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ANALYSIS OF LAND USE CHANGES USING REMOTE SENSING AND GIS TOOLS IN THE PERI URBAN ECOSYSTEMS OF DAR ES SALAAM

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ABSTRACT: *Land use changes in peri urban areas have resulted from urban expansion and have attracted many researchers during the last two decades. In this paper, urban expansion and their spatial growth patterns of the Dar es Salaam City has been studied over a period of 30 years (1980-2010) through statistical classification approaches based on the remotely sensed images obtained from sensors both Landsat TM5 and SPOT4. The research method included, mapping of land use changes using multi-temporal images, land use/land cover change as detected by applying remote sensing tools. Thereafter, based on the results of image classification, the analysis of land use/land cover changes was made. A model of urban expansion is also analysed by applying diverse technologies of the GIS. Research shows that land use/land cover change detection using remote sensing and GIS are good means of research of urban expansion. In addition, times series data of land use/land cover changes reveal temporal spatial change useful in determining timely planning intervention. Moreover, the analysis of the ecosystems and general urban expansion as established by land use/land cover changes in meticulous areas can be carried out. It is recommended that the national land related policies are reflective of these findings.*

KEYWORDS: change detection, urban expansion, spatial growth, land use change and ecosystem.

INTRODUCTION

The land use/land cover change in peri urban ecosystem services is a complicated process; several factors have influences on this process, including both physical aspects and human aspects. On the one hand, accelerated urban expansion is usually associated with and driven by the social-economic factors; on the other hand, the process of urbanization has a considerable impact on the economics of the society in that area (He, 2006; Mahesh, 2008). For substantial development, municipal authorities need tools to monitor how the land is currently used, assess future demand, and take steps to assure adequacy of future supply; for a better planning of future urban development, municipal authorities need to know situation of urban expansion and in what way it is likely to move in the years to come (Mahesh, 2008). So the detection of urban land change is important for officials and planner in the local government.

The main change of land use/land cover in peri urban areas can be described as other type of land use converting into urban land. Unfortunately, the conventional survey and mapping techniques are expensive and time consuming for the estimation of urban expansion and such information is not available for most of the urban centers, especially in developing countries. As a result, increased research interest is being directed to the monitoring of urban growth using GIS and remote sensing techniques (Epstein et al., 2002).

Many models for urban growth prediction, such as the cellular automata (CA) model and land conversion in the urban fringe area, have been developed (Wu, 1998; Li and Yeh, 2002; He et al., 2008). Among these models, Geographical Information System (GIS) based urban models have been widely used (Yeh and Li, 1998; He et al., 2005). In practice, however, the use of these models has been limited in urban growth analysis because of the difficulty in obtaining all of the required factors or enough data for the model.

Lambin and Strahler (1994) showed that the detection of land-cover change processes by remote sensing is improved when using both spectral and spatial indicators of surface condition. They suggested that while spectral indicators are more sensitive to fluctuations in primary productivity associated with the inter annual variability in climatic conditions, changes in landscape spatial pattern are more likely to reveal long term and long lasting land cover changes.

Therefore, in this paper, we take Dar es Salaam City ecosystems as an example, based on remotely sensed data (Landsat TM and SPOT images) in fifteen years interval (1980, 1995 and 2010), detecting Dar es Salaam's land use/land cover change from 1980 to 2010 by means of remote sensing and GIS.

STUDY AREA, AREA DESCRIPTION AND DATA USED

Study Area

The Dar es Salaam City was selected as the study area, because it is one of the most typical urban expansion cities. The research mainly focuses on urban expansion towards major ecosystems (forests and rivers) in peri urban areas of the three municipalities namely Ilala, Kinondoni and Temeke. The area where this study was conducted covers settlements in peri urban Dar es Salaam located between 10-35 Kilometers from the city centre and surrounding major ecosystems such as forest (Coast Forest) and river system

Mzinga River System

Mzinga River System has its origin from Kazimzumbwi Forest Reserves in the hills of Kisarawe District and empties its waters to the Indian Ocean. It crosses settlements such

as Chanika, Msongola, Mbande, Chamazi, Kongowe, Tuangoma, Vikindu, Rangitatu and Mbagala Kuu. Growth of the settlements along Mzinga River System has been manifested through increase in spatial extent of the built up area surrounding the river. Spatial growth is triggered by population increase in Dar es Salaam which increases pressure of land use development as well as activities such as sand quarrying, cattle grazing, irrigation agriculture and brick making.

Mpiji River System

Mpiji River System has its origin from the hills of Ruvu South Forest Reserve where various tributaries such as Kiruvya, Bumburu and Kibungobungo join at the confluence of Kiluvya and Mailimoja forming Mpiji River. The river runs along Pande Forest reserve, Mpiji Magowe, Mabwepande, cuts Bagamoyo road near Bunju B settlement and finally empties its waters to the Indian Ocean in Mbweni Settlement. The river separates Kinondoni district in Dar es Salaam region with Kibaha and Bagamoyo districts in The Coast Region. Most of the development activities are taking place along where the river passes and where production activity is taking place such as sand quarrying and surveyed plots. This has been due to the fact that a large coverage of settlements that surround it especially Mabwepande, Mbweni and Bunju were the 20,000 surveyed government plots project where housing construction activities are rapidly carried out.

2.2.3 Pande Forest System

Pande Forest system is also located in the peri urban settlements of Dar es Salaam about 35 Kilometers from Dar es Salaam City Centre along Bagamoyo Road. The land uses surrounding the forest reserve have also been changing. Residential development in settlements of Mabwepande, Mpiji Magowe, Msakuzi, Nyakasangwe and Vikawe has been increasing since 1980 but rapid growth is manifested since 1990s.

2.2.4 Pugu Forest Ecosystem

The National Census Reports, 2012 show that 65,684 people inhabit the communities surrounding Pugu forest ecosystem area where 70.6 percent (46,373 people) are in 4 settlements namely Pugu, Majohe, Buyuni and Chanika. The main economic activities in the area include subsistence farming (food and cash crops), charcoal making and petty businesses. The crops grown include maize, cassava, paddy, palm, potatoes, peas and fruits. Non farming activities include charcoal making and selling as well as pole cutting and selling (Kashaigili 2013; Malugu, 2007; Burgess and Dickinson, 1993).

Data Used

The main spatial data sources used in this study were obtained from Survey and Mapping Department in the Ministry of Land and Human Settlements and also from Geo Network, Dar es Salaam.

Table 2.2 Data Used for land use analysis

Image used	Season	Resolution/Scale	Data Source
Aerial Photograph- 1975	Dry	1:125,000	Surveys and Mapping Division, DSM
1980 Land sat Multispectral scanner Path/Row 166/65	Dry	30m resolution	Geo Network, *Dar es salaam*
1995 Land sat Thematic mapper Path/Row 166/65	Dry	30m resolution	Geo Network, *Dar es salaam*
2010 Land sat Thematic mapper Path/Row 166/65	Dry	30m resolution	Geo Network, *Dar es salaam*
2012 Satellite image	Dry	5m resolution	South Africa Digital Globe

METHODOLOGY

In order to obtain the percentage area change, percentage change and Land use change per year, the change detection analysis was done by post classification approach (Kashaigili *et al* 2013 and Majaliwa, 2010). The spatial overlay analysis was performed (Reusing, 2000) in Arc GIS environment resulting into attribute tables. Finally the attribute table generated was transferred to MS-Excel where land use changes in periods 1980-1995; 1995-2010 and 1980-2010 were computed as shown in equations 1, 2 and 3

$$Annual\ rate\ of\ change = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{t_{years}} \quad \text{.....1}$$

$$\%\ Change_{year\ x} = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{\sum_{i=1}^{n} Area_{i\ year\ x}} x\,100 \quad \text{.....2}$$

$$\%\ Annual\ rate\ of\ change = \frac{Area_{i\ year\ x} - Area_{i\ year\ x+1}}{\sum_{i=1}^{n} Area_{i\ year\ x}\ x\ t_{years}} x100 \quad \ldots\ldots 3$$

Where; $Area_{i\ year\ x}$ = area of cover i at the first date, $Area_{i\ year\ x+1}$ = area of cover i at the second, $\sum_{i=1}^{n} Area_{i\ year\ x}$ = the total cover area at the first date and t_{years} = period in years between the first and second scene acquisition dates.

RESULTS AND DISCUSSIONS

Results

The outcomes of land use/land cover change detection were maps of land use pattern (maps 4.1 to 4.12) from 1980 to 2010 from settlements surrounding river ecosystem and forest reserve ecosystem.

Land Use Types

Seven major land uses were identified in the study area (Table 4.1).

Table 4.1: Land uses and their description as have been used in land use maps

S/No	Land Use	Description
1	Built up	Combines residential, commercial, industrial, and institutional as one land use
2	Residential/agricultural	Includes the areas that consist of scattered residential houses and agriculture
3	Agricultural	Consists of all the area zoned for crop cultivation
4	Conservational	Consists of 40 meters buffer along all rivers
5	Infrastructural	All the land covered by lines of infrastructure
6	Forest Reserve	Consists only the area where Pugu and Kazimzumbwi Forest Reserves are found
7	Open/Grazing	The area where no development is found

Land Use Change Detection in Settlement Surrounding River Systems

The changes in River ecosystems were detected from 1980 to 2010 which showed relative proportions of change for each land category in 1980, 1995, and 2010.

Maps 4.1 to 4.6 below provide a visual picture of land use and land cover change in settlements that surround Mzinga and Mpiji Rivers from 1980-2010 respectively.

In 1980, more than 50 percent of the study area was covered by grassland, wetland, cultivated land and industrial. By 1995, the percentage coverage of these three land

categories had changed to 44 percent, 15 percent and 36 percent, respectively, and by 2010, the percentage of wetland had decreased to only 21 percent as a result of reclamation, while the percentages of other two land-use classes had increased to 18 percent and 39 percent respectively.

The proportional contribution of institutional, industrial and settlements also increased during the 30-year time period. These changes emphasize a drastic decrease in the ecologically important wetlands and a concomitant increase in production orientated land uses. By 1995, the percentage coverage of these three land categories had changed to 44 percent, 15 percent and 36 percent, respectively, and by 2010, the percentage of wetland had decreased to only 21 percent as a result of reclamation, while the percentages of other two land-use classes had increased to 18 percent and 39 percent respectively.

The proportional contribution of institutional, industrial and settlements also increased during the 30-year time period. These changes emphasize a drastic decrease in the ecologically important wetlands and a concomitant increase in production orientated land uses.

The spatial overlay analysis was performed using Arc GIS resulting into attribute tables (Table 4.1 and 4.2). The tables shows that land use area in hectares and percentage coverage in years 1980, 1995 and 2010 have changed. Finally the attribute table generated was transferred to MS-Excel where changes in land use/land cover from 1980-1995; 1995-2010 and 1980-2010 were computed.

Table 4.1Land use areas, percentage coverage, area change, percentage change and annual rate of change from 1980, 1995 and 2010 surrounding Mzinga River

SNO	LAND USES/COVERS	1980		1995		2010		Area change (Ha)		% Change		Annual Rate of Change (Ha/year)	
		Area (Ha)	% coverage	Area (Ha)	% coverage	Area (Ha)	% coverage	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)
1	Concentrated Built up area	275.51	5.27	487.59	14.21	1,691.50	32.37	212.08	1,203.91	43.50	71.17	14.14	80.26
2	Sparsely built up area	340.49	6.52	838.19	19.36	1,156.18	22.13	497.70	317.99	59.38	27.50	33.18	21.20
3	Forest	412.51	7.89	203.08	3.94	152.89	2.93	(209.43)	(50.19)	(50.77)	(24.71)	(13.96)	(3.35)
4	Wetlands	458.41	8.77	220.38	4.08	158.81	3.04	(238.03)	(61.57)	(51.93)	(27.94)	(15.87)	(4.10)
5	Bare land/grassland	3,033.41	58.05	2,679.48	36.64	1,704.61	32.62	(353.93)	(974.87)	(13.21)	(36.38)	(23.60)	(64.99)
6	Cultivated area	672.64	12.87	776.94	21.03	318.01	6.09	104.31	(458.93)	13.43	(59.07)	6.95	(30.60)
7	Institutional	16.76	0.32	10.20	0.35	9.83	0.35	(6.56)	(0.37)	(64.34)	(3.63)	(0.44)	(0.02)
8	Industrial	15.88	0.30	9.75	0.39	33.78	0.39	(6.13)	24.03	(62.91)	71.14	(0.41)	1.60
	Total	**5,225.62**	**100.00**	**5,225.62**	**100**	**5,225.62**	**100**	-	-	-	-	-	-

Table 4.2 Land use areas, percentage coverage, area change, percentage change and annual rate of change from 1980, 1995 and 2010 surrounding Mpiji River

S/NO	LAND USES/COVERS	1980		1995		2010		Area change (Ha)		% Change		Annual Rate of Change (Ha/year)	
		Area (Ha)	% coverage	Area (Ha)	% coverage	Area (Ha)	% coverage	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)
1	Concentrated Built up area	137.72	3.04	234.63	5.17	792.05	17.47	96.91	557.42	41.30	70.38	6.46	37.16
2	Sparsely built-up area	289.99	6.40	478.54	10.55	1391.49	30.69	188.55	912.95	39.40	65.61	12.57	60.86
3	Forest	282.04	6.22	163.35	3.60	52.51	1.16	(118.69)	(110.84)	(42.08)	(67.85)	(7.91)	(7.39)
4	Bare land/grassland	3,038.69	67.02	2,218.58	48.93	1042.03	22.98	(820.11)	(1,176.55)	(26.99)	(53.03)	(54.67)	(78.44)
5	Cultivated area	520.91	11.49	1,191.96	26.29	994.72	21.94	671.05	(197.24)	56.30	(16.55)	44.74	(13.15)
6	Industrial	19.69	0.43	23.87	0.53	27.87	0.61	4.18	4.00	17.51	14.35	0.28	0.27
7	Wetlands	133.87	2.95	105.82	2.33	87.34	1.93	(28.05)	(18.48)	(20.95)	(17.46)	(1.87)	(1.23)
8	Institutional	43.12	0.95	47.96	1.06	52.48	1.16	4.84	4.52	10.09	8.61	0.32	0.30
	Total	4,534.15	100.00	4,534.15	100.00	4534.15	100.00	-	-	-	-	-	-

Figure 4.1 Trends of Land use changes surrounding Mzinga River in years 1980, 1995 and 2010

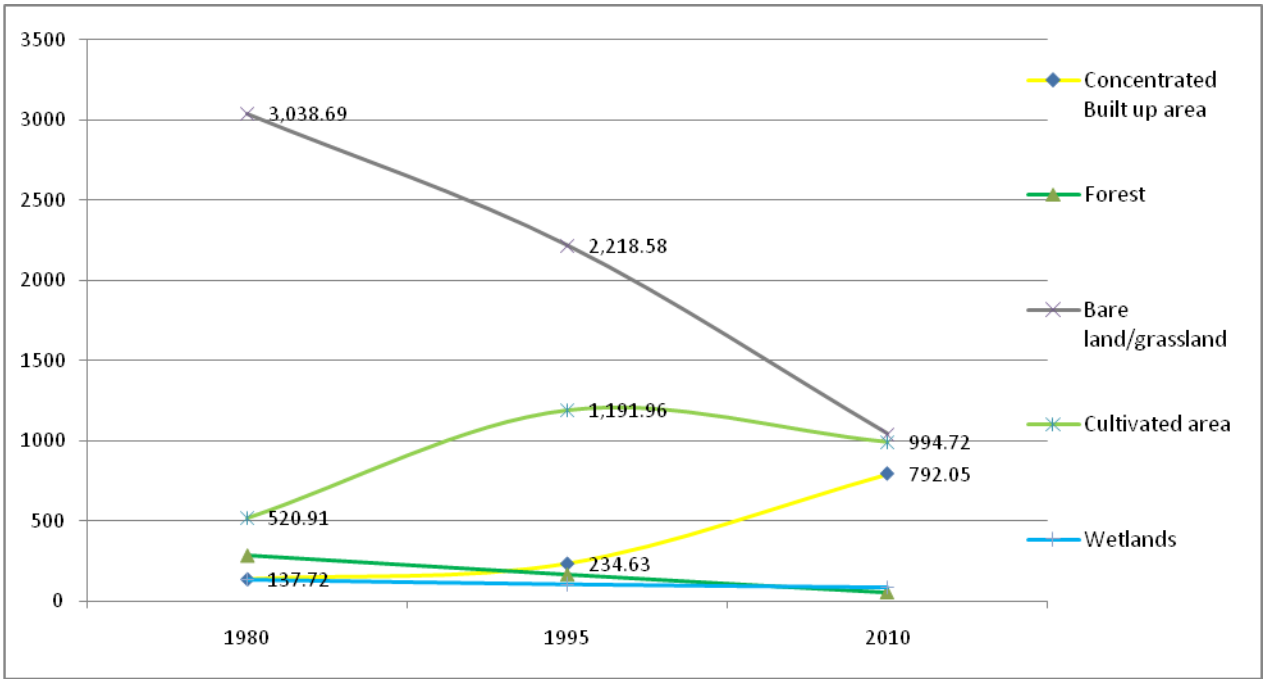
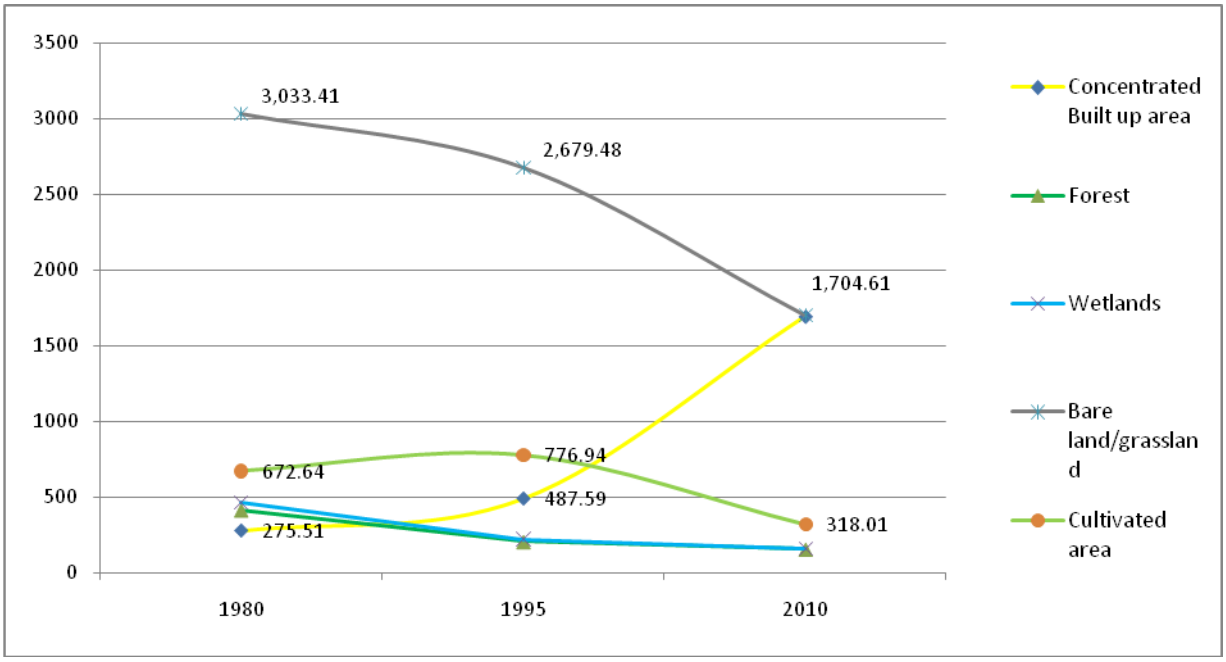
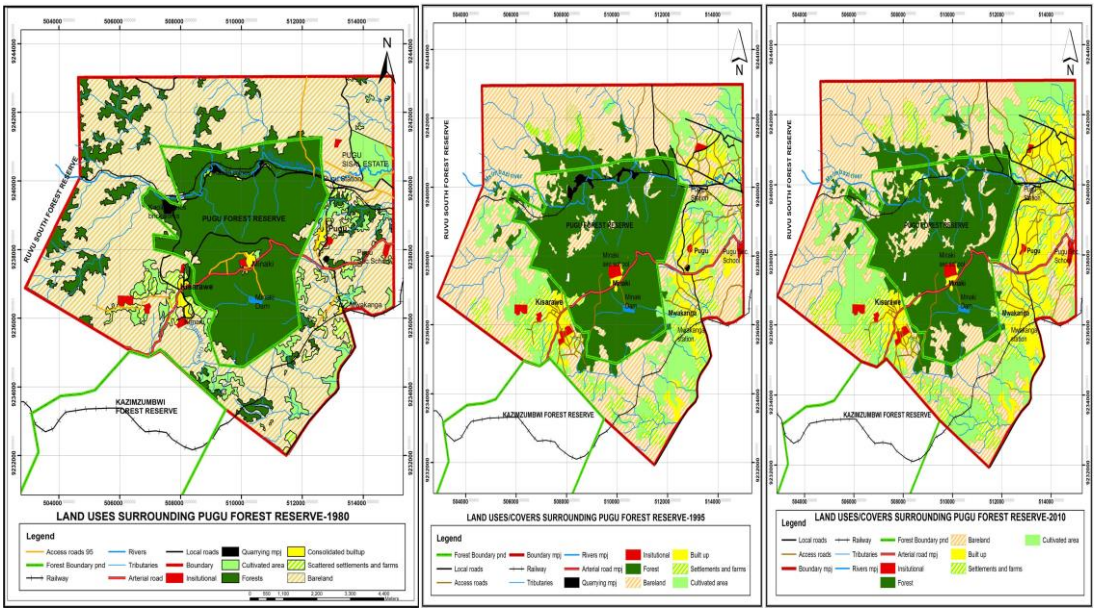


Figure 4.2 Trends of Land use changes surrounding Mpiji River in years 1980, 1995 and 2010



Land Use/Land Cover Change Detection in Forest Ecosystem

Pugu and Pande Forest ecosystems which are also located in the Peri Urban settlements of Dar es Salaam city have also been experiencing rapid changes in terms of forest cover in the period between 1980 and 2010.



Maps 4.7 to 4.12 above provide a visual picture of land use and land cover change in settlements that surround Pande and Pugu forest ecosystems from 1980-2010. The spatial overlay analysis was performed using Arc GIS resulting into attribute tables (Table 4.3 and 4.4). The tables shows that land use area in hectares and percentage coverage in years 1980, 1995 and 2010 have changed. Finally the attribute table generated was transferred to MS-Excel where land use changes in periods 1980-1995; 1995-2010 and 1980-2010 were computed.

Land use changes in peri urban areas that surround Pande Forest reserve have similarities with those that surround Pugu Forest Reserve. In this scenario, the built up area increases with the decrease in the forest cover while the cultivated area increases then starts dropping immediately after 1995. Results from Table 5.7 show that between 1980, 1995 and 2010 the forest cover decreased from 2557.2, 1,396.4 and 804.5 respectively. The built up area gradually increased from 71.1 to 254.3 finally 498.7 in the years 1980, 1995 and finally 2010 respectively while the cultivated area increased from 338.3 hectares in 1980 reached 1169.2 hectares in 1995 then the growth retarded to 1187.7 hectares in 2010 as depicted in the Figures 4.7 and 4.8.

The spatial overlay analysis was performed using Arc GIS resulting into attribute tables (Table 5.5 and 5.6). The tables shows that land use area in hectares and percentage coverage in years 1980, 1995 and 2010 have changed. Finally the attribute table generated was transferred to MS-Excel where land use changes in periods 1980-1995; 1995-2010 and 1980-2010 were computed.

Table 4.3: Land use areas, percentage coverage, area change, percentage change and annual rate of change from 1980, 1995 and 2010 surrounding Pande Forest Reserve

SN	LAND USES/COVERS	1980		1995		2010		Area change (Ha)		% Change		Annual Rate of Change (Ha/year)	
		Area (Ha)	% coverage	Area (Ha)	% coverage	Area (Ha)	% coverage	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)
1	Concentrated Built up area	71.06	1.00	254.29	3.56	498.68	6.98	183.23	244.39	72.06	49.01	12.22	16.29
2	Residential agricultural	459.35	6.43	1,120.31	15.69	1650.35	23.11	660.96	530.04	59.00	32.12	44.06	35.34
3	Forest	2,557.17	35.81	1,396.46	19.55	804.47	11.27	(1,160.71)	(591.99)	(45.39)	(42.39)	(77.38)	(39.47)
5	Bare land/grassland	3,657.10	51.21	3,092.90	43.31	2849.51	39.90	(564.20)	(243.39)	(15.43)	(7.87)	(37.61)	(16.23)
6	Cultivated area	338.25	4.74	1,169.19	16.37	1187.72	16.63	830.94	18.53	71.07	1.56	55.40	1.24
7	Institutional	23.01	0.32	65.67	0.92	84.64	1.19	42.66	18.97	64.96	22.41	2.84	1.26
8	Quarrying	35.29	0.49	42.40	0.59	65.85	0.92	7.11	23.45	16.78	35.61	0.47	1.56
	Total	**7,141.22**	**100.00**	**7,141.22**	**100.00**	**7141.22**	**100.00**	-	-	-	-	-	-

Table 4.4: Land use areas, percentage coverage, area change, percentage change and annual rate of change from 1980, 1995 and 2010 surrounding Pugu Forest Reserve

SNO	LAND USES/COVERS	1980		1995		2010		Area change (Ha)		% Change		Annual Rate of Change (Ha/year)	
		Area (Ha)	% coverage	Area (Ha)	% coverage	Area (Ha)	% coverage	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)	(1995-1980)	(2010-1995)
1	Concentrated Built up area	193.77	2.01	407.83	4.23	1195.06	12.39	214.06	787.23	52.49	65.87	3.50	4.39
2	Residential agricultural	407.92	4.23	1,020.51	10.58	1605.01	16.65	612.59	584.50	60.03	36.42	4.00	2.43
3	Forest	3,441.04	35.69	2,521.57	26.15	1965.08	20.38	(919.47)	(556.49)	(26.72)	(22.07)	(1.78)	(1.47)
5	Bare land/grassland	4,703.39	48.78	4,267.30	44.26	3504.19	36.34	(436.09)	(763.11)	(9.27)	(17.88)	(0.62)	(1.19)
6	Cultivated area	810.89	8.41	1,325.95	13.75	1288.66	13.36	515.06	(37.29)	38.84	(2.81)	2.59	(0.19)
7	Institutional	37.24	0.39	48.18	0.50	50.12	0.52	10.94	1.94	22.71	3.87	1.51	0.26
8	Quarrying	47.89	0.50	50.80	0.53	34.02	0.35	2.91	(16.78)	5.73	(33.03)	0.38	(2.20)
	Total	**9,642.14**	100.00	**9,642.14**	100.00	**9642.14**	100.00	-	-	-	-	-	-

Figure 4.3: Trends Analysis of Land use changes between 1980 and 2010 in settlements surrounding Pande Forest Reserves

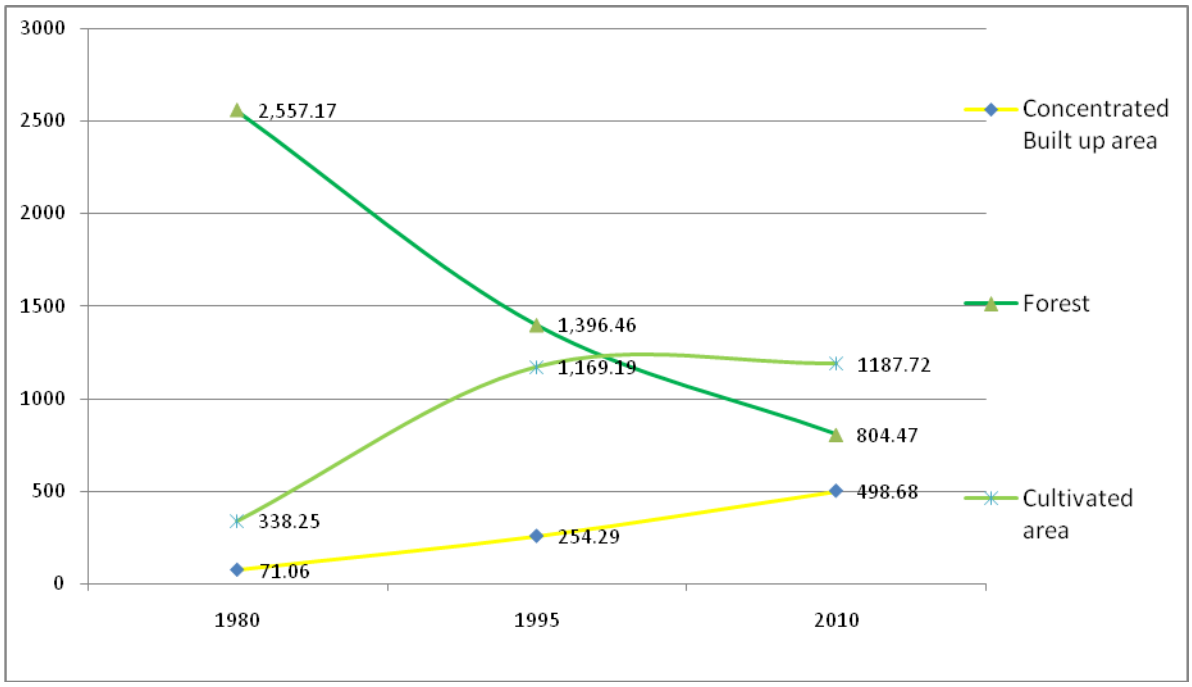
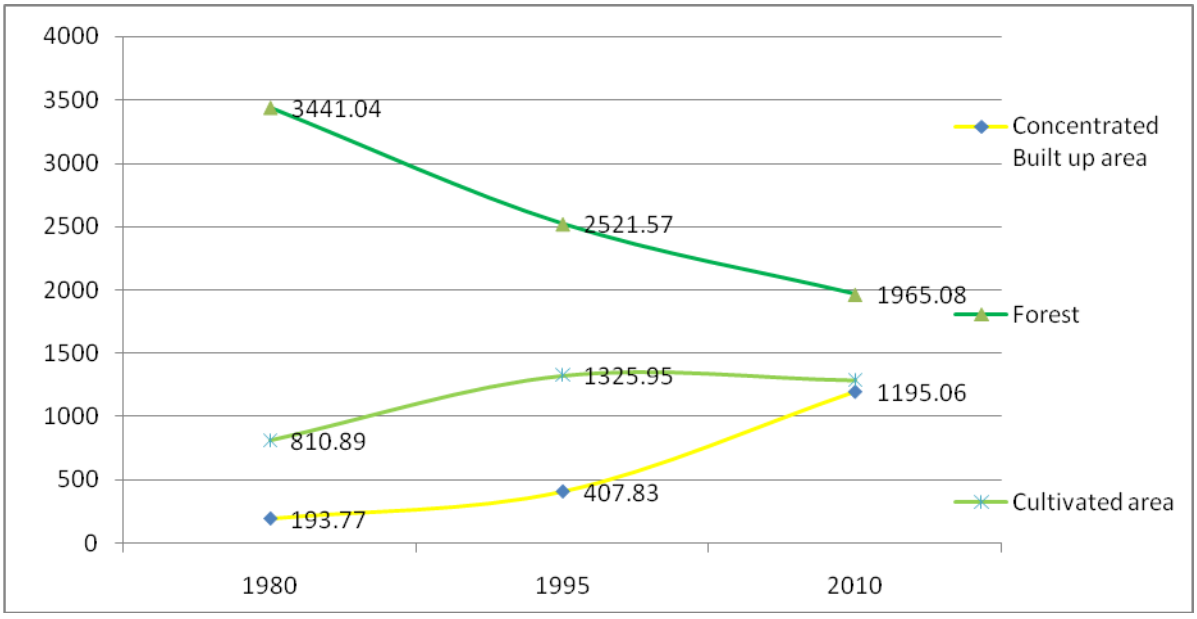


Figure 4.4 Trends Analysis of Land use changes between 1980 and 2010 in settlements surrounding Pugu Forest Reserves



DISCUSSIONS

Land Use Change in Settlement Surrounding River Ecosystems

Emerging from land use patterns presented in Tables 4.1 to 4.2, land uses such as concentrated built up area, sparsely/scattered built up and forest cover particularly mangroves. Other land uses are bare land, cultivated area, wetlands, institutional, quarrying and industrial area. Both analyses show similarities in land use changes between 1980 and 2010. The built up area shows an increase between 1980 and 1995 but more change is between 1995 and 2010. For example, between 1980 and 1995, the annual rate of change per annum for the concentrated built up in areas surrounding Mzinga River was 14.14 hectares per annum while between 1995 and 2010 it was 80.26 hectares per annum. Similarly, in areas that surround Mpiji River, the rates of change per annum in the similar window periods were 6.5 and 37.2 hectares respectively.

On contrary, the increase in the built up area shows an inverse relationship with the forest and wetlands between the similar window periods. While the built up area was increasing, the wetlands and forest covers showed a steady decline. In the period between 1980 and 1995, the annual rate of declining for wetlands was 15.9 hectares for wetland area and 4.1 between 1995 and 2010. The forest cover declined from 14 and 3.4 hectares per annum respectively during the similar periods. In the case of Mpiji River, the annual rate of change for the wetland area between 1980-1995 and 1995-2010 was 0.28 and 0.27 hectares per annum respectively. The forest cover which includes the mangroves along the shores of the Indian Ocean was 7.91 and 7.4 hectares per annum respectively.

In both analyses, the cultivated area shows an interesting scenario. The period between 1980 and 1995 shows an increasing trend of the cultivated area where in Mzinga it was 672.64 hectares while in 1995 it was 776.94 hectares. But in the period between 1995 and 2010 the cultivated area decreased from 776.94 hectares to 318.01 hectares. Quite similarly, in the areas surrounding Mpiji River the same situation of increase in cultivated area is manifested between 1980 and 1995 from 520.91 to 1,191.96 hectares while the period between 1995 and 2010 shows a decline from 1,191.96 to 994.72 hectares.

4.2.2 Land Use Change in Areas Surrounding Forest Ecosystem

Pugu and Pande Forest Ecological System which are also located in the Peri Urban settlements of Dar es Salaam city have also been experiencing rapid changes in terms of forest cover in the period between 1980 and 2010. Maps 5.7-5.9 demonstrate the land use/cover changes in areas that surround Pande Forest Reserve and the results on the cover/land use changes is provided in the Table 5.3 and 5.4 respectively.

Maps 4.7-4.7 provide a visual picture of land use and land cover change in settlements that surround Pande and Pugu forest ecosystems from 1980-2010. The spatial overlay analysis was performed using Arc GIS resulting into attribute tables (Table 4.3 and 4.4). The tables shows that land use area in hectares and percentage coverage in years 1980, 1995 and 2010 have changed. Finally the attribute table generated was transferred to MS-Excel where land use changes in periods 1980-1995; 1995-2010 and 1980-2010 were computed.

Land use changes in peri urban areas that surround Pande Forest reserve have similarities with those that surround Pugu Forest Reserve. In this scenario, the built up area increases with the decrease in the forest cover while the cultivated area increases then starts dropping immediately after 1995. Results from Table 5.7 show that between 1980, 1995 and 2010 the forest cover decreased from 2557.2, 1,396.4 and 804.5 respectively. The built up area gradually increased from 71.1 to 254.3 finally 498.7 in the years 1980, 1995 and finally 2010 respectively while the cultivated area increased from 338.3 hectares in 1980 reached 1169.2 hectares in 1995 then the growth retarded to 1187.7 hectares in 2010 as depicted in the Figures 4.3 and 4.4.

CONCLUSION

Land use/land cover change detection using multi-temporal images by means of remote sensing and ration research of model of urban expansion by GIS are good means of research of urban expansion. Through this process, we obtain the twelve temporal distribution maps of land use in the study area from 1980 to 2010 and the spatio-temporal distribution maps of ratio of urban land represent a strong expansion in urbanization.

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