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Land use Changes and their Impact on the Sustainability of Wildlife Resources in Mumbwa and Lupande Game Management Areas of Zambia

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Abstract: *This study was conducted in two Game Management Areas (GMAs) of Zambia. They were the Mumbwa GMA located in central Zambia and Lupande GMA situated in Zambia's eastern province. The purpose of the study was to determine categories for the use of land, percentages of changes in the use of land, and the impact of varying types of land use on the sustainability of wildlife resources in Zambia. LANDSAT satellite images for 1972, 1984, 1990 and 2013 were used to derive cover maps for different uses of land. Five categories of land use were listed in the two study areas during the 41 year period of observation. In Mumbwa GMA, approximate changes in land use in 2013 were that forest decreased by 12,670 hectares, agricultural use increased by 6,858 hectares, bodies of water decreased by 202 hectares, and built-up areas increased by 9,680 hectares. In Lupande GMA, forest increased by 274,651 hectares, grassland decreased by 162,730, hectares, land used for agriculture decreased by 18,450 hectares, bodies of water decreased by 74hectares and built-up areas decreased by 95,648 hectares.Changes in land use, and encroachment on their habitats indicated that sustainability of wildlife resources in the GMAs of Zambia were under threat. Between 1989 and 2013, wildlife habitats in Mumbwa GMA were reduced by 12.4%. However, for the same period, wildlife habitats in Lupande GMA increased by 104.2%.Wildlife habitat in this paper refers to forest and grassland being the prime habitats for wildlife.*

Keywords: *Land cover change; wildlife resources; Game management area; sustainability*

1. Introduction

Humans have modified about 83 % of the Earth's land surface by changing the way that land was used. Use of land and changes in the cover of land has a major impact on biotic diversity throughout the world (Gala et al. 2000 cited in (Lambin et al. 2001). Changes in the use of land affect wildlife habitats by interfering with various components of biodiversity. Biodiversity is the variety of different types of life found on Earth. It is a measure of the variety of organisms that are present in different ecosystems.Issues relevant to biodiversity include components that include compositional diversity and structural diversity in time and space and the functions that sustain those components (Jingan et al. 2005, Noss 1990 cited in (Scolozzi and Geneletti 2011); (Theobald, Miller & Hobbs 1997). Land use changes may affect wildlife habitats both directly and indirectly. For example, during construction of buildings and roads, natural vegetation is removed. The removal of natural vegetation therefore changes the structure of the habitat. The alteration in the use of land may determine the type of wildlife species to be found in that particular landscape. Furthermore, the movement of species may also be affected by alteration of the habitat (Theobald et al 1997; Damschen et al. 2006; Eigenbrod et al. 2008; Fahrig 2007 cited in (Hamilton et al. 2013).

Intensive land use affects biodiversity through both loss of habitat and its fragmentation (Fischer and Lindenmayer 2007; Damschen et al 2006; Fahrig 2003 cited in (Hamilton et al. 2013). Alteration of land cover has major effects on biodiversity which in turn affects the management of wildlife resources ((Hamilton et al. 2013).

The constant growth in demand of agricultural products to feed the ever-growing population of the world has led to extreme global changes in land use. That will occur as tropical lands are being drastically and rapidly changed from their native features as a result of high demand for food (Costantini, 2015). The change in native features of tropical forests has also been noted in biomes such as grasslands and savannah which have shrunk by drastic amounts (Gibbs et al 2010 cited in Constantine 2015). This has led to loss of biodiversity as well as functional diversity which affect the elements of biodiversity that influence how ecosystems function (Senior et al 2013; Edwards et al 2013 cited in (Costantini 2015). Importantly, changes in the use of land from a more natural to a less natural condition is one of the main threats to biodiversity (Fischer and Lindenmayer 2007; Vitousek and Mooney 1997 cited in (Hamilton et al. 2013).

Changes in the use of land can also disrupt the balance of surface water, runoff and ground water flow. This is because surface runoff and river discharge may generally increase when the vegetation is cleared, especially forest (Foley et al. 2005). This may affect the quality of habitats which then affects the persistence of the population of various species in the particular habitat. The effects of land use changes on biodiversity have increasingly become a concern to conservation scientists (Soule and Terbourgh 1999, Crooks and Sanjayan 2006, Hilty et al. 2006 cited in (Hamilton et al. 2013). This has led to a growing risk of extinction of wildlife populations throughout the world.

In Zambia, as in many other African countries, changes in the use of land have posed a threat to wildlife resources, particularly deforestation and encroachment of their habitats (Watson et al. 2014). Human encroachments on ecosystems in Zambia have already degraded wildlife habitats and threatened the viability of large mammalian wildlife populations (Watson et al. 2014). This study is extremely important as it will provide information on the rate at which wildlife habitats have been reduced by changes in the use of land.

The aim of this study is to assess the impact of land use changes on the sustainability of wildlife resources using an approach based on remote sensing to investigate the extent of land cover changes in Mumbwa and Lupande GMAs of Zambia. These are the changes in land cover for forest and grassland between 1990 and 2013.

2. STUDY AREAS

The study areas were Mumbwa and Lupande GMAs from the central and the eastern provinces of Zambia. Their selection was based on good performances in the collection of revenue by GMAs. Mumbwa GMA is located in Mumbwa district. It covers an area of approximately 3,370 square kilometres. It was proclaimed a GMA in 1972. The GMA lies between longitude 250 58' to 260 30' E and latitude 140 55' to 150 18' S and shares a boundary with the Kafue National Park (KNP) in the north (Figure 1). It is defined as a prime hunting area where highly valued trophy species such as buffalo (*Synceruscaffer)*), lion (*Pantheraleo)* and leopard (*Pantherapardus)* are abundant (ZAWA 2004; Milupi et al 2020). In terms of revenue generation, the GMA is ranked fifth of 21 GMAs where trophy hunting occurs (Lewis, Alpert 1997). This makes it an important revenue generator for both the local communities and Zambian Wildlife Authority (ZAWA) who each obtain 50 per cent of the revenue from hunting. The total human population of Mumbwa GMA is estimated to be 25,712 with the adult population comprising up to 48.7per cent and youths, 28.8per cent while the remaining 22.5% are children(MoH 2010). Mumbwa GMA community comprises subjects in the three chiefdoms of Chibuluma, Kabulwebulwe, and Mulendema who form the wildlife management authority for Mumbwa GMA. Major threats and pressures affecting Mumbwa GMA include poaching and human encroachment (MTENR 2007). Others are charcoal production, illegal fishing when there is a ban on fishing and agricultural activities.

Lupande GMA (Figure 1) is located in the Luangwa valley in the Eastern Province of Zambia. The GMA is 120 kilometres west of the provincial headquarters at the town of Chipata. Lupande GMA is in Mambwe. Geographically the GMA lies between 12 51’ and 13 25’ S and 31 47’ and 32 27’ E. (Figure1). The GMA covers a total area of 4,840 square kilometres. It is bordered by South Luangwa National Park (9,050 square kilometres) on the west, Chipata - Petauke district boundary in the south and Chipata - Lundazi district boundary on the north and East. The total population of Lupande GMA is estimated to be 68,918 people (CSO 2012). Lupande GMA has six chiefdoms namely Kakumbi, Mkhanya, Nsefu, Jumbe, Malama and Msoro.

The annual rainfall of the area is about 800 millimetres. Lupande GMA experiences two seasons being the dry season in May to October and the wet season from November to April). The dominant vegetation in the area includes woodlands such as Miombo(Brachystegia, Isoberlinia, and Julbernardia species), Mupane*(Borassusaethiopus)* andMunga*(Acacia albida)*. The majority of the people of Lupande are subsistence farmers who grow crops such as maize (*Zea mays)*, cotton (*Gossypiumhirsutum), millet (Eleusine*species*)*, sorghum (*Vulgare*species*)*, beans (*Phaseolus vulgaris)*, pumpkins (*Curcubita maxima)* and sweet potatoes (*Ipomoea batatas)*(Nyirenda et al. 2013). Other crops grown in the area include cassava (*Manhot* species), groundnuts (Arachis *hypogea)* and rice (*Oryzasativa)* (Balakrishnon 1992 cited in (Nyirenda et al. 2013).

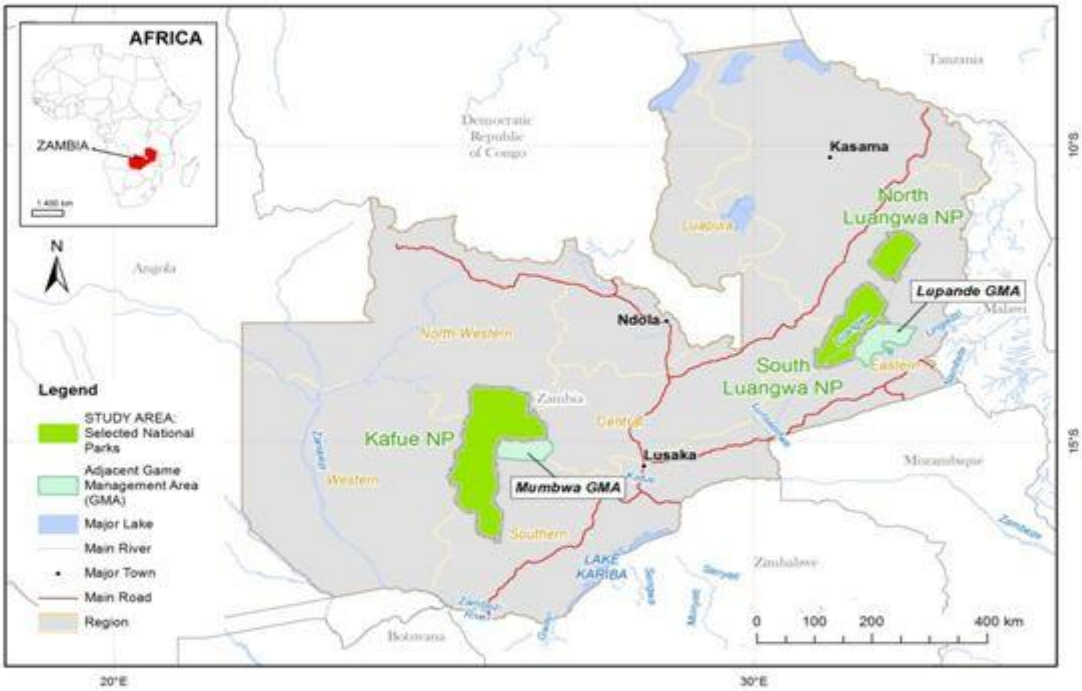

Fig1. *Map of Zambia showing the location of National parks and Game Management Areas.*

3. METHOD

3.1. Remote Sensing

The study was carried out between May and July 2014. The study assessed the sustainability of wildlife resources in Zambia over a period of 41 years. It relied on the images of land use change data produced by the Zambian National Remote Sensing Centre (ZNRSC). A time series of Landsat images from 1972 to 2013 were used for Lupande GMA (table 1) and from 1973 to 2013 for Mumbwa GMA (table 2).

3.2. Image Processing

Images were collected from the ZNRSC archive, Global Land Cover Facility (GLCF) at ftp://ftp.glcf.umd.edu/glcf/Landsat/ and https://glovis.usgs.gov. The images were processed using ENVI 4.8 by Exelis software. The processing involved calibration, mosaicking, masking, classification and post-classification processing. Before the processing was done, pre-processing activities were conducted. This involved collection of ancillary data which included shape files of district and provincial boundaries, game management areas and national parks, schools, roads and health centres. Each respective shape file layer was clipped to the respective area of interest and re-projected to WGS 1984 Zone 35 south. Lupande GMA spans across both Zones 35 and 36 south. However the larger part falls within zone 35 and for this reason the whole area was treated as Zone 35. Details of the images that were used are listed in tables 1 and 2.

Table1. *Details of imagery used for Lupande GMA*

Epoch	Sensor	Year	Path	Row	Scene Date
1	Landsat MSS	1972	182	69	28th September
2	Landsat 5	1984	169	69	3rd September
	Landsat 5	1984	170	69	29th November
3	Landsat 5	1989	169	69	12th May
	Landsat 5	1991	170	69	10th June
4	Landsat 8	2013	169	69	17th July
	Landsat 8	2013	170	69	19th August

Table2. *Details of imagery used for Mumbwa GMA*

Epoch	Sensor	Year	Path	Row	Scene Date
1	Landsat MSS	1973	186	71	29th June
2	Landsat 5	1984	173	70	26th May
	Landsat 5	1984	173	71	26th May
3	Landsat 5	1989	173	70	24th May
	Landsat 5	1989	173	71	24th May
4	Landsat 8	2013	173	70	27th June
	Landsat 8	2013	173	71	27th June

All Landsat images except for Landsat 8 were calibrated and converted to reflectance using the Landsat calibration utilities in ENVI. All bands apart from the temperature band were stacked for each image scene. Stacks of adjacent images covering the areas of interest were mosaicked. Thereafter, the mosaicked stacks were clipped to the area of interest. True colour (321 for Landsat 5 and 432 for Landsat 8) and false colour (742 for Landsat 5 and 753 for Landsat 8) composites of both clipped and complete mosaics were created and viewed in ArcGIS interchangeably and training areas were digitised with the aid of ancillary vector data. Digitized training areas were imported into ENVI and exported further to regions of interest. The regions of interest were associated to respective epoch images through region of interest restoration option.

3.3. Classification Scheme and Land use Land Cover Classes

The process of supervised classification was thereafter performed and maximum likelihood classification was used as the classifier. The resulting classified images were sieved, clumped and majority analysis performed using a 3x3 filter. The number of training areas (regions of interest (ROI)) that were generated for each class and epoch are shown in tables 3 and 4.

Table3. *Number of ROIs generated for Lupande*

Class	ROI by Epoch (ROI Count/ pixels)			
	1972	1984	1990	2013
Forest	24/1223	43/14830	31/1134	31/950
Grassland	12/159	23/375	10/413	15/477
Water	22/265	21/19635	10/495	15/315
Cropland	5/22	15/324	16/536	17/491
Bare Land	10/180	17/345	9/320	10/372
Built Up	5/85	3/32	5/126	7/162

Table4. *Number of ROIs generated for Mumbwa*

Class	ROI by Epoch (Count/ pixels)			
	1973	1984	1989	2013
Forest	21/907	37/8857	45/2299	32/1200
Grassland	17/193	22/444	25/742	24/508
Water	7/209	12/475	15/804	12/644
Cropland	3/19	13/205	12/571	19/509
Bare Land	7/50	1/52	6/104	6/124
Built Up	2/32	3/33	4/77	4/30

3.4. Classification Accuracy Assessment

Assessment of accuracy was conducted only for 2013 imagery for both study areas. No field data was collected for accuracy assessment. Instead, regions of interest were digitized from Google Earth using QGIS. Details of the ROIs used for accuracy assessment are as shown in the attached accuracy assessment files. The Overall Accuracy for Mumbwa GMA was = (1975/2258) 87.4668% Kappa Coefficient = 0.8028 and for Lupande GMA, Overall Accuracy = (937/987) 94.9341% Kappa Coefficient = 0.9272

Further, it is important to note that forest and woodland were classified as separate classes but there was minimal distinction hence they were later considered as a single class and areal extents and ROIs for both classes were summed. However, this was not done for the Mumbwa accuracy assessment which may have contributed to the low accuracy.

4. Results

In Figure 2 and Figure 3, Landsat Maps for 1972, 1984, 1989 and 2013 display pictorially changes in the areas of land used for forest, grassland, water, cropland, built-up areas and bare land over the period of 40 years for Mumbwa and Lupande GMAs.

Table 5 and Table 6 show areas of the different forms of land-cover for the years 1972, 1984, 1989 and 2013 for Mumbwa GMA and Lupande GMA. Table 7 and Table 8 show differences in the areas of the types of land-cover between the various years for Mumbwa GMA and Lupande GMA.

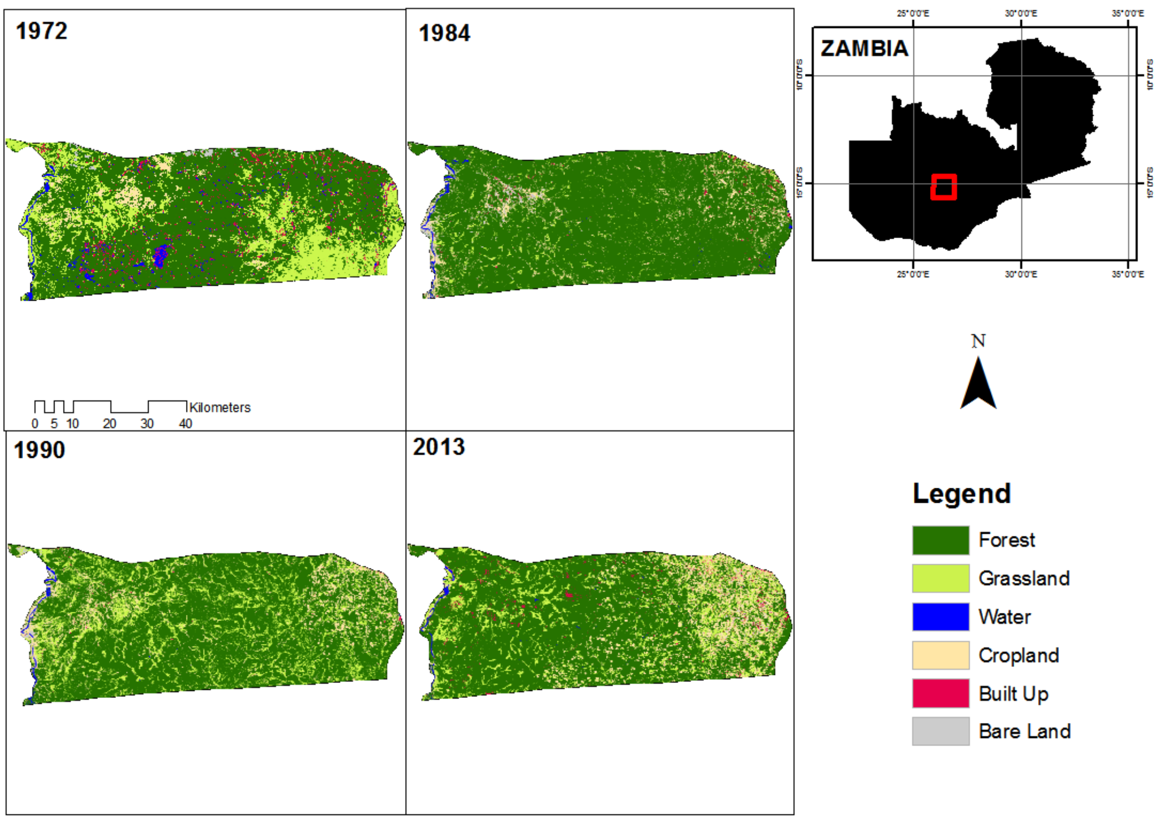

Figure2. *Landsat Maps of Mumbwa GMA for 1972, 1984, 1989 and 2013*

Source: *Field Data, June 2014.*

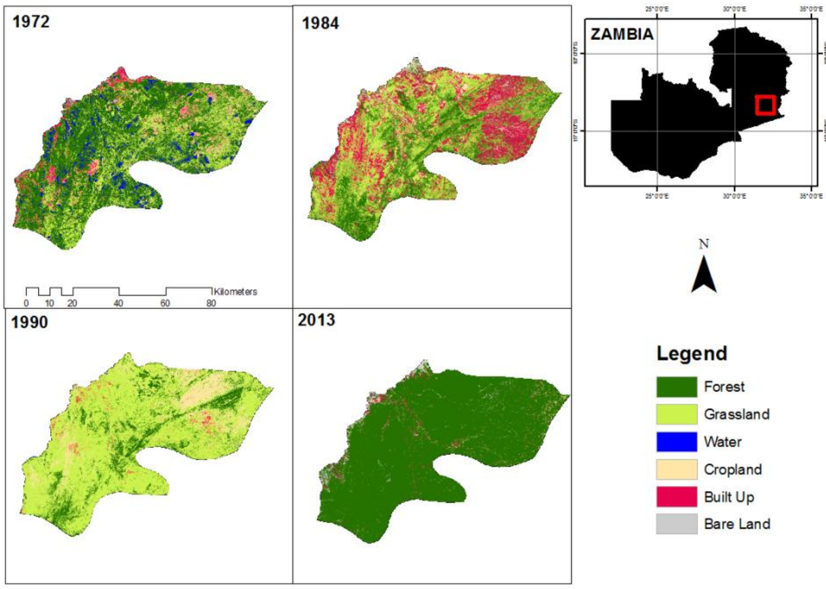

Figure3. *Landsat Maps of Lupande GMA for 1972, 1984, 1989 and 2013*

Source: *Field Data, June 2014.*

Table5. *Areas for the different types of land cover in Mumbwa GMA for the years 1972, 1984, 1989 and 2013.*

Type of land cover	Year			
	1972	1984	1989	2013
	Hectares	Hectares	Hectares	Hectares
Forest	236,196.78	284,877.18	254,832.99	242,464.77
Grassland	74,992.12	19,108.26	56,162.95	51,895.80
Water	7,647.17	1,807.47	1,541.89	1,339.74
Cropland	10,043.31	28,976.31	28,128.62	34,986.51
Bare ground	1,982.54	2,899.44	1,640.10	1,942.11
Built-up area	12,151.26	5,367.69	729.81	10,407.42
Total area	343,013.18	343,036.35	343,036.35	343,036.35

Table6. *Areas for the different types of land cover in Lupande GMA for the years 1972, 1984, 1989 and 2013*.

Type of land cover	Year			
	1972	1984	1989	2013
	Hectares	Hectares	Hectares	Hectares
Forest	245,514.26	66,342.78	135,190.16	409,841.64
Grassland	113,018.09	312,654.6	164,481.36	1,751.31
Water	27,697.40	48,734.91	163.18	89.10
Cropland	23,601.71	170.28	25,137.76	6,692.67
Bare ground	1,845.11	102.87	6,506.85	8,755.38
Built-up area	22,437.59	6,065.64	102,589.12	6,941.52
Total area	434,114.16	434,071.08	434,068.43	434,071.62

Table7. *Change in areas for the different types of land cover in Mumbwa GMA for the years 1972 to 1984, 1985 to 1989 and 1990 to 2013.*

Type of land cover	Year		
	1972 to 1984	1985 to 1989	1990 to 2013
	Hectares	Hectares	Hectares
Forest	48,680.40	30,044.19	-12,368.22
Grassland	-55,883.86	-37,054.69	-4,267.15
Water	-5,839.70	265.58	-202.15
Cropland	18,933.00	847.69	6,857.89
Bare ground	916.90	1,259.34	302.01
Built-up area	-6,783.57	4,637.88	9,677.61
Total area	23.17	0.00	0.00

Table8. *Change in areas for the different types of land cover in Lupande GMA for the years 1972 to 1984, 1985 to 1989 and 1990 to 2013.*

Type of land cover	Year		
	1972 to 1984	1985 to 1989	1990 to 2013
	Hectares	Hectares	Hectares
Forest	-179,171.48	68,847.38	274,651.48
Grassland	199,636.51	-148,173.24	-162,730.05
Water	21,037.51	-48,571.729	-74.08
Cropland	-23,431.43	24,967.48	-18,445.09
Bare ground	-1,742.24	6,403.98	2,248.53
Built-up area	-16,371.95	96,523.48	-95,647.60
Total area	-43.08	-2.65	3.19

For Mumbwa GMA, in Table 7 it is indicated that between 1972 and 1984 the land used for forest increased by 48,680 hectares. Between 1984 and 1989 it decreased by 30,044 hectares. It was reduced further by 12,368 hectares between 1989 and 2013. Grassland cover decreased by 55 884 hectares between 1972 and 1984 but between 1985 and 1989 it increased by 37,058 hectares. However, between 1990 and 2013 there was a decline in the grassland cover of 4,267 hectares, also displayed in Table 7. The cropland increased by 18, 933 hectares between 1972 and 1984, 848 hectares between 1985 and 1989, and 6 858 hectares between 1990 and 2013. Bare land increased by 6,784 hectares between 1972 and 1984. Between 1985 and 1989 it increased, too, by 1,259 hectares and then decreased by 302 hectares between 1990 and 2013. The built-up area in Mumbwa GMA increased by 6,784 hectares between 1972 and 1984, was reduced by 4 638 hectares between 1985 and 1989 but increased again by 9 678 hectares between 1990 and 2013.

In Lupande GMA, as displayed in Table 8, the picture was different as the forest landcover was reduced by179,171 hectares between1972 and 1984 but increased by 68,847hectares between1985 and 1990 and a further 274,651hectares between 1990 and 2013. The grassland cover increased by 199,637 hectares between 1972 and 1984 and declined by 148,173 hectares between 1985 and 1989, but between1990 and 2013 it increased by 162,730hectares.From 1972 to 1984, coverage by water increased by 21,038 hectares. However,between1985 and 1989the cover by water declined by 48,572 hectares and between 1990 and 2013 it increased by 74hectares.LupandeGMA, however, had a reduction in land covered by crops of 23,431hectares between 1972 and 1984 but this changed between 1985 and 1989 when the area covered by crops increasedby24,967 hectares.Between 1990 and 2013, the cover by crops decreased again by 18,445 hectares.Bare land reduced by 1,742 hectaresbetween 1972 and 1984 and further reduced by 6,404 hectarebetween 1985 and 1889. However, it increased by 2,248 hectares between 1990 and 2013. The built up area reduced by 16,372 hectaresbetween 1972 and 1984 but increased by 96,523hectares between 1985 and 1989. However, between 1990 and 2013 the amount of bare land was reduced by 95,648 hectares.

5. DISCUSSION AND CONCLUSIONS

Sustainability of the natural resource is cardinal in natural resource management because it ensures continuity in their use. In Mumbwa and Lupande GMAs, the highly illegal utilization of natural resources such as poaching and encroachment in wildlife habitats confirmed the lack of sustainability and utilization of natural resources in the two study areas. In Mumbwa GMA in particular, the ecological sustainability of Kafue National Park was questionable as there was high encroachment of the park by the local people especially from the Mulendema chiefdom. The encroachment had the effect of shrinking the habitat for wildlife species in the Kafue national park. The high encroachment of wildlife habitats in the two GMAs is confirmed by the Landsat maps of the two areas that were compared for a period of 40 years shown in Figure 3 and Figure 4. The figures show pictorially changes in the areas of land used for forest, grassland, water, cropland, built-up areas and bare land over the period of 41 years.In Mumbwa GMA, as shown in Table 7, it was primarily the increase in the cropland and built-up area in that led to the shrinkage in the habitat for wildlife even though the area of forest and grassland decreased. In Lupande GMA, the land use for forest in 2013 displayed in Table 8 indicateda loss of 274,651hectares for wildlife habitat even though the combined return of grassland and built-up area returned 258,378 hectares for use as a wildlife habitat.

The conclusions of this study were that sustainability of wildlife resources in Zambia is under threat. This was mainly due to encroachments of wildlife habitats by various human activities and changes in the various types of land use. In Mumbwa GMA, the wildlife habitat reduced by12.4% between 1990 and 2013.The reduction of wildlife habitats in Mumbwa GMA was a result of high demand for land used for agricultural activities. For example, land used for the production of crops had increased by 6857.89 hectares.

The shrinking of wildlife habitat in Mumbwa GMA was also confirmed by Simasiku*et al* 2008 and it was attributed to increased settlements and cultivation common in the area. Simasiku*et al.* 2008 further noted that the encroachments were resulting in accelerated loss of habitat as such they were a threat to natural habitat.

However, in Lupande GMA, the wildlife habitat also increased by 104.2% during the same period. The increase was attributed to a decrease of 18445.1 hectares of land used for the production of crops between 1990 and 2013**.**This study found another factor that contributed to an increase in wildlife habitat in Lupande GMA, which was that the South Luangwa Conservation Management (SLCM) and Community Management for Conservation (COMACO)became involved in conservation awareness. This agrees with Milupi *et al.* 2020 and 2021 who observed that sensitization activities through Environmental education promotes sustainability of wildlife resources which in turn increases wildlife species in their habitats. However lack of sensitization was observed in Mumbwa GMA.

6. Acknowledgement

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