Box 536, Njoro, Kenya.

[2]Kenya Marine and Fisheries Research Institute (KMFRI) P.O. Box 81651, Mombasa, Kenya.

[3]World Wide Fund for Nature (WWF) P.O BOX 62440-00200 Nairobi, Kenya.

[4]Regional Centre for Mapping of Resources for Development (RCMRD) P.O BOX 632-00618, Nairobi, Kenya.

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ABSTRACT

Cover change study was carried out within and adjacent to peri-urban mangroves of Mtwapa in Kilifi County using medium resolution Landsat (1990; 2000), SPOT (2009) imageries and a mangrove species vector map of 1992. The objective of the study was to assess the temporal mangrove cover change with respect to the immediate land cover changes surrounding the creek. Between 1992 and 2009 Mangrove forest cover saw a loss of 21%. Land-cover from 1990 to 2009 revealed high rate of upland deforestation (3.85% yr^{-1}) and an increase in agricultural land (13.9% $yr^{-1)}$. There is need for reforestation and conservation of the remaining patches of upland forests as well as establishment of riparian zones to enhance soil retention to minimize sedimentation.

Introduction

Mangrove forests are among the most threatened habitats on earth “[37]”, with human activities being primary driver of mangrove degradation, destruction and loss “[34]”. Compounded with effect from natural disturbances, global forest destruction and degradation could likely worsen, unless drastic measures are taken to protect these fragile ecosystems “[18]”.

Mangrove forests have been lost to urban expansion, tourism development, and other infrastructure needs “[34]”. Mangroves have been cleared for urban expansion in a number of major cities in the world including Singapore, Jakarta, Bangkok, Mumbai (Bombay), Lagos, Free town, and Douala “[34]”. In these areas large tracts of mangroves have been converted to waterfront property, marinas, tourist resorts and golf courses. Moreover, in cases where mangroves are not entirely cleared, development activities can still negatively affect forest health.

Mangroves thrive in areas that receive freshwater run-off and tidal water flushing. The building of infrastructure such as roads, sea defences and drainage canals can create barriers to natural water flow “[34]”. This can have a devastating effect on mangroves because regular flushing with saltwater or freshwater prevents the hyper-salinization of the mangrove environment and protects the supply of nutrients and sediments. Together, the obstruction of both tidal and freshwater flow results in increased salinity of the mangrove environment and leads to reduced forest growth.

Human precautions to cope with climate change may increase the amount of development in the coastal zone. In order to cope with rising sea-levels, heavy engineering is often used to increase the elevation of land through infilling (often with materials dredged from offshore), or to build sea defences to protect against coastal erosion. Both of these methods incurs considerable financial costs, and often provides an only temporary solution “[34]”. The rate of sea-level rise associated with climate change is expected to increase in the coming decades, which will further exacerbate these challenges.

Aquaculture is another land-use activity, which often involves the creation of extensive pond systems in intertidal areas and largely associated with the worldwide losses of mangroves “[39]”. Aquaculture is responsible for more than half (52%) of global mangrove losses “[37]”, with shrimp farming rising in the last decade to more than 50% of global shrimp production “[4]”. Indonesia, Malaysia and South America have recorded highest conversion since 1980’s partly due to conversion for shrimp ponds”[10]”.

Shrimp aquaculture has other serious environmental costs; High yields in intensive shrimp farming can only be maintained through the heavy application of antibiotics, pesticides, and fungicides “[39]”. This results in contamination of surface and ground waters in the form of excess lime, organic wastes, pesticides, chemicals, and disease microorganisms which flush into neighbouring mangroves and environments “[29]”; Shrimp ponds are not sustainable over long time and often abandoned whenever yields or profits drop “[29]”. Very few trees are able to re-colonize the area even 10 years after shrimp ponds are abandoned “[39]”. Moreover, abandoned ponds cannot be restored unless extensive efforts are made to rehabilitate soils which lead to continued clearance of mangroves for new ponds “[34]”.

Agriculture is another land-use activity that is associated with mangrove loss. This has been attributed to the flat and rich organic soils of mangrove forests which make them prime locations for conversion into cash crops farms, especially rice paddies and palm oil plantations. When mangrove areas are converted for agricultural purposes they are first deforested. Then rain water is used to remove salt from the soil and together with costly embankments constructions to protect the area from seawater intrusion.

When the soil salt levels are sufficiently low, the area is then ready for cultivation. However, this conversion is generally not profitable due to the high cost and low return income"[34]". Deforestation and alteration of natural hydrology can cause mangrove soils to dry out and become irreversibly acidic. Such soils are no longer useful for growing crops. Additionally, clearing of mangroves for agriculture can lead to a loss in soil elevation. This requires engineering interventions to prevent flooding "[34]".

In Kenya, Satellite based imagery study between 1965 and 1992 indicated more than 20% decrease in coverage of *R. mucronata* and an increase of almost 35% in sand cover over the same period "[25]". Human influence was the most probable trigger of the observed changes "[25]". Mangrove cover change studies on the twin creeks of Mwache and Tudor, revealed a loss in forest coverage by over 80% between 1992 and 2009 with loses closely being linked to land use changes within the study area "[16, 27]".

Other remote sensing based studies have been on mangrove status "[12; 7]" and species assemblages "[24]. However, little has been done to provide a link between mangrove cover change and upland cover changes in the dynamic peri-urban mangroves; most studies are concerned with the mangrove environment and ignore upland contribution to the processes within mangrove environment.

Study area

Mtwapa Creek is located 15 km from Mombasa City and lies between the Northern Coast of Mombasa county and southern coast of Kilifi county in Kenya 4° 00'S and 39°45'E (Figure 1). The creek is adjacent to Mtwapa Town and is approximately 13.5km in length and opens to the Indian Ocean through a long narrow channel "[26]". It is a tropical estuarine surrounded by vast mangrove swamps, while its offshore area is shielded by extensive share parallel coral reefs. It receives runoff from three seasonal rivers, (KwaNdovu, Kashani and Kidutani).

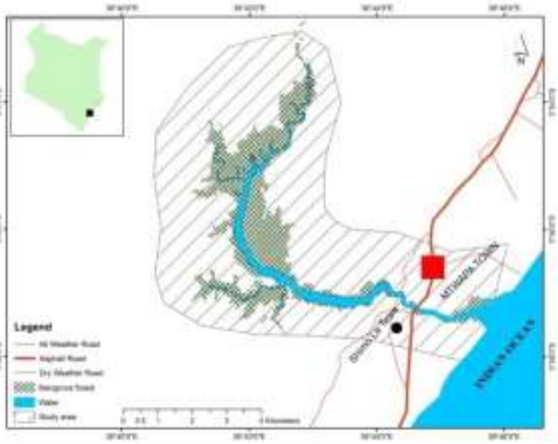

Figure 1: Map of the study area

Mtwapa creek is covered by a multi-species mangrove stand including the species *Rhizophora mucronata*, *Ceriops tagal*, *Avicennia marina*, *Sonneratia alba and Xylocarpus granatum.* It consists of three forest patches (Gung'ombe, Kitumbo and Kidongo: named after adjacent villages) which are situated further landward from the mouth "[26]".

The creek lies in the coastal zone and its climate is determined by factors among them, the inter-tropical convergence zone (ITCZ) and the monsoon winds coming in two seasons. Between December and March the area experiences The Northern Easterly Monsoon (NEM), while from May to October, Southern Easterly Monsoon (SEM) are evident. Mean annual Rainfall within the study area is 1038mm, with peaks in June and July; and the mean annual temperatures range between 23.9^0C and 28.5^0C, for the two seasons respectively "[23]". The highest temperatures of 28-29˚C occur following the Northeast Monsoon from December to April.

Materials and Methods

Image Analysis

Landsat imagery of January, 1990, SPOT images of May, 2000 and January, 2009 and a 1992 mangrove vector map were acquired from a mapping project in (KMFRI) for this study (Figure 2). All the images were registered to WGS 84 UTM Zone 37S projection. Nearest Neighbor re-sampling method was applied for geometric correction for all the images as per "[30; 3]". Image registration was done to 2009 image as the base image, followed by the three other images of 1990 and 2000. Obscurity was removed using atmospheric correction on images to remove effects of the different atmospheric conditions on the reflectance for the three images taken at different temporal periods "[33]".

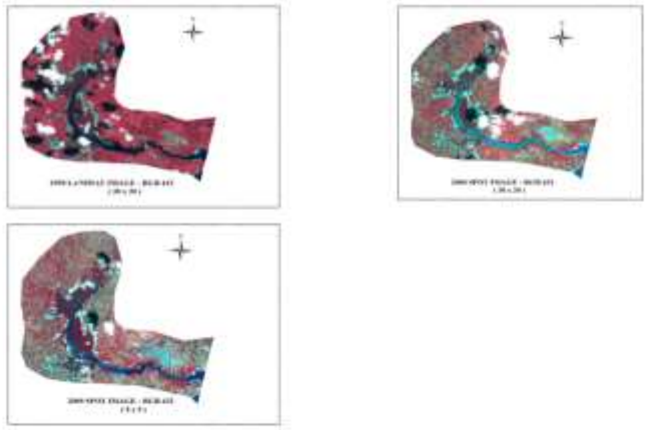

Figure 2: Composite RGB 1990 Landsat, SPOT 2000 and SPOT 2009 images used for cover change detection.

Field survey is essential in identifying features of interest prior to image processing and classification in Remote Sensing "[14]". As a preparation for the same, ISO-CLUSTER unsupervised classification was done on the 2009 image prior to field work to retrieve different spectral classes for creating specific classification training files for classification process. Field survey was carried out across mangrove species aggregation area and across the land cover types within the study area up to a distance of 2km from the mangrove zone, the area to which this study sought to correlate its cover change with mangrove cover change. Land-cover types were located in the field and their position marked using Garmin GPS in UTM coordinates system.

Image processing and classification was done using ArcMAP environment in ArcGIS 10.1 software. Training sites were digitized using ArcMAP in ArcGIS 10.1 to create polygons representing the identified classes in the three images (Landsat image of January, 1990, SPOT image of May, 2000 and SPOT image of January, 2009) and saved as the training files.

Maximum Likelihood classification method was applied for classification for all the three images using the earlier generated training files using ArcMAP environment in ArcGIS 10.1 leading to generation of 6 Land-use/Land-cover classes. Final maps were prepared using ArcGIS 10.1.

Accuracy assessment

Classification accuracy was performed using 180 randomly generated points across the study area (Figure 3).

Overall Accuracy (OA), User's Accuracy (UA), Producer's Accuracy (PA) and Kappa coefficient were calculated to measure accuracy of classification prior to post classification analysis.

Figure 3: 180 randomly generated points used to test the accuracy of the classification

Results

Accuracy assessment

Classification error matrix was generated based on the 2009 SPOT image classes. Both the correctly and incorrectly classified pixels, based on 180 randomly generated points were obtained (Table 1). Most points (140) were correctly classified, obtaining an overall accuracy of 77.78%. User's accuracy and Producer's accuracy for each of the classes showed that satisfactory levels of accuracy were obtained (PA and UA > 50%). Mangrove cover had the lowest UA (33.33%), although its PA was as high as 75%.

Table 1: Accuracy assessment of a supervised classification of 2009 SPOT image for Mtwapa creek

	Reference Data						Row totals	Producer's accuracy	User's accuracy
	Wa	Bu	Sa	Ag	UF	MF			
Class Data									
Wa	8	0	2	0	0	0	10	66.67%	80.00%
Bu	0	3	1	2	0	0	6	100.00%	50.00%
Sa	4	0	23	5	3	1	36	74.19%	63.89%
Agr	0	0	0	74	9	0	83	83.15%	89.16%
UF	0	0	0	7	29	0	36	70.73%	80.56%
MF	0	0	5	1	0	3	9	75.00%	33.33%
COLUMN TOTAL	12	3	31	89	41	4	180		

Diagonal sum=140; Overall accuracy=77.78%. Kappa=0.68. Wa —Water, Bu—Built up, Sa—Sandflat, Ag—Agriculture, UF—Upland forest and MF—Mangroves forest

Mangrove cover

Training polygons on species cover and extent were digitized on 2009 SPOT image and a supervised classification done to determine the distribution and cover of mangrove species. This was compared with a 1992 mangrove species vector map to determine changes in species cover over time. Figure 4 shows the thematic map on the species classes in 1992 and classification results for 2009 in Mtwapa creek.

Table 2: Extent of cover changes in mangrove species between 1992 and 2009

Species	1992	2009	Change
Rhizophora mucronata	349 (50.14)	308 (60.39)	-11.74%
Ceriops tagal	192 (27.59)	174 (34.12)	-9.38%
Avicennia marina	152 (21.84)	28 (5.49)	-81.58%
Sonneratia alba	3 (0.43)	0 (0)	-100.00%
Total	696 (100)	510 (100)	-26.72%

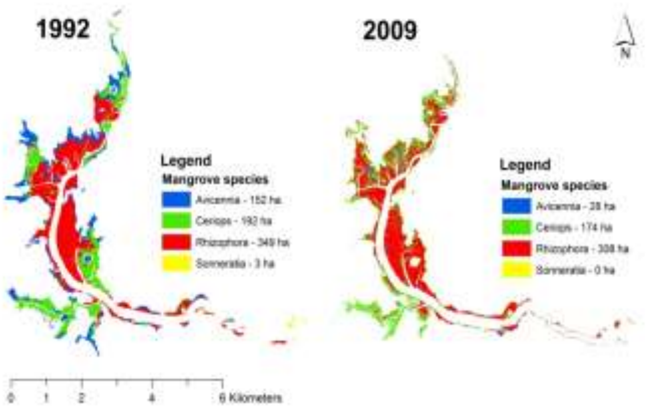

Figure 4: Map of mangrove species shift and change between 1992 and 2009

Between 1992 and 2009, mangrove species have undergone noticeable cover changes (Figure 4). This was accompanied by shifts of species and an example is *Ceriops tagal* zone which in some areas been replaced by *Rhizophora mucronata* in 2009 especially in Majaoni and Mabirikani. All the species recorded a reduction in extent of coverage. Sonneratia alba was the most affected and was not detected in 2009 imagery while previously having occupied 3ha representing 0.43% of the mangrove area. *Avicennia marina* reduced by 81.58%, this is after previously occurring abundantly at the edges of mangrove forest almost in all sites with a total area of 152 ha, which had reduced to 28ha in 2009. Ceriops tagal reduced in cover by 9.38%, from192ha in 1992 to 174ha in 2009. Despite dominating most parts of the forest, Rhizophora mucronata declined by 11.74%, from 349ha in 1992 to 308ha in 2009. For the 17 year period from 1992 to 2009 mangrove cover reduced by 26.72%. This translates to 1.5% of mangrove forest lost annually in Mtwapa creek. Table 2 shows the summary in (ha) and (%) of the species cover dynamics for the 17 years.

Land cover

Training polygons for Upland forest, Agriculture, Built up areas, Mangrove forest, Sandflat and Water were digitized on the 1990 Landsat TM images, 2000 SPOT image and 2009 SPOT image before the classification procedure that output thematic maps with the land cover categories for the study area. The Classification yielded three Land cover maps of the study area which were classified into 6 broad classes. The six classes are Built up, Agriculture, Upland forest, Mangrove forest, Sandflats and Water as shown in the classified maps (Figure 5) and summary of area in ha and percentage covers in Table 3. These maps are the basis of presented information on the primary Land cover changes that have occurred from 1990 to 2009 within the study area.

Table 3: Land cover changes between 1990 and 2009

Land-cover	Change (ha)			% Change		
	1990-2000	2000-2009	1990-2009	1990-2000	2000-2009	1990-2009
Built-Up	111.75	203.31	315.06	348.89%	141.40%	983.64%
Agriculture	1627.49	586.28	2213.77	194.13%	23.78%	264.06%
Upland Forest	- 1780.53	- 677.04	- 2457.57	-53.94%	-42.97%	-73.22%
Mangroves	-206.06	68.72	-137.34	-29.44%	15.66%	-21.30%
Sandflat	250.66	- 173.85	76.81	77.21%	-30.22%	23.66%
Water	-3.32	-7.41	-10.73	-1.19%	-2.67%	-3.84%

The spatial extent of the 1990 Land cover Classes indicates that Upland forest occupied the highest percentage cover of 3301. 10ha (60.29%) and was distributed across the map with the highest concentration observed towards the sea. The second highest was Agriculture (838.37ha, 15.31%) which occurred in patches and scattered around North, South, and the Western parts of the area with very small patches within the mangrove forest reserves. Mangrove forest was third highest and covered 700.00ha (12.78%) on the either sides of the creek. Sandflat occurred next to Mangroves with a cover of (324.64ha, 5.93%) mostly at the edge of the mangrove forest. This was followed by the water 279.36ha (5.10%) which covered the creek channels. Built up area covered 32.03ha (0.58%). It had the least area coverage and appeared as a cluster in the south eastern part of the map.

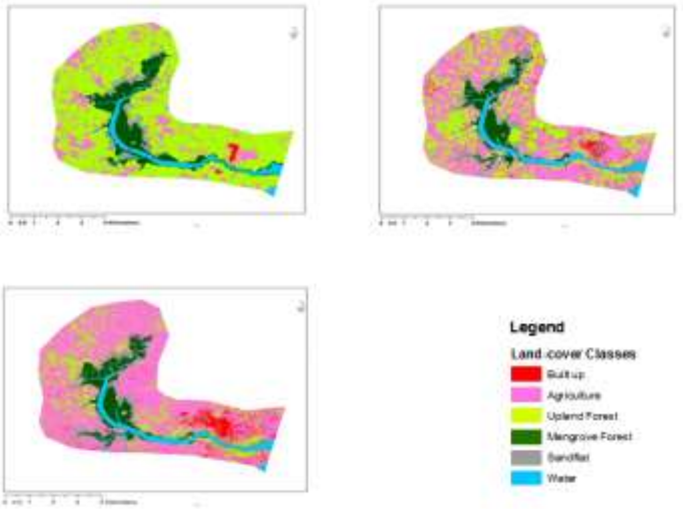

Figure 5: Land cover supervised classification Maps of the study area

The SPOT image of 2000 yielded Land-cover map (Figure 5) with Agriculture occupying the largest area of 2465.86ha (45.03%) as compared to other land-cover classes and distributed almost equally across the study area. This was a 194.13% Increase after previously having a cover of 838.37ha (Table 3). Upland forest was second with an area of 1575.66 ha (28.78%). However, this was a decline of 53.94% from a previous cover extent of 3301.10ha. Sandflat had an area of 575.30ha (10.51%) along the Mangrove forest edges and small patches in the northern and southern parts of the map. This was an increase by 77.21% from 324.64ha in 1990. Mangrove forest occupied an area of 438.85ha (8.01%) in the inter-tidal zone along the edges of the channel. This was a decrease by 29.44% for the 10 years from 1990.Water had an area of 276.04ha representing 5.04% of the area. Built up area had an area of 143.78ha (2.63%) and occurred in clusters in the south eastern part of the map which was an increase by 348.89% as compared to its cover in 1990.

After classification of SPOT image of 2009 Agriculture was found to occupy the largest area of 3052.14ha (56.52%) and occurred in all parts of the map but with more concentration on the northern part. This was a 264.06% increase from 1990. Upland forest was second and covered an area of 898.62ha, (16.64%) with concentration near the Mangrove forest edges in the Northwestern part of the map. This was a very high decrease of 73.22% from 1990 coverage (Table 3). Mangrove forest had an area of 288.63ha (4.97%), representing 21.30 % decrease for the 19 years from 1990. Sandflat had an area of 401.45ha (7.43%) along the mangrove forest edges representing increase from 1990 by 23.66%. Built up had an area of 347.09ha (5.04%) with concentration on the southeastern part of the map and very small patches within the entire scene except the creek Channel. This was the land use that showed highest percentage increase compared to its initial cover, of 983.64% in 1990.

From the analysis above major changes occurred within the19 years between 1990 and 2009. Figure 6 shows the comparative bar graph on changes within a cover type from 1990 to 2009. The great and significant increase and decrease happened within Agricultural area and upland forest area respectively. Agricultural area increased over the 19 years with 194.13% between 1990 and 2000 and 23.78% between 2000 and 2009. Upland forest cover declined over the same period by 53.94% between 1990 and 2000 and by 42.97% between 2000 and 2009. Mangrove cover decreased by -29.44% between 1990 and 2000 and increased by 15.66% between 2000 and 2009.

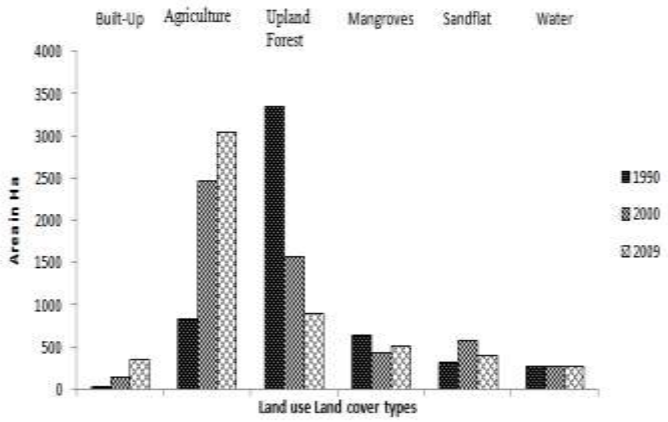

Figure 6: Comparative bar graph for Land-cover changes from 1990 to 2009

Mangroves cover change regression against Land cover changes

Simple linear regression analysis of Mangrove cover against other Land-cover types indicated existence of a statistically significant relationship between Land-cover dynamics and changes in mangrove cover ($p<0.05$), except for built up area where there was no sufficient evidence to show existence of a linear relationship to Mangrove cover changes ($p=0.06516$) (Table 4).

Table 4: Regression analyses of mangrove cover against Land cover changes

Mangrove VS LULC Type	Linear Equations	Correlation coefficient	P-Value	Coefficient of determination
MAN:FOR	$y = -3340.3675 + 9.961*x$	$r = 0.8233$	$p = 0.03843$	$r^2 = 0.0677$
MAN:BU	$y = 594.55650 - 0.7923*x$	$r = -0.5204$	$p = 0.06516$	$r^2 = 0.2708$
MAN:CRL	$y = 6930.5413 - 9.0712*x$	$r = -0.8298$	$p = 0.03769$	$r^2 = 0.6885$
MAN:SA	$y = 1029.3081 - 1.1227*x$	$r = -0.9172$	$p = 0.02609$	$r^2 = 0.8412$

Mangrove cover and Upland forest cover depicted a statistically significant positive correlation coefficient of $R=0.823$ ($p<0.05$). Agriculture had a strong but inverse significant correlation of $R= -0.83$ ($p<0.05$), while Sandflat had a negative correlation of $R=-0.917$ with a coefficient of determination of $R^2=0.841$ ($p<0.05$). Built up had a negative linear relationship of $R=-0.52$ and a very low coefficient of determination of $R^2= 0.27$, with no statistically significant relationship to Mangrove cover change ($p>0.05$).

Discussion

Mangrove Cover change

Among the natural land covers, mangrove forest in Mtwapa area was estimated to have lost about (27%) in the 19 years between 1990 and 2009, translating to 1.5% loss per annum.

This falls within similar rates obtained in mangrove forests from coastal lagoon systems in Mexico, where annual deforestation rates range 0.6–2.4% “[31]”, which is within the global mangrove cover loss range of 1-2% annually “[10]”. Compared to degradation in adjacent Tudor and Mwache creeks of 2.7% annually “[27; 16]”, this study had a lower degradation rate. However, this was higher than estimated mangrove cover loss in the Kenyan coastline at a rate of 18% for 25 year period between 1985 and 2010 which is equal to 0.7% loss annually”[19]”.

This study found the mangrove cover change between 1990 and 2009 to be significant and accompanied with species loss attributed to mangroves diversity decline due to extreme harvesting of most valuable trees “[26]”. Figure 7 below shows anthropogenic associated to degradation of mangroves in Mtwapa.

Figure 7: Illegally cut trees for firewood and charcoal burning in Mtwapa mangrove forest reserve (source: Author).

Species shift recorded is explained by change in forest structure and species from secondary growth “[17]”. It is proven that mangrove species distribution, which is quite a striking aspect depends on the precise interplay of factors among them water level, salinity, pH, sediment fluxes and oxygen potential “[35]”. Among these factors, salinity is a key factor which links the physical environment through the physiology of mangroves to patterns of spatial organization “[32]”. Upland deforestation leads to increase in flooding and increase in fresh water flushing especially during rainy season causing change in salinity levels. This then affects species zonation and is exhibited by species shift with *Rhizophora mucronata* dominating in the entire forest and loss of the salt tolerant species *Avicennia marina* that previously dominated the mangrove forest edges. It is certain that shifts in species due to climate change, forest degradation and loss of habitat connectivity may reduce the protective capacity of mangroves “[20]”.

The rate of mangrove cover loss in Kenya reduced immensely between 2000 and 2010 “[19]”. The finding from this study is a further proof, with a significant decrease in cover loss rate between 2000 and 2009 compared to the first period of 1990 and 2000. Presidential ban on harvesting of mangroves for domestic market in 1982 which took effect in 2000 “[1]”, could have lessened deforestation activities in this period. However, several other factors could have likely been responsible for reduced rates in Mtwapa. These include reforestation and restoration campaigns by Kwetu Training centre under UNDP project whose primary objectives is conservation and sustainable utilization of mangrove resources “[36]”. *Over 190,000 mangrove seedlings were planted between 2007 and 2010 to repopulate areas of coastline forests that had been over-exploited by local communities* “[36]”.

Most of the coastal ecosystems are currently under environmental stress (Figure 8), mainly caused by the growth of the human population and increasing demand for food and services “[2]”. Apart from pressure due to local impacts, they also receive cumulative effects as a result of activities on the uplands “[38]”. Agriculture, forestry, and urbanization have been the main transformers of the natural land cover “[5]”. This has impacted the coastal systems particularly mangrove swamps, where degradation occurs through indiscriminate tree cutting, sedimentation, addition of toxins and species dieback which leads to decreased area, and subsequent loss of connectivity between coastal wetlands and upland ecosystems.

Figure 8: Stressed mangrove ecosystem due to sedimentation resulting from upstream erosion (Source: Author).

Land cover changes

It has been established that the effectiveness of mangroves for coastal protection depends on a range of factor scales related to landscape, community and species “[20]”. Deforestation is considered to be one of the most significant environmental problems globally “[40]. Based on this study, the landscape surrounding Mtwapa creek was predominantly terrestrial forest land in 1990 with 61.29% cover. This has reduced at a very high rate to 16.64% in 2009 with conversions to agriculture and built up areas significantly taking its places. Agriculture and urbanization have been found to be the major accelerators of upland deforestation resulting to loss of biodiversity, change in soil profile and initiation of downstream erosion “[15]”. A similar situation was observed in Mexico whose findings reported conversion of terrestrial forest to agriculture and pasture at high rate of more than 60% entailing nearly to destruction of the entire forest structure and composition within a lagoon system”[21]”.

When soils are exposed due to destruction of vegetation for agricultural purposes (Figure 9) and wood harvesting, surface layers dry and impervious surfaces are produced causing acceleration of surface runoff during rainy season “[8]”. Flood peaks go up quickly and lead to erosion from the bare areas. The high rate of terrestrial deforestation and increase in cropland in Mtwapa is likely to have resulted in flooding and sedimentation within mangrove zone. This is known to affect mangroves “[13; 8]” and could be the reason for enlarged Sandflats taking the spaces of choked mangroves in the study area.

Figure 9: Agricultural activities at the banks of Mtwapa Creek. (Source: Author)

Growth of agriculture in Mtwapa is alarming with current surface area equivalent to 56.52% of the study area from 15.31% in 1990. Together with urban expansion, whose current cover is 5.04% of the study area, they are exerting a lot of pressure on terrestrial forest and general system. Urbanization and its related activities can lead to degradation through siltation and changes in water temperature, water flow, salinity and pollution "[22]". Effects trickle down to loss of biodiversity and pollution that becomes a threat to the mangrove system's health. Trends showed similarity to a study which assessed use of Remote Sensing Data to evaluate the extent of anthropogenic activities and their impact on Lake Naivasha, Kenya between 1986 and 2007. There was 37.2% decrease in forest cover, 103.3% increase in horticultural and irrigated farms and 90% increase in urban settlement placing great pressure on both the quality and quantity of the lake's water resources "[28]".

Anthropogenic degradation of coastal systems is widely known to result to both climate and environmental changes which reduce the resilience of mangroves making them vulnerable ecosystems "[9]". Population growth has been identified to be a key force behind environmental change, especially in developing countries "[6]". In this study Increase in population is highly linked to increase in cropland and built up areas and decrease in upland forest in Mtwapa. This affects the hydrological processes especially land surface flow leading to sedimentation downstream. The trends in population of major urban centers in Kenya show high increase in urban population within the last three decades (Table 5). In the coastal region of Kenya, the statistics have been similar with a rise in population from 1.3 million people in 1979 to 3.3 Million people in 2009 "[30]". This represents 60.6% population growth between 1969 to 2009 equivalent to 2.02% population growth rate annually.

Table 5. Population of urban centres along the Kenyan coast between 1969 and 2009

Name	1969	1979	1989	1999	2009
Kilifi	2,662	….	14,145	30,394	44,257
Lamu	7,403	....	....	....	13,243
Malindi	10,757	23,275	34,047	53,805	84,150
Mombasa	247,073	341,148	461,753	665,018	915,101
Msambweni	....	....	....	....	11,985
Mtwapa	....	....	< 10,000	18,397	48,625
Ukunda	....	....	....	43,946	62,529

Source: Kenya National Bureau of Statistics

Mtwapa urban centre has seen increase in population from below 10,000 inhabitants in 1989, to about 18,397 inhabitants in 1999 and exponential growth to 48,625 inhabitants in 2009 (Table 5) "[30]". This is equal to annual population growth rate of 3.97%. The increase in population is mainly attributed to immigration from other parts of the country "[30]". New settlers obtained pieces of land to settle and do farming at small scale level, while others have engaged in business activities promoting growth of Mtwapa urban centre. This has led to clearance of upland forests for farming land and putting up of structures that have resulted to immense land cover changes.

Conclusion

Land-use within and without the mangrove forest is a critical factor determining its integrity. Within the mangrove forest, both indiscriminate and selective deforestation hampers its natural processes and functions among them being reduced habitats, reduced protective capabilities and lessened ability to capture and store carbon. In the Upland areas human activities especially related to Agriculture and development alter the hydrological processes and initiate soil movement which find its way into the mangrove environment and changes the ideal and natural conditions for the growth and sustainability of the system. This study found high link between mangrove degradation and upland activities involving terrestrial forest loss to cropland and built up areas. Changing Land uses in Mtwapa poses a lot of threat to mangroves and other coastal ecosystems that are interconnected to mangrove environment. High upland forest loss leads to alteration of upland biodiversity, modification of topography especially soil properties and destruction of habitat conditions. Increase in human activities as seen by extension of cropland and built up areas in places where forestry existed; continue to slowly but detrimentally change abundance and spatial pattern of Mangrove forest environment in Mtwapa.

Based on the findings from this study, it is clear that deforestation and forest degradation rates are very high in Mtwapa creek. Integrated and holistic approach is needed to curb the mangrove deforestation and degradation which currently stands at 1.11% annually in this forest. The Protective measures in place should be revised by forest managers especially to stop indiscriminate and selective tree cutting by the local communities. Hot spot areas close to the settlements should be identified and more attention given to secure such areas from illegal loggers.

Restoration efforts should be initiated on degraded areas of the forest to regain the initial state. This should however be done in an integrated manner involving local communities so as to give them a sense of ownership of this resource. There is big potential for conservation with economic based initiatives like PES (Payment for Ecosystem Services) programs which can be in cooperated in mangrove management to provide alternative source of livelihood at the same time promote conservation. This will be a good incentive to the communities to protect and conserve the mangrove forest.

In upland areas, unique blends of climate, geology, hydrology, soils, and vegetation shape the landscape. However human processes and activities drastically change natural processes leading to environmental degradation. With upland terrestrial forest having been lost over the years through urban expansion and disturbance through agricultural activities at large and small scales, drastic rates of destruction on soil properties have taken place. Sedimentation is the resultant effect through erosion process especially during rainy season. Upland Reforestation programs need to be put in place to restore the state and reduce the current effects. Farming is the backbone of most inhabitants from the coastal region. This has been done unfortunately without any conservation efforts of the environment with some of the farming taking place in riparian zones of creeks. Riparian zones should be protected and conservation zone established between the mangrove forest and upland farms.

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