Assessing the Spatial-Temporal Land Use and Land Cover Changes in West District, Zanzibar

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Abstract

Understanding spatial-temporal land use and cover change is essential in developing physical planning strategies in populated and fast-growing towns and cities. This study examined the spatial and temporal changes in land use and land cover in West District in Zanzibar. Remote sensing techniques—including spatial and temporal assessment of land use and land cover changes between 1975 and 2015—were employed to establish the status and trend of land use and land cover changes in the district. Participatory field observation, focus group discussions and secondary data review were also used in data collection. The study findings revealed that between 1975 and 2015 there were spatial and temporal changes in land use and land cover; with one land use and land cover type changing at the expense of another, and vice versa. Also, about 90% of settlements in the district developed at the expense of forest and agricultural lands, leading to rapid landscape changes of 83% in 40 years. At this pace, it is predicted that in the next 40 years the district's built-up area may expand beyond its borders. Such changes are linked, among other factors, to increased population demanding more land for settlements among other domestic needs. This article concludes that land use and land cover in the West District, Zanzibar, depict notable quantitative and qualitative changes. Continuous land use and land cover change detection and modelling for future settings and planning are recommended for sustainable land management.

Keywords: *spatial-temporal, land use, change, remote sensing*

1. Introduction

Land use and land cover changes (LULCC) result from pressure on land resources due to rapid population growth, together with a combination of natural, socio-economic and climatic factors (FAO, 2011; Arunyawat & Shrestha, 2016). The changes raise concern globally, especially in vulnerable isles such as Zanzibar and other Eastern African coastal territories. It threatens the biophysical environment, while built-up areas expand in a sprawl throughout urban fringes. The expansion of settlement, especially in coastal towns, attracts the clearance of forest resources, thereby causing pronounced land use and land cover changes in small interlocked territories and island states (Mayer, 2016). Korme (2013) mapped agrarian transforms to quarrying and settlement with acute deterioration of forests, soils and water resources. The mapping, however,

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does not accommodate critical assessment of the spatial-temporal variations at all local areas for in-depth analyses and outcomes. Kenya and Tanzania, for instance, have experienced several spatial and temporal land use and land cover changes resulting from forest clearances, which have affected the communities' socio-economics and livelihoods (Syombua, 2013; Kironde, 2015; Mwamfupe, 2015). Land, as a basic resource, is under higher stress in Mainland Tanzania's coastal towns and islands, leading to land degradation, loss of biodiversity and decrease in agricultural productivity (Aikaeli & Markussen, 2017).

There is evidence that more than 38% of Tanzania's forest lands—both in the Mainland and Islands (1990–2010)—have been converted to other uses: mainly settlements, agriculture and infrastructures (URT, 2014). In the Zanzibar Isles, forest and farmlands are changed mainly into settlement. Spatial and temporal forest and settlement changes are experienced around the islands of Unguja and Pemba. Coastal villages are modified and converted into towns. The Central District green seems to diminish, while settlements in the West District seem to expand in a sprawl of the Zanzibar town (Kukkonen & Käyhkö, 2012). Despite manual surveys that monitor the development of the town, practised as part of land use administration, the spatial and temporal changes in land use and land cover are not adequately known, and are not very accurate. In turn, this affects smart land use plans and sustainable management of land and the environment. Hence, assessing LULCC in contemporary geospatial science and technologies offers clear understanding of LULC change, thereon improving policy-making, and greatly increases the ability to make projections and quantify the impact of human activity on LULCC. All this may eventually contribute to a more sustainable management of land (Matlhodi et al., 2019).

Theoretical Approaches for Understanding Land Use and Land Cover Changes

To date, there has been an extensive body of literature and theories accounting for land use and land cover changes. One body of literature is based on consumption or a needs-based approach to land use and land cover, inspired by Malthus (1960) and later criticised by Boserup (1965). Malthus had negative expectation of the relationship between land use and land cover changes and population growth. He saw land expansion as an alternative response to increased population pressure, leading to expansion of land use to marginal areas, land fragmentation, decreasing productivity and famine, a pathway to poverty and environmental degradation. Malthus' views were criticised by Boserup (1965) for undermining the role of technological advances in improving land use production and conservation, which will ultimately sustain subsistence needs of the growing population. Despite such criticism, Malthus' perceptions of resource scarcity, as well as the effects of population growth on land resources, cannot be ignored in understanding land use and land cover changes and resource use, since these have some relevance to this study. Malthus raised an awareness of resource scarcity that at some point in time resources may be depleted in terms of quantity and quality. He also recognizes processes that contribute to the scarcity of resources. Such a situation raises concern on the need for conservation and sustainable use of land resources. With increasing population, there are also some possibilities of households to diversify to other income earning activities besides land use, as well as to migrate to other areas with more livelihood earning opportunities (Lyimo, 2005).

It has been argued that demographic pressure acts as a catalyst in compelling farmers to adopt land use intensification through increasing output from limited land by the development and adoption of new technologies, or investment of capital for long-term land improvement (Boserup, 1980; Pingali et al., 1987; Netting, 1993). Similarly, it has been observed that when land becomes scarce due to in-migration, natural population growth or attraction of people to market centres, the desire to intensify output per unit area and higher population density, compel farmers to a land use intensification process (Netting, 1993). Boserup (1981, 1990) further argues that as population density increases, there will be intensive land use, with most of the land between villages inhabited/settled. In such a situation, a point will be reached where small markets emerge as well as urban centres. Thus, market centres will emerge where population density is high and land use will be intensified around such market centres. It has also been argued that since small farm holders do not live in isolation from larger networks of economic exchange or political organization, their desire of goods and services, as well as their resource scarcity link them to external relationships (Netting, 1993; Lyimo, 2005). Thus, other factors such as land tenure system, fluctuation in physical environment, government policy and the market may have influence on land use and land cover changes, suggesting that population pressure is not the only stimulus for land use changes (Tiffen et al., 1994). Another body of literature links land use and land cover changes with markets. Markets, through price incentive, may compel land users to expand their land for production and settlements to meet market demands, consequently leading to land use and land cover changes.

Besides these two approaches, other sources of literature have taken into consideration structural integration of the small households into large spheres of influence and biophysical (ecological) factors, such as climate change, in influencing land use changes. The co-existence of such theories/literature cautions about the complex nature of understanding land use and land cover changes. From their study in Sub-Saharan Africa, Pingali et al. (1987) concluded that population growth and access to markets were the main determinants of land use and land cover changes. It has also been argued that land use and land cover changes are responses to the interaction between demands (consumption or market demands) and the biophysical environment in which it exists (Brush & Turner 1987). Human-environment relationship is shaped by various constraints imposed by the physical environment and technological abilities of households to match these constraints (Blaikie & Brookfield, 1987; Brush & Turner, 1987).

Generally, land use and land cover changes are functions of various socio-economic and biophysical factors, which to a large extent are outside the household sphere of influence. At the same time, the changes are presumed to be influenced by households' desires to meet their livelihood as conditioned by socio-economic factors such as markets, policy, infrastructural development, demographic, and biophysical factors. So, land use and land cover changes are driven by various factors varying in space and time. Such a situation calls for proper LULCC assessment approaches, such as engaging geospatial techniques.

Adoption of Geo-Spatial Techniques

Several models on LUCC have been studied and applied within institutions, yet people experience non-uniform practices that necessitate a spatial-temporal empirical assessment of LULCC (Kamwi, 2017; Mahmoud, 2016; Moseley, 2016). This article raises the need for adopting geospatial techniques in assessing and predicting land use and land cover changes in areas that have limited land space, such as isles, as a strategy for forecasting plans and attracting sustainable land use practices. The models on land use and land cover changes employed in this study include Caetano's (2013) class change detection and image classification. However, the process basically starts with spectral detection from processed images, which are then displayed or identified as land use and land cover classes of concern. This expert-supervised classification nonetheless was employed to identify intended classes of land use and land cover and their change over the study area (Mayer, 2016). Since such a change becomes a composite that cannot easily be studied through human achievement only, geospatial techniques were then used to combine the land use and land cover changes analytical studies over time and space. Geospatial techniques provide an innovative approach for global land use and land cover changes modelling, to support integrated assessments.

Like urban expansion, rural settlement expansion is also based on land availability and accessibility around locations with different inhabitations. Urban areas are more inhabited than rural areas, while coastal towns are respectively vulnerable to LULCC due to frequent spatial changes in a short period of time and space. Geospatial technologies and techniques have emerged as tools and procedures that can accurately detect land use and land cover changes (Habersetzer & Meili, 2016). The use of geospatial techniques such as remote sensing and geographical information system generates confined data on how landscape change affects a study area, and influences physical planning policy reforms (Jazouliet, 2019). Geospatial technologies are costly in terms of materials and skills, but are effective in generating useful information for planning and predictions, especially for future use of land resources. Boori et al. (2015) applied geospatial techniques in modelling urban expansion and produced a model that is an intervening tool for a sustainable city and town development in the region. Matlhodi (2019), on the other hand, employed the technique to evaluate the spatial and temporal land use cover changes in catchment areas.

The evaluation helps in the adoption of not only geospatial models, but also other environmental as well as sustainability models around catchments and other forms of landscape. The use of geospatial techniques in planning capital towns in Mainland Tanzania and Zanzibar has been advocated by Kironde (2015). To facilitate well-informed urban and rural land use planning contexts and methods for sustainable land management, Käyhkö et al. (2010) and Senga et al. (2014) studied the Zanzibar's land cover issues, but without spatial-temporal multi-dimensions. The studies focused on linear attributes on urban, coastal rags and forestry lands *per se* around the isles, and did not integrate land use and land cover changes in the West District, including the Isles' leading growing and changing area in terms of population, agrarian urbanization and land use cover changes. Despite the awareness of the land use and land cover change by the West District inhabitants, no specific study addressing such issues has been documented (Kayhko et al., 2010). This article addresses such a knowledge gap in line with national visions, plans and research agenda (RGZ, 2015).

2. Material and Methods

2.1 Description of the Study Area

The study was conducted in the West District (within Urban-West region of Zanzibar), located 35km off the Dar es Salaam coast (~ 6°S, 39°E) (Figure 1).

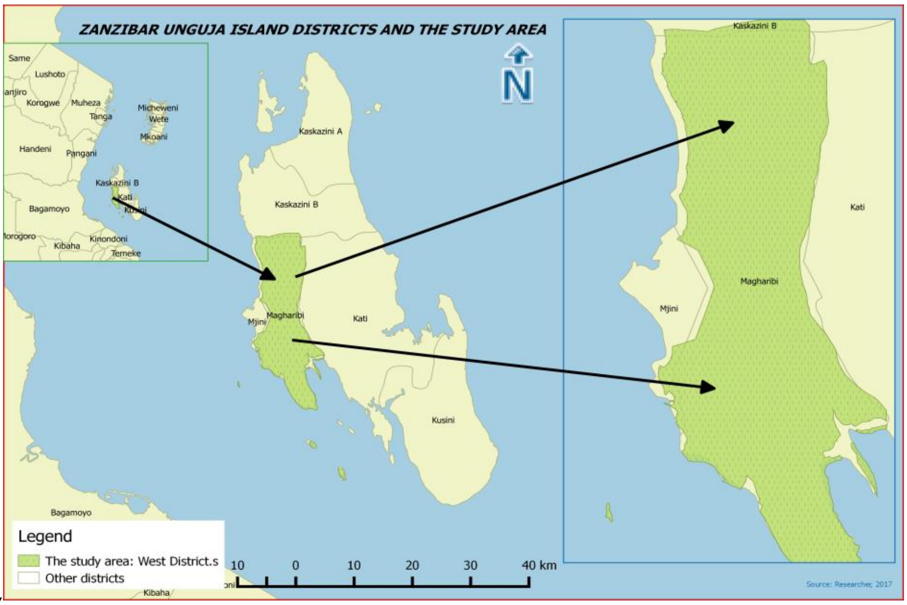

Figure 1: Map of Zanzibar Showing the Location of the Study Area

Source: Tanzania Bureau of Statistics, Researcher lab works (2015)

The area is a semi-autonomous developing island which expands in a sprawl to the Urban West Region. It is characterized by coastal and vegetative agrarian clusters and settlements. It was selected strategically on the basis of its high population growth. According to the Tanzania's population and housing census of 2012, the area has experienced tremendous population growth over time at an estimated growth rate of 5.0%, with a density of 530 people per km^2 (URT, 2013). About three decades ago the district was highly vegetated; however, with time, the district area has experienced high population growth (Figure 2) exerting high pressure on land resources. The district has a total area of 217km^2 of land, where 40% of the 1,303,569 Zanzibar's total population resides. About 50% of the fertile land is undergoing significant biophysical and population changes. The West District landscape is being converted by an increased number of non-farm dwellers, most of whom are immigrants and modifiers of farmlands into settlements.

The major economic activity is small-scale agriculture, which is dominated by coconut and mixed fruits plantations. This activity is gradually being displaced by human settlements and tourist farms. Other activities include fishing and trade. The latter is prospering significantly due to the rise in demand and supply of various goods and services. Rapid population growth is encouraging trade in food and beverages. The district is served by rural producers in Zanzibar, and also imports food from Tanzania Mainland and abroad.

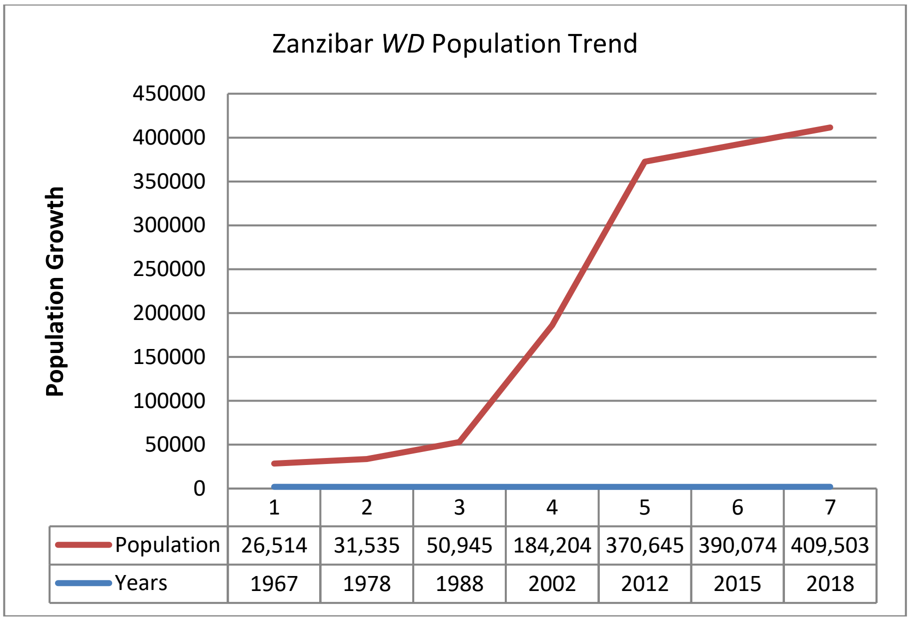

Figure 2: Population Growth Trend in the Study Area (WD)
Source: Zanzibar Statistical Abstract (RGZ, 2020)

2.2 Data Collection and Image Pre-processing

Triangulation of methods was sequentially employed in generating data for this study. These include satellite imagery, field observation and documentary review. Captured data was tabulated to yield quantitative and qualitative outputs. The imageries found a domain towards the results and conclusion of the study.

Satellite Imagery Interpretation and Processing

The satellite images (*USGS*, 2007/2008, 2013/2015) were pre-processed, post-processed, visualized and interpreted (Figure 3). Such procedure is believed to be reliable in measuring resources over the earth's surface. It offers a wide and intense coverage and clear estimations.

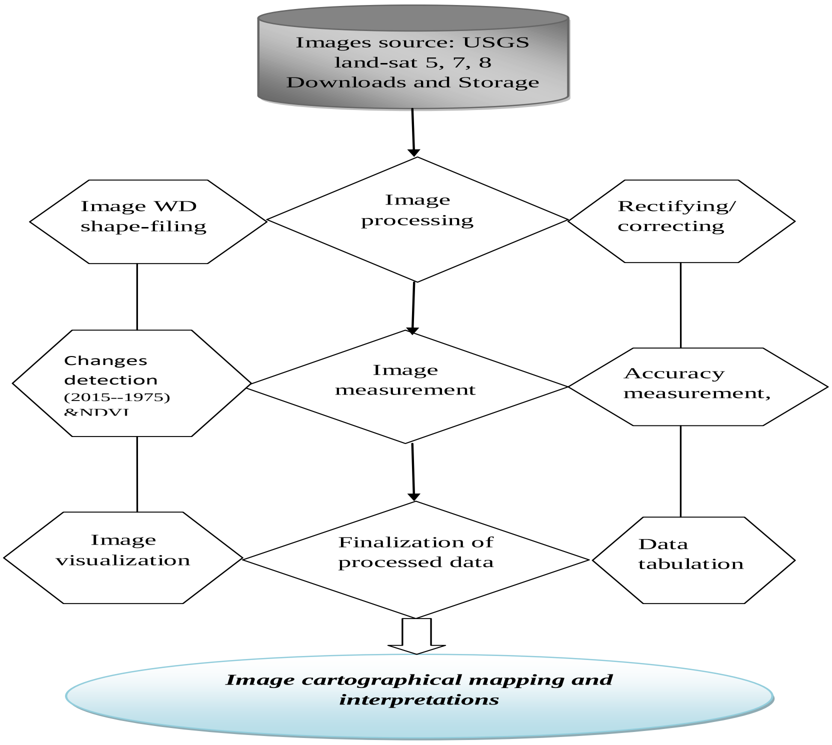

Figure 3: General Framework of Image Data Acquisition and Processing
Source: Adapted from Manonmani et al. (2010)

Different year Landsat (*4/5, 7, 8-TM.ETM (Sensor with Enhanced Thematic Mapper*) images at path/row 166/ (1975 – 2015) were accessed from the *United States Geological Survey* (*USGS*) source. The period 1975-2015 provides a considerable time for the detection of land use cover changes and offers sufficient data for interpretation. The *Quantum Geographical Information System* (*QGIS*) software facilitated image processing and allowed geo-referencing, projection and recording of coordinates. Images were captured using medium pixel resolution (30–60m) under natural colours (*QGIS, RGB* 3–2–1, 4–3–2 or 7–5–3) - *Red, Green and Blue* band series - and then put into a processor for *LUCC* classification. This allowed the calculation of spatial and temporal changes towards outputs.

The data was tabulated for quantitative and qualitative inferences and finalized in cartographical visualization. Some field observations with participatory mapping, document reviews and content analyses were made to justify the analysed primary data towards the conclusion (Nielsen, 2014). Four classes were identified and governed the classification processes: forest, scrub, settlement and bare-lands (Table 1).

Table 1: West District Land Use and Land Cover Changes Assigned Classes

SN	Class	Description
1	Forest	Mixed trees with large and medium species dominated clusters rich in ecosystem within it. They support agro-forests and other related activities.
2	Scrub	Scattered and clustered small trees in bushes (and grass swamps during the rainy season, as well as plantations at rain and dry periods. It spreads in the whole non-settled patches in the WD.
3	Settlement	Built-up clusters and spontaneous around the west coast, forests and scrubs. It developed respectively from the west hub to bordering strips and grasslands. It is intensified with infrastructure.
4	Bare-land	Deforested forest and scrub area due to settlement infrastructure preparations. Swampy and farmland dried during the dry season with no activities is turned into bare lands.

Source: Preliminary Surveys, 2015/2016

Participatory Field Observation

This method played a cross-cutting role from lab-works (imageries), and observation to outdoor transect walks around the study area. The indoor observation was done on the processed satellite images with comparative aerial photographs and drone images. The outdoor or field observation was considerably carried out as 'ground truth' to validate imagery works. The observations facilitated data collection and analysis towards reliable results rich in data for discussion. The method, however, is noted to be time-consuming and cumbersome in analysis, especially when not self-disciplined or recorded well, as noted by Nielsen (2014).

Documentary Review

This involved a review of relevant literature in both published and unpublished articles. Reviewed material consisted of government documents, peer reviewed journal articles, community reports, books and online resources. Also, this included a reviews of past land use and land cover maps and reports, aerial photographs, satellite images and census reports.

Focus Group Discussions (FGDs)

Focus group discussions (FGDs) enable access to a larger body of knowledge of general community information. Group discussions are inexpensive and quicker to conduct than individual interviews with the same number of respondents (Mikkelsen, 1995). According to Kothari (2004), FGDs are generally conducted among 'targeted populations' with the same variables, i.e., social class, lifestyle, user status, level of expertise, gender, age, marital status, as well as cultural differences. In the study area, FGDs were conducted with a group of 10 to 12 people. The members of a group involved local people who had resided in the area for a long time and had knowledge of the various issues relevant to the study, including land use and land cover changes; as well as settlement changes and patterns. Also, main economic activities, as well as demographic issues, were considered.

3. Results and Discussion

3.1 Spatial Temporal Land Use and Land Cover Change

The results of the spatial and temporal land use and land cover changes assessment in the study area are presented in Table 2. The percentage change by land area covered by different land types in km^2 was calculated over a given time duration: 1975 and 2015. Land use and land cover changes assessment between 1975 and 2015 revealed that the forest cover had slightly decreased from 53.61% in 1975 to 50.34% in 2015, while scrub land had decreased considerably from 36.97% in 1975 to 9.50% in 2015. On the other hand, land for settlement increased significantly from 5.59% in 1975 to 32.31% in 2015; while bare land also increased from 3.83% in 1975 to 7.84% in 2015. The observed changes were due to gain or loss of one land use and land cover change type to another.

Table 2: 1975–2015 Interpreting Land Use and Land Cover Changes

ST WD LUCC in km^2&%				
Class-*Year*	**1975**	%	**2015**	%
Forests	116.63	53.61	109.54	50.34
Scrubs	80.43	36.97	20.68	9.50
Bare-Land	8.33	3.83	17.05	7.84
Settlements	12.17	5.59	70.31	32.31
Net Area	**217.56**	**100.00**	**217.58**	**100.00**

Source: Land-sat Image Analysis, 2015

The change analysis involved the calculation of gains and losses and transition matrices for 1975 and 2015. The dynamics of change for each target year 1975 and 2015 were quantified and analysed by computing the area of a specific class category per time window in km^2 (see Table 2). Cross-tabulation matrices detected the changes (Table 3).

3.2 LUCC Detection Matrix

The results of LUCC detection matrix in percentage as well as in area coverage in square kilometres is presented in Table 3. From the table it can be observed that only 8.72% of the scrub remained unchanged; the rest of the classes experienced changes. Forest land depicted a loss of 42.67%, bare-land a loss of 11.27%, and settlement a loss of 37.34%. About 8.43% of bare-land remained unchanged; while 35.61% changed to forest, 43.62% to scrubs, and 12.34% to settlements (see Table 3). Based on this detective matrix analysis, it is apparent that settlement experienced a constant direct expansion at the rate of 27.31%, where most changes or gains experienced were contributed by all other classes. About 36.61% was contributed from the forest, 20.66% from scrubs, and 15.41% from bare-land; with more gain than loss by 6.3%. Through FGDs and direct physical observation it became clear that the loss in settlement land was due to some demolition carried out by authorities. The loss also was related to natural settlement or village decay (dynamic collapse of villages caused by district rural-urban migration).

Table 3: 1975–2015 LUCC Detection Matrix in Square Kilometres

Classes	Forest	Scrub	Bare-land	Settlement	Total	Loss, T-X
1975 - 2015 LUCC Matrix Cross-Tabulation (km²)						
Forest	38.65	7.59	5.38	35.78	87.40	*48.75*
Scrub	63.58	7.01	9.06	30.03	109.68	*46.10*
Bare-land	2.97	3.63	0.70	1.03	8.33	*5.36*
Settlement	4.46	2.51	1.88	3.32	12.17	*7.71*
Total Land	109.66	20.74	17.02	70.16	217.58	*107.92*
Gain T-Y	71.01	13.15	11.64	34.38	*130.18*	**217.58**
1975 - 2015 LUCC Matrix Cross-Tabulation in percentage (%)						
Classes	*Forest*	*Scrub*	*Bare-land*	*Settlement*		*Loss, %*
Forest	58.20	6.51	4.61	30.68		*35.22*
Scrub	42.67	8.72	11.27	37.34		*53.01*
Bare-land	35.61	43.62	8.43	12.34		*5.42*
Settlement	36.61	20.66	15.41	27.31		*6.36*
Gain T-Y %	*30.09*	*9.87*	*11.78*	*48.26*		*100.00*

Source: Landsat Image Analysis, 2015

A similar observation was also made by Kamwi et al. (2017) who reported that significant forest landscapes are converted into settlements and other uses, thus changing their original land covers over space and time in the island states. Zanzibar town in the Urban West Region rose as a common spatial and temporal example in the island, where vegetative land was converted to settlements. Also Juliev et al. (2019) observed that settlements overwhelm forest and water resources, and expand bare-lands and pavements around developing state inland and coastal towns, most of which are unplanned. Squatters portray clearly the total vegetative land depletion compared to those planned settlements where some green spots are considerably found, and trees can be replanted (URT, 2012).

Both loss and gain can sometimes be traced. In assessing the gain and loss of the land use classes in the district, it has been noted that the change of these classes varies. Forest total change was 51.56% with 100% net change; where 45.17% exchanged to other classes at 54.55% gain and 45.17 loss. Scrub totally changed to only 20.51%, of which 42.72% of its area was lost with only a 10.10% gain. The scrub was exchanged for other land use/covers in 42.38% of its area. Settlement exchanged to other covers in only 7.09%, with net change beyond 100% (ever-increased cover at the expense of all other land classes). Only about 0.80% change was detected as unclassified across all classes (Table 4).

Table 4: 1975–2015 LUCC Gain and Loss Output in Square Kilometre

Class	Gain_ *G*	Loss_ *L*	Total Change: *TC = G+L*	Net Change: *NC = G-L*	Swap: *TC-NC*
Forest	71.01	48.75	119.76	22.26	97.50
Scrub	13.15	46.10	59.25	-32.95	92.20
Bare-land	11.64	5.36	17	6.28	10.72
Settlement	34.38	7.71	42.09	26.67	15.42
Sums	**130.18**	**107.92**	**238.1**	**22.26**	**215.84**
Remark					Error 1.74
Class	*%*	*%*	*%*	*%*	*%*
Forest	54.55	45.17	51.56	100.00	45.17
Scrub	10.10	42.72	20.51	-148.02	42.38
Bare-land	8.94	4.97	7.67	28.21	4.93
Settlement	26.41	7.14	20.26	119.81	7.09
Sums	**100**	**100**	**100**	**100**	**99.57**
Remark					Error 0.80

Source: Landsat image analysis 2015

From 1975 to 2015 settlements over-expanded while forest land declined. The truth is linked to the settlement expansion due to the increase in population, which was caused by the pulling factors into the district that arose from the impact of the free-market economy during the 1990s (Senga et al., 2014). The district also attracts in-migrants, attributed to the same economic and political reforms since then. The tourism boom, for example, altered the entire island ecosystem: both urban and rural (Juliev et al., 2019). Moreover, it was revealed through FGDs and participatory field observation that there is a decline in vegetation cover (forests, scrubs, bushes and grassy lands), but not to the extent that needs intervention. This assessment implies that an annual vegetation rate loss with net changes of -5% and -43.14% of forest and scrub, respectively (Table 5).

Table 5: 2015–2018 LUCC Gain/Loss Output in Square Kilometres

Class	Gain G %	Loss L %	Net-Change – NC=G-L %
Forests	30.09	35.21	-5.12
Scrubs	9.87	53.01	-43.14
Bare-lands	11.78	5.42	6.36
Settlements	48.26	6.36	41.90
Total	**100**	**100**	**0**

Source: Landsat image analysis 2015 and Observation, 2016 &2017

From 1975 to 1998 bare-lands were marked by wetland or farm and grasslands during the wet season, and bare soil during the dry season. The situation continues but in clusters with short-time wet conditions due to settlement encroachment in the grasslands; and as far back as 2015. The dry grass- and bare-lands are all converted into settlements as verified during FGDs and field observations in 2018. Similar observations were also reported by Sanger (2013): that land use and land cover in the isles districts undergo persistent changes that cannot be bearable, and hence these have to be assessed to reduce the impact on land sustainability.

3.3 Land Use Cover Change Visualizations

Image visualization can bring an impressive observation in spatial and temporal changes (Abdu, 2019), as done in land use cover of the West District (1975–2015) through images swathing or cross analyses (Figure 4). The visualization concurs with the results of the matrix tables and depicts compatibility. One can clearly observe from Figure 4 that forest cover (dark green) dominated the districts since 1975; while settlements or built-up (red colour) expanded considerably in 2015. Some local participatory mapping done during the field (2018/2019) enabled comparative analysis that interpreted what is visualized from the image processing, and built the determination in describing the meaning or intended data and information. Multiple comparative analyses are supported by land detectors, including that of Juliev et al. (2019) who justify the need of back-up past, real-field or ground-truth, and the existing image processing for visualization accuracy.

The Zanzibar Woody Biomass Survey, reported by the Natural Resource Department (2013), supports the visual impression of the settlement expansion or built-up spots across the forest and scrubland in the district. The penetration brings about vegetative depletion and considerably increases the bare-land. Subclasses of patterns—including scrubs (light green) and bare-land (pink)—also show the loss and gain to each other from 1975 to 2015. Bare-land expanded notably in 2015. The land use cover exchange image (of the two periods) is clearly depicted; and shows how the changing classes share their loss and gains with each other (Figure 5).

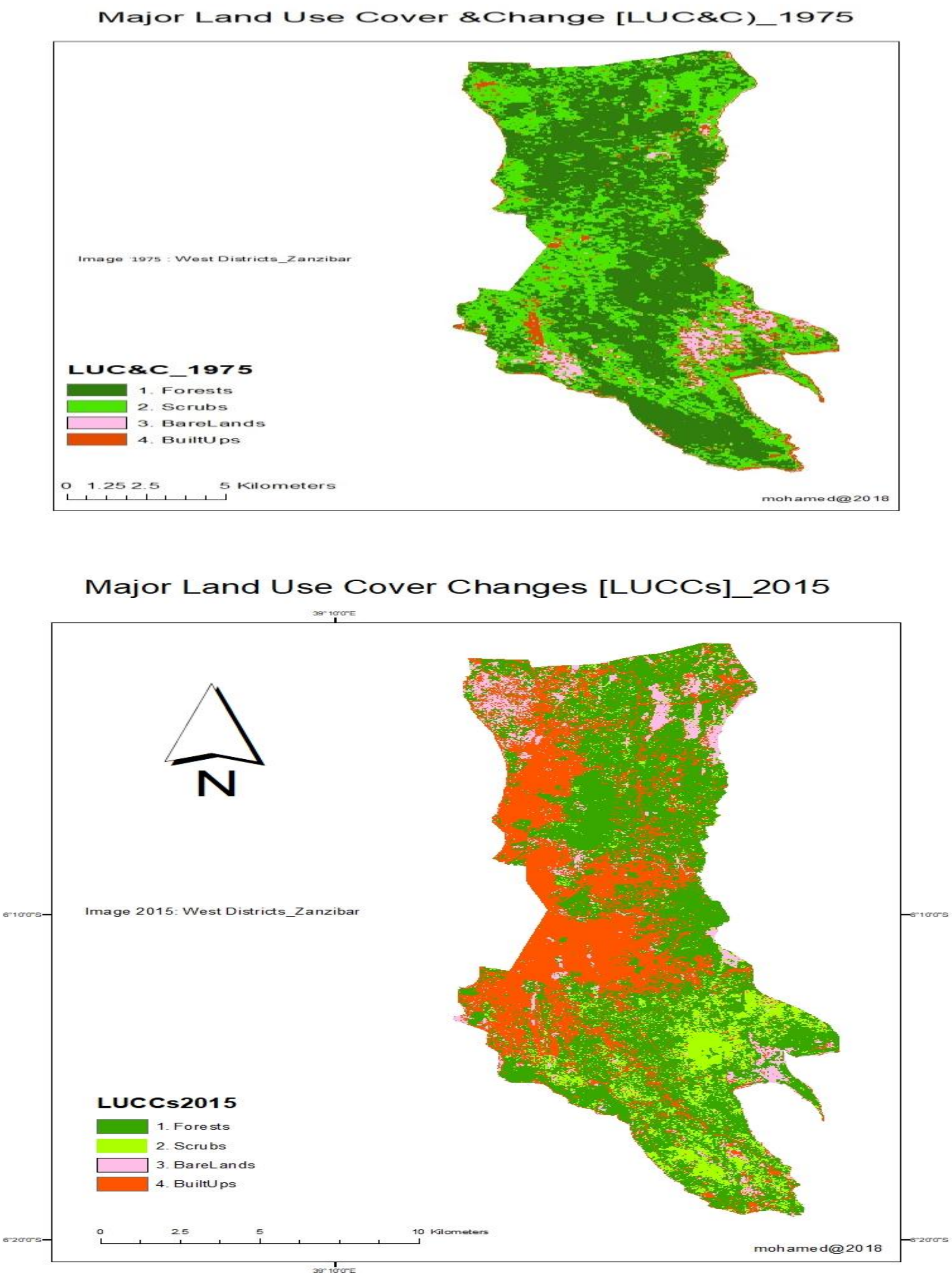

Figure 4: 1975–2015 Land Use Cover Patterns
Source: Landsat Image Analysis 2015

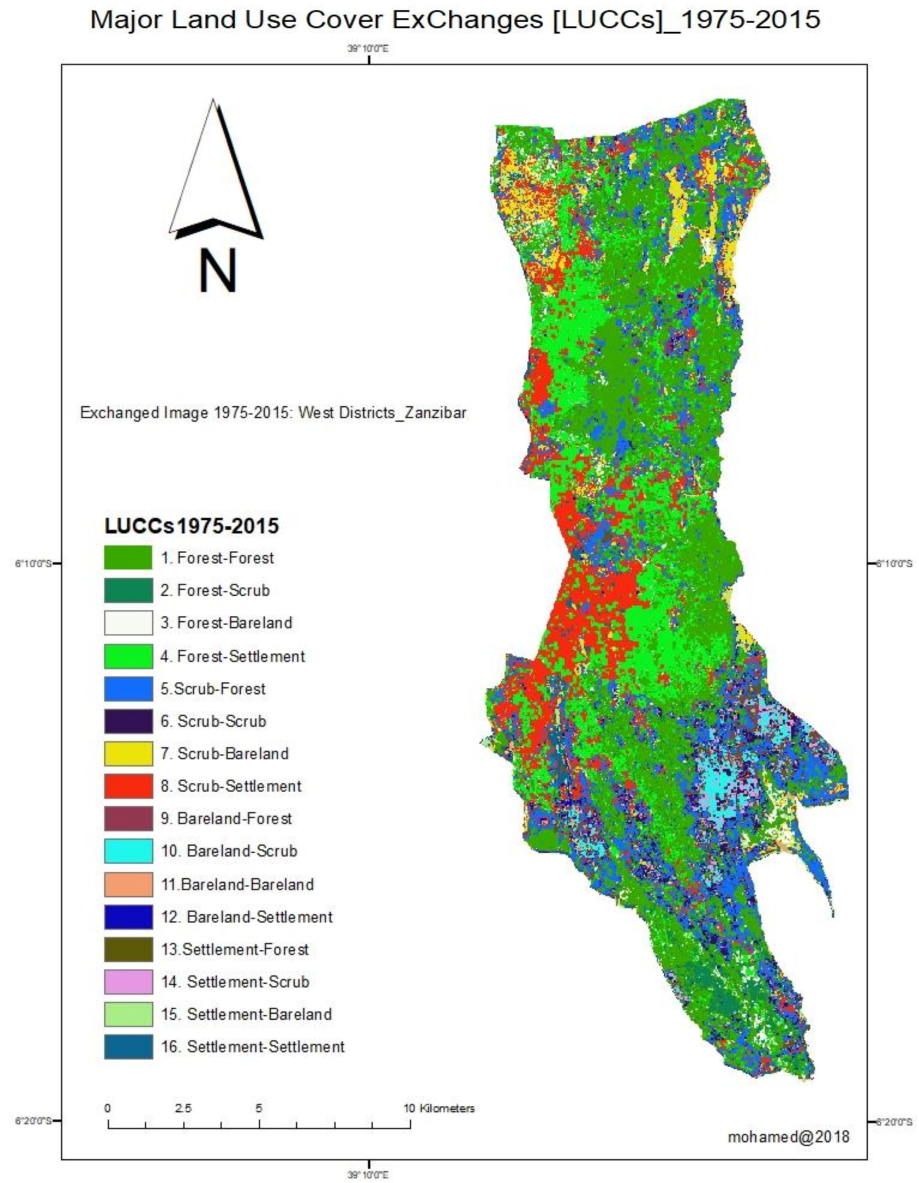

Figure 5: 1975–2015 Land Use Cover Change
Source: USGS landsat image analysis 1975–2015

In his land use cover change trend assessment, Abdu (2019) verified accurately the possibility of land use classes changing consecutively over space and time. The biological patterns such as forests and scrub are more vulnerable to loss, while abiotic ones like settlement gain or increase as found in the West District Zanzibar. The physical observation made in 2018 revealed that built-up areas expand with infrastructure and trade corridors at the expense of forest and farmland. Maintenance of vegetative land is recommended to reduce loss of ecosystem services. A matrix for quantitative analysis visualizes the changes and projections of future trends (Islam et al., 2018). That is why the processed image (Figure 6) has been embedded for more comprehensive analysis and decision (Caetano, 2013). From 2015 onwards, the districts' 2018 vegetative losses depicted significant changing trends in the settlements sprawl (Figure 6). This highlights the future uncertainty of the West District land use land cover changes as argued by Mohammed (2016).

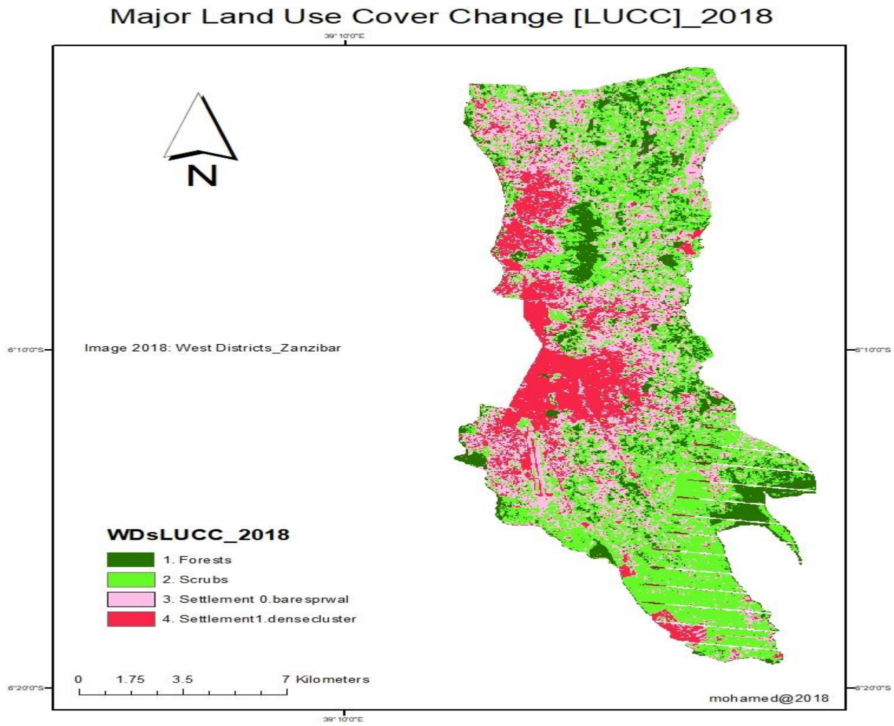

Figure 6: Land Use Cover Change Trend with Forest Decline
Source: Landsat data analysis 2018

3.4 Rating in the Land Use Cover Change

Rate of Change

The rate of change (*r*) has been computed so as to validate the need for land use cover change (Table 6). The rate determines trends in changing land covers (Merem et al., 2018). The results in Table 6 shows that the study area is experiencing decreasing rates of forest and scrub land. The forest in the identified 40 years arithmetically decreases by -0.18, while the scrub decreased by -3.4km^2 annually. Despite the variation in forest decrease between 1975 and

2015, it did not recover its original cover. It has been observed that the forest cover decreased significantly despite existing regulations, restrictions and other protection techniques. The bare land and settlement in all methods—including in the imagery observation—prove they are ever-increasing at 1.8% and 4.4%, respectively (Table 6). Changes in land use cover over time is observed through the forest, scrub and lowland which have shown a decreasing trend, while bare land and settlement have shown an increasing trend. Reserved forest in the district however, is not under significant pressure due conservation efforts (Zanzibar Woody Biomass Survey, 2013).

Table 6: Land Use and Land Cover Annual Changing Rate -1975–2015

WD LUCC* Formulated Rate (*r = ln(A_{t2}-ln(A_{t1})/T2–T1*100)						
Class	**Rate**	**Outputs**	**Forest**	**Scrub**	**Bare-land**	**Settlement**
Forest	-0.18	ln(A2)_km^2	4.69	3.03	2.84	4.25
Scrub	-3.4	ln(A1)_km^2	4.76	4.39	2.12	2.49
Bare-land	1.8	T2–T1_year	40	40	40	40
Settlement	4.4	%	100	100	100	100

Source: Landsat image analysis 2015

Figuratively, the *West District land use cover change* is presented with a clear gain/increase of settlement and bare-land, while scrub is devastatingly cleared. Nonetheless, the forest that has been substantially decreased around the district is intervened with efforts to reserve it in the coming decades. The *LUCC* future trend is the increase-decrease intercept of large settlements against scrubs. The bare land and forest are respectively associated with a significant respectful future trend too (Figure 7).

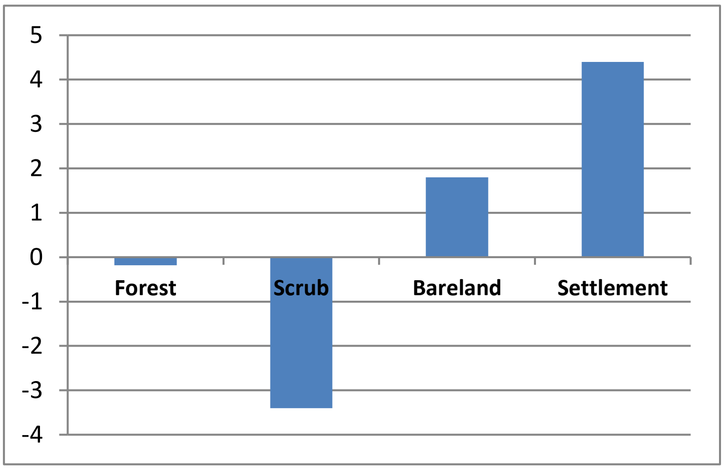

Figure 7: Land Use/Cover Classes Increase-Decrease Dynamic

Source: Imagery and Observational data analysis, 2015 &2017

According to the Zanzibar Woody Biomass Survey (2013) scrubs recover faster in the district due to the nature of the district's deep and fertile soils. However, observation (2018) shows that land commercialization for investment clears the recovered scrubs into bare-land. The capital incidents, nonetheless, leave bare-land longer without investment; and hence it turns into bushes.

3.5 Future Trend of the District Land Use Cover Change

The described rates in Table 6 are also demonstrated with their *spatial-temporal* trends and interceptions (Figure 8). To Fasika et al. (2019), rates determine trends regardless of associated factors. However, to Merem et al. (2018) factors play a key role in response and sustainability. In the Western District, forest and scrub lines have demonstrated a higher value (largest cover) since the early years (1975). They underwent acute variation in the 2000 onwards, and tended to feature total clearance or conversions and higher modification into other land cover classes likely *settlements* (Figure 8). Some documents from land-related departments, including municipal unpublished reports, are optimistic that the green within the district will remain due to interventions and controls.

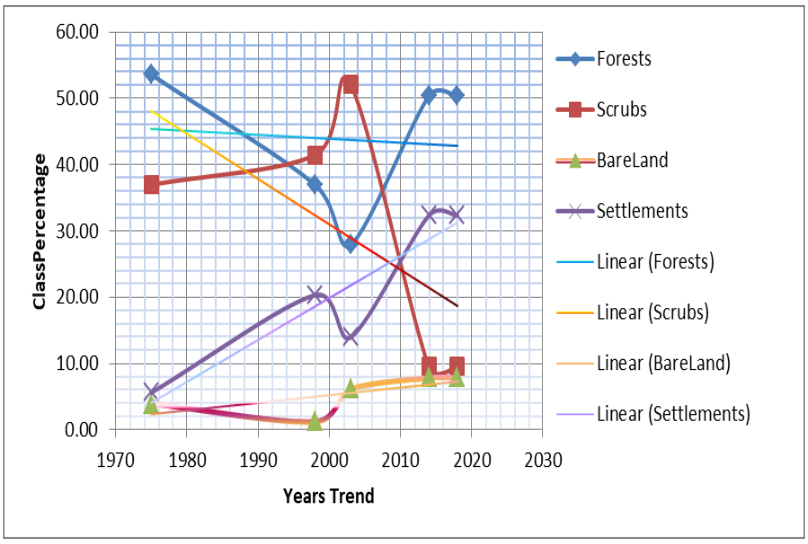

Figure 8: Land Use/Cover Change Trend
Source: Imagery and Observational Data Analysis, 2015 & 2017

Bare-land and settlements emerged from the natural vegetation covers in the 1970s. Early modification and conversion of forest and scrub land into settlement was below 10%, but increased to about 50% in a decade. According to Ali et al. (2015), the West District settlement is experiencing land use and land cover change at an alarming rate.

Settlement growth becomes one of the central themes in sub-urban land use cover change, like that of the West District. Physical developments—including housing, power supply and other infrastructure and supporting services—are put into progress indicators. Such development has to be further studied, consulted and projected (Ysunza & Neill, 2013). In the coming 15 to 30 years (2030–2045) settlement in the district is expected to reach about 31% to 63%, with respective change of identified land use land cover classes of the total West District land (Table 9). At an 83% rate of change, settlement will cover 42% of the total land by 2055. Ali et al. (2015) concurred that settlement will overrun the 217km² of the district's borders into neighbouring Central, North and South districts of Unguja Island.

Table 9: Changing Projection of Settlement in West District

WD Settlement Future Dynamic in years_km²					
Years to come	**Change_C** *(r*years)*	**Change_C** *(%)*	**Ref. Area** *RA*	**Exp. Area** *C+RA*	**Exp. Area %**
15	66	31.29	70.31	136.31	23.30
30	132	62.58	70.31	202.31	34.59
40	176	83.44	70.31	246.31	42.11
Total	**70**	**177.31**	**210.93**	**584.93**	**100.00**
Residual (Total – Net Land)		77.31	140.93	367.35	62.80

Source: Imagery and observational data analysis, 2015 & 2017

Figure 9 describes the future occupation of the settlement area. Increased settlement is arithmetically anticipated to occupy the entire West District.

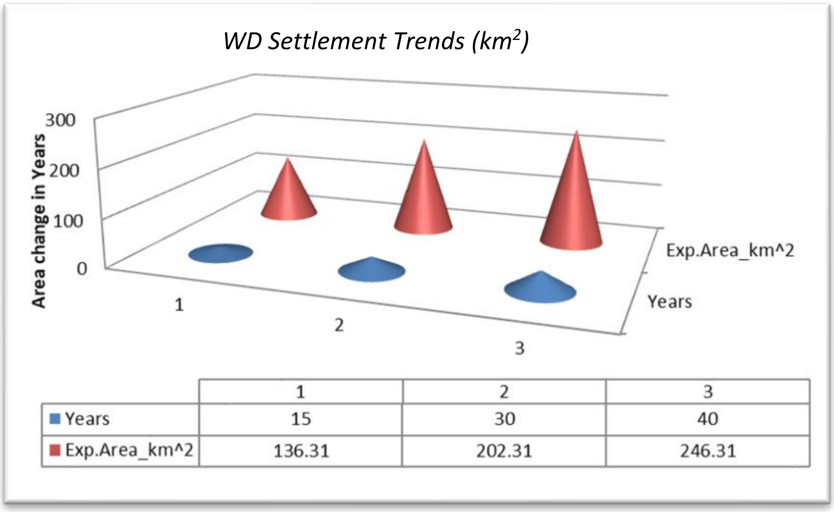

Figure 9: Settlement Trend in Coming Years
Source: Imagery and observational data analysis, 2015 &2017

The observation shows that settlement growth around the district urbanizes the vegetative farmland with a sprawl. The urban sprawl is linked to population increase due to the district pulling character. The growth destines for administrative reforms due to changes in socio-economic and livelihood opportunities (Karataş, 2016). The need for administrative extension means more districts and municipalities being declared around the growing Zanzibar town. The town tendered master plan, for example, is now advocated to occupy the whole Urban West region. Literature however, advocates for finding base plans and policy reforms on land use (Mazmanian et al. 2013) for proper and sustainable use of land in the area (Dang et al., 2017; Rioux et al., 2017).

4. Conclusion and Policy Recommendations

In the last four decades, more than 80% of scrub and forest cover and farmlands in the West District have been converted into settlements due to population growth and its associated impacts. About 90% of the settlements has developed on a vegetative cost in the district. Bare-land has increased to more than 12% from 2% between 1975 and 2015. In early 1975, land cover in the District contained more than 95% green vegetation dominated by thick rainforests and minor scrubs. However, by 2015 the forest cover had decreased by more than 60% for settlement and infrastructure development, while altering the district's landscape scenes as well.

Despite the recovery of the district greenland over some decades, the depletion has been notably observed in the last decade, and significantly increased the pavement through built-up to more than 80%. The settlement-vegetation exchange in the district cut across every part of the land cover, and it is encroaching the district borders outwards. The study projects that change in land use and land cover in the next four decades will turn into 100% settlements, from the original renowned green in the last decades. We can concludes that land use and land cover in the West District, Zanzibar, depict notable quantitative and qualitative changes. Therefore, it is recommended that the detection and modelling of land use and land cover change should employ the latest geospatial technologies for effective assessment and future investment. Regular assessment of land use and land cover changes is recommended to update existing policies and empirical land use plans towards sustainable management of the land resource.

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