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Land use/land cover change and implications for ecosystems services in the Likangala River Catchment, Malawi

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ABSTRACT

Likangala River catchment in Zomba District of Southern Malawi is important for water resources, agriculture and provides many ecosystem services. Provisioning ecosystem services accrued by the populations within the catchment include water, fish, medicinal plants and timber among others. In spite of its importance, the River catchment is under threat from anthropogenic activities and land use change. This paper studies land uses and land cover change in the catchment and how the changes have impacted on the ecosystem services. Landsat 5 and 8 images (1984, 1994, 2005 and 2013) were used to map land cover change and subsequent inventorying of provisioning ecosystem services. Participatory Geographic Information Systems and Focus group discussions were conducted to identify provisioning ecosystems services that communities benefit from the catchment and indicate these on the map.

Post classification comparisons indicate that since 1984, there has been a decline in woodlands from 135.3 km^2 in 1984 to 15.5 km^2 in 2013 while urban areas increased from 9.8 km^2 to 23.8 km^2 in 2013. Communities indicated that provisioning ecosystems services such as forest products, wild animals and fruits and medicinal plants have been declining over the years. In addition, evidence of catchment degradation through waste disposal, illegal sand mining, deforestation and farming on marginal lands were observed. Population growth, urbanization and demand for agricultural lands have contributed to this land use and land cover change. The study suggests addressing catchment degradation through integrated method where an ecosystems approach is used. Thus, both the proximate and underlying driving factors of land-use and land cover change need to be addressed in order to sustainably reduce ecosystem degradation.

1. Introduction

Life on our planet is entirely dependent on the services provided by earth's natural systems. Ecosystems Services is defined as the benefits derived from nature i.e. food, clean water, flood control, climate regulation by forests, nutrient cycling etc (Millennium Ecosystem Assessment, 2003). There is scientific evidence that Ecosystem Services are linked to human wellbeing. The study "Voices of the Poor" conducted in 23 countries revealed that wellbeing is defined by majority of poor as "basic material minimum requirements for a good life," such as food, shelter and livelihoods which arise from nature and its ecosystem services (World Bank, 2000). The Economics of Ecosystems and Biodiversity (TEEB) report in 2010 highlighted the dependence of livelihoods on ecosystems (UNEP, 2010). Therefore, it is crucial that we need to protect nature and the ecosystem services it provides (Environmental Protection Agency, 2012; World Resource Institute, 2012).

However, growing population pressure and the drive for economic growth makes human beings themselves contribute to damaging nature and its services thereby causing negative feedbacks (Ehrlich and Ehrlich, 2012; Saehoon and Peter, 2012; Millennium Ecosystem Assessment, 2003). It has been observed that deforestation increases soil runoff and siltation of water. In addition, deforestation affects the forests ability to provide its micro climate regulation service (Biswas et al., 2012; Calder et al., 2007). Human activities such as construction of buildings and farming on wetlands affects its water regulation service, thus causing flooding in other areas. These examples demonstrate that altering ecosystems services by human activities may have negative

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feedbacks on human wellbeing.

Ecosystem services are affected by land use and land cover change (LCC) and satellite remote sensing techniques have been applied extensively for monitoring actual and spatial change in a variety of natural environments (e.g. Townsend, 2002; Wilson and Sader, 2002; Cohen et al., 2003; Dowson et al., 2003; Jin and Sader, 2005; Claessen et al., 2009). Remote sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management, land-use mapping, and planning. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system functions, patterning, and change at local, regional, as well as at global scales over time (Lambin et al., 2001).

Previous land use and land cover change study in Likangala River catchment was done by Jamu et al. (2003). The authors analysed land use from 1982 to 1995 using black and white aerial photographs. Assessment of vegetation cover focused on the impacts of catchment degradation on fish, soil erosion, river flow, siltation and water quality within the Likangala River catchment. Jamu et al. (2003) pointed out that increasing deforestation has contributed to increasing sediments in the river and there was a net increase in agricultural land. The authors stated that afforestation activities were reducing soil loss in the catchment.

In Malawi, populations depend on the provisioning services provided by ecosystems, such as water, crops, fish, medicinal plants and timber. This article examines the land-use/cover change in the Likangala River catchment over a 29-year period (1984–2013) using Landsat data (TM and OLI) imagery. The focus was largely on the land cover changes such as woodland, urban area and agricultural land, which are linked to provisioning services in the catchment. An understanding of what the provisioning ecosystems services are, its benefits accrued by population within the catchment and appreciation of the changes in land use which affect ecosystems services also formed part of the research.

2. Study area

Likangala River is located in Zomba District and is situated between latitude 15°22′0–15°30′0 S and longitude 35°15′0–35°37′ E (Fig. 1).

The river originates at Zomba Mountain and flows along varying topography through towns and farmlands located between elevations of 1265 m and 790 m above sea level and has a length of 50 km covering 756 km^2 (Chidya et al., 2011). It is an interesting and important river; it flows through both urban and rural areas and provides water for domestic uses and irrigation. The river flows into Lake Chilwa, a wetland of international significance; a Ramsar Site and UNESCO Biodiversity Reserve (UNESCOPRESS, 2006; Ramsar, 2000; Birdlife International, 2011).

On Zomba Mountain, pine plantations and a mixture of indigenous and exotic tree species are found. Subsistence agriculture is practiced in the rural areas, with maize being a predominant crop. The large estates where tobacco, cotton, maize and other crops are grown have been in existence since the 1960s. Likangala Rice Irrigation scheme was established in 1969 (Ferguson and Mulwafu, 2003) and is 415 ha in size. Communities living in the catchment benefit from many provisioning services and these are inventoried in this paper.

3. Materials and methods

Methodology followed was an analysis of remotely sensed data to detect land-use changes and a combination of participatory geographic information system, focus group discussions to map and inventory provisioning ecosystem services.

3.1. Data sources

3.1.1. Remote sensing data

Landsat TM images of 1984, 1994, 2005 and Landsat OLI-8 of 2013, all captured in October/November were acquired from USGS website. The strategy for selecting Landsat imagery for development of land cover database for the Likangala River catchment was governed by available multi-temporal images, vegetation phenology and image quality (cloudiness, haze).

3.1.2. Inventory of ecosystem services

Participatory Geographic Information System (PGIS), which is a combination of participatory rural appraisal and geospatial technology, focus group discussions, and semi structured questionnaires were used to inventorise ecosystem services (Pullanikkatil, 2015). Communities in rural areas within the catchment area were asked to map provisioning ecosystem services using locally available materials such as chalk powder, sand, stones and grass. This exercise was done separately for women and men in groups of 20–30 (Table 1) from 7 locations within the catchment area (Fig. 1). Once the participants have mapped their services, a photograph of the map was taken. Communities were asked to identify provisioning ecosystems services that they benefit from the catchment and indicate these on the map (Pullanikkatil, 2015). A global positioning systems (GPS) at 0.5 m accuracy was used to store coordinates of each service identified for further analysis in ArcGIS 10 software. Furthermore, focus group discussions with different groups based on livelihoods such as fishermen, farmers, hunters, traders and others were conducted at seven locations within the catchment to validate the PGIS exercise. All formal meetings and interviews were recorded, and transcripts made, with the transcripts later read back to the interviewees and discussion group members for validation.

3.2. Data processing analyses

3.2.1. Image analysis and land use classification

A pre-processing step was necessary to improve the quality of the data. The pre-processing included geometric registration between image scenes and all the Landsat images were georeferenced by the process of co-registration. This process is aimed at minimizing geometric distortions in an image caused by systematic and unsystematic sensor errors. All the images were resampled using the nearest neighbour option and was projected to the Universal Transverse Mercator (UTM) system. Root mean square errors of less than one pixel resolution were achieved. The images were registered in the *MalawiGP UTM Zone36/Arc1950* datum projection system to match them with available *in situ* vector data (Malawi Government and Satellitbild, 1993). According to Richter (1996) an atmospheric correction has to be carried out, if optical data are used for multi-temporal classification approaches. Therefore, all the Landsat data were atmospherically corrected, which resulted in improved data quality.

A supervised maximum likelihood digital image processing was employed by defining training sites, on the image, which are representative of each desired land use/land cover category (Jensen, 2005) and for which area statistics were generated. The classification for this was done using Erdas 2013 software. It should be noted that due to the marked boundary portrayed by the rice irrigation scheme, estates and urban areas, image analyst in ArcGIS