

## **TIME SERIES ANALYSIS OF ENCROACHMENTS IN MWEKERA FOREST RESERVE USING REMOTE SENSING AND GIS**

(Conference ID: CFP/391/2017)

Kennedy Kanja (*Author*)

GIS dept. Community Markets for Conservation  
COMACO  
Mpika, Zambia  
[kkanja@itswild.org.com](mailto:kkanja@itswild.org.com)

Workson Siwale 2nd Affiliation (*Author*)

School of Natural Resources, Department of  
Biomaterial Sciences  
Copperbelt University  
Kitwe, Zambia

Malawo Mweemba 2nd Affiliation (*Author*)

School of Natural Resources,  
Kapasa Maakasa Campus, Copperbelt University  
Kitwe, Zambia

**Abstract** — Rapid population growth and rural-urban migration amidst limited job opportunities lead to overexploitation of forest reserves. In this study, Zambia's Mwekera national forest reserve was used to quantify processes of land-cover change based on remote sensing data. The study also tested the effectiveness of remote sensing data in monitoring land use changes. Supervised classification was done on three Landsat images for the three periods (1990, 2000 and 2010) using the ERDAS Imagine 2010 program for three classes; Forest Areas, Open Fields and Settlements. The classified images were then converted into polygons and geoprocessed using ArcMap 10.2.2. Pivot table in Microsoft Excel was used to analyse the land use changes between the periods 1990 to 2010. A total of 6,120 hectares of forested areas were lost to other land use services between the periods 1990 and 2000. Between the periods 2000 and 2010 a total of 1777 hectare of forested areas were lost to other land use services. The conclusion is that Mwekera forest reserves have seen so much encroachment through settlements and other land use services such as agriculture. Though ground control data was not available for the

three periods that were observed, remote sensing data proved to be useful in monitoring land use changes over time as per the findings of this study.

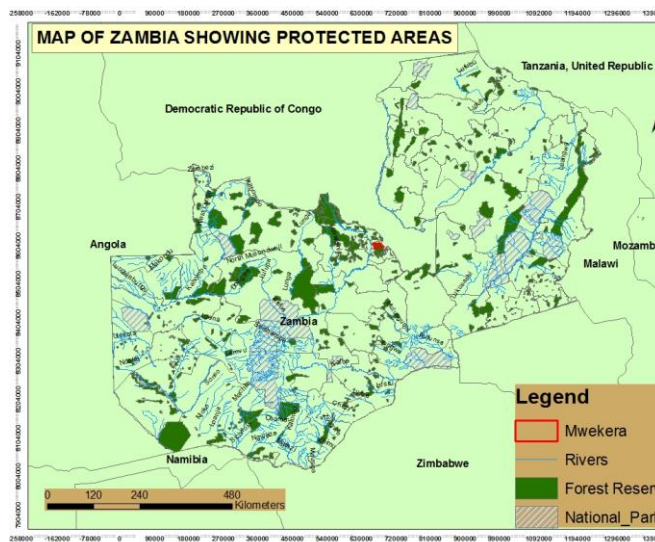
**Keywords** — GIS; Remote Sensing; Encroachment; Forest Reserve; Mwekera; Land Use Change.

### I. INTRODUCTION

Zambia is endowed with a rich diversity of ecosystems, including vast areas of wetlands, albeit amidst numerous and intense threats to their sustenance. The ecosystems are home to a wide variety of fauna and flora species. There are 481 forest reserves, figure 1 below, comprising 173 national forests and 308 local forests (Forests Act, 2015). Rapid population growth and rural-urban migration amidst limited job opportunities leads to overexploitation of forest reserves. Worse still, a large percentage of Zambians depend upon either fuel wood or charcoal for their domestic energy supply. This trend indicates the extent to which natural resources are threatened (ETOA, 2011). There has been rampant encroachment on Zambia's protected forest landscapes including Mwekera National

Forest in the last few years. This has resulted in the loss of substantial parts of the forest cover through clearing for agriculture, settlements, charcoal production, logging and other human activities.

Figure 1: Map showing protected areas in Zambia



Monitoring of temporal and spatial changes in forest ecosystems is very decisive in the decisions taken when making forest management plans. Questions such as by how much has the forested areas been converted into farm fields and/or by how much has the forested areas been encroached by illegal settlers can be addressed. Findings from such studies can provide a number of planning decisions such as estimating the amount of carbon stored and also the incorporation of fragmented areas into afforestation. Mapping and evaluating human encroachment (hereafter termed just 'encroachment') typically employs remote sensing data; however, the total human footprint in the landscape has been inaccurately mapped in African savannas largely because savannas are dynamic and resilient systems frequently experiencing dramatic periods of green up and

fire that obscure or complicate detection of land use changes (Fritz et al. 2011; Pfeiffer et al. 2012; Riggio et al. 2013). In particular, very few studies have been undertaken to assess the extent of human encroachments in forest reserves in Zambia.

To help assess the extent to which encroachments have gone in forest reserves in Zambia using Remote Sensing and GIS, Mwekera forest reserve is used as a case study between the periods late 1980s to 2010.

## Encroachment

There has been a high threat on a global scale imposed on biodiversity, climate change and watershed protection caused by human activities (Olupot et al, 2006). Protected areas globally face these threats by humans seeking land for a variety of uses (Horowitz, 1997). Encroachment started way back in the 1970's. Many governments have used different strategies to deal with encroachment of protected areas (Horowitz, 1997), FAO (1999) and Olupot et al (2006) show that an estimate of about 65.1 million hectares of forests have been destroyed between 1990 and 1995. Many protected areas especially in developing countries are affected by degradation of ecosystem which involves logging, hunting, cultivation, and fires (Olupot et al, 2006). High population pressure in sub Saharan Africa, has led to continued encroachment in protected areas hence calling for conservationist to seek for growing pressures (Olupot et al, 2006).

## Aim of the Study

The aim of this study is to assess land use conversions in Mwekera Forest Reserve starting from the late 1980s up until 2010. The study also aims at monitoring the effectiveness of time series analysis of remote sensing data in form of free Landsat images to monitor encroachments in protected areas such as forest reserves.

## II. METHODOLOGY

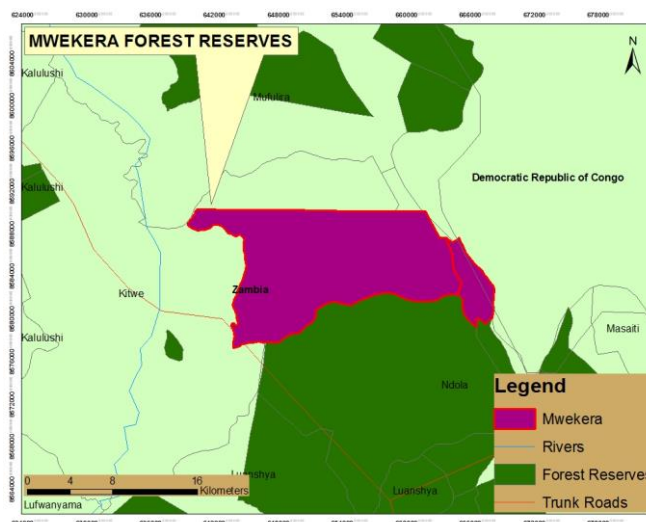
### A. STUDY AREA

Mwekera forest reserve appearing in figure 2 below, one of the national forests, was used in this study as a case study owing to the vast diversity of its ecosystem as well as its importance for practical lessons for students at Zambia Forestry College as well as students from the school of natural resources of the Copperbelt University. Under the Forests Act No. 4 of 2015, "all land comprised in a National Forest shall be used for - (a) the security of forest resources of national importance; (b) the conservation of ecosystems and biological diversity; (c) improved forest resource management and sustainable utilization of forest resources; and (d) the management of major water catchments and head waters, subject to the Water Resources Management Act, 2011." (Forests Act, 2015).

Mwekera National Forest was established in 1946 through a statutory instrument number 72 of 3rd May, 1946 with an original size of 27,500 acres. The purpose of the reserve was the conservation of the forest which formed a catchment area for Mwekera stream. The Zambia Forestry College was established within the reserve thereby making the students, staff and their families the only legal human settlers within the reserve.

Landsat MMSs and Landsat ETM encompassing Mwekera forest reserves were acquired free of charge from the internet; first one was taken on 2/06/1989, the second one was taken on 13/05/2002 and the last one was taken on 11/07/2009.

Figure 2: Mwekera Forest Reserve



### B. Method

The use of remote sensing techniques and geographic information systems, which are effective techniques for collecting, analyzing and presenting data on natural resources, provide great facilities so that temporal and spatial changes in forest resources can be comprehended.

In this study, supervised classification was done on the three Landsat images for the three periods (1990, 2000 and 2010) using the ERDAS Imagine 2010 program for three classes namely Forest Areas, Farms/Open Fields and Settlements. The classified images were then converted into shapefiles using ArcGIS and later intersected. Pivot table in Microsoft Excel was used to analyse the land use changes between the periods 1990 to 2010.

## III. RESULTS

### A. Land use change between 1990 and 2000

Table 1 shows that between 1990 and 2000, a total of 6032 hectares of forested areas were converted into farm fields/ open areas, also a total of 1233 hectare of forested areas were converted into Human Settlements. Putting all land use changes together, a total of 6,120 hectares of forested areas were lost to other land use services between the periods 1990 and 2000.

TABLE 1: LAND USE CHANGES IN HECTARE (HA) BETWEEN 1990 AND 2000

Land Use	Area in Ha		
	1990	2010	Change
Fields/Open Areas	4471.168146	5399.9	928.7
Forest	15682.5519	7786.2	-7896.3
Settlements	1449.443704	8417.1	6967.7

of 6,153 hectares of forested areas were converted into Human Settlements. Putting all land use changes together, a total of 7,896

Land Use	Area in Ha		
	1990	2000	Change
Fields/Open Areas	4471.2	9674.4	5203.2
Forest	15682.6	9562.8	-6119.8
Settlements	1449.4	2366.0	916.5

hectares of forested areas were lost to other land use services between the periods 1990 and 2010.

TABLE 3: LAND USE CHANGES IN HECTARE (HA) BETWEEN 1990 AND 2010

*B. Land use changes between 2000 and 2010*

From Table 2 it can be seen that between 2000 and 2010, a total of 1822 hectares of forested areas were converted into farm fields/ open areas, also a total of 2992 hectares of forested areas were converted into Human Settlements. Putting all land use changes together, a total of 1777 hectares of forested areas were lost to other land use services between the periods 2000 and 2010.

TABLE 2: LAND USE CHANGES IN HECTARE (HA) BETWEEN 2000 AND 2010

Land Use	Area in Ha		
	2000	2010	Change
Fields/Open Areas	9674.4	5399.9	-4274.5
Forest	9562.8	7786.2	-1776.6
Settlements	2366.0	8417.1	6051.1

*C. Land use change between 1990 and 2010*

Table 3 shows that between 1990 and 2010, a total of 3,900 hectares of forested areas were converted into farm fields/ open areas, also a total

*D. General Observations of Results*

Figure 3, Figure 4 and Figure 5 show land use maps for Mwekera forest reserve for the years 1990, 2000, 2010 respectively after performing supervised classification in ERDAS Imaging 2010.

Figure 3: Mwekera forest reserve land use map as of 1990

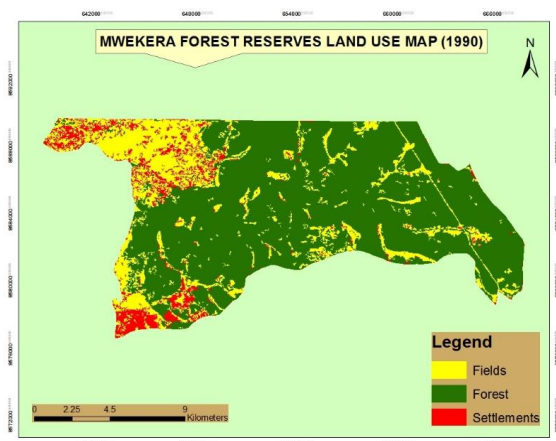


Figure 4: Mwekera forest reserve land use map as of 2000

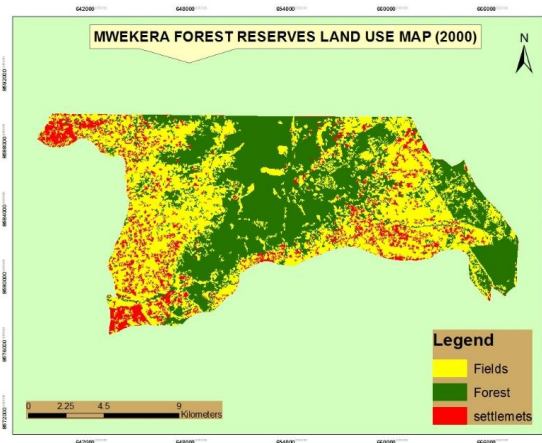
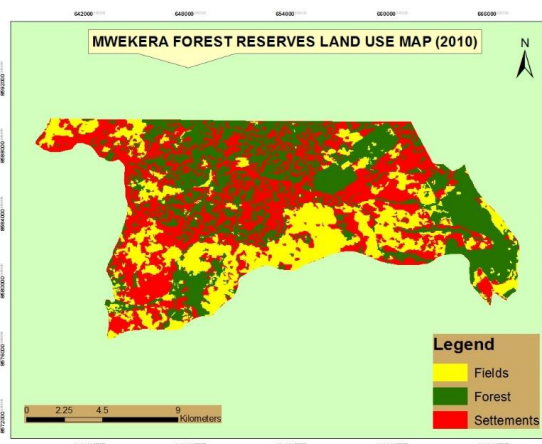


Figure 5: Mwekera forest reserve land use map as of 2010



#### IV. DISCUSSION AND CONCLUSION

The findings of this research are that as of 2010 Mwekera Forest Reserves had only about 7,800 hectares of forests remaining and this goes in line with the findings of (Shitima, 2005). In his Master's thesis report titled "Forest Conservation and People's Livelihoods: Explaining Encroachment on Zambia's Protected Forest Landscapes –The Case Of Mwekera National Forest, Kitwe, Copperbelt" Shitima (2005), reported that there was a consensus among foresters both within the reserve and those from the School of Natural Resources (formerly school

of Forestry) at Copperbelt University that the reserve had lost so much of its tree cover that whatever remained constituted less than then 10,000 hectares based on their surveys with students in the forest reserve. From 1990 to 2010, much of the then forested areas have been turned into settlements representing about 6100 hectares of land. This can be attributed to the migration of miners who had lost their jobs from nearby mining townships such as Kitwe, Ndola and Luanshya. Similar reasons of encroachments in forest reserves were reported by Shula (2012), through his master's thesis report in which he reported that most of the squatters in Kalulu forest reserve in Kabwe moved into the forest after being retrenched, reaching retirement or after non-renewal of job contracts.

Predominantly, charcoal making results in the conversion of dense forest and open forest to woodland/open fields while bad farming practices triggers shifting cultivation which together with settlements within the forest results into bare land.

Various studies and analyses all point to the fact that forests are being depleted at a very fast rate in Zambia inclusive of forest reserves. FAO (1999) and Olupot et al (2006) indicated that an estimate of about 65.1 million hectares of forests have been destroyed between 1990 and 1995. This again concur with findings of this study where about 1000 hectares of Mwekera forest reserves were converted into human settlements and a further 6000 hectares cleared for other land use services such as farming and other developmental projects between the same periods. Also, Petit et al (2001), in their study of land use change in the region of Lusitu in the Southern province of Zambia indicated an average annual rate of land-cover change of 4.0% over the last two decades and that the major changes in the region occurred during the 1986–1992 period and led mainly to the conversion of

natural vegetation into agricultural lands and then bare soils.

In line with the aims of this study, it can be concluded that Mwekera forest reserves have been so much encroached through settlements and other land use services such as agriculture and others. Though ground control data was not available for the three periods that were observed, remote sensing data has proved to be useful in monitoring land use changes over time as the findings of this study concur with other previous studies.

## References

- [1] FAO report, (1999). [pub.iges.or.jp/modules/envirolib/upload/1506/attach/7-reference.pdf](http://pub.iges.or.jp/modules/envirolib/upload/1506/attach/7-reference.pdf). Reference.pdf. Viewed on 7\10\2013
- [2] Forests Act, 2015. Government of the Republic of Zambia.
- [3] Fred, G. R. W., Matthew, S. B., Milanzi, J., and Nyirenda, M., 2015. Human encroachment into protected area networks in Zambia: implications for large carnivore conservation. Reg Environ Change 15:415–429
- [4] Fritz, S., See, L., McCallum, I., Schill, C., Obersteiner M., Van del Velde M., Boettcher, H., Havlik, P., Achard, F., 2011. Highlighting continued uncertainty in global land cover maps to the user community. Environ Res Lett 6(4):044005
- [5] Horowitz, L. S., 1997. Encroachment on Protected Areas by Small-Scale Actors: An Examination of the Issues. Study commissioned by Conservation International, Washington,DC.
- [6] Olupot, W., and Chapman, C. A., 2006. Human Encroachment and Vegetation Change in Isolated Forest Reserves, the Case of Bwindi Impenetrable National Park in Uganda., [http://chapmanresearch.mcgill.ca/Pdf/206\\_Olupot%20%20Chapman.pdf](http://chapmanresearch.mcgill.ca/Pdf/206_Olupot%20%20Chapman.pdf) viewed on 7\10\2013.
- [7] Petit, C., Scudder, T. and Lambi, E., 2001. Quantifying processes of land-cover change by remote sensing: resettlement and rapid land-cover changes in south-eastern Zambia. International Journal of Remote Sensing, vol. 22, no. 17, 3435–3456
- [8] Pfeiffer, M., Platts, P.J., Burgess, N.D., Swetnam, R.D., Willcock, S., Lewis, S.L., Marchant, R., 2012. Land use change and carbon fluxes in East Africa quantified using earth observation data and field measurements. Environ Conserv 1–12. doi:10.1017/S03768929 12000379
- [9] Riggio, J., Jacobson, A., Dollar, L., Bauer, H., Becker, M., Dickman, A., Funston, P., Groom, R., Henschel, P., de Iongh, H., Lichtenfeld, L., Pimm, S., 2013. The size of savannah Africa: a lion's (Panthera leo) view. Biodivers Conserv 22:17–35
- [10] Shitima, E. M., (2005). Master Thesis report; Forest Conservation and People's Livelihoods: Explaining Encroachment on Zambia's Protected Forest Landscapes –The Case of Mwekera National Forest, Kitwe, Copperbelt. Department of Geography Norwegian University of Science and Technology (NTNU).
- [11] Shula, D. K., 2012. Master Thesis report; An appraisal of communication against deforestation used by the Forest Department in encroached forests, a case study of Kalulu forest reserve in Kabwe. UNZA
- [12] Zambia Environmental Threats and Opportunities Assessment (ETOA) 2010.