Dynamics of land use and land cover changes in the Pugu and Kazimzumbwi Forest Reserves

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Abstract

Urban growth contributes to land use and land cover changes in protected forest reserves primarily through conversion of peri-urban areas into settlements, agriculture and unsustainable harvesting of ecosystem services to meet demands of the population in the peri-urban and urban areas. It has been widely argued that increased anthropogenic activities have altered the forest cover for Pugu and Kazimzumbwi Forest Reserves. Nonetheless, these arguments are little supported by quantitative data. A study on the dynamics of land use and cover changes in the Pugu and Kazimzumbwi Forest Reserves therefore investigated long-term changes that have occurred as a result of human activities in the areas for the periods 1985-1995 and 1995-2010. Landsat TM and ETM+ images were used to locate and quantify the changes using remote sensing and GIS techniques. Perceptions of local people on historical changes and drivers for the changes were also collected from three neighbouring villages and integrated in the assessment. The analysis was augmented by statistical analysis of 30 years historical rainfall and temperature records from Dar es Salaam and Kisarawe Climatic Stations. The study revealed remarkable decline in closed forest area in the latter period at -1.7 ha/year for Kazimzumbwi Forest Reserve (KFR) and -1.53 ha/year for Pugu Forest Reserve. The woodland variably decreased during the 1985 and 1995 period for both PFR and KFR but increased for PFR and decreased for KFR in the latter period. Unlike for closed forest and woodland, the cultivated land and built up area increased between the two periods for both forests reserves, while other covers variably increased or decreased between the years. The peoples' perceptions and drivers for the changes are presented and discussed together with the land use and land cover change analysis. The study concludes that, there has been remarkable changes in land use and cover in the catchment and these require concerted actions to reverse the changes and enable the forest reserves contribute to REDD initiatives.

Key words: *Kisarawe, Pugu Forest Reserve, Kazimzumbwi Forest Reserve, Land use and Land cover change, Remote sensing, GIS, climate variability and change, SPSS, perceptions*

1.0 Introduction

Urbanization, triggered by urban population growth, is one of the key drivers of land use and land cover[1] changes (LULCC) in peri-urban environment. This is true particularly in the global south where urban-land development process to the large extent over-step the urban-land use planning process. According to IHDP (2005), peri-urbanization is a "highly dynamic process where rural areas, both close to but increasingly also distant from, city centres becomes enveloped by or transformed into, extended metropolitan regions". The growth of peri-urban areas involves a complex adjustment of social and ecological systems as they become absorbed into the area of the urban economy (IHDP, 2005). Most importantly, urbanization changes lifestyles ultimately associated with demographic transitions, increasing expectation about consumption, and potentially a weakened understanding of production-consumption relationship (Lambin *et al*, 2001). Peri-urban areas fulfill key functions for the urban and rural areas. To the urban areas they provide

[1] Land cover is the biophysical attributes of the earth's surface while land use is the human purpose or intent applied to the biophysical attributes (Lambin *et al*., 2001).

sources of food, energy, water, building materials, biodiversity and ecological services (IHDP, 2005). Peri-urban areas also function as a key interface between urban and rural areas through the provision of essential services to rural areas. However, peri-urban areas also suffer the negative consequences of urban areas including land use and land cover changes and degradation of natural resources (IHDP, 2005).These LULCC directly impact biotic diversity worldwide, contribute to local and regional climate change as well as to global climate warming and are the primary source of soil degradation. Also by altering ecosystem services, LULCC affect the ability of biological systems to support human needs (IHDP, 2005, Lambin *et al*., 2001)

Trends in urban land use changes where peri-urban land uses change from agricultural or forests to urban uses are a global phenomena which pervades across the continents. It has been established that since 1970s, the built up areas of the cities in rapidly urbanizing parts of Latin America and Asia was doubling after every 15 to 20 years. Between 1975 and 2000, for example, when the annual average population increase of urban areas was 56 million, about 267,000 hectares of land were transformed from peri-urban and rural lands to the urban fabric (UN-Habitat, 1999 in Lupala, 2001).Most of the unguided peri-urban growth have developed into informal settlements. Due unguided peri-urban development, between 30 and 70 percent of settlements in most of the developing countries have grown into informal settlements (UN-Habitat, 1999).

The dynamics in urban land use changes for Dar es Salaam show a rapid increase in spatial expansion of the built up areas over years. Between 1891 and 2002, the extent of the built up area of Dar es Salaam increased from 122 hectares to 57,211 hectares. Exponential expansion is noticeable starting from 1963 to present decades where the built up area increased from 3080 hectares in 1963 to 57211 hectares in 2001. The distribution of land uses in the city show informal settlements sprawling into previously remote locations. While in 2002 only small proportions of informal settlement areas were developed close to the city, these have since spread at a distance between 3 and 16 kilometres with proportions varying between 20% and 35% (Hill and Lindner, 2007. These informal settlements constituted the predominant land-use type beginning at a distance of 6 km from the CBD in 2002 (Hill and Lindner, 2007).

The expansion of the Dar es Salam city has had considerable impacts on coastal forests surrounding Dar es Salaam City particularly Kazimzumbwi and Pugu Forest Reserves. Once considered one of the mini centres of endemism within the East Africa costal forest mosaic (Burgess and Clarke, 2000), Pugu and Kazimuzumbwi forest reserves have suffered severe degradation associated with land use and land cover changes on the surrounding forest boundaries and within the forest reserves respectively. Land use changes occur mainly due to conversion of forest reserve areas into peri-urban settlement and agriculture. On the other hand, land cover changes are caused by illegal human activities in the forest reserves including logging, charcoal burning, cutting of trees for construction purposes, and sand/gravel quarrying. These activities are driven by demands for land and forest products from the population in the communities surrounding the forest reserves and to the large extent by the increasing demands of the population from Dar es Salaam City. Existing assessments shows that between 1991 and 2000 open woodlands in the forest reserves declined by 29.1% while land cover and use under grassland with cultivation increased by 16% over the same period (Mulugu, 2007). As result,

increased encroachment in Pugu and Kazimuzumbwi has infringed the biodiversity of the forest reserves affecting their capacity to provide the forest ecosystem services.

Although Pugu and Kazimzumbwi protected forests offer a significant potential to REDD initiatives in Tanzania, *due to its location and relative short distance to the commercial capital,* internalizing the linkage of urban and peri-urban within the coastal forest conservation and management strategies remain a pervasive challenge which requires quantitative research to understand the physical and socioeconomic drivers for coastal forest degradation and deforestation. To contribute to that understanding, this study assess the dynamics of land use and land cover changes in the Pugu and Kazimuzumbwi Forest Reserves that have occurred as result of human activities between 1985 and 2010. The study contributes to the analysis of drivers of LULCC for the CCIAM project "*Analysis of the impact of urban land use and climate change on coastal forest ecosystem and management*".

2.0 Methodology

2.1 Description of the Study area

The project area transcends across the administrative boundaries of Dar se salaam Region and Kisarawe District. It lies between 38.7E and 39E and 6.5S to 7.08S. It has an estimated coverage of 484 square Kilometres. The larger part of this area is covered by the non-forest and non settlement areas covering 338.5 square kilometres or 70 percent of the total area followed by the two forest reserves which occupy a total area of 78 square kilometres or 16 percent of the total area. Settlements abutting the two forest reserves include the agglomeration at Pugu Kajiungeni that comprised the settlements of Pugu Kajiungeni, Mwakanga and Majohe; Buyuni and another agglomeration at Chanika. These two major settlement agglomerations are located within Dar es Salaam region. On the part of Kisarawe District, the settlements considered were Kisarawe town, and a series of settlements along Kazimzumbwi Road that includes the villages of Vigama, Kazimzumbwi, Kisanga, Sungwi, Masaki and Gumba (Table 1). At the centre of this area are the two forest reserves of Kazimzumbwi and Pugu covering 53.77 and 24.19 square kilometres respectively (Figure 1). The estimated land coverage by each of these land uses or villages is summarized in Table 1.

To the west of this area lies the Ruvu South Forest Reserves are farms and bushland to the larger of the southern and north eastern parts. Topographically, the area rises from 80m from east to about 750m above mean sea level towards the southern slopes in Kisarawe, east of Sungwi Village that marks the southern border between Dar es Salaam and Kisarawe. In terms of accessibility, the Dar es Salaam-Maneromango road that passes through Kisarawe town is the main spine that links between Dar es Salaam and settlements in Kisarawe District. The Pugu Kajiungeni-Chanika Road serves the Buyuni and Chanika agglomeration with ultimate link to Chamazi settlement in Dar es Salaam.

While Kazimzumbwi Forest Reserve was gazzeted as early as in 1936, the Pugu Forest reserve was gazzeted in 1954 while. The Kazimzumbwi Forest Reserve has an area of 5377 hectares and is located on the Pugu Hills between 120 and 280 metres of altitude. The Pugu Forest Reserve has an area of 2419 hectares. Just 40 years ago Pugu and Kazimzumbwi forest was a much larger forest extending to within 10km of Dar es Salaam. The forest reserves contain four main vegetation types: dry forest which is found on some of the ridges and hillsides; moist forest with an extra groundwater supply of

moisture along the watercourses and in the steeper-sided valleys; dense impenetrable thickets on many of the ridge tops (Ahrends, 2005).

Table 1: Coverage of the project area

Region/District	SN	Settlement/ Village	Area in sq km	Percentage of total area
Dar es Salaam	1.	Chanika	8	1.7
	2.	Buyuni	7	1.4
	3.	Mwakanga	6	1.2
	4.	Majohe	6	1.2
	5.	Pugu Kajiungeni	9	1.9
Kisarawe	1.	Kisarawe town	6.5	1.3
	2.	Masaki	3	0.6
	3.	Sungwi	6	1.2
	4.	Kisanga	5	1.0
	5.	Kazimzumbwi	6	1.2
	6.	Gumba	1	0.2
	7.	Tondoroni	3	0.6
	8.	Kipera	1	0.2
Forest Areas	1.	Pugu	24.19	5.0
	2.	Kazimzumbwi	53.77	11.1
Non-settlement, non forest reserve areas			338.5	69.9
TOTAL			465	100.0

Source: Based on area calculation from a topographic sheet of 1987

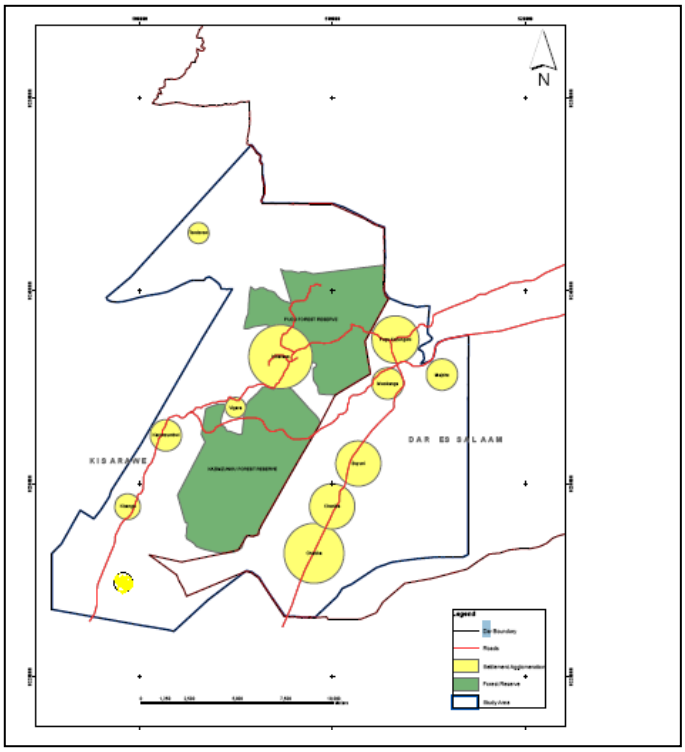

Figure 1: Area of study-Dar es Salaam and Kisarawe.

The key factors that were considered in delimiting the study area were as follows;

- The fact that the foci of the study is on the two forest reserves of Pugu and Kazimzumbwi, delineation of settlements that surrounding these reserves was the major criteria.
- The boundary of the study area was also delimited by the distribution of settlements surrounding the forest reserves. The fact that surrounding settlements lie on both Dar es Salaam Region and Kisarawe District, the study area boundary transcends across the administrative boundaries of these two areas.
- While the settlements in Dar es Salaam present peri-urban characters of settlements with rapid growth both in terms of population and land uses changes (Figure 2), settlements in Kisarawe are much more rural in character. Both sides have varying influences in the two forest reserves.

2.2 Methods

2.2.1 Land cover on Forests

Remote sensing and Geographical Information System (GIS) techniques were used to characterize the land use and land cover using satellite images and other ancillary data to deliver: i) information on land use dynamics, ii) land-cover map, and iii) area change statistics. Satellite imagery scenes - Landsat TM and ETM+ for p166r65 acquired in July for the years 1985, 1995 and 2010 (Table 2) with very minimum or free from clouds and limited seasonality, were obtained from the image supplier.

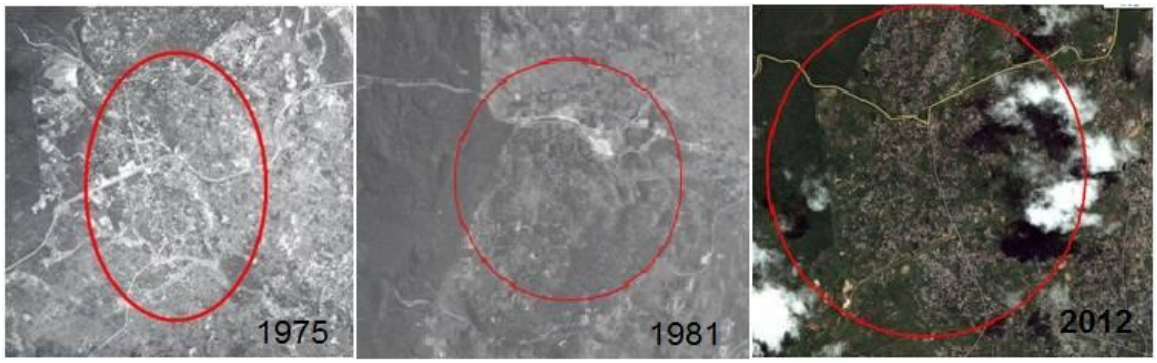

Figure 2: Land use changes and housing densification in Pugu Kajiungeni (1975-2012)

Table 2: Remotely sensed data used in the analysis of land use/cover change

Image Sensor	Path/Row	Acquisition date	Season
Landsat TM	166/65	1985	Dry
Landsat ETM+	166/65	1995	Dry
Landsat ETM+	166/65	2010	Dry

The image scenes of year 1985 and 2010 had already rectified except for the 1995. Based on the rectified imagery of 1985, and after enhancement using a 4, 5, 3 color composite band combination for both images, the 1995 image scene was geometrically rectified and registered to the UTM map coordinate system UTM zone 37 South, Spheroid Clarke 1880, Datum Arc 1960, using 2nd order polynomial function and nearest neighborhood interpolation with an overall RMS error of less than 1.5 pixels. A swipe command in ERDAS Imagine software was used to check the conformity of the rectified images.

Images were subset to the study areas using an Area of Interest function in ERDAS Imagine software to reduce the size of images and speed up the processing, followed by unsupervised

classification and preparation of base maps for the ground truthing work. To ensure consistence of nomenclature, the Hunting and Technical Services (1995) vegetation cover classification system was used. Field work for ground truthing and participatory mapping with the communities was conducted to collect information on the land use and cover categories, verify and modify land covers in the base map and for collecting reference data for accuracy assessment. A hand held Global Positioning System (GPS) was used to map locations of various features and sampled land cover observations. Using the collected ground truth data, and Google earth images, final classification was done using supervised Maximum Likelihood Classifier (MLC) into seven classes of interest (Closed Forest, Woodland, Bushland, Grassland, Cultivated land, Bareland, Built area). This was followed by post-classification comparison (Jensen, 1996; Mundia and Aniya, 2006; Kashaigili and Majaliwa, 2010) to asses land use and cover changes. Other details on the final maps like the drainage system, road network were extracted from the images and augmented from other sources like topographical maps at 1:50,000.

2.2.2 Socio-economic analysis

A socio-economic survey was conducted in three locations in the study area (Buyuni/Majohe and Chanika in Ilala District and Masaki in Kisarawe District) in order to identify and assess the socio-economic drivers of land use changes including the community's perception of climate change and variability and their implication on coastal forest degradation. Chanika and Buyuni/Majohe represented peri-urban environment for Ilala District while Masaki was identified to represent the rural setting for Kisarawe District. Key informant interviews with agricultural extension staff in the study areas, focus group discussion and semi-structured questionnaire were used to collect socio-economic data. Focus group discussion involved about ten members from each of the study area. The members were drawn from the communities representing men, women, elderly and youths. Prepared checklist was use to guide the focus group discussions. The semi-structured questionnaire was administered to a total of 150 households representing 50 randomly selected households from each of the three study locations. SPSS and Microsoft Excel computer programs were used to analyse collected data and to characterize the socio-economic condition of the study communities.

The questionnaire was also designed to capture perceptions of the study communities on climate variability and change using the indicators of rainfall variability between seasons and years, trends in temperature increase for the past 10 years and occurrence of extreme events such as droughts and using indigenous knowledge. Perceptions of climate variability and change is complemented with the time-series analysis of annual rainfall, number of rainy days, seasonal rainfall variability and extreme events from thirty years rainfall and temperature for Dar es Salaam and Kisarawe using Instant Statistical Software. The climatic data were collected from Tanzania Meteorological Agency (TMA) in Dar es Salaam.

3.0 Results and discussions

3.1 Land use and land cover changes of the forest reserves

3.1.1 Land use/cover mapping (1985-2010)

The land use /cover maps of Pugu Forest Reserves for the year 1985, 1995 and 2010 are presented in Figures 3, 4 and 5respectively, while for Kazimzumbwi Forest Reserves are presented in Figure 6, 7, and 8. Generally, the maps show the variation in cover coverage between the three periods under consideration.

3.1.2 Land use/cover change detection (1985-2010)

Tables 3 and 4 present the cover area, changed area and the rate of change between 1985 and 1995; 1995 and 2010 for Pugu and Kazimzumbwi Forest Reserves respectively. The results for PFR (Table 3) indicate that in the year 1985, the closed forest covered 56.3% of the areas followed by woodland 18.3%, bushland 16.9 %, bareland 6.0%, built area 1.7%, grassland 0.8% and cultivated land 0.04%. The area under closed forest that occupied 1361 ha (56.3%) in 1985 increased to 1584 ha (65.5%) in 1995 and decreased to 1028 ha (42.5%) in 2010 indicating an increase in closed forest area of about +223 ha (+9.2%) between 1985 and 1995; a decline of -556 ha (-23%) between 1995 and 2010. Woodlands that occupied 443 ha (18.3%) in 1985 declined to 174 ha (7.2%) in 1995 and increased to 383 ha (15.8%) in 2010 indicating a decrease in woodland area of about -269 ha (-11.1%) between 1985 and 1995; and an increase of +209 ha (-8.6%) between 1995 and 2010. Unlike for closed forest and woodland, the cultivated land and built up area increased between the two periods under consideration. Other covers (bushland, bareland and grassland) variably increased or decreased between the years.

In KFR (Table 4) the closed forest occupied 1860 ha (34.6%) in 1985 followed by the woodland 1705 ha (31.7%), grassland 795 ha (14.8%), bareland 417 ha (7.8%), built area 347 ha (6.5%), bushland 239 ha (4.4%) and cultivated land 14 ha (0.3%). The area under closed forest that occupied 1860 ha (34.6%) in 1985, increased to 2143 ha (39.8%) in 1995 and declined to 1322 ha (42.5%) in 2010 indicating an increase in closed forest area of about +282 ha (+5.2%) between 1985 and 1995; a decline of -820 ha (-15.3%) between 1995 and 2010. Woodland that occupied 1705 ha (31.7%) in 1985 declined to 1319 ha (24.5%) in 1995 and 838 ha (15.6%) in 2010 indicating a decrease in open woodland of about -386 ha (-7.2%) between 1985 and 1995 and -481 ha (-8.9%) between 1995 and 2010. As for PFR, cultivated land increased between the two periods, while other covers variably increased or decreased between the years.

As revealed from Table 3 for PFR, the closed forest cover increased at a rate of +0.92 ha/year over a period of 10 years (i.e. 1985-1995) and declined at a rate of -1.53 ha/year for a period of 15 years (i.e. 1995-2010)assuming a linear increase. The woodland declined at a rate of -1.11 ha/year between 1985 and 1995 but increased at a rate of +0.58 ha/year between 1995 and 2010.

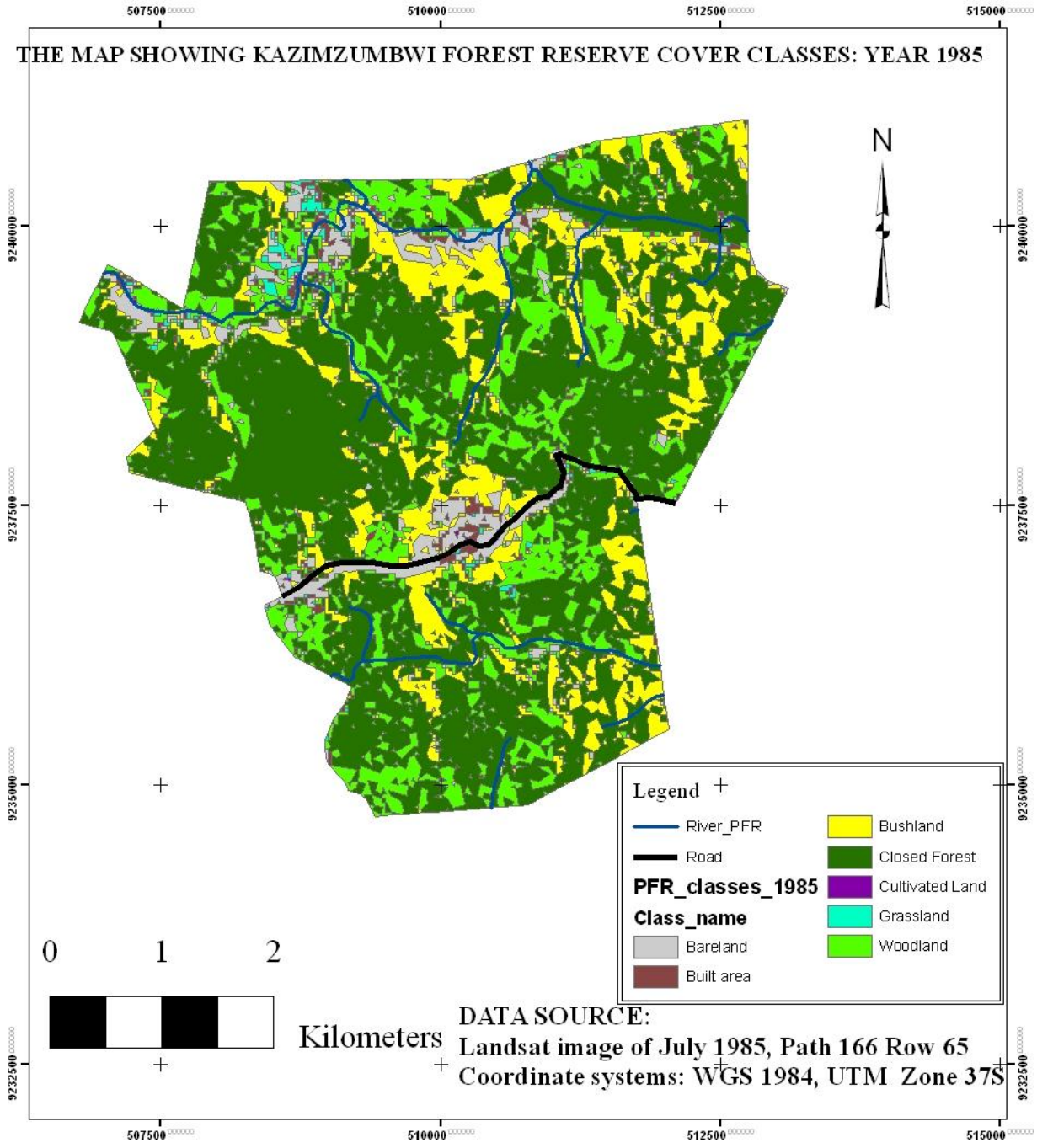

Figure 3: Land use / cover map of Pugu Forest Reserve for 1985

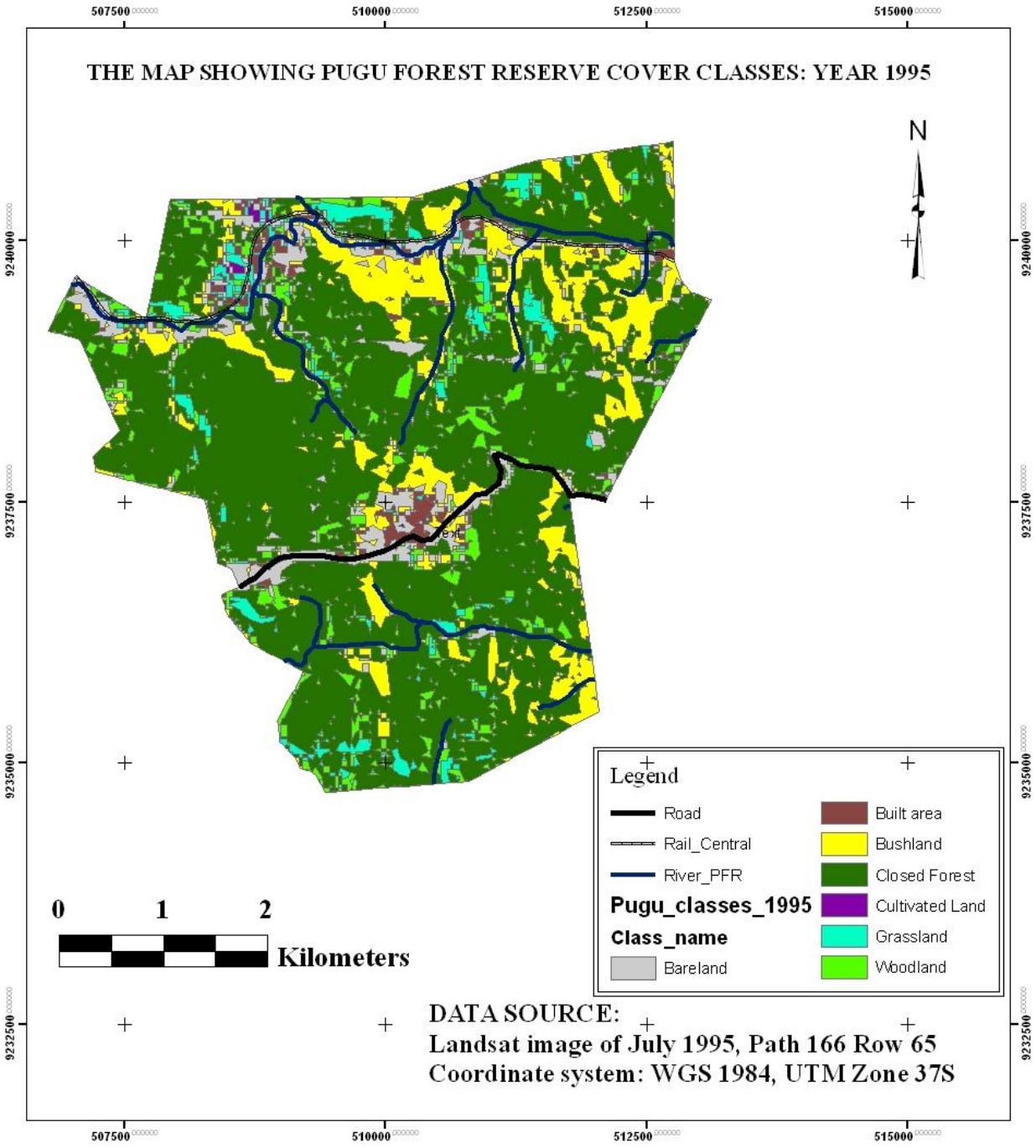

Figure 4: Land use / cover map of Pugu Forest Reserve for 1995

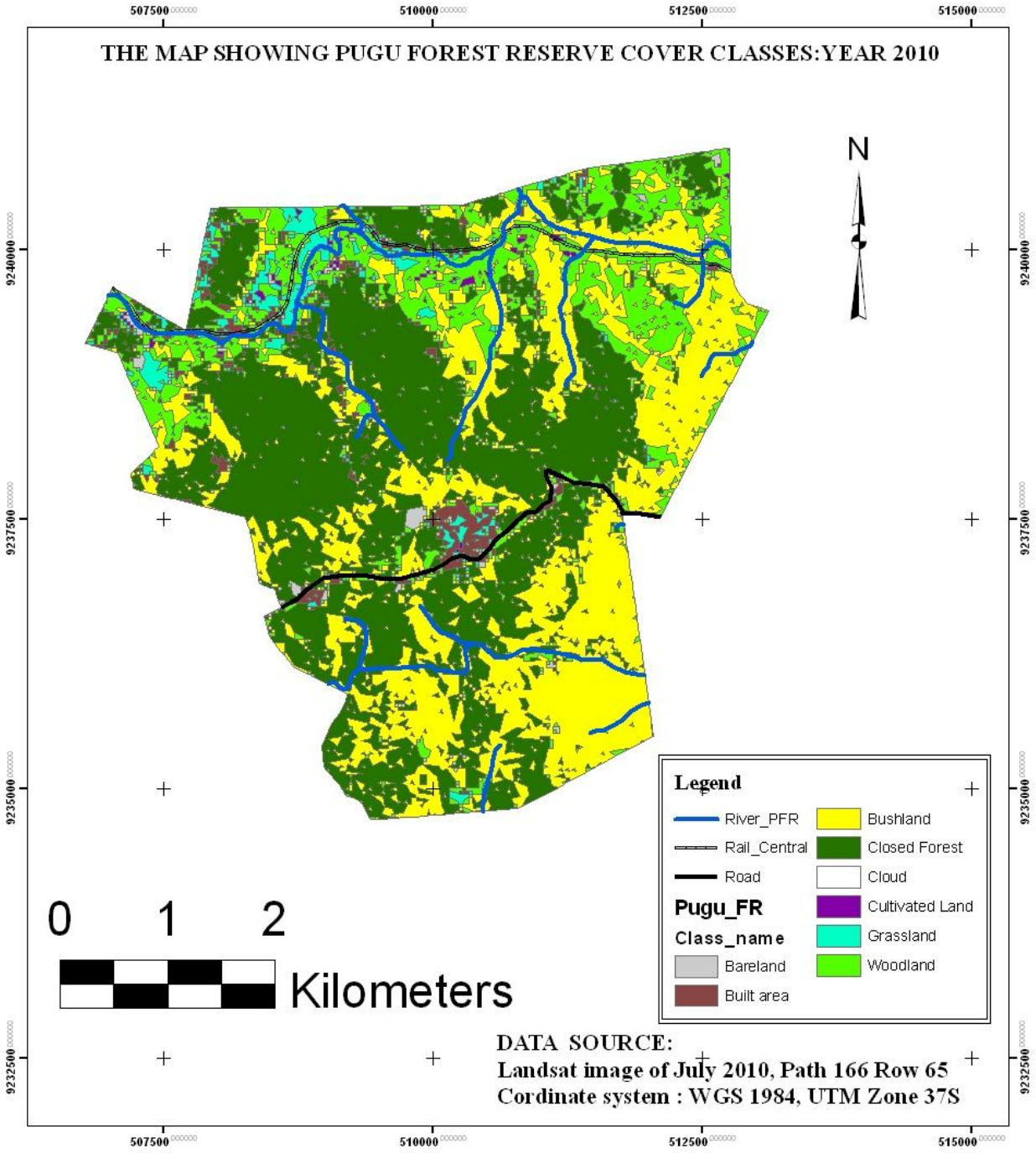

Figure 5: Land use / cover map of Pugu Forest Reserve for 2010

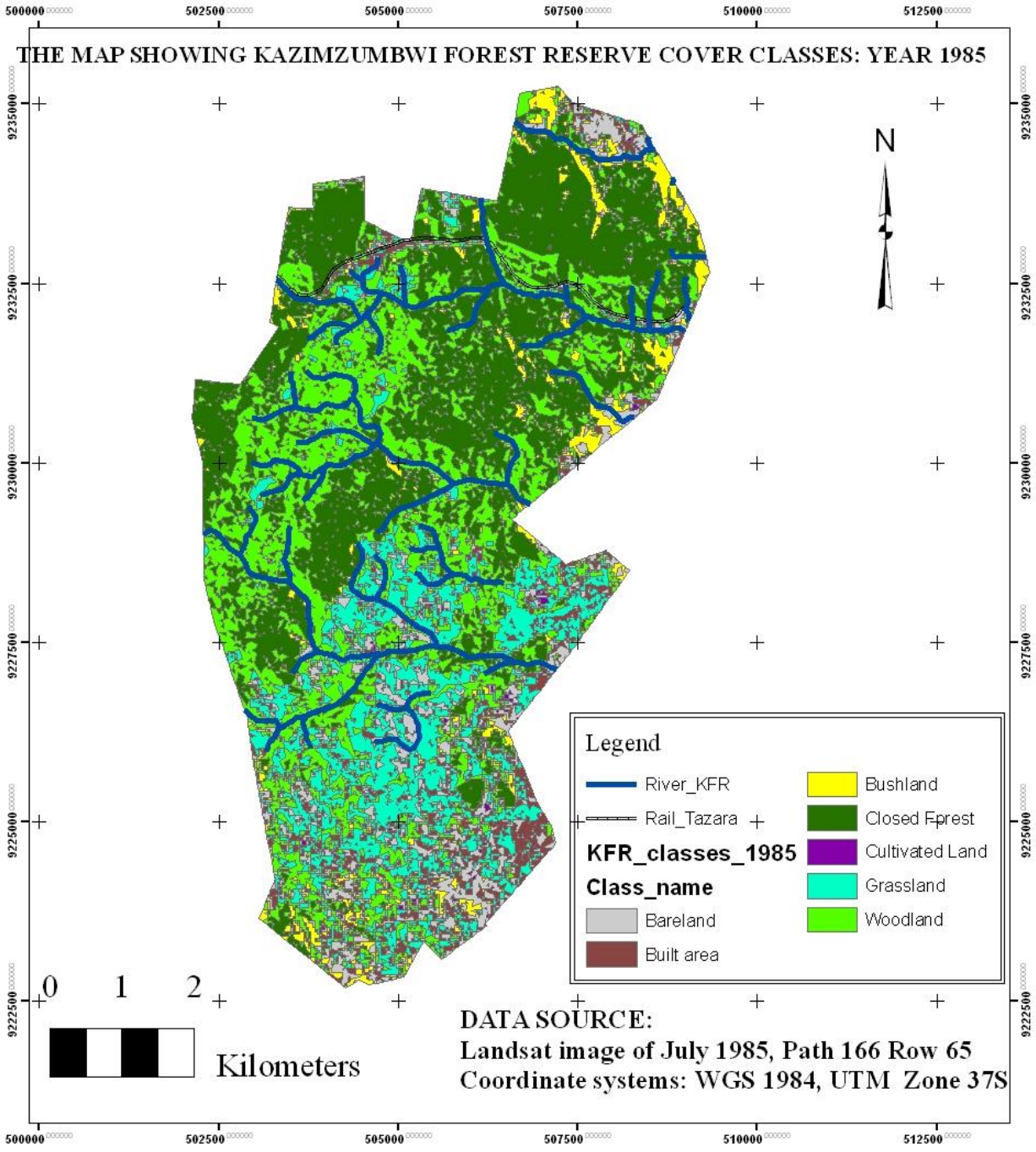

Figure 6: Land use / cover map of Kazimzumbwi Forest Reserve for 1985

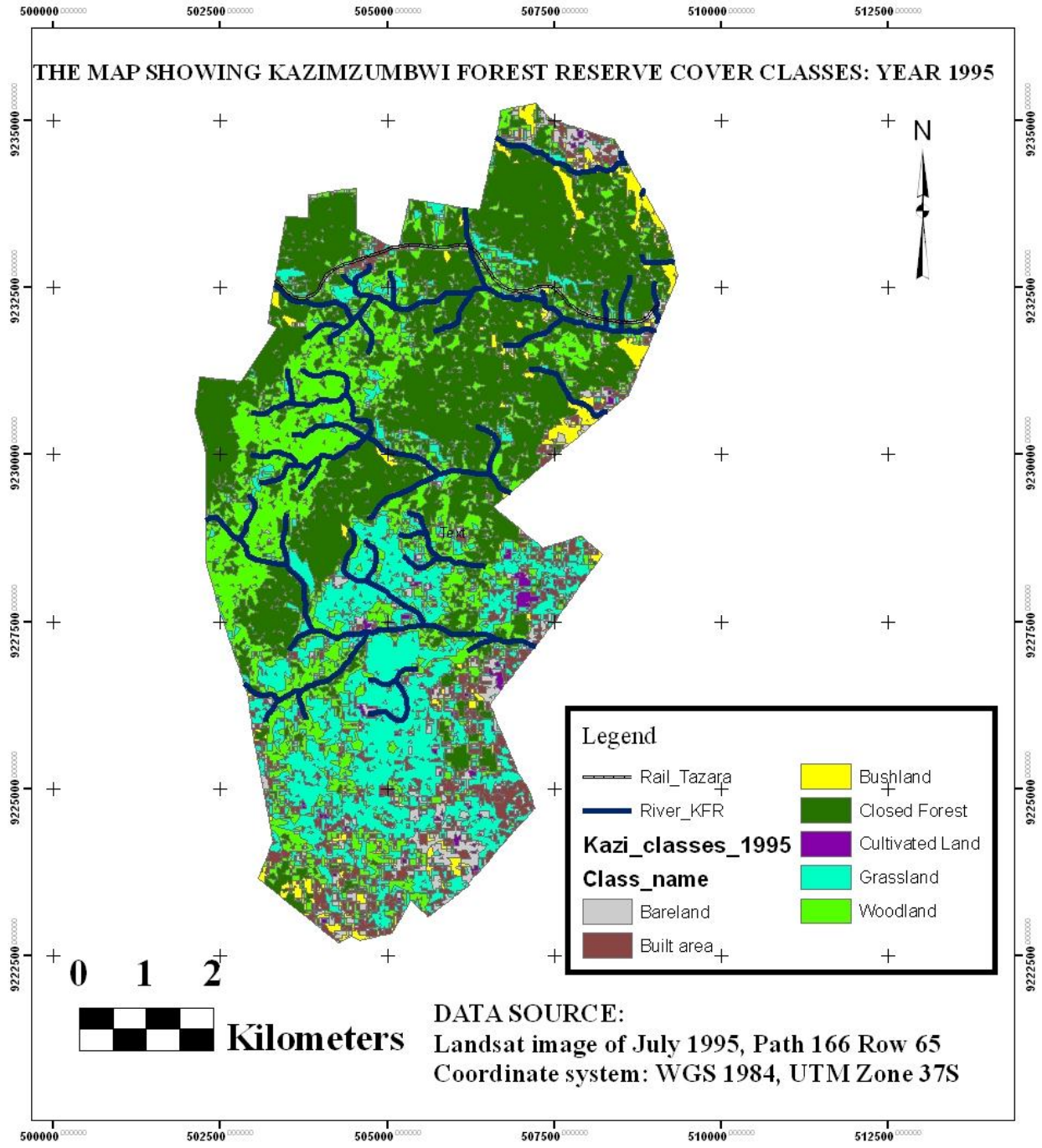

Figure 7: Land use / cover map of Kazimzumbwi Forest Reserve for 1995

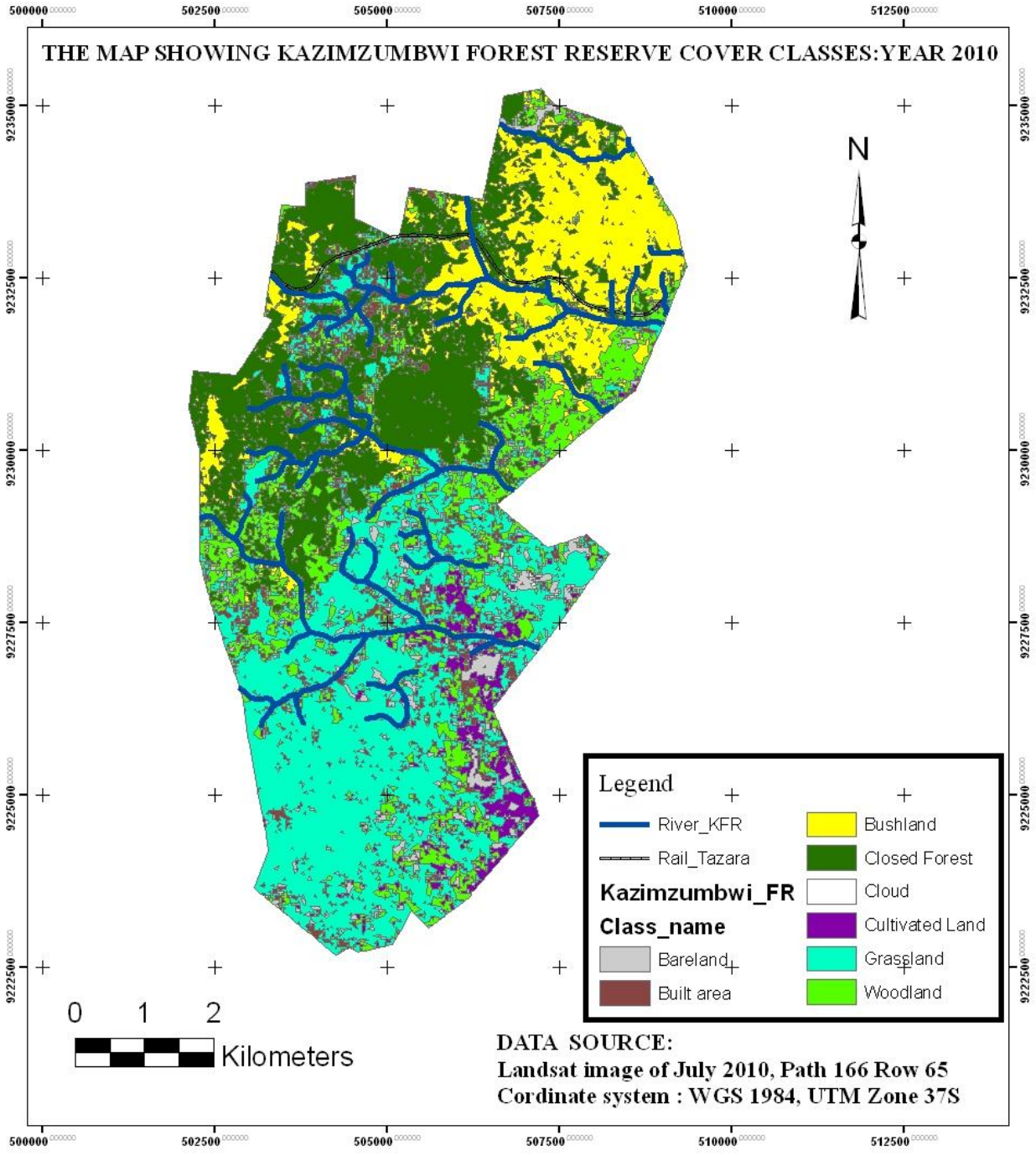

Figure 8: Land use / cover map of Kazimzumbwi Forest Reserve for 2010

Unlike for closed forest and woodland covers, the cultivated land increased consistently at a rate of +0.01 ha/year for the entire periods. Likewise, the built area increased at a rate of +0.07 ha/year and +0.02 ha/year between 1985-1995 and 1995-2010 respectively. For KFR, the closed forest cover increased at a rate of +1.56 ha/year over a period of 10 years (i.e. 1985-1995) and declined at a rate of -1.7 ha/year for a period of 15 years (i.e. 1995-2010). Woodland declined at a rate of -2.13 ha/year between 1985 and 1995, and -1.0 ha/year between 1995 and 2010. Unlike for closed forest and woodland covers, the cultivated land increased at a rate of +0.17 ha/year and +0.28 ha/year for the two respective periods.

3.1.3 Analysis and implications of the detected changes

The land use/cover dynamics for the two periods under considerations have been revealed. The closed forest was found to change between the study periods with more changes occurring in the latter period unlike the former. The woodland variably decreased during the 1985 and 1995 period for both PFR and KFR but increased for PFR and decreased for KFR in the latter period. It is possible that the increase in closed forest cover between 1985 and 1995 unlike the latter period is attributable to reduced forest disturbance and thus allowing regeneration. The decline in cover in the latter period might be due to clear felling of trees mainly for charcoal, firewood, and increased settlement and agricultural activities. This has also been accentuated by local people during the interviews. The expansion in settlement and cultivated areas reflects on the land use transformation in the two forest reserves.

3.2 Socio-economic drivers for land cover and land use changes

3.2.1 Population increase

Communities near the forest reserves; in particular the existing peri-urban areas of Pugu Kajiungeni, Pugu statation, Buyuni and Chanika have experienced increased population since the late 1990s due to immigration from Dar es Salaam City. In Chanika, people migrated to the area from the early 1980s in search of agricultural land. Later in the 1982 the migrants engaged in charcoal production and from 1985 they started to establish permanent settlement in the village. Similarly areas in Buyuni/Majohe have been experiencing increased immigration trends since 1990s. During the field data collection for this study, community members reported that migrants from Dar es Salaam moved and settled to the area around the year 2000 while other immigrants targeted acquisition of agricultural land.Population increase in the peri-urban areas surrounding the forest reserves has resulted to increased pressure on natural resources. For example high population pressure in Yongwe-Chanika was reported to increase the problem of water availability for domestic use compared to the past ten years when sufficient water was available in fairly good quality. Further the currently available water from the traditional waters sources is increasingly becoming salt.

Analysis of immigration pattern from the three study sites shows that 57% of the questionnaire respondents were not natives of the Dar es Salam Region (Figure 9). Those who were natives of Dar es Salaam region and Ilala district represented only 9% and 11% of the respondents in the two study communities. In Buyuni and Chanika respondents who were native to the study communities were only two and one percent respectively while at Masaki they represented 20%.

Table 3: Cover area, changed area and the rate of change between 1985 and 1995; 1995 and 2010 for Pugu Forest Reserve

Cover class	1985		1995		2010		Change area (ha)		% Change		Annual rate of change (ha/year)	
	Cover area (ha)	% Cover coverage	Cover area (ha)	% Cover coverage	Cover area (ha)	% Cover coverage	(1985-1995)	(1995-2010)	(1985-1995)	(1995-2010)	(1985-1995)	(1995-2010)
CF	1361.0	56.3	1584.0	65.5	1028.0	42.5	223.0	-556.0	9.2	-23.0	0.92	-1.53
OF	443.0	18.3	174.0	7.2	383.0	15.8	-269.0	209.0	-11.1	8.6	-1.11	0.58
BL	144.0	6.0	177.0	7.3	22.0	0.9	33.0	-155.0	1.4	-6.4	0.14	-0.43
BA	41.0	1.7	57.0	2.4	66.0	2.7	16.0	9.0	0.7	0.4	0.07	0.02
BU	410.0	16.9	333.0	13.8	845.0	34.9	-77.0	512.0	-3.2	21.2	-0.32	1.41
CL	1.0	0.04	4.0	0.2	9.0	0.4	3.0	5.0	0.1	0.2	0.01	0.01
GL	19.0	0.8	90.0	3.7	65.0	2.7	71.0	-25.0	2.9	-1.0	0.29	-0.07
Total	2419	100	2419	100	2419							

Note: CF=Closed Forest, WL=Woodland Forest, BL=Bareland, BA=Built area, BU=Bushland, CL=Cultivated Land and GL=Grassland

Table 4: Cover area, changed area and the rate of change between 1985 and 1995; 1995 and 2010 for Kazimzumbwi Forest Reserve

Cover class	1985		1995		2010		Change area (ha)		% Change		Annual rate of change (ha/year)	
	Cover area (ha)	% Cover coverage	Cover area (ha)	% Cover coverage	Cover area (ha)	% Cover coverage	(1985-1995)	(1995-2010)	(1985-1995)	(1995-2010)	(1985-1995)	(1995-2010)
CF	1860.0	34.6	2142.0	39.8	1322.0	24.6	282.0	-820.0	5.2	-15.3	1.56	-1.70
OF	1705.0	31.7	1319.0	24.5	838.0	15.6	-386.0	-481.0	-7.2	-8.9	-2.13	-1.00
BL	417.0	7.8	235.0	4.4	200.0	3.7	-182.0	-35.0	-3.4	-0.7	-1.00	-0.07
BA	347.0	6.5	390.0	7.3	237.0	4.4	43.0	-153.0	0.8	-2.8	0.24	-0.32
BU	239.0	4.4	175.0	3.3	859.0	16.0	-64.0	684.0	-1.2	12.7	-0.35	1.42
CD	0.0	0.0	0.0	0.0	9.0	0.2	0.0	9.0	0.0	0.2	0.00	0.02
CL	14.0	0.3	44.0	0.8	181.0	3.4	30.0	137.0	0.6	2.5	0.17	0.28
GL	795.0	14.8	1072.0	19.9	1731.0	32.2	277.0	659.0	5.2	12.3	1.53	1.37
Total	5377	100.0	5377	100.0	5377							

Note: CF=Closed Forest, WL=Woodland, BL=Bareland, BA=Built area, BU=Bushland, CD=Cloud, CL=Cultivated Land and GL=Grassland

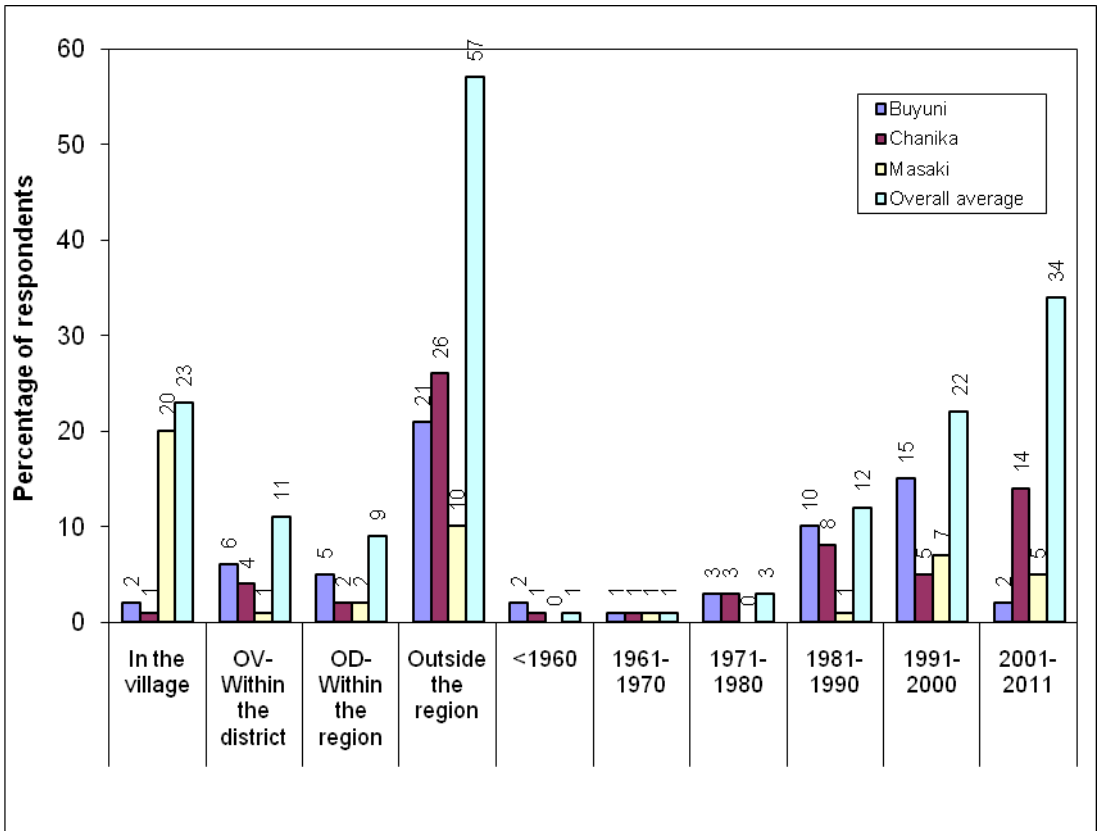

Figure 9: Immigration pattern in the peri-urban areas

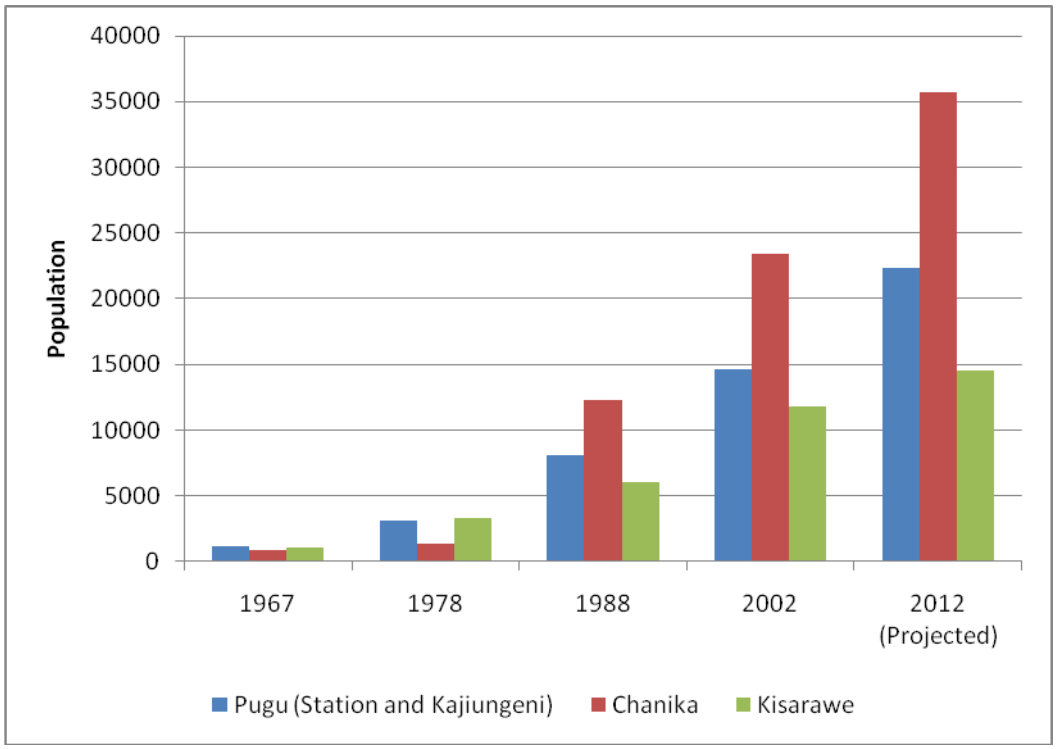

Figure 10: Population growth in peri-urban areas surrounding Pugu and Kazimzumbwi Forest Reserves (Data source: NBS)

Immigrants therefore constitute majority of the population in Buyuni and Chanika while the natives constitute majority of the population in Masaki which represent a rural area. This finding implies that peri-urban areas act as receptors of population spill-over resulting from rural-urban migration for Dar es Salaam City

Although immigration trends in Buyuni and Chanika dates back to pre- 1960, the trends have consistently increased from the 1971-1990 period. Respondents who migrated during this period represented three percent of the respondents while those who migrated during the 2001-2011 period represented 34 %. The 2002 population for Pugu (Kajiungeni & Station) and Chanika represented 80% and 91% population increase respectively since 1988 (Figure 10). Although each of the study communities experienced varying degree of immigration pattern there is generally an increasing trend of immigration in the study area.

Increased pressure on natural resources due to population growth in peri-urban areas surrounding Pugu and Kazimzumbwi forest reserves has contributed to increased dependence on forest resources over the last twenty years. For example73% of the respondents from the three study communities reported to depend on the forest reserves for firewood and 23% depend on the forests for charcoal. Other services which communities derive from the forest reserves included fruits and building materials.

3.2.2 Agriculture expansion

Population increase in the peri-urban areas is linked with growth of settlement and agricultural farms (Malugu, 2007). This is a typical and traditional phenomenon of demands for services created by the population in the newly developed settlements. In the peri-urban areas of Buyuni and Chanika, agriculture is still a predominant livelihood activity among the community members representing 51% of the respondents to the household questionnaire. In Buyuni/Majohe it was found that community members are even categorized into various socio-economic groups (*i.e., poor, intermediate and well-off*) depending on ownership of farmland and ability to commercialize agricultural production. Households owning farms between 1 and 2 acres are categorized as poor while those with farms between 2 and 4 acres are categorized as intermediate. Well-off families are those who own more than 4 acres of land. These were mainly people who had moved into the area from Dar es Salaam or they still operate from Dar es Salaam City. The main crops produced by the farmers in the peri-urban areas are horticultural crops including water melons, cucumbers, okra, egg plants and green peppers. They also produce maize, cassava, rice and sweet potatoes for food consumption. One percent of the respondents were engaged in livestock keeping (cattle and chicken). Horticultural crops are produced for commercial purposes to supply the local market in Buyuni and Chanika as well as outside markets in Dar es Salaam City. The availability of markets for horticultural produce has resulted into expansion of commercial horticulture production which is done to the extent of being practiced in river banks and valley bottoms. This practice contributes to soil erosion and land degradation.

Agriculture, which is *associated with population increase*, is one of the key drivers to land cover and land use changes within and in the surroundings of Pugu and Kazimzumbwi protected forest reserves. In an analysis of land cover and land use change of the forest reserve and adjacent areas, Malugu (2007) observed that the area under grassland with cultivation increased by 16% from 1991 to 2000 while open woodland had declined by 29.4% during the same period. The decrease in open woodland was due to opening up of

new farms planted with perennial and permanent crops such as palm and cashew (Malugu, 2007). Land cover under settlement had increased from 1.4% to 1.6%. The southern part of Kazimzumbwi is the area which experiences serious woodland degradation due to high encroachment by Chanika and Buyuni peri-urban areas.

3.2.3 Non agriculture Activities

Non agriculture activities which contribute to forest degradation include charcoal burning, firewood collection, harvesting of poles for construction and logging for timber on a marginal scale. Majority of the communities members surrounding the PKFRs are characterized by income poverty and lack of alternative strategies for their livelihoods. Harvesting and selling of forest products is therefore the only easy and quick option to make living in the communities surrounding the forest reserves. A survey which was conducted in Buyuni and Chanika for this study found that 46% and 17% of the respondents depend on firewood and charcoal respectively from Kazimzumbwi Forest Reserve. However, surprisingly none of the respondent households indicated dependency on forest related products as one of their primary and secondary source of income. This might have been contributed from their knowledge about the protection status of the forest reserves whereby extraction of any product from the forest is illegal.

Proximity to Dar es Salaam city which provide the main market for forest products encourage cutting of tree for charcoal, firewood and construction purposes. During field work for this study it was learnt that, the majority of the people coming to Kisarawe in connection to charcoal production are mainly from Dar es Salaam City where most of the charcoal is sold. The persistent increase in price of charcoal and firewood has attracted many people to engage in this activity. This is a typical reflection of the energy use bias whereby fuel wood provides over 98 percent of energy in rural areas and approximately 90 percent in urban areas. In Dar es Salaam for example, the price of charcoal increased from Tshs 2,500 per sack (approx 100kg) in 1998 to Tshs 4,000 per sack in 2001. Current prices (2011) of the same sack stands at Tshs 40,000.The price of a bundle of firewood increased from Tshs 800 to 2400 between early and late 1990s. The persistent increase in price in charcoal has motivated people to shift from the non-paying agricultural activities to off-farm activities including charcoal sale. The sale of forest related products was revealed by Kahyarara, Mbowe and Kimweri (2002) to have more financial returns compared to agriculture activities along the coastal forest zone. While sales from agricultural products for farmers amounted to TShs 27,000 in one year, the average income from charcoal sellers averaged TShs 54,000 per year. The conclusion from these results was that income generated from forest-related activities was higher and may be twice the income generated through agricultural activities" (Kahyarara, Mbowe and Kimweri; 2002). It is not surprising therefore that shifting of people's livelihoods from typically agricultural to forest products is largely motivated by the higher returns associated in the new activity.

3.3 Climate variability and change in the study area

Communities in the study areas perceive that there is climate variability and climate changes over the past ten years in the study areas. Indicators of climate change and variability included decreasing rainfall trends, increasing incidences of droughts, unpredictable rainfall patterns, disappearance of wetlands and failure to predict on-set of rainy season using traditional indicators and indigenous knowledge.

For example local community members in Buyuni reported to have experienced decrease of rainfall pattern for the past ten years. Before 2003 they used to receive good *Vuli* and *Masika* rains but currently *Vuli* rains have almost completely disappeared and *Masika* rains comes late (until April for some years) and stops earlier. In Chanika, community members reported to experience difficulty in determining the onset of rainfall using local or indigenous knowledge compared to 1980s and 1990s. In the past the following indicators were being used to determine on set of rainfall season (Table 5):

- Moon direction could determine onset of rainfall season; however, currently this is no longer the case.
- Appearance of a cluster of stars locally know as *Kilimia* and *Mpini wa Kata*; seen at a distance (around midnight). Currently they are unable to do such predictions using these stars.
- Insect e.g. *Mzungu, Nyenze* (these normally dig down on the ground); and *Nyela* (these are normally found above the ground). These insects are no longer available in the study areas.
- Appearance of certain types of clouds was used to provide an indication of short or long rains. These clouds are no longer seen during the daylight.

Table 5: Community's perception of climate change and variability

Community	Indicators of changing climate and variability	Indicators still in use for determination of on-set of rainfall	Extreme events

Buyuni	• Decreasing trend of rainfall (past 10yrs)
	  o Unpredictable
	• Increasing incidences of droughts
	  o Increasing food insecurity
		• Appearance of certain insects (*Sangaugimbi, Vakule, Vikanikani*)
		• Appearance of certain plants (*Tindiga*)
			• Heavy storms
			• Floods (1989/90)
			• Extreme high temperature
			• Mzinga river changed to seasonal
			  o Disappearance of Hippopotamus

Chanika	• Unpredictable rainfall patterns compared to early 1990s
	  o Vuli (*Oct-Dec*)
	  o Masika (*Mar-Jun*)
	• Yongwe used to be a wetland with Mzinga river flowing throughout the year
	• Failure to predict on-set of rain season using traditional indicators and indigenous knowledge
	  o Moon direction
	  o Appearance of cluster of stars (*kilimia na Mpini wa Kata*)
	  o Occurrence of insects (*Mzungu, Nyenze*)
	  o Appearance of certain types of clouds		

Only few indicators such as appearance of certain insects (*Sangaugimbi, Vakule, Vibaruti, Vikanikani*) and plants (*Tindiga*) are still in use to determine rainfall season. Apart from unpredictable rainfall patterns, extreme events such as heavy storms and flooding have been noted. Also Mzinga River which was perennial has become seasonal resulting into disappearance of hippopotamus, fish and increased river sedimentation. Changes in rainfall pattern, particularly drought have considerably affected agriculture production in the study communities due soil moisture stress. As result of increasing rainfall variability, agriculture dependent households have been driven into food insecurity situation.

To confirm community's perception on climate change and variability in the study

area, statistical analysis of 30 years rainfall and temperature records for Dar es Salaam and Kisarawe climatic station was made. The climate of the study site is described as sub-tropical with two main seasons; the short rainy (*Vuli*) season, which starts in October and ends in December and the long rainy (*Masika*) season, which starts in March and end in May. Dry season occur between June and September as well as from January to February. The rainfall pattern has been fluctuating for the past ten years with incidences of complete short rain season failure in three previous years.

The historical analysis of rainfall data for 30 years for Dar es Salaam and Kisarawe areas, on which the study sites are located indicate clear decadal climate variability. From 2000 to 2010, the annual total rainfall for Dar es Salaam and Kisarawe has declining trend (Figure 11). The number of rain days has also decreased during the same period (Figure 12). For example, in the most recent decade (2000-2010), the total number of rain days has decreased respectively. This implies that there is a strong decadal variability of rainfall across the study areas with a decreasing trend.

The seasonal variability is also evident from the historical records as it was mentioned by the participants during the socio-economic study. Analysis of rainfall records also shows that there is a strong yearly variability of seasonal rainfall pattern within the study sites, both for *Vuli* and *Masika* rainy seasons (Figure 13). For example a year to year seasonal variability of up to 600mm from 1995 to 1997 is evident for vuli season. Closer analysis of total rainfall by seasons for Kisarawe and Dar es Salaam (Figure 13 & 14) indicate negative trends both for *Vuli* and *Masika* in the recent 10 years.

Analysis of 30 years temperature records for Dar es Salaam and Kisarawe weather stations indicates increasing trends of minimum and maximum temperature from 1995 consistent with the period of declining rainfall (Figure 15). The trend for the maximum temperature shows that the coastal areas have warmed for almost two degrees for the past 30 years. However, a strong annual and decadal variability for both average maximum and minimum temperature with an increasing trend is shown by the trend analysis.

Extreme temperature events constitute climate variability and change. Such extreme temperature events are observed from the analysis of temperature extremes for Dar es Salaam for 30 years. Temperature greater than 35 degrees is not common for Dar es Salaam and is described as an extreme event. The analysis shows that most of the temperature greater than 35 degrees in the region coincided with the cropping seasons for *Vuli* and *Masika* (Figure 16), which currently start from November to December and from March to May. Such coincidence could accelerate drought spells and contribute to crops failure. The temporal distribution of maximum temperature greater than 35 degrees has increased in the recent decade (Figure 17). For the first decade (1-10) from 1981 to 1990 maximum temperature events were only five. In the next decade (1990-2000) the events increased to six, and they have reached to 8 cases in the recent decade ending 2010.

Analysis of long term rainfall and temperature data for Dar es Salaam and Kisarawe weather station shows that rainfall pattern for *Vuli* and *Masika* and the trends in temperature in the recent decade are consistent with community's perception on declining rainfall trends, increasing temperature and the increased incidences of droughts. The annual total rainfall, numbers of rain days and seasonal total rainfall for *Vuli* and *Masika* have consistently declined for the past 10 years while the average maximum and minimum

temperatures have increased during the same period. Rainfall variability between and within seasons and rising temperature affect agriculture production in the study areas due to reduced soil moisture for the crops. In the recent decade, seasonal rainfall which is important for agriculture production in the study areas has decreased below the long term average. Climate variability and change has emerged as one of the challenges which contribute to changing livelihood patterns among community members from agriculture to non agricultural activities including charcoal making, harvesting of firewood and other forest related products. These forest livelihood based activities contributes to degradation of the forest reserves.

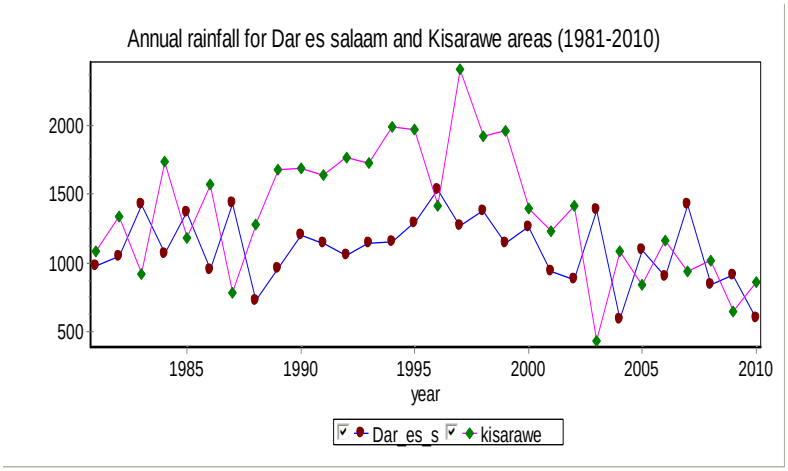

Figure 11: Annual rainfall for Dar es Salaam and Kisarawe (1981-2010)

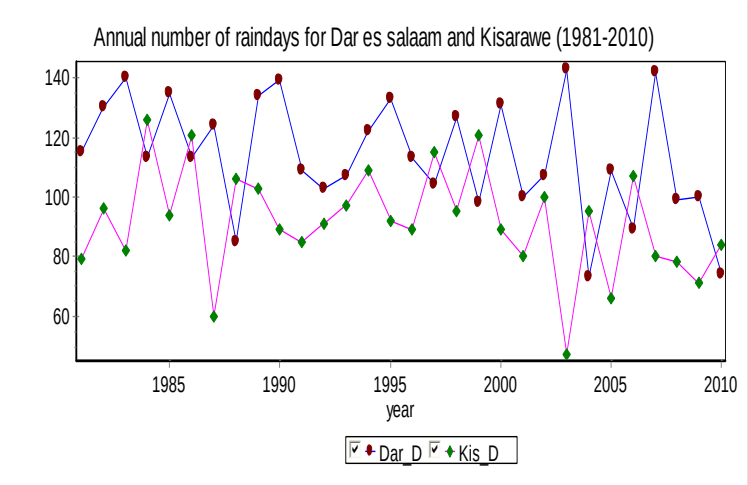

Figure 12: Annual number of rain days for Dar es Salaam and Kisarawe (1981-2010)

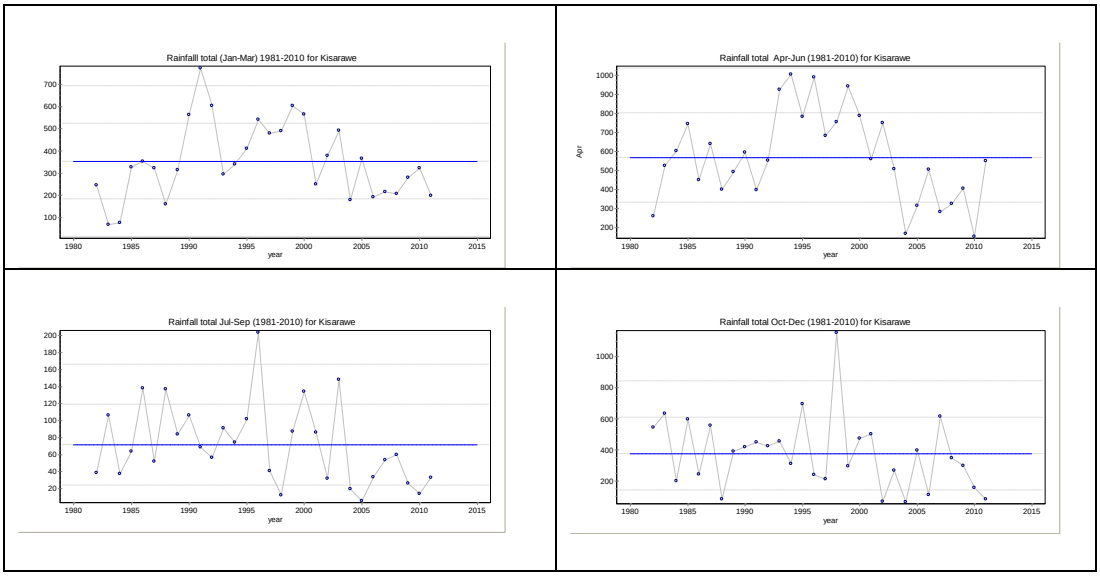

Figure 13: Total rainfall by seasons for Kisarawe (1981-2010)

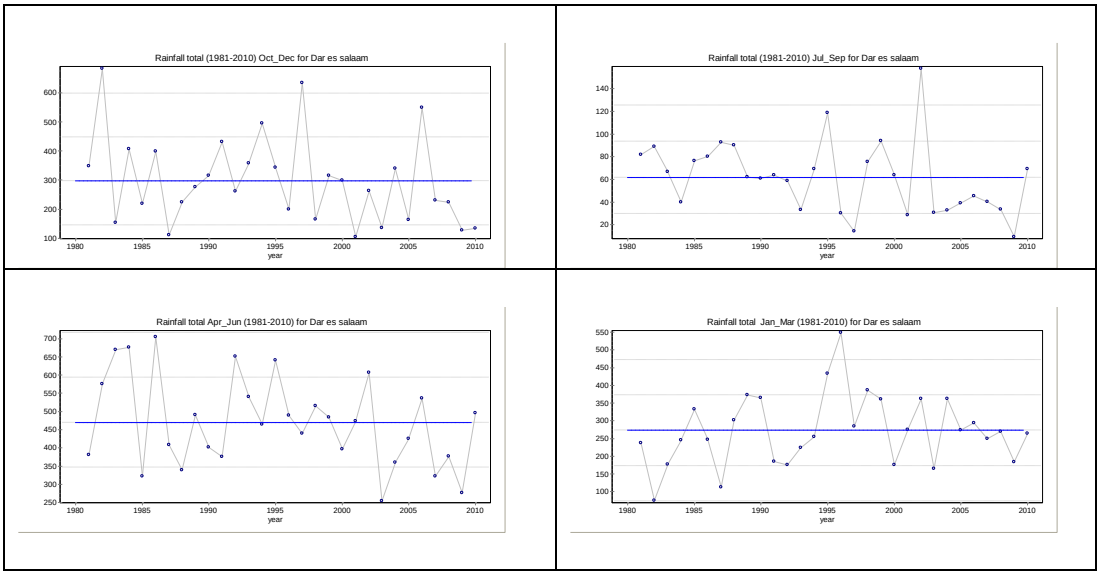

Figure 14: Total rainfall by seasons for Dar es Salaam (1981-2010)

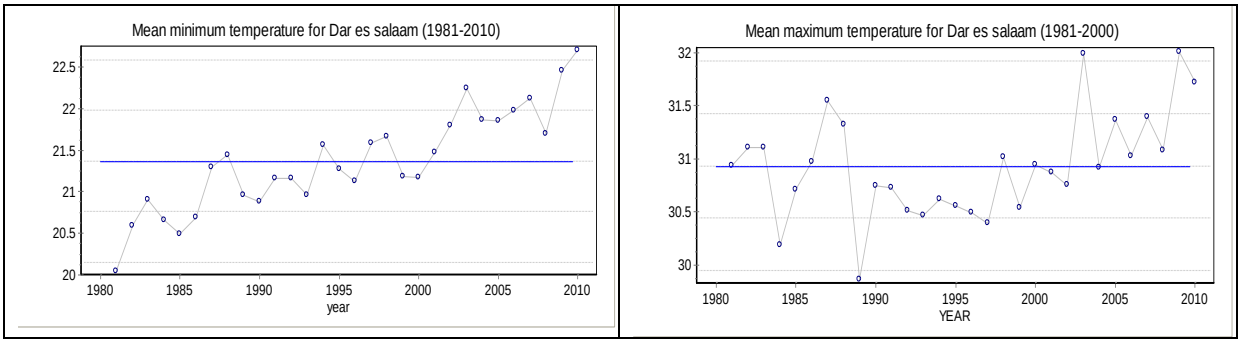

Figure 15: Average Minimum and Maximum temperature for Dar es Salaam (1981-2010)

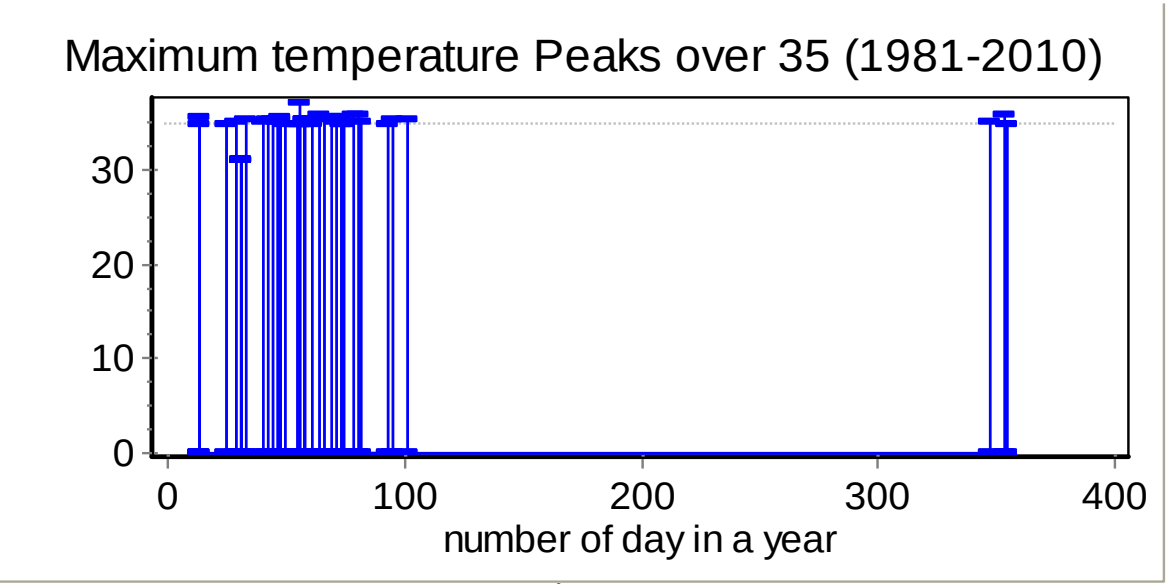

Figure 16: Maximum temperature peaks over 35^{0}C for Dar es Salaam (1981-2010)

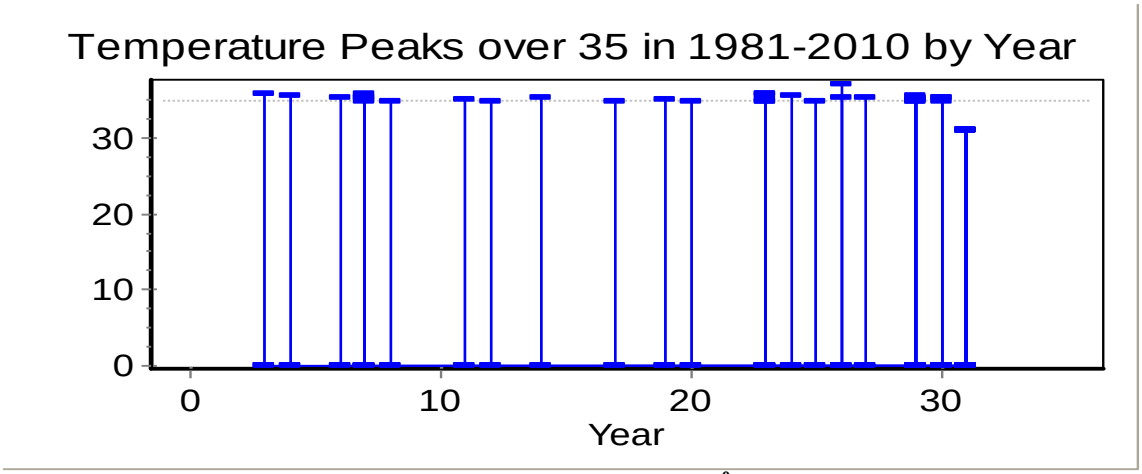

Figure 17: Temporal distribution of temperature peaks over 35^{0}C for Dar es Salaam (1981-2010

3.4 Changing community livelihood pattern

Communities in the peri-urban areas are experiencing livelihood challenges due to a number of factors. These include increased pressure on resources from increasing population that transforms community's into more urban environment, declining agricultural production of traditional crops such as cassava, groundnuts, maize and passion fruits. Agriculture production was reported to have declined in the study areas due to climatic changes and variability, increased crop diseases and declining soil fertility among other causes. According to the community members, climatic changes and variability is identified by declining rainfall amount and increasing rainfall variability, increasing temperature over the last ten years, drying of cassava crop for the past three consecutive years, and increased incidence of diseases pests for crops and livestock.

With declining soil productivity it is increasingly becoming difficult to obtain good crop harvest without using farm manure. Further, prolonged use of chemical fertilizers was also reported to contribute to degradation of land. As result of declining agriculture production, farmers are shifting to production of high value horticultural crops and have taken

the advantage of urban demands on the vegetables. Also dependency on forest resources was reported to have increased, a factor which contribute to decline of forest resources and disappearance of wildlife in the forest reserves. For example 46% and 17% of the respondents in Buyuni and Chanika reported to depend on forest resources for firewood and charcoal respectively. Other forest products which community's depend include wild fruits, mushrooms, building poles and fodder for livestock.

4.0 Conclusion

The study concludes that, there has been remarkable changes in land use and cover in the forest reserves. These changes are driven by population increase in the peri-urban areas, anthropogenic activities associated with population pressure in pursuit of demand in peri-urban and urban areas and climate change and variability which intensify resource extraction from the protected forests. Observed climate change and variability from the statistical analysis of 30 years records of rainfall and temperature for Kisarawe and Dar es Salaam are consistent with community's perception of climate change and variability indicated by declining and unreliable rainfall trends, increasing temperature and increased incidences of droughts over the last ten years. The revealed land cover/use require concerted actions to reverse the changes and enable the forest reserves contribute to REDD initiatives.

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