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Multi-temporal Analysis of Land Use and Land Cover Change Detection for Dedza District of Malawi using Geospatial Techniques

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Abstract

Land use and land cover (LULC) changes attributed to anthropogenic activities are one of the fundamental drivers of local, regional and global environmental changes. Studies of LULC have become vital in enhancing our understanding and monitoring of environmental change. This study analysed LULC changes dynamics for the years 1991, 2001 and 2015 using remote sensing and GIS in Dedza district of Malawi. In the analysis, both supervised and unsupervised classification algorithms were performed on each image. An overall accuracy of the classification achieved for the classified images was 91.86%. The results revealed that forest land, water bodies, wetlands and agricultural land drastically declined while built-up areas and barren land substantially increased between 1991 and 2015. The long-term annual rate of change declined for water bodies from 5.54% ha^{-1} to 1.74% ha^{-1} within the period of study. Likewise, the forest land, agricultural land and built-up area experienced increased annual rates of change from 1.71% ha^{-1} to 1.94% ha^{-1}, 0.02% ha^{-1} to 0.11% ha^{-1} and 7.22% ha^{-1} to 9.80% ha^{-1} respectively. Post-classification comparison of the classified images based on the transition matrix indicated that approximately 61.48% of the total forest land in 1991 was converted to barren land in 2015 while about 2.70% of agricultural land in 1991 has been converted to built-up land in 2015. This study, therefore, provides reliable LULC data which captured the extent and rate of land use changes that has occurred in the Dedza district of Malawi for the period ranging from 1991-2015. It is believed that the trends identified in this study would be useful in guiding planners and decision-makers of land management and policy decisions geared towards a more sustainable natural resource management strategy in the Dedza district and other districts of similar setting. It is recommended that a study be undertaken to establish the apparent socio-economic and spatial drivers of the LULC changes between 1991 and 2015 over Dedza district of Malawi

Keywords: LULC, supervised classification, remote sensing, geographic information system

1. INTRODUCTION

Land use and land cover (LULC) changes predominantly caused by anthropogenic activities are one of the central components of local, national, regional and global environmental changes (Lambin et al. 2003; Jensen 2005). According to IGDP (1999), LULC changes also reflect the culmination of interactions between climate, ecosystem process, biogeochemical cycles and other biodiversity indicators. Studies of LULC have therefore become vital to understanding and monitoring environmental change and related processes while these types of studies also provide valuable information that can be used to inform more sustainable natural resource management strategies. The LULC changes have significant environmental and socio-economic impacts especially for rural inhabitants involved in land-based livelihoods. The direct and indirect impacts of land use and land cover changes have also been linked to losses in wildlife, deteriorating biodiversity, changes in plant species composition, desertification, deforestation, changes to nutrient, carbon and water cycles, as well as unplanned urban expansion (Verburg et al. 2000; Lambin et al. 2001; Brooks et al. 2002; Verburg et al. 2004; Ifamitimehin and Ufuah, 2006; Maitima et al. 2010; Ujoh et al. 2011; Kamwi et al. 2015). An understanding of LULC changes is also important in the context of trying to unravel land use conflicts especially in cases where conflicts linked to competing land uses tend to escalate in proportion to rising population numbers.

In a developing country like Malawi with an increasing population and increased pressure on natural resources (linked to contending land uses), there is a great demand for accurate, detailed and current spatial data that can be used to inform management decisions. Remote Sensing (RS) and Geographic Information Systems (GIS) are well-recognised, powerful and cost-effective tools that are effective for mapping and characterizing natural resources as well as tracking alterations in the landscape over time (Miller et al. 1998; Welch et al. 2002; Parmenter et al. 2003; Wang and Moskovits, 2001; Manandhar et. al 2009; Zhang et al. 2017). According to Adeniyi and Omojola, (1999) and Zhang et al. (2002), RS data covers large geographic extents and has high temporal coverage. This type of data therefore provides valuable information regarding the processes, location, rate, trend, nature, pattern and magnitude of LULC changes while GIS is useful for mapping and analysing the patterns captured in the remotely sensed data. The RS and GIS technologies have, thus, added a new dimension to the interpretation and understanding of LULC dynamics (Hathout 2002; Herold et al. 2003; Lambin et al. 2003;Li et al. 2005; Yuan et al. 2005; Wu et al. 2006; Jat et al. 2008; Serra et al. 2008). The knowledge generated by means of applying these two methodological tools is therefore deemed instrumental in assessing and monitoring the availability of natural resources, which can help planners and decision makers to identify crucial resources and prioritize management/conservation efforts (Satyanarayana et al. 2001; Shriver et al. 2005; Wilkinson et al. 2008). The information about the past LULC changes also aids in understanding the present changes and their consequences on the natural resource base.

Dedza District like any other district in Malawi has experienced several major transformations in terms of LULC over the past 25 years. There is however, a general lack of comprehensive, detailed, accurate and current LULC change maps for the district. To fill this identified information gap, this study assessed the LULC changes that occurred between 1991 to 2015 in Dedza District of Malawi. With this study, the researcher thus seeks to enhance the current understanding of the spatial pattern, trend and rate of land use and land cover changes in the district. It is anticipated that this information would help in establishing a landscape context for the natural resource base which would provide planners and decision-makers with a better understanding of how natural resource management fit into a broader landscape context. The results from this study could thus be used as a spatial baseline to inform land management and policy decisions made by planners, researchers, environmentalists and other stakeholders. Decisions regarding themes like urban expansion, water management, food security, climate change management, deforestation and land degradation could thus be informed by the spatial trends identified in this study. Further, reliable LULC change data over time is imperative for greenhouse gas reporting for climate change documentation and management (Haack et. al. 2014).

2. MATERIALS AND METHODS

2.1 Study area

Dedza District is located in the central region of Malawi with a latitude 14°15'45.8" S and longitude 44°11'01.1" E and about 86 km from Capital city of Malawi, Lilongwe (Figure 1). It is the third largest district in the central region of Malawi and covers a total area of approximately 3,624 km^2 (Government of Malawi 2013). It borders Mangochi district to the West, Salima district to the North East and Lilongwe district to the north. The district is divided into three topographic zones namely; Lilongwe plain (altitude 1100-1300m), the Dedza highlands (1200-2200m) and the Dedza escarpments (1000-1500m). Dedza town experiences a cool climate with mean annual temperatures ranging from 14ºC to 21ºC. The annual rainfall for Dedza District ranges from 800mm to 1200mm and falls between mid-November to mid-April. The initial results of the 2008 census reported the population of the district at 623,789, with an increase of 28% compared to the 1998 data.

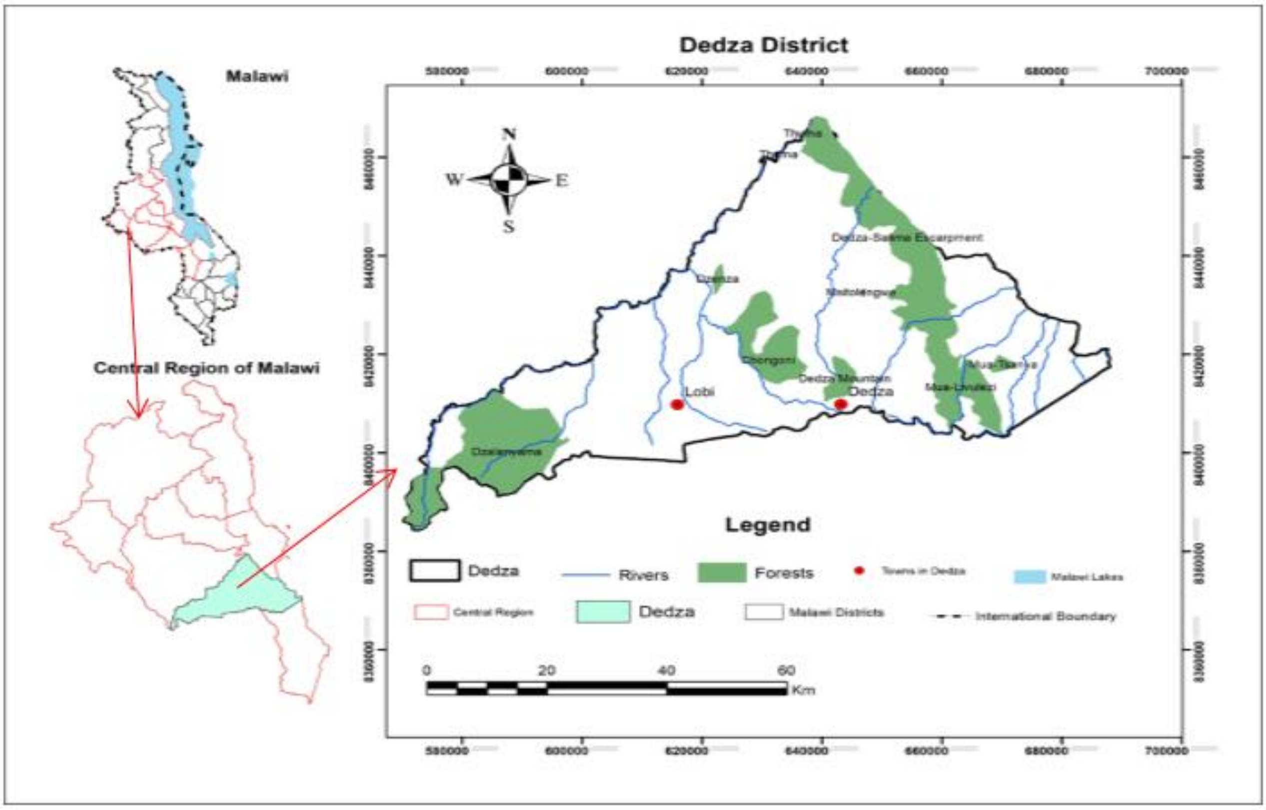

Figure 1. Map of Dedza District

Most of the people in Dedza district live in rural areas where they predominantly practice subsistence farming with commercial rice growers concentrated along the lakeshore. The district is also blessed with perennial rivers which include Linthipe, and Diampwe II and Lifisi Rivers. The district has two Government Timber plantations namely Dedza mountain Plantation (2,046.23 ha) and Chongoni Plantation (5,270.00 ha) found within Dedza Mountain and Chongoni Forest Reserves respectively. Other Forest Reserves include; Mua-livulezi, Mua-tsanya, Msitolengwe, Dzenza and Dedza-Salima Escarpment Forest Reserves. The dominant land cover features include agricultural fields, forest, water and settlements.

2.2 Data acquisition and image processing

Different types of satellite imagery are available for LULC analysis. However, when carrying out studies to monitor LULC changes, Landsat imagery is preferred due to temporal resolution coupled with near and mid-infrared bands which allow close examination of vegetation and landscape features (Zeledon and Kelly 2009). Three cloud-free Landsat 5 (TM), Landsat 7 (ETM+) and Landsat 8 (OLI) satellite data were used in this study and the images were selected based on their availability and quality. The images were acquired within the same yearly season to help reduce seasonal and varying sun positions effects. Table 1 presents the detailed characteristics of the data used in this study.

Table 1. Characteristics of the Landsat images used for the study

Satellite	Sensor	Path/Row	Spatial resolution (m)	Date of acquisition	Source
Landsat 5	TM	168/070	30	1991-09-16	USGS
Landsat 7	ETM+	168/070	30	2001-09-19	USGS
Landsat 8	OLI	168/070	30	2015-09-18	USGS

The standard image processing techniques that were performed on the three satellite images using QGIS 2.16.2 and ArcGIS 10.6 include; extraction, geometric correction or georeferencing, atmospheric correction, topographic correction, layer stacking (band selection and combination), image enhancement and subsetting (clipping). The three images were registered to a common UTM Zone36N with WGS 84 projection parameters.

2.3 Image classification

Jensen (2005) defines image classification as the process of categorizing an image into a smaller number of individual classes based on the reflectance values. The images were classified based on physiographical knowledge of the study area, ancillary information, the researcher's local knowledge and visual interpretation of each LULC class supported with the use of the historical function of Google Earth. The six (6) classes with their associated descriptions are shown in Table 2. A hybrid supervision algorithm was employed in this study. Unsupervised classification algorithm was first performed on each image because supervised classification was not able to separate barren land and built-up areas from agricultural areas due to spectral reflectance confusion. Then, the supervised classification was performed.

Table 2. LULC classification scheme used in the study area

LULC class	Description
Water bodies	Rivers, permanent open water, lakes, ponds, reservoirs
Wetland	Permanent and seasonal grasslands along the lake, river and streams, marshy land and swamps
Agricultural land	All cultivated and uncultivated agricultural lands areas such as farmlands, crop fields including fallow lands/plots and Horticultural lands.
Forest	Protected forests, plantations, deciduous forest, mixed forest lands and forest on customary land.
Built-up area	Residential, commercial and services, industrial, socio-economic infrastructure and mixed urban and other urban, transportation, roads and airport.
Barren land	Areas around and within forest protected areas with no or very little vegetation cover including exposed soils, stock quarry, rocks, landfill sites, and areas of active excavation.

2.4 Accuracy assessment of the images

Accuracy assessment of a classified image is an important step in LULC change analysis. A stratified random sampling method was used to collect a total of 221 reference data to ensure that all five (5) LULC classes were adequately represented depending on the proportional area of each class. Google earth images were used to extract reference data. The accuracy assessment was performed on satellite 2015 image only. Accuracy assessment was not performed on 1991 and 2001 images due to the unavailability of ground validation data in the form of aerial photographs and archived Google earth images. The same image classification method used for 2015 classified map was however adopted for both 1991 and 2001 images. The accuracy assessment was determined using Kappa coefficient, overall accuracy, producer's and user's accuracies derived from the confusion (error) matrix (Congalton and Green 2009; Liu et al. 2007). The Kappa coefficient report the relationship between the classified map and reference data (Lillesand and Keifer 2000). The error matrix computed the overall accuracy of six (6) land use classes individually and collectively. The Kappa coefficient was computed using equation proposed by Jensen and Cowen (1999).

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \text{ x } x_{+1})}{N^2 - \sum_{i=1}^{r}(x_{i+} \text{ x } x_{+1})} \quad (1)$$

Where: K = Kappa coefficient of agreement; N = Total number of observations (sample points); X_i = Observation in the line *i* and column *I;* X_{i+} = Total marginal of the line *I;* X_{+1} = Total marginal of the column *i*

2.5 Change detection analysis

2.5.1 Land use and land cover change transition matrix

Change detection quantifies the changes that are associated with LULC changes in the landscape using geo-referenced multi-temporal remote sensing images acquired on the same geographical area between the considered acquisition dates (Ramachandra and Kumar 2004). The study employed a post-classification comparison (PCC) change detection method to detect the LULC changes of two independently classified maps that occurred between two different dates of the study period (Jensen 2005). Post-classification comparison is the most common technique used to compare maps of different sources despite having a few limitations. The approach provide comprehensive and detailed "from-to" LULC change information as it does not require data normalization between the two dates (Coppin et al. 2004; Jensen 2005; Teferi et al. 2013; Aldwaik and Pontius 2013). The use of the PCC technique resulted in a cross-tabulation matrix (LULC change transition matrix) which was computed using overlay functions in ArcGIS. Gross gains and losses were also calculated for three periods: 1991-2001, 2001-2015 and 1991-2015. The computed LULC change transition matrix consisted of rows (displaying LULC class category for time 1, T_1) and columns (displaying LULC class category for time 2, T_2) as shown in Table 3.

Table 3. General LULC change transition matrix for comparing two maps between observation times

		Time 2 (*T₂*)						
		LULC 1	**LULC 2**	**LULC 3**	**LULC 4**	**LULC 5**	**Total T_1**	**Loss**
Time 1 (T_1)	LULC 1	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{1+}	$A_{1+} - A_{11}$
	LULC 2	A_{21}	A_{22}	A_{23}	A_{24}	A_{25}	A_{2+}	$A_{2+} - A_{22}$
	LULC 3	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}	P_{3+}	$A_{3+} - A_{33}$
	LULC 4	A_{41}	A_{42}	A_{43}	A_{44}	A_{45}	A_{4+}	$A_{4+} - A_{44}$
	LULC 5	A_{51}	A_{52}	A_{53}	A_{54}	A_{55}	A_{5+}	$A_{5+} - A_{55}$
	Total T_2	A_{+1}	A_{+2}	A_{+3}	A_{+4}	A_{+5}	**1**	
	Gain	$A_{+1} - A_{11}$	$A_{+2} - A_{22}$	$A_{+3} - A_{33}$	$A_{+4} - A_{44}$	$A_{+5} - A_{55}$		

Note:

A_{ij} = the land area that experiences transition from LULC category *i* to LULC category *j*

A_{ii} = the diagonal elements indicating the land area that shows persistence of LULC category *i* while the entries off the diagonal indicate a transition from LULC category *i* to a different category *j*

A_{i+} (total column) = the land area of LULC category *i* in T1 which is the sum of all *j* of A_{ij}

A_{+j} (total rows) = land area of LULC category *j* in time 2 which is the sum of over all of *i* of A_{ij}

Losses ($A_{i+} - A_{ii}$) = proportion of landscape that experiences gross loss of LULC category *i* between time 1 and 2

Gains ($A_{+i} - A_{ii}$) = proportion of landscape that experiences gross gain of LULC category j between time 1 and 2

2.5.2 Annual rate of change

According to Teferi et al. (2013), the net change is the difference between gain and loss and it is always regarded as an absolute value. The annual rate of change of LULC at three different periods (1991-2001, 2001-2015 and 1991-2015) was also calculated according to procedures introduced by Puyravad (2003), Teferi et al. (2013) and Batar et al (2017).This equation provides a benchmark for comparing LULC changes that are not sensitive to the differing periods between the study periods.

$$r = \left(\frac{1}{t_2 - t_1}\right) \times ln\left(\frac{A_2}{A_1}\right) \quad (2)$$

where: r is the annual rate of change for each class per year; A_2 and A_1 are the class areas (ha) at time 2 and time 1 respectively and t is time (in years) interval between the two periods.

2.5.3 Gains and losses of LULC (Net change)

Net change is the difference between the gain and loss (Teferi et al. 2013). The gains and losses of the land use and land cover during the study period were derived from the cross tabulation of 1991, 2001 and 2015.

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3. RESULTS

3.1 Accuracy assessment

Table 4 shows the error matrix results for the 2015 classified map. The overall accuracy for the 2015 classification map was 91.86%. Built-up areas produced the lowest producer's accuracy (61.54%) which may be attributed to the reflectance of the roofs of the houses (iron sheets and thatching grass) that appeared to be rocks and agricultural land. Similarly, the kappa coefficient was found to be 0.866. Therefore, the map set the minimum accuracy requirements to be used for the subsequent post-classification operations.

Table 4. Confusion (Error) matrix for 2015 LULC change map

		Referenced Data							
	Class	**Water**	**Wetland**	**Forest**	**Agriculture**	**Barren**	**Built-up**	**Row Total**	**User's accuracy (%)**
Classified image	Water	10	0	0	0	0	0	10	100
	Wetland	0	9	1	0	0	0	10	90
	Forest	0	1	19	0	0	0	20	95
	Agriculture	0	0	2	125	2	5	134	93.3
	Barren	0	0	5	0	32	0	37	86.5
	Built-up	0	0	0	2	0	8	10	80
	Column Total	10	10	0	127	34	13	221	
	Producer's accuracy (%)	**100**	**90**	**70.4**	**98.4**	**94.1**	**61.5**		

Overall accuracy = 91.86%, Kappa coefficient = 0.866

3.2 Land use and land cover change dynamics

Figure 2 shows the LULC maps for the 6 classes under investigation. During the entire study period (1991 – 2015), agricultural land and barren land were the predominant LULC classes (Table 5). In 1991, agricultural land, forest area, barren land, built-up area, wetlands and water covered 71.3%, 24.53%, 2.64%, 0.20%, 0.96% and 0.37% of the study area respectively. The areas under agricultural land, forest area, wetlands, water bodies drastically decreased from 71.3% (267,977.43 ha), 24.53% (9,939.15 ha), 0.96% (3,626.73 ha), 0.37% (1,380.60 ha) in 1991 to 69.41% (260,879.31 ha), 1.66% (6,237.63 ha), 0.71% (2,680.29 ha) and 0.24% (899.55 ha) in 2015. On the contrary, barren land and built-up areas significantly increased from 24.53% (92,185.38 ha), 0.20% (761.67 ha) in 1991 and 25.85% (97,174.62 ha), 2.13% (7,999.56 ha) in 2015.

The annual rate of change revealed a varied changing progression for each LULC category throughout the study period (Table 5). The long-term annual rate of change considerably declined for water, wetlands and barren land from 5.54% ha^{-1} to 1.74% ha^{-1}, 2.05% ha^{-1} to 1.26% ha^{-1} and 0.27% ha^{-1} to 0.22% respectively within the entire period of study (1991 – 2015). In the same period (1991 – 2015), the forest area, agricultural land and built-up area experienced overall increased annual rates of change from 1.71% ha^{-1} to 1.94% ha$^{-1,}$ 0.02% ha^{-1} to 0.11% ha^{-1} and 7.22 % ha^{-1} to 9.80 ha^{-1} respectively.

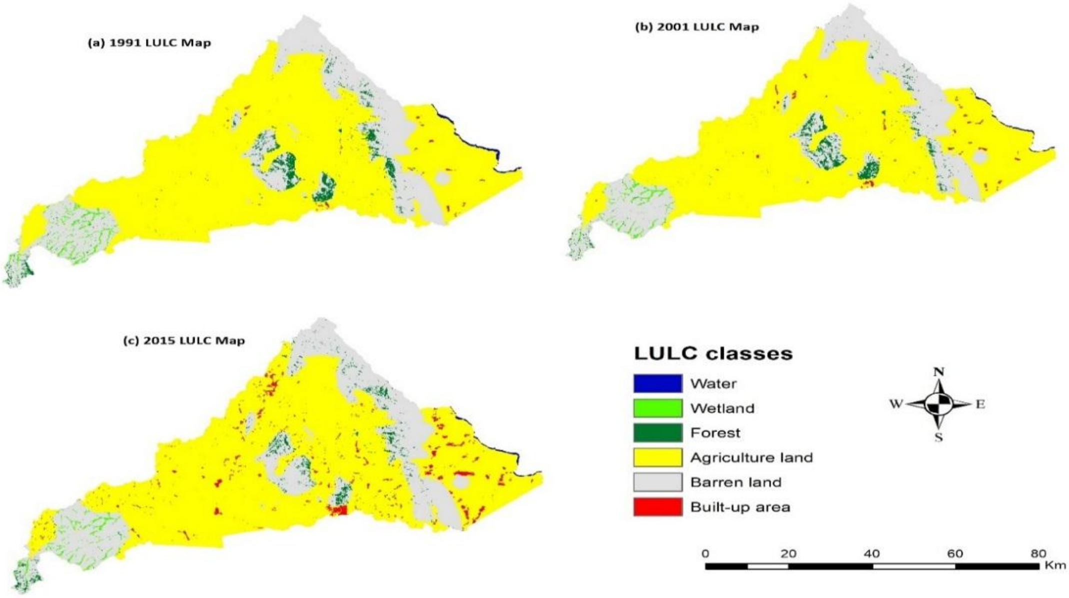

Figure 2. LULC maps for 1991, 2001 and 2015

3.3 Land use and land cover change (transition) matrix

The LULC change matrix (Table, 6, 7 and 8) for the periods 1991 – 2001, 2001 – 2015 and 1991 – 2015 shows the distribution of main transitions in the six (6) LULC categories used in this study. The study has revealed that there were major changes and transition among the six LULC classes. Between 1991 and 2001, the forest area experienced the highest transition with 52.70% (5,237.37 ha) of its total area in 1991, the majority being converted to barren land (4,541.31ha), agriculture land (631.80 ha) and 64.26 ha to the other classes (Table 6). In the same period, 46.5%, 43.1%, 34.8%, 6.8% and 1.5% of the total areas of wetlands, water bodies, built-up areas, barren land and agriculture land were changed to different classes. Agricultural land experienced the least transaction when observing 98.52%, 96.74%, 96.03% of its total agriculture land in the periods 1991 – 2001, 2001 – 2015 and 1991 – 2015 respectively. Most of the agricultural land in these periods was converted to barren land and built-up areas. During the 24 year period of study, forest experienced the highest transition with 69.77% of its total area being converted to other classes (Table 8). The Post-classification comparison of the classified images based on the transition matrix depict that ~61.48% of the total forest land in 1991 has been changed to barren land in 2015 while about 2.70% % of agricultural land in 1991 has been converted to built-up land in 2015.

Table 5. LULC change trend and annual rate of change of the study area

Land cover type	1991		2001		2015		Change %[b]			Annual change rate (%)[c]		
	Ha	%[a]	Ha	%[a]	Ha	%[a]	(1991-2001)	2001-2015	1991-2015	(1991-2001)	2001-2015	1991-2015
Water	1,380.60	0.37	793.26	0.21	899.55	0.24	-0.16	0.03	-0.13	-5.54	0.90	-1.78
Wetland	3,626.73	0.96	2,954.07	0.79	2,680.29	0.71	-0.18	-0.07	-0.25	-2.05	-0.69	-1.26
Forest	9,939.15	2.64	8,354.70	2.22	6,237.63	1.66	-0.42	-0.56	-0.98	-1.74	-2.09	-1.94
Agriculture	267,977.43	71.30	267,469.83	71.16	260,879.31	69.41	-0.14	-1.75	-1.89	-0.02	-0.18	-0.11
Barren	92,185.38	24.53	94,731.66	25.20	97,174.62	25.85	0.68	0.65	1.33	0.27	0.18	0.22
Built-up	761.67	0.20	1,567.44	0.42	7,999.56	2.13	0.21	1.71	1.93	7.22	11.64	9.80
Total area	**375,870.96**	**100.00**	**375,870.96**	**100.00**	**375,870.96**	**100.00**						

[a] percentage of each class out of the total area; [b] percentage change in the class; [c] percentage the annual rate of change in each class

Table 6. Land use and land cover change matrix between 1991 and 2001

LULC	Water	Wetlands	Forest	Agriculture	Barren	Built-up	Total 1991
Water	**785.61**	7.83	0.09	587.07	-	-	1,380.60
Wetlands	0.27	**1,939.95**	51.12	34.11	1,601.28	-	3,626.73
Forest	0.18	60.39	**4,701.78**	631.80	4,541.31	3.69	9,939.15
Agriculture	3.15	23.58	201.87	**264,010.50**	2,687.58	1,050.75	267,977.43
Barren	4.05	922.32	3,399.84	1,940.94	**85,901.49**	16.74	92,185.38
Built-up	-	-	-	265.41	-	**496.26**	761.67
Total 2001	**793.26**	**2,954.07**	**8,354.70**	**267,469.83**	**94,731.66**	**1,567.44**	**375,870.96**

Note: The bold numbers indicate the unchanged LULC proportions from 1991 to 2001

Table 7. Land use and land cover change matrix between 2001 and 2015

LULC	Water	Wetlands	Forest	Agriculture	Barren	Built-up	Total 2001
Water	**745.56**	2.70	2.88	40.59	1.35	0.18	793.26
Wetlands	0.81	**1,749.15**	52.47	22.77	1,128.87	-	2,954.07
Forest	2.07	71.01	**2,320.56**	328.23	5,625.99	6.84	8,354.70
Agriculture	151.11	8.46	373.32	**258,741.54**	1,579.77	6,615.63	267,469.83
Barren	-	848.97	3,487.95	1,503.27	**88,836.21**	55.26	94,731.66
Built-up	-	-	0.45	242.91	2.43	**1,321.65**	1,567.44
Total 2015	**899.55**	**2,680.29**	**6,237.63**	**260,879.31**	**97,174.62**	**7,999.56**	**375,870.96**

Note: The bold numbers indicate the unchanged LULC proportions from 2001 to 2015

Table 8. Land use and land cover change matrix between 1991 and 2015

LULC	Water	Wetlands	Forest	Agriculture	Barren	Built-up	Total 1991
Water	**889.02**	5.31	-	484.92	-	1.35	1,380.60
Wetlands	0.72	**1,842.48**	30.96	40.14	1,712.34	0.09	3,626.73
Forest	1.08	53.28	**3,004.56**	737.19	6,110.19	32.85	9,939.15
Agriculture	8.46	16.38	397.98	**257,349.69**	2,960.01	7,244.91	267,977.43
Barren	0.27	762.84	2,803.86	2,162.61	**86,391.99**	63.81	92,185.38
Built-up	-	-	0.27	104.76	0.09	**656.55**	761.67
Total 2015	**899.55**	**2,680.29**	**6,237.63**	**260,879.31**	**97,174.62**	**7,999.56**	**375,870.96**

Note: The bold numbers indicate the unchanged LULC proportions from 1991 to 2015

3.4 Gain and loss of land use and land cover (Net Change)

The net change in terms of gains and losses for each LULC class during the 1991 – 2001, 2001 – 2015 and 1991 – 2015 are depicted in Figure 3. As shown in Figure 3, between 1991 and 2015, the highest loss was observed in the forest land (1,584.45 ha), followed by wetlands (672.66 ha), water bodies (587.34 ha) and agricultural land (507.60 ha) while barren land and built-up areas progressively gained by 2,546.28 ha and 805.77 ha respectively. On the other hand, between 2001 and 2015, agricultural land experienced the highest loss (6,590.52 ha) followed by forest cover (2,117.07 ha). During the whole period of study (1991 – 2015), the built-up areas and barren land gained 7,237 ha and 4,989.29 ha of land respectively. In the same period, the highest loss was experienced by agriculture land (7,098.12 ha), followed by forest cover (3,701.52 ha), wetland (946.44 ha) and water (481.05 ha).

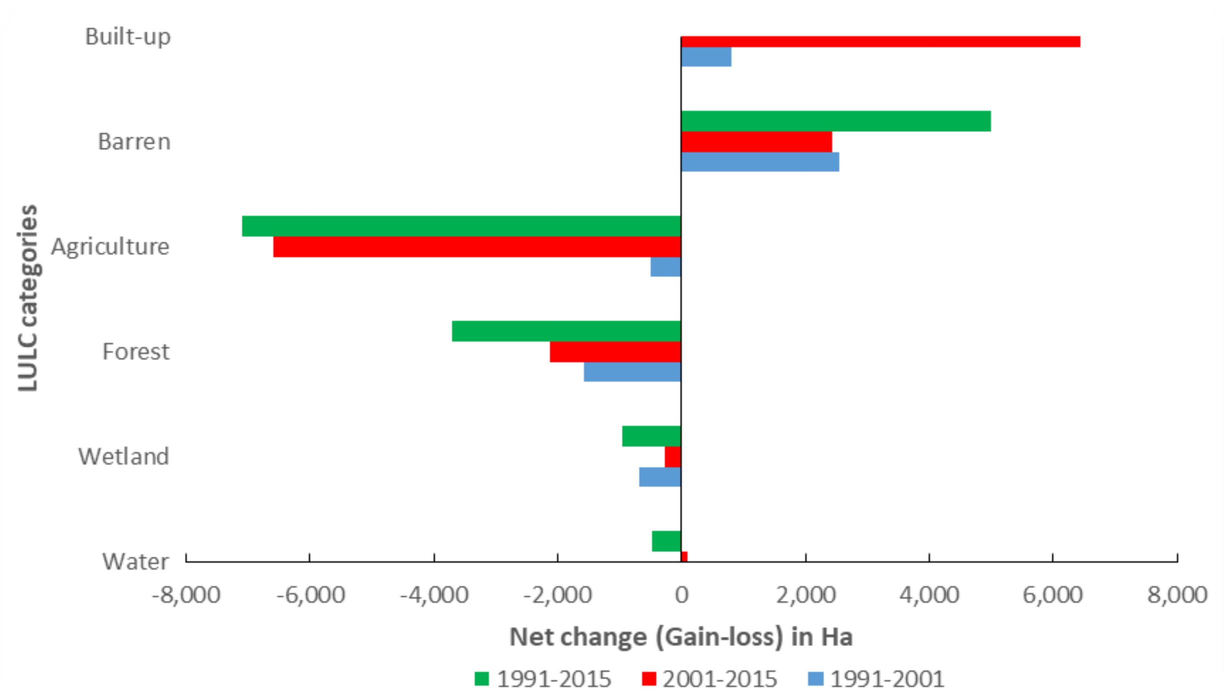

Figure 3. Net change (Gains - losses) for each LULC class for the study period

5. DISCUSSION

The accuracy assessment is an important step in image classification and the quality of the thematic map from satellite image is determined by its accuracy. Information on the accuracy and precision of the classified maps is essential in order for the end-users to utilize the generated maps effectively (Smits et al. 1999; Plourde and Congalton 2003; Manandhar et. al 2009).The results from accuracy assessment of the LULC maps varied among the LULC classes. The results of accuracy assessment in this study revealed excellent results despite some errors which could be attributed to spectral confusion between built-up areas, barren land and agriculture land. Collating with the minimum 85% accuracy stipulated by Anderson et al. (1976) and Kamusoko and Aniya (2007), the overall accuracy (91.86%) statistics obtained in this study satisfied the minimum accuracy (85%) of satellite-derived LULC maps kappa coefficient (0.866) which is above 80% representing a strong agreement (Ramita et al. 2009). The results were also adequate for subsequent and continuous post-classification comparison of change detection operations. The higher overall accuracy achieved in this study could be attributed to the utilization of more ancillary data during the process of image classification.

In terms of the change detection analysis, the results reveal that significant LULC changes occurred during the 24 year study period (1991 - 2015). The major land use in Dedza district is agricultural land. This is a true reflection of the Dedza district since it is characterised by farming as the main socio-economic activity (Government of Malawi 2013). Thus, most communities in the study area show a high level of dependency on agricultural activities. Moreover, the results revealed that despite being the most dominant land-use in the area, agriculture land use on customary land has been on a decline from 1991 to 2015. The results also revealed that the land originally (1991 and 2001) under agricultural production was being converted into either built-up area for settlements or has lapsed into barren land. But, while the percentage of land initially under agricultural production (customary land) has been on a decline there have also been new pockets of agricultural land emerging elsewhere in the district. This trend was evident in the percentage of forest land, water bodies and wetlands being converted into agricultural land. Echoing this trend, the study also found that barren land was increasingly being converted to agricultural land as indicated in the Tables 6, 7 and 8. This trend thus provides a clear indication that there are encroachment activities through the creation of new gardens especially in the government forests. Population growth and a loss in soil fertility on customary lands where agricultural production initially concentrated are seen as key drivers of the identified trends. The demand for cultivation increased as the population increases as well in the study area. Farmers in Dedza practice rain-fed agriculture. This type of agriculture requires more land in order to meet the needs for the growing population (Palamuleni et.al 2010).

The decline in the wetlands and water bodies identified in the study is also seen as an indication that the availability of agriculture land is becoming a problematic issue in the district. The analysis revealed that wetlands are being converted into agricultural land but this trend is happening at slower annual rate than other land use change trends identified during this study. During a field visit, the reasons for the reduction in the percentage of the water bodies and wetlands observed from the remotely sensed data became very clear as there was also a significant increase in cultivation along the river and stream banks in the district. The observed trend aligns with the findings of Pullanikkatil et al. (2016) who concluded that the land use changes of Likangala River catchment in Malawi was due to cultivation of river banks, deforestation, and natural resource over-exploitation were some of the threats to provision of sustainable ecosystem services in the catchment. Poverty coupled with increased demand for agricultural activities motivate people to cultivate in marginal lands such as hill slopes, streams, river banks and wetlands. Globally, results have shown that wetlands have decreased in the past years due to land clearance and drainage as a consequence of urban, agricultural and industrial development activities (Asselen et al. 2013).

Increased settlements were observed along the roads, lakeshore areas, wetlands and surrounding the forest reserves in the study area. Increase in built-up areas during the 24 year interval used for the study could be attributed to increasing demand for land from the growing population as well as the infrastructure developments that are taking place in Dedza district. In other words, the increase in population implies conversion of other LULC classes into settlements and barren land could be a reason for the general increase in the settlements across Dedza district. Thus, the drastic conversion of agricultural land and barren land to built-up area is an indication that Dedza town is being developed for residential, commercial, academic and business purposes. The individual and property developers in the study are converting wetlands and agriculture land into built-up areas without any considerations of concomitant detrimental environmental impacts. An increase in the number of roads in the study are could not only promote economic development but also facilitating forest degradation and deforestation if local communities are in proximity with natural resources as forests

Forest resources continue to be renowned as an important natural resource for the livelihoods of local communities living in close proximity to them (Angelsen and Wunder 2003; Yemiru et al. 2010). The results from this study have shown that forest cover has significantly declined (2.64% to 1.66%) from 1991 to 2015 in Dedza district. The increase in the barren land is also an indication that there is increased deforestation and forest degradation. This declining trend in terms of forestry has also been confirmed by a study conducted by Mauambeta et al. (2010) who reported that forest cover in Malawi declined from 47% of the total land area in 1975 to 36% in 2010. The decline in forest cover might be due to unsustainable tree felling for charcoal, firewood and increased settlements in the study area. According to GoM (2013), forest resources in Dedza district continue to dwindle due to increased demand for charcoal, fuelwood, poles and timber as a result of population growth in Lilongwe City and surrounding districts which provide markets for these forest products. About 94% of the population in Malawi do not have access to electricity and depend on biomass for their energy needs (Ruhiinga, 2012). Further, the majority of the local communities surrounding forests in Dedza district are characterized by poverty and lack of alternative livelihoods. Therefore, the decline in forest cover can be attributed to poverty and rapid population growth which create enormous pressure, competition and over-dependence on natural resources such as forests, water, and land resulting in unsustainable extraction of these resources which will have implication on biodiversity, habitat ecosystem services and people's livelihoods. Additionally, the increasing rate of deforestation in the study area can be attributed to increasing demand for arable land for food production. The increased barren land in the study area seems to imply that forest restoration activities such as afforestation and reforestation activities are lagging behind in the study area. The conversion of forest land to agricultural land implies encroachment through farming in the forest reserves.

6. CONCLUSION

The study has demonstrated that integrated use of remote sensing and GIS techniques can assess and quantify the nature, rate and extent of LULC changes and thereby contribute towards an improved understanding of the process of LULC change. The overarching conclusion of this study is that Dedza district has undergone major LULC alterations between 1991 and 2015. During this 24-year interval the, the study area has experienced a decline in forest land, agricultural land, water bodies and wetlands during the 24 years of study period. There is also substantial increase in built-up areas and barren land between 1991 and 2015. Forest land and agricultural land will likely continue to decrease due to population growth, human settlements coupled with poverty and demand for land to grow food to meet the needs of the people in the study area. The results have shown that the decline in forest land and increase in barren land will lead to forest degradation and deforestation with implications on people's livelihoods, biodiversity and ecosystem services. The LULC changes that has taken place during the past 24 years is a reflection of the influence of local and national policies and human impacts on the study area which has resulted in the increased built-up areas and barren land. Majority of the agricultural land being converted to built-up areas has an implication on food security and supply of forest goods and services as fertile agricultural land is lost to increased built-up areas and infrastructure development. The major LULC changes observed in this study requires urgent intervention from forest managers, environmentalists, decision makers and other stakeholders to address the issues of forest degradation and deforestations, urban or built-up area expansion, loss of agricultural land, wetlands and water bodies in the study area.

This study, therefore, provides LULC change information for understanding the LULC changes that took place in Dedza district between 1991 and 2015. The information will provide essential planning tools for planners, researchers, environmentalists and other stakeholders for sustainable management of natural resources in Dedza district. Based on the findings of this study, it is recommended that the study on the drivers of LULC change in the study area be studied to understand the proximate and underlying causes of these changes. It is also recommended that appropriate steps should be undertake by decision-makers in the study area to protect and restore the forests and effective and efficient natural resource management plans be put in place for sustainable development programs in Dedza district.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors

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