Uganda Journal of **Agricultural Sciences**
ISSN: 1026-0919 (Print); 2410-6909 (Online)
Volume 18 Number 2 (2018) pp. 93 – 101
DOI: http://dx.doi.org/10.4314/ujas.v18i2.3

https://www.ajol.info/index.php/ujas

Land Use Change using Geospatial Techniques: The Case of Awoja Watershed in Ngora District in Eastern Uganda

Sarah Akello [1,*], Nelson Turyahabwe [1], Paul Okullo [2] and Jacob Godfrey Agea [1]
[1] School of Agricultural Sciences, Makerere University. [2] Nabuin Zonal Agricultural Research and Development Institute
*Corresponding author. 7062, Kampala, Uganda sarahakellok@yahoo.com +256 782 734 449

Abstract. This study used remote sensing and Geo-graphical Information System (GIS) to assess the status of Awoja watersheds in Ngora district of Eastern Uganda. Landsat ETM Images covering the whole of Ngora district and part of Lake Kyoga of two time periods was carried out in the period April to July 2015. This was acquired using USGS Earth Explorer. The images were processed and enhanced with ERDAS 2014 software to aid information extraction and analysis. Land cover change analysis was performed using ENVI 5.3 software. Supervised classification method with maximum likelihood algorithm was performed to obtain land use/ cover types. Five land use/cover types were identified: open water, wetland, tree cover, agriculture and built up area. The findings indicate a fivefold increase in built up area by 154.27km^2 (i.e. 375%) and open water increased by 8.7 km^2 (i.e. 55.33%). Wetland, tree cover and agriculture reduced in area by -1.0km^2 (i.e. 5.1%), - 48.07 km^2 (i.e. 34.46%) and -114.0km^2 (i.e. 51.05%), respectively. These changes mainly resulted from deforestation, wetland encroachment, poor attitude and over population. Unless, appropriate watershed restoration strategies are designed through afforestation, law enforcement on culprits, continuous sensitisation of the watershed community on the causes of degradation, the over 1,700,000 individuals whose livelihoods depend on Awoja will continue to suffer the effects of degradation. There is need to advocate for non-consumptive projects as alternative sources of income.

Keywords: Remote sensing, GIS, Watersheds.

INTRODUCTION

Whereas watersheds are recognised for their contribution to livelihoods, the main cause of degradation has been alternate human activities resulting into land cover change (Hari et al., 2015). A watershed is an area of land draining into a common body of water and is comprised of soil, trees, vegetation and water along with the people and animals that are the integral part of the system (Wani 2009; Townsend et al., 2011). Land use/cover change is often used as a precautionary indicator of watershed status (Garroway et al., 2012; Filgueira et al., 2015). Watershed status refers to the position of affairs at a particular time, especially in terms of vegetation, water, soil and biota (Steven et al., 2012). Land use change is increasingly becoming a centre of debate in the current global change phenomena directly related to livelihoods (Víctor et al., 2013). This high rate of land use/cover change is escalating globally (Palmer, 2009; Townsend et al., 2011; Krumhansl et al., 2015). Additionally, population growth, increased conflict on resource use and limited alternatives are partly the reasons for this change (Turyahabwe et al, 2013; Qingqing, 2015; Junguo et al., 2015). The pressure on watershed resources has affected the original land use/cover. Land use/ cover change is the intended employment of land management strategy placed on the land cover by human agents to exploit land cover and it reflects human activities like agriculture, mining among others (Zubair, 2006; Rawat et al., 2013; Bajocco et al., 2015). This change results into reduction in associated quality and availability of these resources (Tesfaye, 2011; Tsehaye, 2013). In India for instance, there has been an increase in land cover/ use change specifically in built- up areas and sand bars by 88.8% (Rawat et al., 2013). On the other hand, in Egypt, land cover/ use changes show significant decline in agricultural land among other land uses (Ibrahim & Mosben, 2015). Ideally, effective watershed management entails regulated off take of watershed resources to meet the socio-economic needs of the people without degradation and the interaction between water, biota and soil, stable in structure and functions (Qingqing, 2015). A healthy watershed must have clean air, water and biota for a well- balanced system that sustains many forms of life (Kevin et al., 2012).

In Uganda, land use/ cover change is an environmental challenge (Mbogga et al., 2014; UBOS, 2015). The rate of land use/ cover change was estimated at 7% in 1990 and now stands at 11% with eastern Uganda registering the highest rate of 20% (UBOS 2011 ; Mary et al, 2014). Awoja watershed in Kyoga Water Management Zone of eastern Uganda with an area of 10 Km^2 is a key watershed degradation hotspot with a perceived degradation rate of 76% compared to 63% from Lake Victoria crescent and 41% in the south western farmlands of Uganda (NEMA, 2008). In the last two decades, several strategies including sensitisation, training, tree planting, establishing soil and water conservation structures were put forward by both the government and development partners to protect and restore the degraded watersheds (Ministry of Water and Environment, 2013; World Bank, 2013;). Most of these strategies were geared towards improving the livelihoods of the communities living in the watersheds. In eastern Uganda, two such projects were implemented between 2007 and 2013. The projects implemented were Farm Income Enhancement and Forest Conservation (FIEFOC) and the Community Based Wetland and Biodiversity (COBWEB). The FIEFOC Project provided assistance to private forest owners to plan for and manage their forests, especially those located in watersheds. This was through restoration planting (World Bank, 2013). The COBWEB aimed at restoring biodiversity (Crested crane, shoebills) in Lake Bisina, Awoja watershed area. This was through restoration planting including training on tree nurseries establishment, establishment of alternative sources of income for the community through ecotourism and initiation of a Savings and Credit Cooperative Organisation (SACCO). All these were aimed at restraining the community from over exploiting the watershed.

Awoja watershed supports over 1,700,000 individuals that derive their livelihood from it, with a contribution of over USD 200 as earnings from papyrus harvesting and mat making per household annually (IUCN, 2005). In spite of this, the watershed continues to face increasing degradation, even with government and development partner efforts to restore it. Although studies conducted within Awoja watershed indicate failure in restoration efforts due to high population growth and increased demand for watershed resources, little is known on the magnitude of this change in terms of land use/ cover (Mutekanga et al., 2013; Mbogga et al., 2014). Unless the change in land use/cover in Awoja is known government and development partners may not design appropriate approaches for restoration. This paper addresses this gap and avails empirical evidence on the status of Awoja watershed in Ngora district in Uganda and shows the extent to which it has changed. The findings contribute to the achievement of the Sustainable Development Goal 15 and its agenda that addresses degradation by ascertaining land use/ cover change of Awoja for appropriate restoration.

MATERIALS AND METHODS

Description of the Study Area

This study was conducted in Awoja watershed of eastern Uganda basing on its high degradation rate in the last two decades of 20%, compared to the national average of 11% (Ministry of Water Environment, 2013). Additionally, it had the highest perceived degradation rate of 76% compared to 63% from Lake Victoria crescent and 41% in the south western farmlands of Uganda (Nelson et al., 2013). Specifically, Ngora district was selected because it occupies a greater part of Awoja watershed. It also piloted the two restoration intervention projects, the FIEFOC and COBWEB.

Ngora district is found in North Eastern Uganda which lies approximately between latitude 1^{0}10’ North and 1^{0}35’ North and longitudes 33^{0}30’ East and 34^{0}20’ East as shown in Figure 1. Ngora is bordered by the districts of Kumi in the east, Serere to the West, Soroti in the North West, Katakwi in the North and Pallisa to the South. It covers a total area of 715.9 km^2, with 177 km^2 and 331km^2 (19 %) as land and open water bodies respectively. The main water bodies include Lake Bisina, Lake Nyaguo, Lake Meito and Lake Nyasala. Over 93% of the households are engaged in agriculture with a population density of 267.5 persons /km^2, which is higher than the national average of 174 persons /km^2 (UBOS, 2015).

The sub counties of Mukura and Kapir were chosen because they were the implementing sub counties, besides having the highest average household numbers of 5.3 and 5.2, respectively above the national average of 4.7 (UBOS, 2015). The parishes of Moru-Kakise and Mukura were chosen purposively because they were the implementing parishes for both COBWEB and FIEFOC interventions.

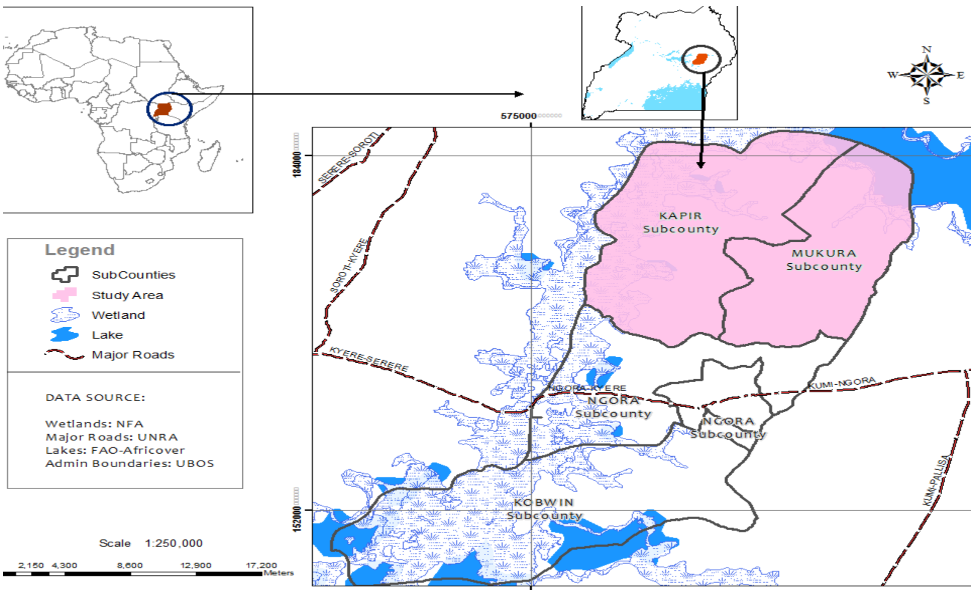

Figure 1. Awoja Watershed in Ngora District

Data collection and Analysis

Research Design

This paper uses an ex post facto design to acquire data used in the analysis. This research design best suits investigations where an intervention has taken place and data is collected.

Quantification of watershed land Use/ Cover Changes

Remote Sensing

Suitable processing of Land sat ETM Images covering the whole of Ngora district and part of Lake Kyoga (path 171, Row 59), of two time periods (May, 2007 and May, 2013) during the period April – July 2015 was carried out. This was acquired from USGS Earth Explorer (Scaramuzza, 2011; USGS, 2015). The two time periods were considered before and after the two projects' implementation in order to establish the changes that may be attributed to these two projects. The change in land use/cover is shown in Figure 2. The down loaded images were processed and enhanced with ERDAS 2014 software to aid information extraction and analysis. Land cover change analysis, were performed on the processed images using ENVI 5.3 software (Rawat et al., 2013). The corrections made were meant to reduce inconsistencies in the satellite images which are inherent in the images because of differences in acquisition conditions including variation in sun zenith angles. Supervised classification method with maximum likelihood algorithm was performed to obtain land use/cover types. The classification was adopted from a similar study by Rawat et al., (2013). Five land use/cover types were identified and used in this study, namely; (1) open water (2) wetland (3) tree cover (4) agriculture and (5) built up area. Post-classification detection method was employed to develop change detection matrix. Quantitative area data in square kilometres and their percentages, overall land use/cover change as well as gains and loss in each category between 2007 and 2013 were compiled as shown in Table 1.

Ground truthing using Global Positioning System (GPS)

The classified images were validated in a ground truthing exercise that involved use of a GPS to collect geographic coordinates for each vegetation cover type. To improve the image classification accuracy, a validation exercise was held.

Field Observation

During the field work, observations were also made to verify the information obtained on the satellite images down loaded.

RESULTS

Spatial and Temporal Changes in Watershed Use/ Cover

For the period 2007 to 2013, there were marked increase in change of built up areas and open waters in Awoja watershed as shown in (Table 1 and Figure 2). The increase in the built up area was found to be fivefold the size it was in 2007. Built up area in 2007 covered 41.12 km^2 and by 2013 it had increased to 195.39 km^2. This change of 154.27 km^2 accounted for 375% rise in the built up area. The area of open water increased from 15.73 km^2 to 24.43 Km^2, representing a 55.33% increment of 8.7 km^2. These changes are evidenced in the significant reduction in land under tree and vegetation cover.

Conversely, a reduction in land use/ cover was registered mainly in the tree cover and agricultural land categories. The tree cover reduced from 139.63km^2 to 91.56km^2

representing a 34.46% decrease. The agricultural land cover category reduced by 114km^2 (from 223.35 km^2 to 109.35 km^2), a reduction of 51.05%. However, the least change of 5.1% (1km^2) was noticed in wetland use/cover category which reduced from 16.24 to 15.24 km^2.

Table 1. Percentage change in Land Use/ Cover Categories between 2007 and 2013 (Km^2)

Land use/ cover categories	2007	2013	Change in land use/ cover	% change
Open water	15.73	24.43	8.70	55.33
Wetland	16.24	15.24	-1.0	-5.1
Tree cover	139.63	91.56	-48.07	-34.46
Agriculture	223.35	109.35	-114.	-51.05
Built/bare area	41.1	195.39	154.27	375

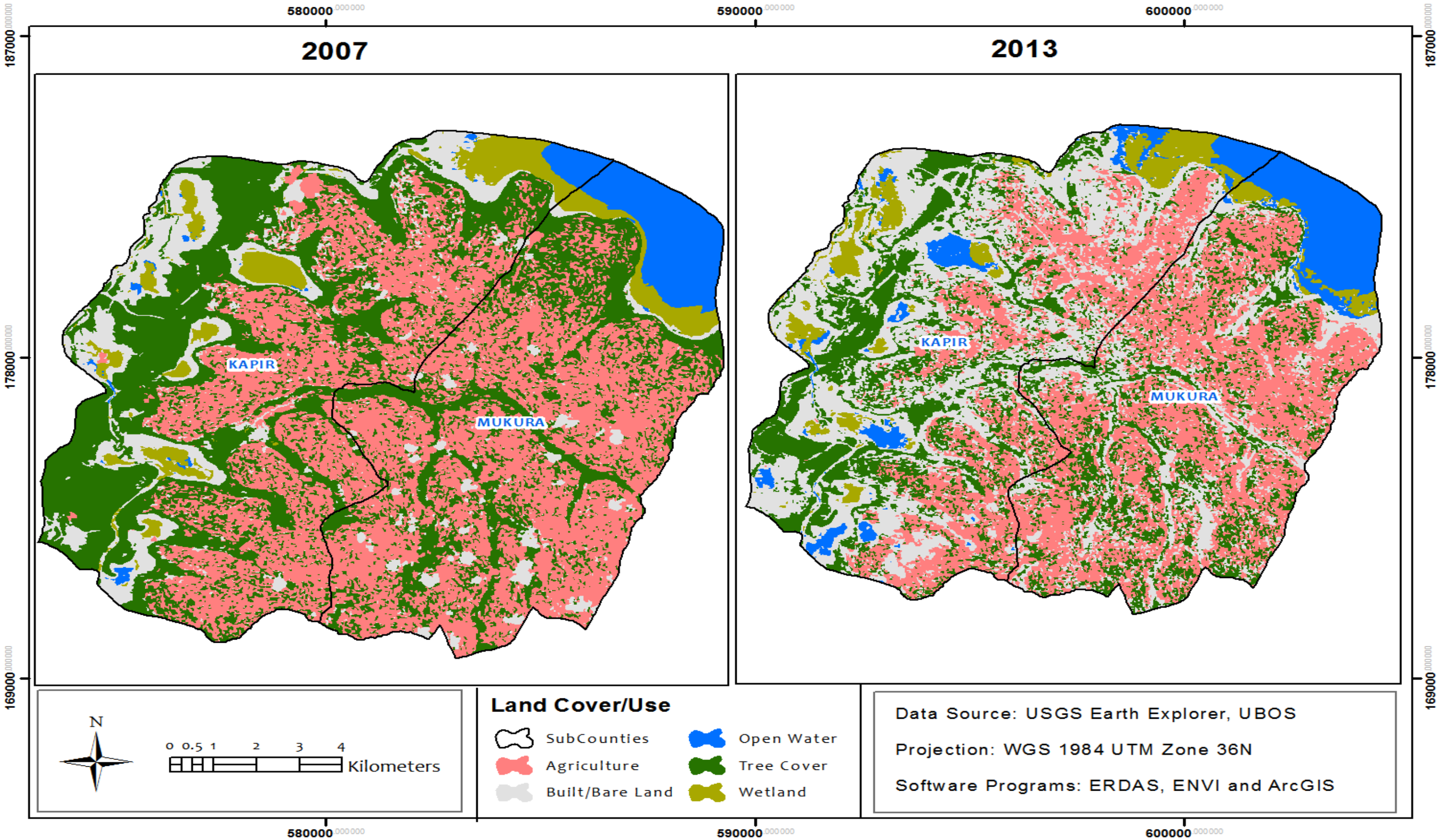

Figure 2. Land cover/ use change from year 2007 to 2013

DISCUSSION

The research findings suggest change in land use/cover in Awoja watershed area in Ngora district, North Eastern Uganda for the period 2007 – 2013. The spatial and temporal changes presented are the basis for discussion. As earlier mentioned, the built up area increased fivefold by 154.27 km^2 signifying a 375% rise. This is explained by the high population increase of 12,119 and 13,312 for Kapir and Mukura sub counties from the period 2002 and 2012 according to the national population and housing census. The number of individuals in the age bracket 18 years and above is highest in Kapir and Mukura, registered at 9,197 and 12,498 respectively (Ngora district development plan, 2015). This implies that the young couple had to establish their homes hence the increase in the built up areas as they settlement. Consequently, the need to establish trading or urban centres for provision of basic commodities such as sugar, salt in the watershed led to clearing land areas to build houses.

Whereas in Uganda, according to Kaggwa et al., (2009), agriculture is the principle cause of watershed degradation, this study disagrees with the watershed restoration sites in Kapir and Mukura sub counties in Ngora that indicated that it's not agriculture but built up area that is the main source of degradation. The findings are also not in agreement with those of Tesfaye (2011) in Ethiopia, which found that agriculture is the main cause of watershed degradation. However, the findings concurs with Ibrahim and Mosben (2015) findings in Mansoura and Taikha watershed areas of Egypt which showed an eight fold increase in the built up areas from 28 km 2 to 255 km^2 from 1985 to 2010 that largely contributed to watershed deterioration. The decline in land use/ cover size in tree cover and agricultural land categories of 48.07km^2 and 114km^2 respectively was because agricultural land was taken over by settlement. Part of the area which was taken up for settlement and urbanisation was formerly for agriculture hence the decline in area under agriculture. Therefore those involved in agriculture have abandoned it for petty trade like Motorcycle riding (boda boda) and selling of basic household items like salt, match boxes, cloths while others are engaged in alternative sources of income such as baking chapatti and brewing local brew (*waragi*) thereby diverting the youth who search for quick money.

Conclusion

This study provides evidence on the status of land use/ cover changes in Awoja watershed in Eastern Uganda from 2007 to 2013. The major causes being deforestation, wetland encroachment and over population as the communities clear more land for settlement and utilise the watershed resources. Unless this trend is reversed, over 1,700,000 individuals whose livelihoods depend on Awoja will continue to suffer negative effects of degradation. These findings confirm that human activities are the main causes of degradation.

This findings advocate for projects that are non-consumptive (e.g. apiculture and ecotourism). Alternative sources of income other than those from the watershed resources is encouraged so as to reduce pressure on the resource well as continuous sensitisation of community on the dangers of degradation by technocrats.

CONFLICT OF INTEREST

The corresponding author indicated that she was a service provider for FIEFOC project but never worked in the study area hence did not influence the quality of this research. The co-authors have not declared any conflict of interests either.

ACKNOWLEDGEMENT

We acknowledge funding from RUFORUM. In addition, the support of

Enuru Thomas and Apiny Mary Irene as research assistants is acknowledged.

REFERENCES

Bajocco S, Ceccerelli T, Smiraglia D, Salvati L and Ricota C (2015). Modelling the ecological niche of long term land use changes: The role of biophysical factors. *Ecological indicators* 60(2016)231-236

Filgueira R, Chapman JM, Suski CD and Cooke S.J. (2015).The influence of watershed land use cover on stream fish diversity and size-at- age of a generalist fish. *Ecological indicators* 60(2016) 248-257

Garroway K, Shannon S, Gavin K and Peter H J (2012). Nova Scotia Watershed Assessment Program Part A – *Discussion Paper*

Hari GR., Dennis M F & Karine E (2015) Spatial dynamics of land cover change in a

Euro-Mediterranean catchment (1950–2008), *Journal of Land Use Science*, 10:3, 277-297, DOI: 10.1080/1747423X.2014.898105

Ibrahim R H and Mosben R K (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Dagahlia governorate Egypt.

IUCN (2005). From Conversion to Conservation – Fifteen Years of Managing Wetlands for People and the Environment in Uganda. Kampala, Uganda: WID; Nairobi, Kenya: IUCN Eastern Africa Regional Programme.

Junguo L, Qingying L and Hong Y (2015). Assessing water scarcity by simultaneous considering environmental flow requirements, water quantity and water quality. *Ecological indicators* 60(2016) 434-441.

Kaggwa R, Hogan and Hall B (2009). Enhancing Wetlands' Contribution to Growth, Employment and Prosperity. Kampala: UNDP/NEMA/UNEP Poverty Environment Initiative.

Krumhansl K, Jamieson R and Krkosek (2015).Using species traits to assess human impacts near shore benthic ecosystem in the Canadian Artic. *Centre for water resources studies*, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada. Ecological indicators 60(2016) 495-502

Mary K G and Diisi J (2014). State of the Environment Report for Uganda. Kampala: *National Environment Management Authority.*

Mbogga M., Malesu M. De, Leeuw, J (2014). Trees and watershed management in Karamoja, Uganda. Evidence on Demand, UK DOI: http://dx.doi.org/10.12774/eod_hd.december2014.mboggametal].

Ministry of Water and Environment (2013). The National Forest Plan 2011/12 – 2021/22. *Directorate of Environment affairs*, Kampala, Uganda

Mutekanga F P, Kesslee A., Leber K and Visser S (2013). The Use of Stakeholder Analysis in Integrated Watershed Management Experiences from the Ngenge Watershed, Uganda. *Mountain Research and Development* 33(2):122-131.

NEMA (2008). Pilot Integrated Environment Assessment of the Lake Kyoga Catchment in Uganda. *National Environment Management Authority* (NEMA), Kampala.

Ngora District Local Government. (NDLG).2015

Palmer MA (2009). Reforming Watershed Restoration: Science in Need of Application and Applications in Need of Science. University of Maryland *Centre for Environmental Science, Solomons*, MD 20688, USA. Estuaries and Coasts (2009) 32:1–17

Palmer MA, Bernhardt ES, Allan JD, Lake PS, Alexander G, Brooks S, Carr J, Clayton S, Dahm CN, Follstad Shah J, Galat Dl, Loss SG, Goodwin P, Hart DD, Hassett B, R. Jenkinson, G.M. Kondolf, R. Lave, J.L. Meyer,. O'donnell

TK, Pagano L and Sudduth E (2008). Standards for Ecologically Successful River Restoration. *Journal of Applied Ecology*. 2005 42, 208–217

Qingqing Z, Junhong B, Laibin H, Binhe G, Qiongqing L, Zhaoquin G (2015). A review of methodologies and success indicators for coastal wetland restoration. *Ecological indicators* 60: 248- 257

Rawat JS, Vivekanand B, Manish K (2013).Changes in land use /cover using geospatial techniques. A case study of Ramnagar town area, district Nainital, Uttarakhand, India. *The Egyptian journal of remote sensing and Space*.

Scaramuzza H (2011). Filling Gaps in Landsat ETM Images. http://www.yale.edu/ceo.

Steven H, Sean N Gordon, Peter Eldred, Mark Isley, Steve Wilcox, Chris Moyerand Heidi Andersen. Watershed status and trend. *General Technical Report* PNW-GTR-856 February 2012

Tesfaye H D (2011). Assessment of sustainable watershed management approach. Case study lenche dima: tsegur eyesus and dijjil Watershed. *Msc. Thesis*. Ethiopia.

Townsend PV, Harper RJ, Brennan PD, Dean C, Wu S, Smettem KRJ and Cook SE (2011). Multiple environmental services as an opportunity for watershed restoration. *Forest policy and Economics* 17(2012) 45-58

Turyahabwe N, Tumusiime DM, Willy K, Tweheyo M & Bashasha B (2013). Wetland Use/Cover Changes and Local Perceptions in Uganda. *Sustainable Agriculture Research;* Vol. 2, No. 4; 2013 ISSN 1927-050X E-ISSN 1927-0518

Tsehaye G & Mohammed A (2013). Land use/land cover dynamics and their driving forces in the Hirmi watershed and its adjacent agro-ecosystem, highlands of Northern Ethiopia. *Journal of Land Use Science*. 10. 1080/1747423X.2013.845614

UBOS (Uganda Bureau of Statistics) 2015. Statistical abstract. Kampala: Uganda Bureau of Statistics

USGS (2015). Earth Explorer. http://earthexplorer.usgs.gov/

Víctor HDZ, Carmen R.R P, José RFM & Francisco JMP (2013). Land-use changes in a small watershed in the Mediterranean landscape (SE Spain): environmental implications of a shift towards subtropical crops*, Journal of Land Use Science*, 8:1, 47-58, DOI: 10.1080/1747423X.2011.620992

Wani SP, Sreedevi T K., Reddy TSV, Venkateswarlu B and Prasad CS (2009). Community watershed for improved livelihoods through consortium approach in drought prone rain-fed areas. *Journal of hydrological Research and development*.3:55-77, Kothapally India: Adarsha Watershed.

World Bank (2013). Development of the Awoja Catchment Management Plan in the Kyoga Water Management. Zone Contract: 7164726. *Final Stakeholder Engagement Report*.

Zubair AO (2006). Change detection in land use and land cover using remote sensing data and GIS. A case study of Ilorin and its environs in Kwara state, *Msc. thesis*, University of Ibadan Nigeria.